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SPATIAL ROBUSTNESS: DOUBLE-DESIGN AND THE DEMOCRATIZATION OF SPACE, AN EXPLORATION OF DESIGNING FOR MULTIPLE USES

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SPATIAL ROBUSTNESS: DOUBLE-DESIGN AND THE DEMOCRATIZATION OF SPACE

An Exploration of Designing for Multiple Uses

by

MICHAEL WARREN ARKINSTALL CASSIDY

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Copyright statement

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I could not have undertaken this work without the blessing and engaged support of my partner, Marcia Abrosimova: her determination that I should return to painting as soon as the thesis is finished provided a regularly refreshed incentive to get it done.

Author’s declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

Publications and presentations at conferences:

SPATIAL ROBUSTNESS: why all new buildings must be designed to last for at least one hundred and fifty years (Cassidy. M; Brown. R; de Wilde. P) has been accepted for publication by Int|AR, Journal of Interventions & Adaptive Reuse, Rhode Island School of Design.

The author participated in the PGR architectural Symposium, 5 May 2021, and in several informal presentations and discussions within the architectural community of Plymouth University.

Other relevant publications by the author are referred to in the main body of text and details are in References.

Word count of main body of thesis: 79,678

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GUIDE FOR READERS

Personal remarks by the author are shown thus.

General text is 11pt Tahoma, two-line spaced.

Footnotes generally are shown thus; 9pt Tahoma, single-line spaced.

Footnotes in green are selected quotations from interested professionals responding to an invitation to comment on the ideas presented in this thesis. Comments are further summarized in CHAPTER SIX and all the details can be found in APPENDIX SEVEN.

References follow APA format (7th edition) interpreted by Zotero.

ABSTRACT

SPATIAL ROBUSTNESS: DOUBLE-DESIGN AND THE DEMOCRATIZATION OF SPACE

An Exploration of Designing for Multiple Uses

by Michael Warren Arkinstall Cassidy

Differing attitudes to the expected life and value of architecture characterize the sustainability debate, yet space itself is rarely mentioned. The buildings for which architecture is responsible comprise both space and materials. While it is taken for granted that some existing buildings can be reused productively, this cultural phenomenon has not influenced the design of the new stock. While content to revere old buildings, the qualities that make them valued have not influenced design principles for new projects. Should new buildings be designed and built for their initial use only, often to be demolished as soon as the initial purpose has run its course, or should they be designed to last? The quality of the space being built influences its long-term robustness. The quality of construction being used influences the resource equation.

The conservation of resources and the avoidance of waste would be regarded as self-evident goals for any logically principled enterprise. The provision of buildings with material- and use-longevity begins to address important current environmental questions. In developing this logic, this thesis explores the conceptual and technical feasibility of designing buildings to accommodate sequences of uses. The concept of

"Double-Design" responds to this challenge by allowing for both initial and later uses.[1] The idea goes beyond a simple recommendation to incorporate adaptability towards support for the radical proposition that buildings should last for a very long time and should be useful for as long as they last. Thus Double-Design would ensure that flexibility and adaptability help both the initial use and subsequent uses. The compatibilities amongst the physical characteristics of buildings for different uses are assessed so that the initial design will allow for future change. Buildings need to be designed to achieve physical longevity with an associated capacity to continue functioning with smooth transitions between uses.

A longitudinal case study of an educational building covering fifty years of use confirms the need to accommodate an extensive range of uncertainties in architectural design. This reinforces the requirement that flexibility and adaptability must be incorporated in design if lasting usefulness is to be achieved. Studies of flexibility and adaptability have confirmed their value. But there has been no exploration of the full extent to which multiple uses could be accommodated *because* of the intention of the original design. Establishing the value of the Double-Design concept would represent an important contribution to knowledge. The development of generative design software covering engineering and architecture may make the evaluation of designs possible based upon multiple sets of performance criteria related to different anticipated or possible uses.

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[1] **As a term it is very catchy but I sense what you are really pushing at is double/triple/quadruple/perpetual design – this is more than a single alternative use which double would imply (Andrew Carr).**

Several approaches to implementation are suggested, including the mandatory application of Double-Design using legislation. Resource conservation criteria covering materials and energy would need to be incorporated within health and safety regulations if the public interest is to be redefined. Favourable responses to the concept of Double-Design from the UK and international experts are recorded.

The responsibility for commissioning new space reflects a particular distribution of economic and social power, and the physical environment will need to respond as this changes. Such a response will be more readily achieved if all new buildings incorporate Double-Design, thus improving the fit between future space needs and future available space and leading, albeit slowly, to a democratization of space.

New logic in using resources emerges from this analysis, suggesting long-lasting materials are to be used to provide building infrastructure: the outer shell. In contrast, short-life sustainable or recyclable materials are to be used for the more frequently changed and responsive interior fit-outs.

CHAPTER ONE: PERSONAL EXPERIENCE

When the author retired from day-to-day architectural practice in 2009, there was time to consider some of the questions that remained unanswered from more than fifty years of professional architectural and planning work. In coming late to academic practice, there was a need to recognize the extent to which experience had influenced the starting point for research. A balance has been sought between a philosophical appreciation of buildings and an idea that is capable of practical implementation: an idea that could make a difference to the way buildings are designed, built and used; further, an idea that could change the relationship between a profession and its custodians and users.[2] Professional experience has led to a very particular set of conclusions about the nature and shortcomings of architectural design. Relying upon a wide range of sources of knowledge, including direct experience, the research is inevitably qualitative in nature.

As Denzin and Lincoln say:

> Qualitative research is multimethod in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. Qualitative research involves the studied use and collection of a variety of empirical materials. (Denzin & Lincoln, 1998, p. 3)

Groat and Wang distinguish between three types of theory: positive, normative and polemical. Positive theories are descriptive, causal and explanatory theories that are

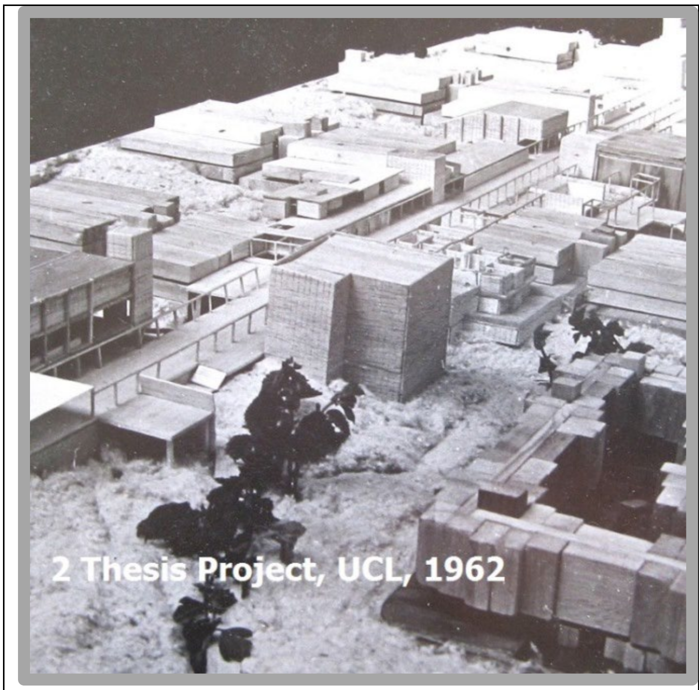
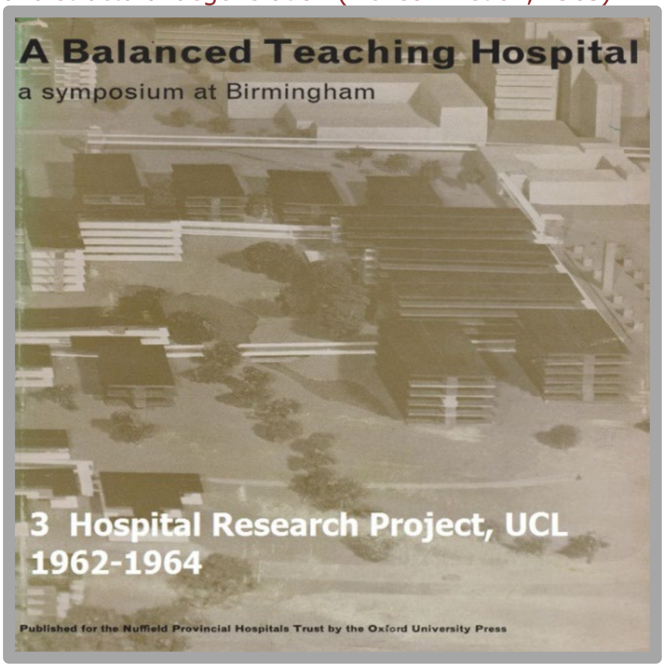
[2] Custodian is used in this thesis to signify the owner or developer or manager of buildings while the user signifies the occupant.

able to predict future behaviours of the systems they describe, developed from a disinterested position of the researcher. Normative theories describe value judgements related to a discipline of research, possibly to identify desired lines of actions and decisions to assist policy makers or decision takers in achieving identified, often utilitarian, goals. Polemic theories of design are theories where the theorist is actively involved in promoting a new set of values or a value system that changes the existing one. In polemical theory the theorist is involved with the subject of study from a position of power (Groat & Wang, 2002, pp. 78–87).

Given the declared intention for this research to have a practical outcome, aspects of both normative and polemical theories are engaged. Bailey also sees grounded theory combining the phases of concept measurement and hypothesis construction with the verification phase (Bailey, 1994, p. 55). Elaborating the grounded theory approach to qualitative data analysis, Strauss sees this as "the development of theory, without any particular commitment to specific kinds of data, lines of research, or theoretical interests" (Strauss, 1987, p.6). The data arising from these experiences, together with the analysis and reassessment of the data, have not arisen as part of an intentional search. However, as Strauss and Corbin suggest, "Grounded theories, because they are drawn from data, are likely to offer insight, enhance understanding and provide a meaningful guide to action" (Strauss & Corbin, 1998, p. 12). The iterative processes involving data collection, data analysis and theory building, with free communication linking them, offer a good description of the way in which the analysis and reassessment of experience has led, in this particular case, to the themes and issues that have initiated the research. The position of an architectural research worker emerging from many years of professional experiences cannot be expected to be free from opinions (Groat & Wang, 2002, p. 181). The inherent flexibility of grounded theory is helpful in allowing both deduction (elaboration) and verification as much as induction (theory conception) (Strauss, 1987, p. 11). The architectural design process itself, with the development of hypothetical designs for subsequent testing and modification, echoes the iterative nature of grounded theory.

As a brief personal introduction to this research, noted here are events, experiences and responsibilities that support the belief that the ideas developed are important and timely.

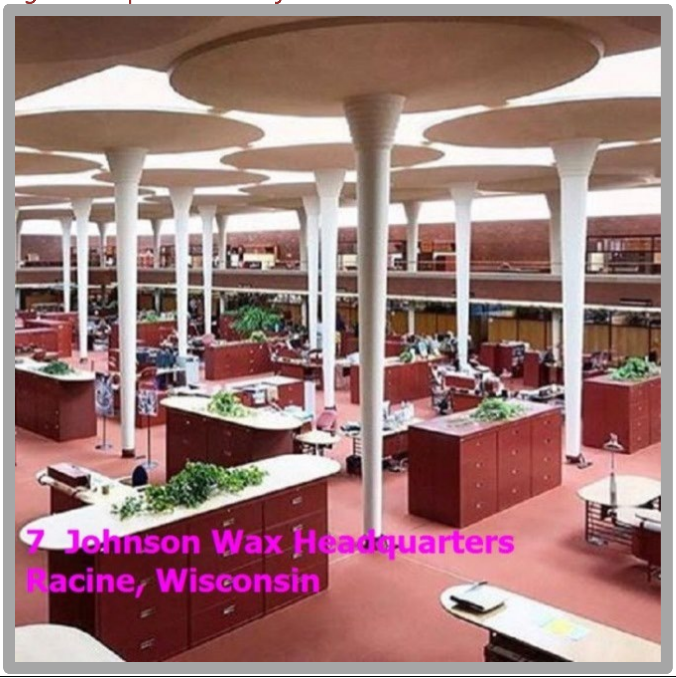
EXPERIENCE	**EMERGENT THEMES AND ISSUES**
1 As a student at UCL in 1960, during a visit to the newly completed Alton estate (LCC architects department), the job architect explained that the "problem" of the user's curtains had been solved by the architect choosing an outer layer that was stitched to an inner layer chosen by the user (tenant). It seemed to me, at the time, absurd that the architect's concern was for the external appearance of the building at the expense of the freedom of the tenant to choose his/her curtains. 	Need to legitimise the extent of architects' responsibility in context of user choice.
2 As a student at UCL in 1962, my thesis design project (with Louis Hellman and Robin Moore) proposed a new university able to expand along a main street and at right angles to the street. While achieving a crude potential for growth, this concept was based upon a particular model of academic organization and looked unable to respond to real change within the institution (see Chapter Four below).	Concern for design to accommodate institutional growth and change. This interest was reinforced throughout a professional career which included the design for many large institutions including hospitals and universities.

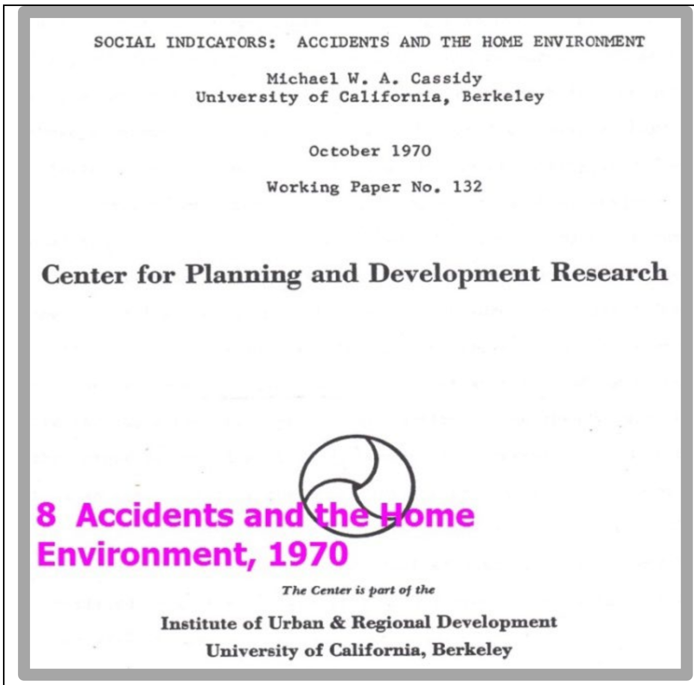
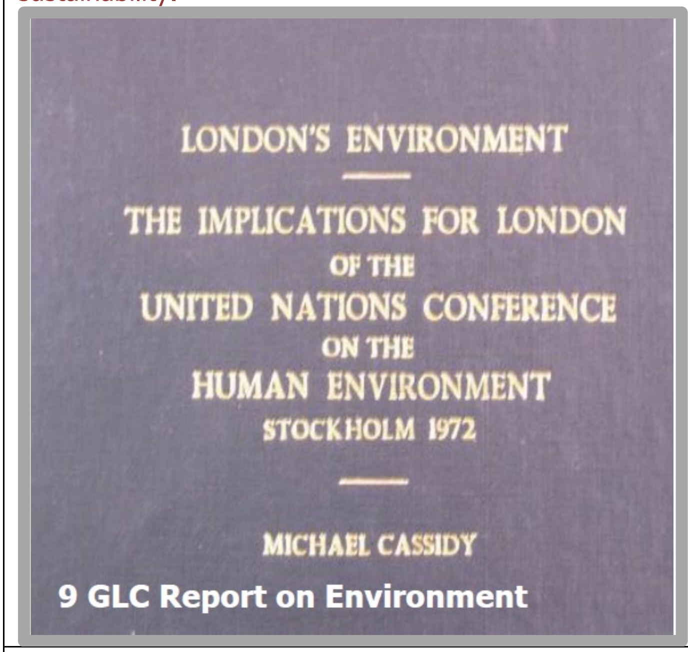
 2 Thesis Project, UCL, 1962	
3 As a research architect with the Hospital Research Unit at UCL from 1962 to 1964, I worked on studies of the growth, change and ageing of hospitals with Peter Cowan, developing ideas about functional obsolescence and structural degeneration (McKeown et al., 1965).  3 Hospital Research Project, UCL 1962-1964	Concern for design to accommodate institutional growth and change.

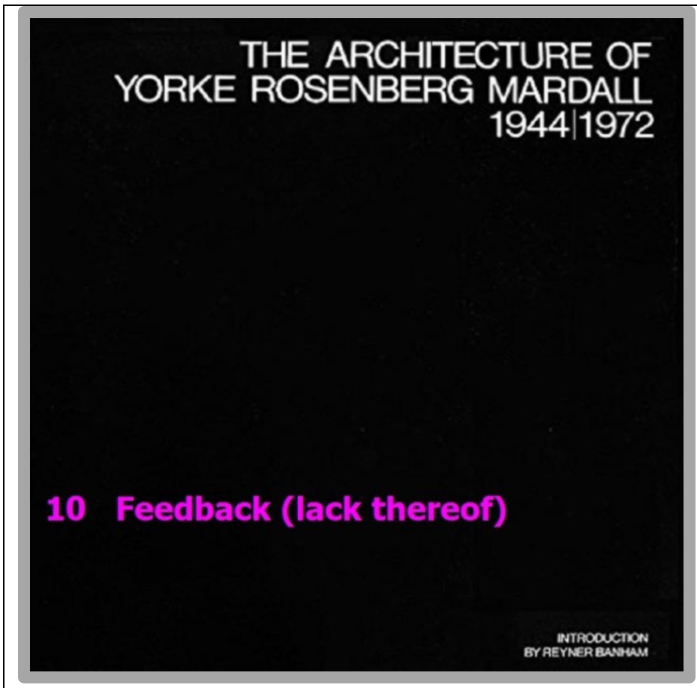
<table>
<tr>
<td>4 In 1963, I worked with the architect John Weeks. He observed that hospitals were taking 15 years to complete and that by the time they were finished, the equipment was almost certainly out of date. His solution was to design and build a serviced shell and to allow the users to choose, collect and install their equipment as they moved in to the finished building. (see GUST later) Weeks had also developed ideas around the concept of indeterminacy that were to influence the design of Northwick Park Hospital as well as the notion of Duffel coat architecture, in which, just as in the navy during the second world war, a limited range of coat sizes accommodated the needs of all shapes and sizes of personnel.

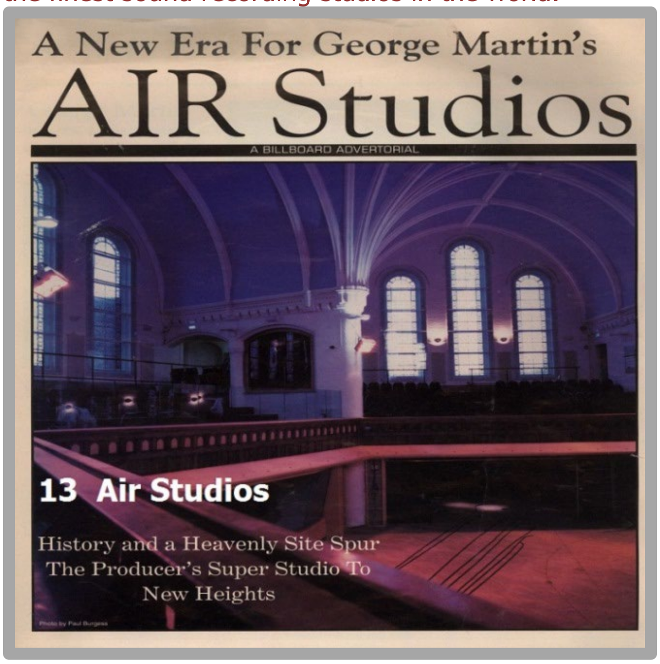
</td>
<td>Separation of building shell from fit-out.</td>
</tr>
<tr>
<td>5 In 1964, I was able to develop the ideas responding to the needs of growth, started in the thesis of 1962, by means of a tartan grid for Warwick University which was less tied to the initial organizational structure. (This will be discussed in more detail as a case study) Designing a new university in the UK, it became clear that the traditional scientific departmental structure was dissolving into "schools of study" and that building connectivity needed to match and facilitate the growth and change that seemed inevitable (see Chapter Four).</td>
<td>Opportunity to put into practice ideas about growth and change and interior flexibility.</td>
</tr>
</table>

	
6 In 1967, the plan for the new John Radcliffe teaching hospital in Oxford incorporated some of the same ideas and allowed for varying degrees of penetration by research activity into clinical zones. 	Opportunity to put into practice ideas about growth and change and interior flexibility.

7 Visiting Frank Lloyd Wright's Johnson Wax building in 1968, I was told that I had arrived on an auspicious day: the first day upon which technical and laboratory equipment (normally white) had been delivered to the users of the building without being painted terra-cotta colour in fulfilment of the architect's instructions. The architect had died some ten years earlier yet his influence had remained: I wondered if this ethereal architectural influence was justified and it raised a question in my mind about the theoretical limits of legitimate professional jurisdiction. 	Need to legitimise the extent of architects' responsibility in context of user choice.
8 Working under the guidance of Melvin Webber in 1970 at the University of California, Berkeley, and as a contribution to the search for social indicators, I studied the phenomenon of accidents in the home, appreciating the overriding significance of human interaction with the built environment as central to successful architectural design (Cassidy, 1970).	Placing human activity as central to design.

 SOCIAL INDICATORS: ACCIDENTS AND THE HOME ENVIRONMENT Michael W. A. Cassidy University of California, Berkeley October 1970 Working Paper No. 132 Center for Planning and Development Research The Center is part of the Institute of Urban & Regional Development University of California, Berkeley **8 Accidents and the Home Environment, 1970**	
9 In 1972, as head of the Environmental Studies Group in the Greater London Council, I wrote a report on the implications for London of the UN Stockholm Conference that anticipated today's concerns for sustainability.  LONDON'S ENVIRONMENT THE IMPLICATIONS FOR LONDON OF THE UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT STOCKHOLM 1972 MICHAEL CASSIDY **9 GLC Report on Environment**	Establishing architectural design as a potential contributor to environmental goals.
10 In 1975, I tried to persuade my architectural partners to commission post occupancy studies of the firm's completed buildings but this was not supported.	Suggests a profession seriously disengaged from the importance of user feedback.

	
11 In 1979, I joined Brian Taggart, who had recently completed a project for IBM in which individual workstations were given control over their local environment: this recognized the importance of individual preferences rather than the "standard" levels of comfort usually specified. 	Illustrated the possibilities of handing over control and choice of local environmental conditions to users.
12 In 1984, the government of Kuwait were unable to say what the new Bayan Palace conference centre would be used for after the conference was finished: it transpired that the Emir of Kuwait set up his office in the conference centre rather than move to the newly designed government buildings in the city centre.	The change of use from residence to office was effected without difficulty.

 12 Bayan Palace, Kuwait, 1984-1986	
13 In 1997, I helped Sir George Martin convert a Victorian Church in north London to Air Studios, one of the finest sound recording studios in the world.  13 Air Studios	The change of use from church to recording studio was effected with much difficulty and ingenuity.
14 As part of the design for GUST, a new private university in Kuwait, the faculty were able to choose both their furniture and their office layout: thus coming close to fulfilling Weeks' ideas about furniture procurement. The design philosophy for the project embraced the concept of user control with sophisticated IT-based management of all environmental and media controls.	Illustrated the possibilities of handing over control and choice of local environmental conditions to users.

 14 Gulf University for Science and Technology,	
15 The re-use of buildings in Mexico, where I lived from 2009–2015, illustrated the extreme ingenuity of a people determined to make good use of every space at every time of the day. In a small town in central Mexico, the old courtyard villas are now art galleries, restaurants, offices, cafes, libraries, open markets, and shops of every kind. Some more humble spaces house two or even three distinct functions: a car wash during the day becomes a taco bar when night falls; a shop sells juices and muffins in the morning, candy and plastics all day, and puddings and gelatin in the evening.  15 San Miguel de Allende, Mexico	Changes of use readily achieved through small-scale spatial compatibilities.

Responding to the needs of institutional clients, whose patterns of growth and change placed unexpected demands upon the design of their buildings, led back to research work at University College, London into the growth, change and ageing of hospitals. Understanding how institutions change was a prerequisite of an appropriate planning and design response to projects like universities and hospitals that have featured over my fifty years of professional experience. The specific responses included making allowances for growth and connectivity and incorporating modular design to facilitate internal flexibility. In short, buildings needed to accommodate uncertainty. After more than fifty years of architectural practice, helping to design accurately around the requirements of demanding custodians (indeed, writing design guides and advocating new approaches to the establishment of user needs) (Cassidy, 1967; Cassidy & Darvill, 1967), it must be recorded as a significant epiphany that the author now seeks to build for the future and casts the initial custodian as a provider of space for the future.[3] The apparent conflict between the interests of the initial custodian and future custodians and users is to be overcome by designing to satisfy BOTH through the agency of Double-Design.

If all buildings can last longer, use fewer materials, minimize their carbon footprint, and facilitate internal change, custodians can indeed feel justifiably proud.

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[3] The epiphany can be traced to a point in time at which the absolute focus upon an individual project was replaced by the "big picture" which revealed individual projects in the context of wider environmental concerns.

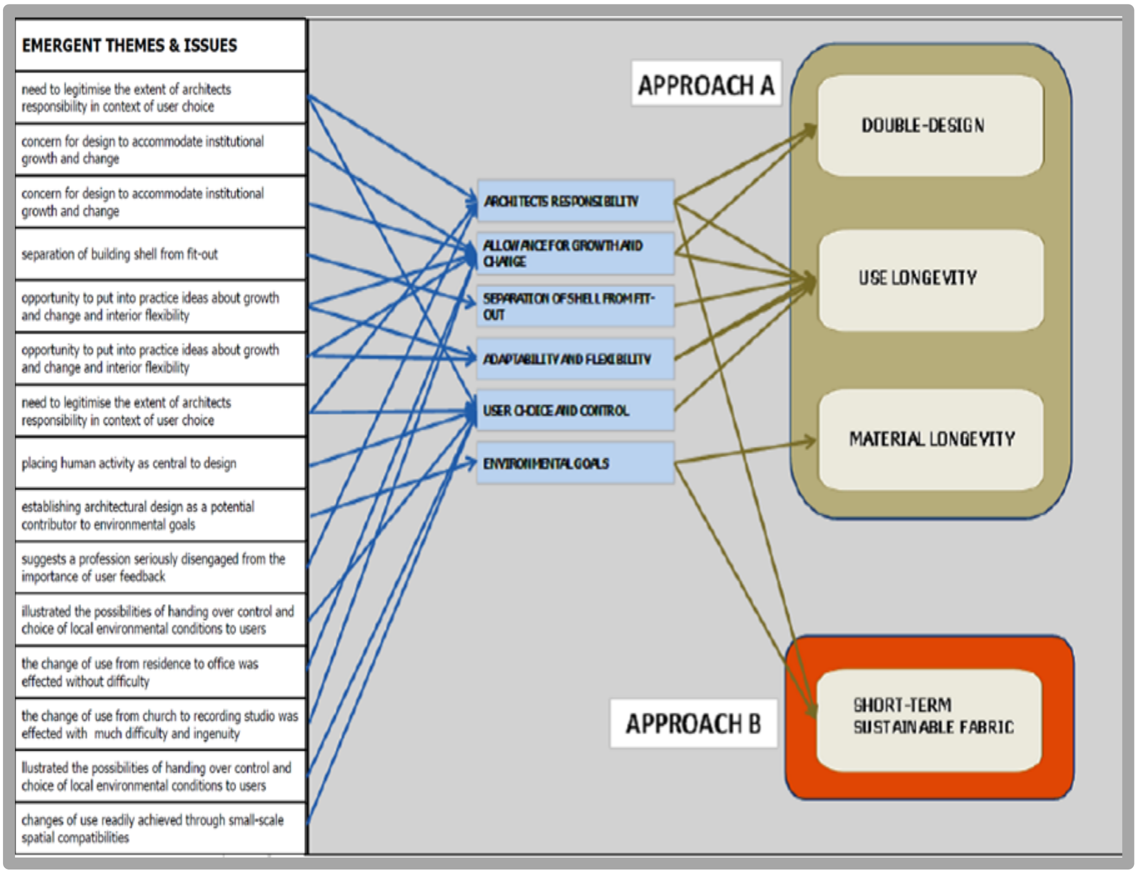

Figure 1.1 shows how the emergent themes have given rise to six major factors that lead to the central themes of this research:

- Architects responsibility
- Allowance for growth and change
- Separation of shell from fit-out
- Adaptability and flexibility
- User choice and control
- Environmental goals

The diagram distinguishes between approach “A,” which envisages Double-Design achieving use and material longevity, and approach “B,” in which some limited environmental goals may be achieved.[4] These approaches are developed below.

Consideration of the future is an essential element in the thesis. Design is, by definition, for the future. One of my earliest projects was Warwick University Science Buildings. Studying how this project has been used since 1966 presented an opportunity to examine how buildings respond to uncertainty.[5] This case study (Chapter Four below) helps to define the range of uncertainties to which buildings and their custodians must respond together with the range of interventions deployed to maintain a building physically and functionally.

Figure 1.2 indicates the broad structure of the thesis.

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[4] For example, in addition to using recyclable materials, periodic reuse also features in ‘Clarice’, a city which recycles relics. As the city declines, its survivors “grabbed everything that could be taken from where it was and put it in another place to serve a different use: brocade curtains ended up as sheets” (Calvino, 1997, pp. 106–107). Other examples of plunder are given in Appendix One.

[5] The interest of the author is limited here to the behaviour of the buildings and their occupants. The broader historical context is covered by Troiani & Carless: “Since 1998, UK universities have steadily been forced, because of the withdrawal of government funding, to focus on ‘academic capitalism’ to better compete in the global higher education marketplace…… rather than give greater democratic freedoms and powers through pedagogically enabled mobility to improve the status of all individuals, neoliberalism accentuates urban inequality and inaccessibility in the city and in nation states. The continuous upgrading cycle of university estates consumes local cultures” (Troiani & Carless, 2021a, p. 3).

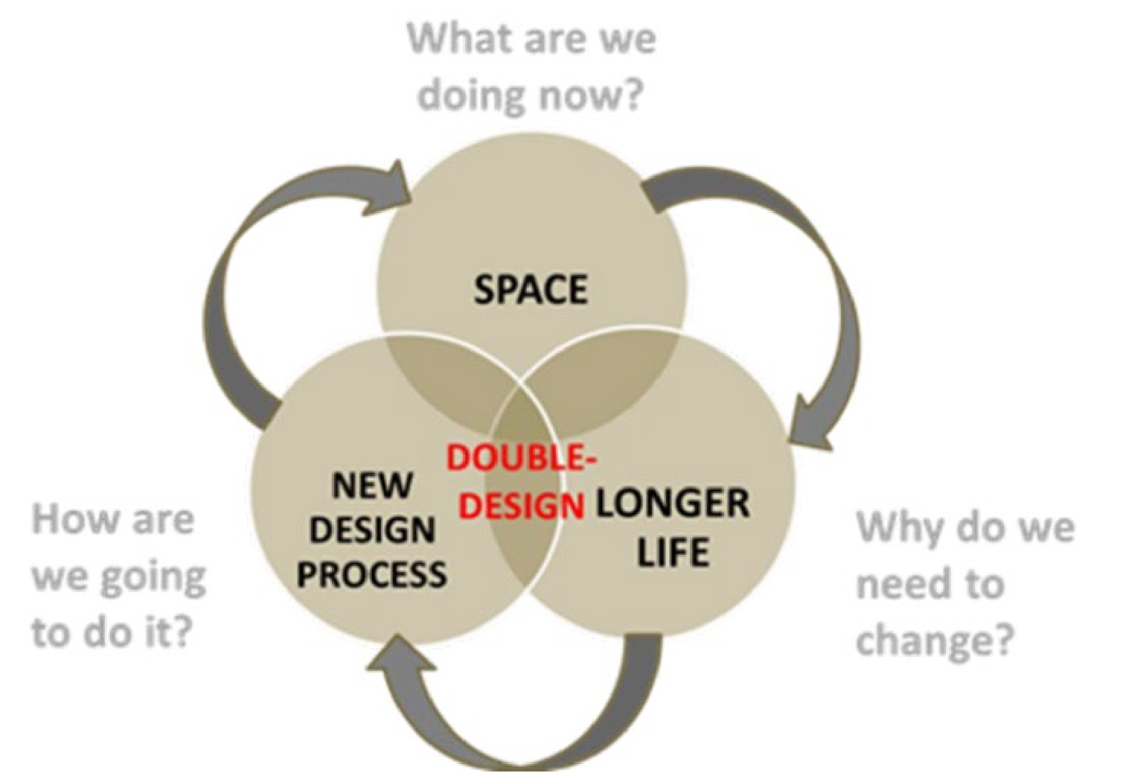

Figure 1.2 Describes the broad scope of the thesis with an examination of what is done now followed by an assessment of the need to change and a review of how change is to be achieved

CHAPTER TWO: AMBITION

I am not interested in erecting a building but in presenting to myself the foundations of all possible buildings (Ludwig Wittgenstein)[6]

The themes generated by the personal experiences described in Chapter One raise unresolved questions. The ambition of this exploration is to show how they can be resolved through the application of Double-Design. The implementation of Double-Design would affect the way design and building are undertaken in the future. The concept of Double-Design incorporates the advantages from making all buildings last longer in the context of fundamental changes of use. Extending the life and the usefulness of buildings requires a new approach to architectural design and construction. A new building would be required to respond to changes within its initial use and respond to future uses.

This exploration references the many academic fields contributing to design intelligence. There are research teams in many parts of the world examining aspects of these ideas, and the concept of Double-Design builds on these foundations. It offers a comprehensive approach to achieving the necessary changes and, over time, to improving and democratizing the building stock. Exploring the potential of the Double-Design concept could make a significant contribution to knowledge facilitating a shift in

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[6] This quotation is included here as it expresses the desire of the author to change the philosophical foundations of design for all buildings. The author first came across this quotation in an article in the New York Times (Hyde, 2008) but then found it had originally come from a book devoted to Wittgenstein's one house (Wijdeveld, 2000, p. 174), the story of which is illuminated by Sennett (Sennett, 2009, pp. 254–263) and intellectually dramatized by Last (Last, 1986).

the mind-set of architects and custodians that will lead to the design of long-lasting *and* fully functional buildings.

Reviewing underlying assumptions

In the light of the unanswered questions already identified, it is opportune to review the assumptions that have underpinned a built environment that has increasingly succumbed to the values of a capitalist economy. Architecture carries a banner for the values and needs of its custodians and finds itself out of touch when those values and needs change. With some ingenuity, the inherited estate may sometimes be turned to good use to serve the incoming requirements and the changing values they represent. Yet a strategic choice remains: is it better that new buildings should be designed and built for their initial purpose only, to be killed off, demolished, abandoned as soon as that purpose has run its course (Cairns & Jacobs, 2014), or should they be designed to last and to be used productively well beyond the first use so that architecture may serve more readily the changing needs of society over a more extended period? (Kincaid, 2002). Double-Design is envisaged as a response to the changing demands made upon architecture.

Amount and Nature of Space

The amount of space provided and the nature and quality of space contribute to society's social and economic life. To some degree, these aspects of space are connected. For example, providing additional space to give some flexibility and robustness affects the amount of space needing consideration. However, this thesis is primarily concerned with the nature of space and not with the appropriateness of the amount of space allocated to specific activities.[7]

Architecture and its use by society are interdependent, and the interaction between them is needed to understand how architecture can contribute to spatial robustness. The amount and nature of space change over time and are determined by what people do with their time. Fuller and McHale dramatize the changing quantities of "optionally investable time" (leisure) enjoyed by primitive man (three years out of eighteen years expected life), agricultural man (eight years out of thirty-five) and industrial man (twenty-seven years out of seventy) (Buckminster Fuller & McHale, 1963). As Cunningham observes:

> Time cannot be understood on its own. Its closest relationship is to space, for time is necessarily passed somewhere, in bed, at work, at home, in the pub and so on. The politics of time, particularly time for leisure, intermesh with those of space, for somewhere to spend it. Time is also bound up with class and the power relationships that go with it for the legitimacy of ways of spending time has never been free of legal, governmental and cultural constraints. (Cunningham, 2016, p. 5)

The changing demand for space is illustrated by the new building types introduced in the first three decades of the twentieth century: "New possibilities emerged as a result of technological developments, while social changes created new demands. Some buildings, especially of new types for new functions, were particularly appropriate to the age in which they were built; a number have remained highly relevant in the succeeding years. Above all, the twentieth century produced innovatory buildings" (Forsyth, 1982, p. 1). The 'new' building categories, requiring a response, included

[7] Holidaying in Greece, the author was shocked to come across vast shells of unfinished orthodox churches in the same neighbourhood as smaller finished churches, filled to overflowing. He discovered that local priests are responsible for assessing the size of congregation and for raising the funds to build the church. Thus priests are tested to come up with the best match between users and space!

motor racing circuits and garages, car parks, coach stations, airship hangars, airfields and airports, power stations, health centres, swimming pools and lidos, cinemas, film production studios, and broadcasting studios. An up-to-date version of Forsyth's book would include supermarkets, data hubs and distribution warehouses.[8] These examples demonstrate the need to regard change as an unending characteristic of human activity.

Approach and Methodology

Whether dictated by short-term economics or fashion, the unresolved questions already highlighted have not been addressed by the institutions and professions that could be expected to shoulder responsibility. Consolidating an answer to those questions would require:

- The adoption of design criteria for accommodating growth and change through flexibility and adaptability
- Designing buildings specifically to enable easy reuse for functions not originally envisaged
- Designing buildings with long physical life and the capacity to remain functionally effective for the whole of their physical life

The approach to finding the necessary answers to the questions starts with examining how buildings and people interact through the lifetime of a building, incorporating its conception, design, construction and use. This is covered philosophically in Chapter Three (Space, Society and Architecture) and in Chapter Four with a longitudinal case study examining the uncertainties faced by institutional custodians and users.

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[8] Or, as suggested by British Land, reported in The Guardian, all three: "This specific part of the market, where customer requirements are evolving rapidly and demand is strong but supply of the right kind of space is highly constrained, will require innovative solutions to increase density and repurpose space in central London" (Partridge, 2021).

It is recognized that the concepts explored in this thesis build upon the work of several academic and professional contributions. The extensive use of quotes throughout the thesis is an explicit and intentional method of archival research, allowing for a full appreciation of context to emerge from the juxtaposition of key excerpts.

Chapter Three describes the parallel operatic processes of structural degeneration and functional obsolescence that apply to materials and use. Innovative approaches to material robustness are being developed, in which “a structure that is robust could also be active, lean, adaptable, and error-correcting” (Tibbits, 2021, p. 58). Modern technology enables materials longevity targets to be set and achieved, so the accompanying challenge is to keep the building useful for as long as it lasts physically.

Chapter Four is focused upon the range of uncertainties encountered in the use of an institutional building as an indication of the need for design to allow for change as a central feature of building performance. Examination of an educational institution reveals how much of the use of buildings is influenced and sometimes controlled by factors wholly outside the original building brief. If architecture is to serve society, the awareness of such a wide range of influences must lead to a professional obligation to allow for uncertainty.

Chapter Five (Moving Forward) develops the specification for a new approach to design and explores supportive topics, including the classification of activities and the importance of user participation and control. Compatibility matrices identify which future uses could be compatible with which initial uses. Politically, Double-Design has to be seen as in the public interest, and its successful implementation is most likely to be achieved through legislation.

Chapter Six summarizes the positive responses of professionals to the invitation to comment on Double-Design. The impact of Double-Design is anticipated in Chapter

Seven (Implementation), and Chapter Eight offers conclusions and topics for future research. Appendices cover historical examples of building reuse, background data on building stock, a classification of interventions, current thinking about product design and suggestions for teaching the use of completed buildings, a schedule of use class orders with associated floor-to-floor heights and the detailed responses to invitations to comment on the ideas behind Double-Design.

Consequences of Double-Design

By designing from the start for future changes of use, the hypothesis is that fewer resources will be consumed over the life of the building and that there will be less waste of material and time. The prospect of designing and constructing buildings that can last physically for, say, 150 years or more gives rise to the question of whether they can continue to be used effectively over that period. As a result, there is a renewed interest in adaptability and flexibility as design concepts that will contribute to a *longevity of usefulness* to complement a *longevity of physical lifespan*. Some traditional forms of construction (stone and timber for example) may also facilitate long life. The alternative must also be considered. Can buildings be designed with intrinsically sustainable materials that do not need to last 150 years or more? The counter-argument to Double-Design is to deploy sustainable or recyclable materials and demolish/reuse them when structural degeneration or functional obsolescence kicks in. This approach would not achieve the smooth transition enabled by Double-Design from one use to another within a long-lasting space. It would rely upon comprehensive reconstruction to change use rather than upon interior adaptation, as with Double-Design. Indicative costs for buildings in use suggest that the longer-life options represent better value for money.

Implementing a design strategy that takes these themes into account will depend upon the political redefinition of the public interest to achieve high-level environmental standards. A simple definition of the public interest fulfils the needs of this argument. Meyerson and Banfield offer just such a definition; a decision "is said to be in the public interest if it serves the ends of the whole public rather than those of some sector of the public" (Meyerson & Banfield, 1955, p. 322). Despite their efforts to clarify five differing conceptions of the public interest, they recognize that any concrete manifestations of the public interest will inevitably attract controversy. This comes as no surprise at a time in which worldwide agendas claiming to espouse the public interest are promoted without any apparent political or scientific sanction.[9]

A redefinition of the public interest could suggest that custodians entrusted by society to build new spaces should have a duty to achieve high performance from their buildings. In this way, the public interest requirements would apply to all custodians so that development would take place on a level playing field. Moreover, buildings achieving long life and long usefulness would contribute to robustness and sustainability within the redefined public interest.

The public interest is already firmly embedded in health and safety and other regulatory legislation. However, while sustainability has been widely accepted as a legitimate societal goal, the space and longevity aspects of sustainability have been

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[9] For example, the World Economic Forum states that "The Forum strives in all its efforts to demonstrate entrepreneurship in the global public interest while upholding the highest standards of governance. Moral and intellectual integrity is at the heart of everything it does. Our activities are shaped by a unique institutional culture founded on the stakeholder theory, which asserts that an organization is accountable to all parts of society. The institution carefully blends and balances the best of many kinds of organizations, from both the public and private sectors, international organizations and academic institutions" (*World Economic Forum Mission Statement*, 2021).

largely ignored: the focus has been upon materials and energy use. Yet, extending the physical life of buildings and their usefulness for the whole of that extended life may help achieve real value for money, reduce waste, and speed up change from initial function to subsequent functions, as well as encouraging the active participation and engagement of users and custodians in the ongoing optimization of space-use over time.

There are many examples of beneficial reuse of all manner of buildings through the agency of refurbishment in all its forms. However, there are very few instances in which a building has been designed from the start to accommodate future, let alone unknown uses.

Most of the commentaries regarding architecture and its place in the world have been written from an exo-architectural perspective, from outside looking in, and in many cases, from the outside looking in and back. It has proved difficult for journalists, architectural historians, and even architects to make the long-term use of buildings as compelling to the public as an iconic image. If architecture is to be improved, it is by understanding better the endo-architectural processes, what happens within the design process itself. The contributions of research-orientated professionals directly involved in design are especially valuable in illuminating the inner workings of the design process (Duffy, 1992).

Studies of buildings in use are now more commonplace than before, yet the lessons learned have yet to be adopted systematically into everyday practice. As Cooper observes:

> After decades of neglect, a new research agenda is slowly emerging for POE [post-occupancy evaluation] in Britain. This agenda has at least three separable but intertwined strands:
>
> (1) POE as a 'design' aid – as a means of improving building procurement, particularly through 'feedforward' into briefing

> (2) POE as a 'management' aid – as a 'feed-back' method for measuring building performance, particularly in relation to organizational efficiency and business productivity
>
> (3) POE as a 'benchmarking' aid for sustainable development – for measuring progress in the transition towards sustainable production and consumption of the built environment. (Cooper, 2001, p. 161)

There needs to be less emphasis on the container and more on the contained. The unpredictability of human behaviour inhibits our understanding of how to design for what happens inside buildings. An appropriate response to this recognition gives rise to architecture as a potentially significant contributor to uncertainty management as an increasingly important goal of social policy.

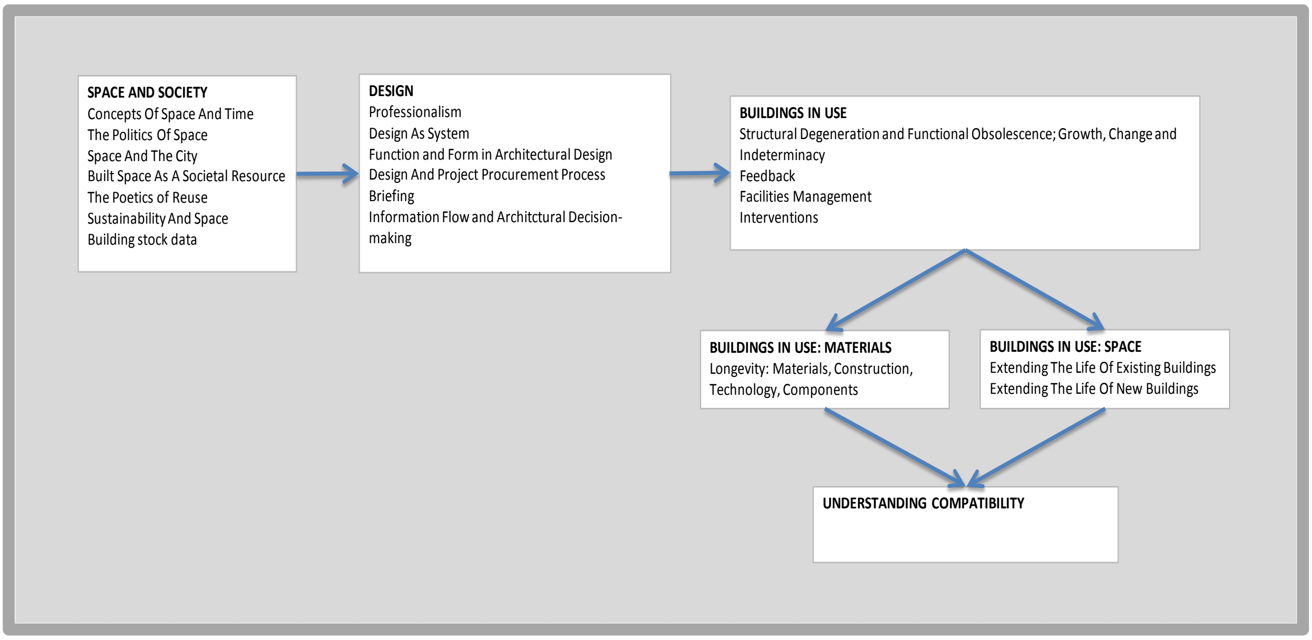
With very little guidance on briefing/programming for the future, there is an inevitable tendency to design tightly around a single use specified by the custodian. The commodification of buildings and products, even of professional services, has contributed to designing for the short term, at the lowest cost and to the lowest permissible standards. Less easily quantified design objectives, including the wellbeing and happiness of users, have been set aside.

Society is forced to rely upon ingenuity to change the use of buildings from the initial purpose. Kincaid asserts that it is now "no longer reasonable to assume that most new-build stock will remain within its original class of use" (Kincaid, 2002, p. 18). Ingenuity will still be needed to address changes in use in existing buildings but will be powerfully complemented by Double-Design, the principles of which can also apply to reusing existing buildings.

As part of the new design process, alternative building designs can be subjected to sophisticated evaluations to establish unprecedented physical performance levels. Inevitably, these techniques have focused upon readily measurable and reliably predictable factors. However, strategic functional issues relating to space itself and spatial responses to the uncertainties inevitably associated with building use have yet to be fully incorporated into the design process.

The focused awareness of the environmental characteristics of materials used for construction, together with the application of Double-Design, could lead to a radical shift in the provision of enclosed space. This shift could be achieved through developing Duffy's layers, in which different layers contributing to a complete building are kept apart to allow for their separate replacement. The long-lasting elements like structure would use the long-lasting materials, while interior fit-out could be made of recyclable or short-life materials.

CHAPTER THREE: SPACE, SOCIETY AND ARCHITECTURE



3.1 SPACE AND SOCIETY

3.1.1 Concepts of Space and Time

Space and time are central to what architecture is about. The enclosure of space and its use over time are essential ingredients of architecture. As a concept, Double-Design is relevant because architecture must be seen occupying time as well as space. Given the central importance of how activities inhabit space, it is important to see how time and space have been regarded. In the *Critique of Pure Reason*, Kant argues that our representations of time and space are *a priori* rather than empirical, that they are intuitions rather than concepts, and that they are mind-dependent, or ideal, rather than real (Bernecker, 2012). Kant states "It is therefore not merely possible or probable but indubitably certain that space and time, as the necessary conditions of all inner and outer experience, are merely subjective conditions of all our intuition" (Kant, 2007, p. 86). Kant believed that the concepts of space and time are integral to all human experience, as are our concepts of cause and effect (Warburton, 2011, p. 111).

Without an innate concept of space, we would literally have nowhere to go (Lemetyinen, 2012). This idea is echoed in Kelly's assessment of psychological space: "A person's processes are psychologically channelized by the way in which he anticipates events" (Shaw & Gaines, 1992, p. 46).

Borden and Rendell deploy history and critical theory to counter the inward looking and somewhat self-indulgent accounts of architecture "according to their own concerns" (Borden & Rendell, 2000, p. 4). Although the analytical lens of critical theory may take us too far from practice to have direct value, it does enable a fuller and more persuasive understanding of the context of architecture "challenged and constrained by a set of institutional practices that draw their power from as diverse a range of sources as capital and economics, national and municipal governments, dominant classes, smaller yet mobilized interest groups, territorialized zones and cultural conventions" (Borden & Rendell, 2000, p. 5). They argue that architecture is not diminished by "theorized interpretations but, conversely, is found once again and made richer, more significant to the world in general" (Borden & Rendell, 2000, p. 8). While it is undoubtedly within architecture that change will be needed, the understanding that will lead to change, and indeed guide it, will come from history, from theory and from political insight. The balance between duration and succession in the use of space is explored by Carr (Carr, 2017, p. 95).

Till draws attention to the occasional interdependence of architecture with philosophy, enjoying the negotiations between them while seeking a balance between theory and practice: architects have confused concepts of space with its representation. (Till, 2000, p. 284). Lefebvre pursues the concern about the relationship of space with activity:

> What is urgently required here is a clear distinction between an imagined or sought-after 'science of space' on the one hand and real knowledge of the production of space on the other. Such a knowledge, in contrast to the dissection, interpretations and representations of a would-be science of space, may be expected to rediscover time (and in the first place the time of production) in and through space. To picture space as a 'frame' or container into which nothing can be put unless it is smaller than the recipient, and to imagine that this container has no other purpose than to preserve what has been put in it – this is probably the initial error. […] Space may express function and thus present readable signs to everyone rather than being neutral. (Lefebvre, 1991, p.140)

Unnervingly, contemporary science adds a different perspective to the discussion of time and space: "Quantum superposition suggests that particles can exist in two separate locations at once" (Bennett, 2015). Rather than two entities being in two different places at the same time, Double-Design could have the effect of producing a capacity for two (or more) different uses in the same place but not necessarily at the same time.[10]

3.1.2 The Politics of Space

The idea that buildings can be designed for multiple future uses recognizes that the political, social and economic context of architecture changes over time. The distinction between place and space, together with the philosophical interdependence of space and time show that while the design process produces a fixed place, this place is the container for activities that are far from fixed and subject to varying degrees of uncertainty. The design process is, indeed, focused upon producing something spatial

[10] Nevertheless, the idea of "quantum architecture" would be especially attractive were it not already in use for the design of next-generation computers (*Advancing Quantum Architecture, Short Name: Aqua*, 2021).

that is finite at its time of inception and construction but, thereafter, subject to the exigencies of use and transformation. The dichotomy is that of a building as object, fixed in time, and of a building as a container of human activities that occupy time as well as place. This formulation finds echoes in de Certeau, for whom there is a contrast between strategies that relate to an already constructed place and tactics relating to the practices of everyday life within that structure. Thus strategies are interpreted in terms of space, and tactics in terms of time (de Certeau, 1984). The social interaction between people and space is considered by Foucault, who describes the emerging interdependence of space with political power:

> The house […] remains an undifferentiated space until the 18th century. There are rooms that can be used interchangeably for sleeping, eating or receiving guests. Then, little by little, space becomes specified and functional. A perfect illustration can be found in the development of working-class housing projects between the 1830's and 1870's [sic]. […] Spatial arrangements are also political and economic forms to be studied in detail. (Defert, 2008, p. 10)

Marxist critics regard space as a product of particular economic and social circumstances. Lefebvre asserts that space is distributed in accordance with the current distribution of power in society:

> The ruling class seeks to maintain its hegemony by all available means, and knowledge is one such means. The connection between knowledge (savoir) and power is thus made manifest, although this in no way interdicts a critical and subversive form of knowledge (connaissance); on the contrary, it points up the antagonism between a knowledge which serves power and a form of knowing which refuses to acknowledge power. (Lefebvre, 1991, p. 10)

As Olivier explains:

> Several theorists furnish one with the means to understand these ways in which humans are spatially orientated, or – as Merleau-Ponty might say – "intervolved" with space. Henri Lefebvre, for example, has formulated a tripartite typology of historically and socially "produced" space that disabuses one of the idea that space is always "just there" in monotonously homogeneous form. In a manner that reminds one of Kant's 18th-century description of space and time as "forms of intuition" that (together with the categories of the understanding, such as causality) constitute human "reality", Lefebvre regards space as nothing passively given, but, on the contrary, as actively "produced" by human beings. (Olivier, 2012)

In Lefebvre's scheme of things, political forces are obliged to produce their own space and those that do not do so are discounted. This fails to take account of the question whether a space changes with its use. He cites the Paris student's protests of 1968, claiming that the students changed the space but only temporarily allowing the closed nature of overall social space to be preserved for the elite. (Lefebvre, 1991, p. 56).

An observer as acute as Lefebvre should recognize that it is not inevitable that the reuse of space for a use not originally intended is going to be, in his words, inappropriate. He really should be able to see a little further into the future and understand how the reuse of space can help redress or change the allocation of space to suit future distributions of power. The application of Double-Design would change the capacity of the built environment to accommodate necessary changes. However, the application could not determine that the changes were for the better.

Architectural space is an indicator of the distribution of power. The responsibility for commissioning new space or for refurbishing and re-using existing space reflects a particular distribution of economic and social power that happens to obtain at a given time. Over time, this distribution of power will change and the physical environment that is to serve the future will need to follow suit. This process will be helped if the environment commissioned to meet the present perceived needs includes provision for future change. Does this threaten the architect's professional neutrality? That architects choose to undertake some work and not other work simply confirms that there is no neutrality.

As Pallasmaa argues:

> An awareness of the social and political implications of architecture arose in Finland during the 60s and this was reflected in the values of the architectural profession; instead of the traditionally impartial role of the architect as a trusted expert, he/she was seen as an active participant in the allocation of collective resources. Excessive personal expression was viewed critically and judged regressive. (Pallasmaa, 2000, p.97)

The theory of architectural place and space is further developed by the phenomenological analysis of Norberg-Schulz: "it is practical to distinguish between space and character. Similar spatial organizations may possess very different characters according to the concrete treatment of the space-defining elements (the boundary) […] On the other hand it has to be pointed out that the spatial organization puts certain limits to characterization, and that the two concepts are interdependent" (Norberg-Schulz, 1976, p. 418).

Echoing Merleau-Ponty, he goes on to assert that "Human identity presupposes the identity of place" (Norberg-Schulz, 1976, p. 419). Further, "man cannot be understood in isolation from his 'environment' […] our understanding of the world is always related to man" (Norberg-Schulz, 1979, p. 35). The significance of place and our interdependence with the physical environment must be clearly recognized. Yet the transitional nature of the activities that occupy the spaces, coupled with the uncertainty and risk of everyday experience, support the need for the symbolic certainty afforded by the solidity of architecture (Callon, 1984) (Takacs, 2011), and go some way to explain the reverence afforded to buildings (Lowenthal, 2015).

The political context of space is well understood by Massey, who sees space very much as a social product contributing to the multiplicity of simultaneous activities. She draws attention to the importance of the unfinished nature of space (Massey, 2009).

3.1.3 Space and the City

The interactive relationship between spaces available and activities that need to be accommodated plays an important part in determining the effectiveness and continuing success of human enterprise (Cassidy, 1970). This applies as much to an individual family as to institutions and corporations. The design of the new stock, together with the capacity of the surviving stock to accommodate changing needs, will influence every aspect of social and economic growth. The design of an individual building as well as the reuse of an existing building have to be seen as contributing to the totality of building stock (Batty, 2013) (Sevtsuk, 2011). New buildings, existing buildings and reused existing buildings contribute to the building stock. Hence, changes to each of these categories will affect the overall stock.

Buildings are replaced over time. Despite the suggestion that the city is going to benefit from the additions of some kinds of spaces more than others, there does not seem to have been any attempt to ensure that this message gets through to those with the power to commission new space. The market-driven decentralized commissioning process relies upon the custodians and their architects to take into account the potential contribution that space can make to future activities. There are currently no incentives for custodians to look beyond their immediate and known requirements when starting a new project. Michael Batty, looking at the city as a phenomenon susceptible to scientific analysis, views design as "embedded in networks of those who have a stake in a problem, and the process of generating new designs as one of communicating and resolving conflicts between different views of the future" (Batty, 2013, p. 302). Society's needs for resource conservation are, nevertheless, disconnected from the custodians who are in a position to address those needs.

It is at the level of the city and its infrastructure that sustainably robust development will be important in the future. Such development will be the aggregate of individual design projects. Unless these individual elements are robust, they cannot be expected to contribute to a robust whole (Sevtsuk, 2011). Sevtsuk suggests reasons for interest in improving the design for growth and change at the level of the city:

- To accommodate the expansion of global cities
- To satisfy demand for the systematic redevelopment of existing urban areas
- To allow for the innovations that are changing the balance between labour- and capital-intensive activities

(Sevtsuk, 2011, p. 4)

Buildings are commissioned, designed, built and occupied in response to a need that is identified by an entity with sufficient energy, competence, influence and finance to make it happen. The resulting built space is added to the existing stock. No matter what the initial intention may have been, this process is underpinned by a purely morphological sequence of relationships which provides the spatial context, the stage, upon which human behaviour and activity take place. In helping towards the greater longevity of buildings, Double-Design must be seen as an enabling mechanism, avoiding the dangers that arise when design is specific to one set of requirements. Double-Design will contribute to the resilient city. As Coaffee & Lee suggest: "Urban resilience provides an operational framework for reducing the multiple risks faced by cities and communities, ensuring there are appropriate levels of resources and capacities to mitigate, prepare for, respond to and recover from a range of shocks and stresses" (Coaffee & Lee, 2016, p. 3). Emphasis must be placed upon designing an environment that is open, permissive and non-constraining. The nature of activities therefore needs to be addressed and this is considered below in section 5.1.3.

3.1.4 Built Space as a Societal Resource

The built environment comes about through a complex mechanism of decision-making within a legal framework of land ownership and control. Since development takes place over time, at any given time there will be buildings of many different ages and buildings at many different points along their life-cycles. The significant prolongation of the life of buildings by the application of Double-Design will affect the overall profile of the building stock.

3.1.5 The Poetics of Reuse

Although this thesis examines an approach to design that is inevitably applicable to the future, there are lessons to be learned from looking back, lessons not limited to the specifics of feedback on the performance of individual buildings. The context for any such lessons is set by Lowenthal:

> We efface traces of tradition to assert our autonomy and expunge our errors, but the past inheres in all we do and think. Residues of bygone lives and locales ceaselessly enrich and inhibit our own. Awareness of things past comes less from fact-finding than from feeling time's impact on traits and traces, words and deeds of both our precursors and ourselves. To know we are ephemeral lessees of age-old hopes and dreams that have animated generations of endeavour secures our place-now to rejoice, now to regret-in the scheme of things. (Lowenthal, 2015, p. 1)

Having elaborated the many ways in which the past has been regarded, with nostalgia, with contempt, with aversion and affection, Lowenthal seems reluctant to embrace fully the significance of reusing the past to solve practical problems of today. The merit of reusing existing buildings is certainly not limited to their 'cultural and historic' value but is often the result of hard-nosed practicality; found to be cheaper and quicker than new-build. He argues, instead, that: "Without adaptive reuse most artefacts and memories would soon perish; altering records and relics to present-day purposes prolongs their existence. […] only what later eras can appropriate has a chance of survival" (Lowenthal, 2015, p. 514).

He draws attention to the largely regressive impact of 'heritage' as a theme underlying preservation and conservation: "the world's most imposing monuments were built in a bad cause" (Lowenthal, 2015, p. 588). It is the intention of Double-Design to have a *progressive* effect to the extent that it will achieve or at least contribute to the democratization of space. While this research focuses upon the practical value of designing for future change, it is important to recognize the extraordinary impact that buildings have upon the imagination and values of successive civilizations. It would be wrong to leave the discussion of the ubiquitous and operatic themes of functional and material change experienced by buildings without a brief review of how such changes have been recorded, regarded and interpreted. The way the past is regarded has a significant effect upon the propensity to value some inherited buildings rather than others and to be overprotective of buildings just because they are old. Preservation has been called a 'dangerous epidemic' by Koolhaas and over-zealous conservationists have given rise to many problems for custodians and their architects (OMA/AMO, 2010).[11] Many buildings are re-used, as noted above. But to make the best of the spaces we already have there needs to be a change in mind-set that encourages pragmatism unencumbered by nostalgia for the past. The acceptability of reusing spaces will need to increase if more buildings are designed specifically for reuse. If the nostalgia is to be neutralized, the satisfactions derived from it and elaborated by Lowenthal will need to find another outlet. Although the ways in which the past is used are covered comprehensively by Lowenthal, he omits reference to the simple and practical reuse of inherited space. Lowenthal describes: "past fulfilments under the terms familiarity; guidance; communion; affirmation; identity; possession; enhancement; and escape. No boundaries delimit these desiderata, and their benefits often dovetail. A sense of identity also enriches; familiarity provides guidance. Revival-style building simultaneously justifies the present and suggests a refuge from it" (Lowenthal, 2015, p. 86). Buildings throughout history have been subject to reuse, their material has been subject to plunder for reuse and recycling. Examples of these processes are given in Appendix One.

3.1.6 Sustainability and Space

The Oxford online dictionary suggests for sustainability: "the ability to be maintained at a certain rate or level", while the main definition of robust is "strong and healthy; vigorous". Subsidiary meanings are:

1 (of an object) sturdy in construction, and

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[11] The author's own attempts to extend a tiny non-listed barn are testament to this phenomenon.

2 (of a system, organization, etc.) able to withstand or overcome adverse conditions: Uncompromising and forceful.

Applied to a building, the concept of robustness usefully incorporates aspects of construction [1 above] with an ability to adapt to change [2 above]. The addition of spatial emphasizes the relevance to building design (Oxford, 2018; Bentley et al., 1985).

The Brundtland Report states that:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs. (Brundtland, 1987, p. 1)

The physical built environment is one of the most significant arenas for the interaction of human activity with environment. Architecture needs to be more effective and sustainable, yet the environmental sustainability debate has focused upon the material and energy-consumption consequences of design rather than upon the nature of the space that is being provided and the extent to which future generations of building users should be able to adapt and expand the spaces to suit their priorities (Loftness et al., 1994; Baker, 2009; Cotgrave & Riley, 2013).

Among the fifteen principles to guide action to achieve environmental sustainability, Morelli includes: "design for re-usability and recyclability" and "design (or redesign, as appropriate) manufacturing and business processes as closed-loop systems, reducing emissions and waste to zero" (Morelli, 2011, p. 6).

The response to the Brundtland report has given rise to studies of the process by which a transition can be made towards a sustainable future. The developing field of sustainability transition starts from the premise that long-term compatibility of economic and environmental sustainability can be established (Markard et al., 2012) (Twomey & Gaziulusoy, 2011).

Given the importance of environmental sustainability, it is surprising that the assumptions that underpin architectural design have not been examined more critically. Professional practice is based upon a contractual relationship between a specific custodian and the architect. However, much of the design and the completed building and the way it is built are determined by regulations imposed upon the process in the public interest to protect the safety and health of the users and of society at large (Imrie & Street, 2011). For the built environment to make the greatest possible contribution to sustainability, it is necessary to look beyond the interests of the initial custodian and users and to set out the clear aim of achieving a built environment that is durable, flexible and adaptable, and sustainable. In short, an environment that is more robust (Langston, 2014). As Robinson has asserted, "sustainability is necessarily a political act, not a scientific concept" (Robinson, 2004, p. 382). Till has described the context for modern architecture in dramatic terms:

> The founding principles of design as defined in the modern project are, at best, challenged by the climate emergency, at worst made irrelevant by it. By the modern project, I mean the project of the past two centuries that is defined by the principles of *progress, growth, order and reason.* […] The climate crisis fundamentally disrupts the value system and with it the cultures and identities, on which design has thus far been founded […]The climate emergency presents not so much new opportunities, but a radically new set of demands and conditions, which bring with them radically new social contexts which need design to think through them. (Till, 2020, p. 4)

Briefly developing this theme, Till looks at *design before project* and *design after project*, the latter sounding very much like Double-Design.

Despite the widespread recognition of the environmental importance of sustainability and a wealth of literature arising from the general interest in sustainability, specific references to space are rarely comprehensive and frequently vague. The United Nations Conference on the Human Environment was an international conference convened under United Nations auspices held in Stockholm, Sweden, from June 5–16, 1972. It was the UN's first major conference on international environmental issues and marked a turning point in developing international environmental politics. The Greater London Council commissioned a report on the implications for London of the UN conference, carrying forward the discussion. Background papers covered the ecological context of development, population growth, the price of technology and the use of resources. Although the report by the GLC led directly, within the council, to the establishment of comprehensive energy-saving and recycling policies, the impact on building design was limited to the recommendation that "the architectural profession should instigate further research into the design of homes which could be easily expanded or contracted according to the changing needs of the occupants" (Greater London Council, 1975). Since the 1980s, sustainability has been used more in the sense of human sustainability on planet Earth, and this has resulted in the most widely quoted definition of sustainability as a part of the concept "sustainable development", that of the Brundtland Commission of the United Nations on March 20, 1987: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, 1).

As Mulligan argues:

> The 1987 publication [...] proved to be a turning point in giving the word sustainability the meaning it now carries globally. The Brundtland Report firmly established the principle that the challenge to achieve sustainability involves an interplay between environmental and social factors. The convening of the Stockholm conference, in turn, reflected the steady growth of global awareness about global 'limits' which is often attributed to the fact that people living in the 1960s saw, for the first time, images of our rather lonely looking blue planet taken from circling spaceships. A number of organisations began to use the word 'sustainability' during the 1970s; however the Brundtland Report must be given credit for making the word popular and for articulating its key implications. (Mulligan, 2014, p. 1)

The UN Reports from the 1980s are strong on general goals and weak on detail with no reference to space or design. The thrust of early texts on sustainability is summarized by Loftness et al: "sustainable design offers architecture of long term value through 'forgiving' and modifiable building systems, life-cycle instead of least-cost investments, and 'cherishable' delight and craftsmanship." The revitalization and reuse of buildings are seen as contributing to "more sustainable", together with "loose-fit and forgiving" (Loftness et al., 2011, p. 29). They continue: "Sustainable design is a collective process whereby the built environment achieves new levels of ecological balance in new and retrofit construction, towards the long term viability and humanization of architecture" (Loftness et al., 2011, p.29). Even the otherwise encyclopaedic BRE documentation, which is intended to provide comprehensive guidance on benchmarking building design for sustainability, is very short on detail. However, Figure 3.1, taken from BRE, does suggest design measures allowing for future adaptation.

	Accessibility	Spatial adaptability	Expandability
Fabric and structure: – External walls – Cladding – Ground and first floor – Roof	Use of products or systems which allow easy replacements	Location of structural components within the floor space	Provision to add extensions or alterations to increase building capacity
Core and local services: – Mechanical and electrical – Plumbing – Stairs and lifts – Fire	Inclusion of facilities management requirements and construction design management feedback for future operational needs.		Provision of capacity in infrastructure to enable future expansion and adaptation
Interior design: – Finishes – Floors – Interior walls – Connections	Use of products or systems which allow easy replacements.	– Layout in standardised grids – Use of inherent finishes to allow replacement – Use of standardised material sizes	– Identifying or recognising potential future functional requirements – Efficient use of space to allow for any increase in occupancy

Figure 3.1 Design measures allowing future adaptation (BRE, 2018)[Table 10.13 from BRE, SD5078: BREEAM UK New Construction 2018 (BRE, 2018), 273.]

Handbooks for the achievement of sustainability have very little to say about space, focusing more on building form and orientation[12] and their impact on energy efficiency. Considering the choice of refurbishment versus new build, Baker asserts: "initially, the environmental impact of refurbishment will almost always be less than demolition and new build. This is because all the materials carry embodied energy. Furthermore, the demolition process and waste disposal creates carbon emissions as well as other waste disposal impacts" (Baker, 2009, p. 3).

As Cotgrave and Riley argue: "It seems very logical to assume that, by its very nature, the process of refurbishment is more sustainable than that of a new building and, to an extent, this is true [...] retaining and remodelling of existing facilities and buildings reduces the amount of new construction work that is required" (Cotgrave & Riley, 2013, p. 95).

In their review of work on sustainability indicators, Singh et al. report on several assessment methods that reference cities, but these are usually concerning resource use and pollution. The potential contribution of space to sustainability is implied through references to the city, energy and other resource consumption, and human comfort rather than identified clearly in its own right (Singh et al., 2009). Dahl alerts us to the difficulties of developing valid indicators of sustainability, especially ones that are inclusive of values (Dahl, 2012). The principles of sustainability are, however, incompatible with the consumerism demanded by the forces of globalization. Nowhere

[12] This is not to diminish the value of looking carefully at orientation as a significant design factor: for a large institutional project in Kuwait, the author showed that 16% of energy could be saved through the optimum choice of orientation.

is this incompatibility clearer than in the field of the built environment, in which proponents of sustainability are set against those who seek to support the commodification of buildings and the associated deregulation of control.

This thesis is concerned primarily with enclosed space, with buildings and their use. Buildings are intended to fulfil a function, to accommodate specific activities. The activities themselves may or may not contribute to sustainability. When it comes to the additional, that is, the non-functional, contribution that spatial considerations can make towards sustainability, there are four principle components:

1. The amount of space: since the provision, enclosure and production of space imply the use of resources, the smaller the space, the fewer resources will be required. This goes to the heart of understanding whether the allocation of space is appropriate to needs or fair in a wider social and political context.[13]
2. What the space is made of: how we provide space, together with how we use it and reuse it over time, will affect the deployment of resources.
3. How it is arranged: the provision of space in buildings influences the development of cities and their supporting infrastructure, which, in turn, affects resource use.
4. The service demands that buildings make in terms of flows, for example, of energy, air and water.

Moore and Rydin set out the position of sustainable construction in the context of broader international concern for sustainability:

> The term 'sustainable construction' is used to cover techniques of construction alongside matters of development and urban design. It can encompass community and accessibility concerns alongside more strictly environmental concerns. Thus, sustainable construction envelops both technological shifts in terms of the production process (e.g. materials, on-site energy use and waste reduction), as well as cultural and behavioural adaptations towards the types of

[13] The basis for establishing what is an appropriate amount of space for an activity is a subject for future research.

buildings or environments produced as outputs (i.e., eco-homes, carbon-neutral buildings, sustainable communities, etc.). (Moore & Rydin, 2008, pp. 233–234)

They draw attention to a bifurcation "between a technical/industry agenda and an aspirational and generalized urban planning agenda" (Moore & Rydin, 2008, p. 240).

Loftness et al. provide a comprehensive framework for the understanding of the scope of environmental performance: (Loftness et al., 2005, p. 197). Figure 3.2 refers.

	Physiological needs	Psychological needs	Sociological needs	Economic needs
Performance criteria specific to certain human senses, in the integrated system				
1. Spatial	Ergonomic comfort Handicap access Functional servicing	Habitability Beauty, calm, Excitement, view	Way-finding, functional adjacencies	Space conservation
2. Thermal	No numbness, frost-Bite; no drowsiness, heat stroke	Healthy plants, Sense of warmth, Individual control	Flexibility to dress the custom with . . .	Energy conservation
3. Air Quality	Air purity; no lung problems, no rashes, cancers	Healthy plants, not closed in, stuffy No synthetics	No irritation from neighbours Smoke, smells	Energy conservation
4. Acoustic	No hearing damage, Music enjoyment Speech clarity	Quiet, soothing; activity, excitement 'alive'	Privacy, communication	
5. Visual	No glare, good task illumination, way-finding, no fatigue	Orientation, cheerfulness, calm, intimate, spacious, alive	Status of window, daylit office 'Sense of territory'	Energy conservation
6. Building Integrity	Fire safety; structural strength plus stability; weather-tightness, no out-gassing	Durability, sense of stability Image	Status/appearance Quality of constant 'Craftsmanship'	Material/labour conservation
Performance criteria general to all human senses, in the integrated system				
	Physical comfort Health	Psychological comfort Mental health	Privacy Security	Space conservation Material conservation
	Safety Functional Appropriateness	Psychological safety Aesthetics Delight	Community Image/status	Time conservation Energy conservation Money/investment Conservation

Figure 3.2 sets out the dimensions for the comprehensive assessment of building performance; from (Loftness et al., 2005, p. 197)

Loftness et al. set out the context for performance improvement:

Investment in high-performance, sustainable building design and technologies is limited by first-cost decision-making. Environmental designers often argue for broad sustainability objectives without further detail, as expressed in the AIA/UIA declaration of Interdependence for a Sustainable Future "Sustainable design integrates consideration of resource and energy efficiency, healthy buildings, ecologically and socially sensitive land-use, and an aesthetic sensitivity that inspires, affirms and ennobles." However, investors and clients will need to

> understand the specific quality differences of sustainable design alternatives – component by component – if they are to move beyond least-first-cost decision-making. (Loftness et al., 2011, p. 13)

As Loftness et al. continue:

> Studies have demonstrated that modest 2–4 per cent cost increases can achieve Silver and Gold level LEED certification, ensuring improvements for sustainability with short term cost paybacks. While invaluable arguments for introducing sustainability, these modest cost increases are locking architects and engineers out of true quality improvements in a wide range of building materials, components and systems that are critical to ensuring: indoor air quality, thermal control, lighting control, network access, privacy and interaction, ergonomics, and access to the natural environment. (Loftness et al., 2011, p. 14)

The strength of their study is in showing how the benefits of high-performance buildings extend well beyond the short-term financial and, even, beyond the conventional life-cycle cost analysis:

> 1. First Cost/Mortgage Savings through Quality Packages Integrated System Savings over Individual Components Quality and Modularity with JIT Purchasing over Redundancy
>
> 2. Facilities Management Cost Savings Maintenance, Repair, Energy, Water, other Utilities, Cost of Discomfort, Failure costs, employee retention and training
>
> 3. Individual Productivity Cost Savings: (skill-based, rule-based, knowledge-based jobs) Speed and Accuracy, Effectiveness, Creativity, Motivation, Absenteeism
>
> 4. Organizational Productivity Cost Savings: Profit, Time to Market, Customer Attraction and Retention, Recognition and Publicity, Continuous Work Flow, Real Estate Effectiveness, Team/Multi-disciplinary Creativity
>
> 5. Attraction/Retention or Turnover Cost Savings: Time and Cost to Attract, Quality Attracted, Training Costs, Retention Rates
>
> 6. Tax/Code/Insurance/Litigation Cost-Savings Utility & Tax Incentives, Tax Depreciation, Code Compliance, Insurance & Litigation Costs
>
> 7. Health Cost Savings: Workman's Compensation, Medical Insurance Costs, Health Litigation Costs, Environmental Evaluation & Remediation, Lost Work Time
>
> 8. Spatial Renewability Cost Savings Organizational Churn Labour and material costs for reconfiguring workstations and workgroups, HVAC/lighting/networking system modification costs, occupant down-time
>
> 9. Technological Renewability Cost Savings: Technological Churn Networking: data/power/voice change, hardware/software change, training/mentoring costs, organizational/workspace and environmental/conditioning response costs
>
> 10. Salvage/Waste Cost Savings Organizational, Technological, Environmental Modifications, Activity related waste, Aging & Wear, Obsolescence, Salvage Value. (Loftness et al., 2011, p. 15)

Their comprehensive review of case studies in support of each of the categories subject to enhanced performance concludes:

> Sustainable design is a collective process whereby the built environment achieves new levels of ecological balance in new and retrofit construction, towards the long term viability and humanization of architecture…sustainable design merges the natural, minimum resource conditioning solutions of the past (daylight, solar heat and natural ventilation) with the innovative technologies of the present, into an integrated "intelligent" system that supports individual control with expert negotiation for resource consciousness. Sustainable design rediscovers the social, environmental and technical values of pedestrian, mixed-use communities, fully using existing infrastructures, including "main streets" and small town planning principles, and recapturing indoor-outdoor relationships. Sustainable design introduces benign, non-polluting materials and assemblies with lower embodied and operating energy requirements, and higher durability and recyclability. Finally, sustainable design offers architecture of long term value through 'forgiving' and modifiable building systems, achieved through life-cycle instead of least-cost investments, and through timeless delight and craftsmanship. (Loftness et al., 2011, p. 29)

Although the work stops short of forecasting the enhanced building life that would accrue from adopting all the high-performance characteristics outlined, the comprehensive range of innovations and their demonstrated value to the users and custodians of buildings are indicative of the scope for change in building performance.

Moffat and Russell recognize the importance of government responsibility in the achievement of sustainability together with the role of adaptability:

> If adaptability is embraced in public or private policy, it may be necessary to relate adaptability to basic principles of sustainable development, such as stewardship and intergenerational equity. From this perspective, the responsibility of the designer or developer is to meet the client's needs and expectations without compromising those of future building owners and users. A design team that is committed to sustainable, environmentally sound building needs to take the extra effort to identify opportunities for enhancing adaptability and to estimate the related cost and environmental advantages. (Moffatt & Russell, 2001, p. 7)

There are substantial problems arising from the demolition of buildings, and extending their useful lives will have unexpected and possibly quantifiable benefits.

Construction and demolition waste (C&DW) accounts for about 33% of the total generated waste in Europe (Eurostat, 2016) and has therefore a high importance from both a waste management and a resource efficiency perspective (Pacheco-Torgal et al., 2013). Reusing C&DW materials has the twofold effect of avoiding the landfill of inert materials and reducing the use of non-renewable natural resources (Vieira and Pereira, 2015). Thus, C&DW has been identified by the European Commission as a priority stream (European Commission DG ENV, 2011) due to the large amount generated and the high potential for re-use and recycling (*Geospatial-Characterization-of-Building-Material-Stocks_2017_Resources--Cons.Pdf*, 2017.)

In this light, it is not surprising that the Luxembourg National Research Fund has supported the development of a framework for the characterization of building material stocks and the assessment of the potential environmental impact associated with the end-of-life of buildings at the urban scale to support decisions on waste management strategies.

The potential contribution of construction to a sustainable future has been argued by governments, interest groups and private institutions. In late 2019, the World Green Building Council introduced its important report on climate change as follows:

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> The built environment sector has a vital role to play in responding to the climate emergency. With buildings currently responsible for 39% of global carbon emissions, decarbonising the sector is one of the most cost effective ways to mitigate the worst effects of climate breakdown.
>
> In 2018, in line with the ambitions of the Paris Agreement and to accelerate the built environment sector towards a 1.5ºC pathway, World Green Building Council (WorldGBC) launched the Net Zero Carbon Buildings Commitment. Our aim was to inspire and promote advanced climate leadership focused on achieving net zero **operational carbon** at individual building level and at mass scale from businesses and government. Yet operational carbon emissions are only part of the story.
>
> The urgent need to go further and faster requires a new response and a new vision for our sector. This vision sees a highly connected value chain radically reducing both embodied and operational carbon, improving wider lifecycle environmental impacts, and contributing as effectively as possible to the UN Sustainable Development Goals. To achieve our vision, we must take urgent action to tackle upfront carbon while designing with whole life carbon in mind. We have set timeframes for our vision in response to global climate goals and demonstrating the level of ambition needed. (WGBC, 2019, p. 7)

Thus it is argued that "decarbonising the sector is one of the most cost-effective ways to mitigate the worst effects of climate breakdown" (WGBC,2019, p. 7). Setting aside the climate-change deniers, critics still argue that the assumptions made about climate change and its effective mitigation through improved design need to be re-examined. Mahdavi accepts the proposition from the Intergovernmental Panel on Climate Change (IPCC) (also supported by WGBC above) that "the ramifications of environmentally relevant developments and phenomena (energy and resource depletion, climate change) for people and the planet are likely to be disastrous and irreversible". But he expresses doubts as to whether "buildings have a considerable role in causing and hence also in effectively counteracting such developments". He also questions whether "building performance simulation represents an essential instrument for mitigating buildings' environmentally relevant impact" (Mahdavi, 2020, p. 28).

He seeks evidence that the building sector can contribute as much as stated and, more specifically, whether building performance simulation can make a difference.

He asks: "is there empirical evidence suggesting that it actually has a unique and significant impact on buildings' long-term environmentally relevant performance?" Finally, he identifies several potential weaknesses in the validity of simulation models:

- Oversimplification of factors
- Lack of integration of simulation models within overall design process models
- Lack of expertise in the use of models
- Uncertainty relating to assumptions on input variables

Mahdavi seeks to explain these difficulties and, indeed, to try to overcome them, with reference to the importance of what users of buildings actually do. Data-driven models that do not take into consideration the range of behaviours observed are intrinsically incomplete. He summarizes his analysis of these weaknesses as follows:

> Providing simulation results in terms of single values is not automatically fallacious, if such results are not meant to imply accurate predictions of future circumstances but are used, for example, to gauge designs against applicable benchmarks or compare different designs. Provision of uncertainty ranges of computed values of performance indicators can be highly useful (even necessary) but should be derived from statistically processed actual observational data in the relevant domain. (Mahdavi, 2020, p. 29)

It is also possible to view the simulation models used in evaluating alternative designs as one among many choosing techniques. For example, the scoring of weighted criteria that may be agreed by all parties to a design process has often been used as an aid to decision making (*Guidance Stage 5: Options Appraisal*, 2017).[14] Mahdavi does not argue that buildings do not contribute to environmental problems but that the mitigation of such problems makes a minimal contribution to the overall problems. He concludes: "The building sector's share of negative global environmental impact is large. However, in the face of boundary conditions – pertaining mostly – to population growth and lifestyle issues, improved building design and operation strategies have comparatively a rather limited potential toward effective reduction of global environmental impact" (Mahdavi, 2020, p. 8).

He nevertheless makes it clear that "it does not take the services of a world simulation platform to figure out that problems we evade tend to remain unresolved, and may well turn into hopeless ones – if they have not already" (Mahdavi, 2020, p. 8).

Placing a particular contribution, however small, in the context of global-scale issues may represent a negative, even depressing and challenging, narrative. An alternative

[14] Option appraisals have been used for many years as a way to help choose amongst alternative policy options, for example, in the NHS, and to select from alternative designs at an early stage in order to develop the selected option in more detail. Such rational and semi-rational processes in no way guarantee a good, or even a rational, outcome. An option for a headquarters building in Kuwait was chosen as the one that allowed the chairman to have an office overlooking the sea.

interpretation would be to recognize that anything that can be done should be done. Hence, within each professional or policy domain, there needs to be action researched and initiated if the accumulated effects are to be consistent with survival.

In their review of decision-making where environmental factors are important, Gulch & Baumann suggest that the custodians:

> Must have access to information about the consequences of selecting each alternative and be able to combine this information with the expected utility, which in turn discounts or weighs outcomes by the probability of their occurrence. This implies that the behaviour of the 'economic man' in neoclassical economic theory is always rational. However, descriptive decision-making studies […] have shown that individuals do not make rational decisions, especially when uncertainty is involved because of complex and long-term consequences, which is typical for environmental decision making. […] These limitations entail that tools based on the neoclassical theoretical paradigm will always be beset with severe shortcomings concerning their use in handling environmental aspects. (Gluch & Baumann, 2004, pp. 572–573)

There are four inherent limitations in neoclassical economic theory that restricts its use in an environmental context:

- It cannot handle decision-making under genuine uncertainty since it assumes that the decision-maker is always rational and has access to complete information concerning alternatives and outcomes.
- It assumes that alternatives are always available. With such a view, irreversible changes, such as the extinction of species, are not considered a problem since they can be 'replaced' without changing the ecosystem.
- It ignores items that have no owner, such as the natural environment.
- It over-simplifies multi-dimensional environmental problems, assuming that everything can be expressed as a one-dimensional unit, such as monetary figures.

The United Nations Agenda 21 goals for sustainability are not universally supported. Research based upon the achievement of goals that were later abandoned, for whatever reason, could scarcely be regarded as objective and robust. Research that seeks to deal with the reality of the political world would find a more secure starting point if there were a clear consensus.

Dickson provides an account of the concerns about Agenda 21:

While the name might sound a bit ominous, Agenda 21 is a voluntary action plan that offers suggestions for sustainable ways local, state and national governments can combat poverty and pollution and conserve natural resources in the 21st century. 178 governments – including the U.S. led by then-President George H. W. Bush – voted to adopt the program, which is, again, not legally binding in any way, at the 1992 U.N. Conference on Environment and Development in Rio de Janeiro. According to Caitlin Dickson:

> It wasn't long after Agenda 21 was introduced that right-wing opposition began to swirl. The SPLC (Southern Poverty Law Center), points to Tom DeWeese as one of the first to pounce on the U.N. plan. In 1998 DeWeese founded the American Policy Center, a group based in Remington, Va., that focuses on "environmental policy and its effect on private property rights" and "the United Nations and its effect on American national sovereignty." The SPLC report quotes DeWeese as describing Agenda 21 as a "blueprint to turn your community into a little soviet," promoted by non-governmental organizations that pressure governments to enforce it. According to DeWeese, "It all means locking away land, resources, higher prices, sacrifice and shortages and is based on the age old socialist scheme of redistribution of wealth."
>
> As recently as 2012, the SPLC writes, the Republican National Committee's platform included the line, "We strongly reject the U.N. Agenda 21 as erosive of American sovereignty." (Dickson, 2017, p. 2)

To be sure, not all of Agenda 21's opponents are on the right of the political spectrum. The group Democrats Against U.N. Agenda 21 hosted a conference on the plan in California in 2011. Its founder wrote the book *Behind the Green Mask: U.N. Agenda 21,* (Koire, 2011) which claims the plan will ultimately lead to the U.S.'s economic demise.

While the American right is concerned about the invasive power of the state, Koire argues that the increased density of settlements necessary to achieve Agenda 21 will lead to the intentional de-settlement of rural areas.

Reverting to the operatic themes of building degeneration and functional obsolescence, it is clear that while simulation may have something useful to say about the former, related to more or less predictable physical conditions and material, it will have a great deal less to contribute to modelling the latter, dominated as it is by the exigencies and uncertainties of human activity. In seeking to optimize the comparison of different design options with respect to both these grand themes, it may be necessary to reconcile the deployment of Bayesian inference (for the building degeneration theme) (Menberg et al., 2019) with less scientific decision-making including experience and judgement (for the functional obsolescence theme) (Flyvbjerg, 2004).

In coming to an understanding of 'sustainability' as an operable and meaningful concept, Schroeder argues:

> A multiplicity of architectural practices in response to sustainability has emerged. These pluralistic practices can be characterized by "'disagreement about design priorities, the role of technology, the importance of aesthetics, the relationship of natural and built environment and the degree of optimism and pessimism that the current state of sustainable architectural practice should invoke.'" […] I argue that it is important to shift attention to the ways in which sustainability becomes transformed and displaced (that is, translation) within specific practices targeted at materialization. (Schroeder, 2018, p. 3)

This leads him to "a pragmatic approach by shifting attention from buildings themselves to the design practices that are making buildings" (Schroeder, 2018, p. 3). Thus encouraged, the steps in the non-linear design process need to be looked at afresh, attention being "shifted from buildings themselves to the practices that assemble buildings" (Schroeder, 2018, p. 3). He concludes his review of sustainability in action as follows:

> Those using the adjective 'sustainable' in connection with a newly created building seek to assign it a particular status quo, a form of black-boxing: sustainability 'achieved' and 'materialized'. I argue that architectural practitioners should actively engage in debates on how and how far sustainability can be translated into particular design tasks and settings. I suggest that it is necessary to step back, eliminate the adjective 'sustainable' when describing practices and artefacts, and instead think about how to give the concept meaning – about how it is enacted – in design practice. To face the controversies over how to address sustainability seems a more promising approach than to pretend that there is no divergent opinion about it (Schroeder, 2018, p. 13).

With doubt about both the meaning and the realizability of sustainability, the question arises as to whether it can legitimately be regarded as an appropriate design goal. Yet sustainability is intrinsically logical and encompassed within even broader and more self-evidently reasonable goals like 'avoiding waste' and 'protecting nature'. Confronted by the conflicting claims regarding the appropriate action to take on environmental problems, it is helpful to seek some higher-level definitions of the problem, some heuristics that may be less contaminated by warring and opportunistic political positions. All too often, however, the wisdom and common sense readily available have been watered down to a 'lowest common denominator' by the processes of political expediency. For example, the UNESCO Declaration of Ethical Principles concerning Climate Change promises "ethical principles of decision-making, policy formulation, and other actions related to climate change, but goes on to list anodyne and unenforceable principles " (UNESCO. General Conference; Records of the General Conference, 39th Session, Paris, 2017). The analysis of Huutoniemi and Willamo provides more profound insight into this field. They suggest that neither reductionism nor holism provides an adequate framework within which to work:

> Neither approach, however, provides analytical tools to understand or deal with complexity as an emergent and variable property of an open system, resulting from intricate interactions amongst multiple components which are not necessarily complex in themselves. […] Since complex systems cannot be defined conclusively – indeed, there is no stepping outside complexity – all holistic descriptions of human–environment interaction are based on a model of this interaction, which necessarily reduces the complexity of the systems. There is no objective way to do this reduction; instead, a series of choices behind particular approximations of the whole is needed with respect to how to define the system, what system functions and outcomes are important, what measures to take to make things better, and what is considered an improvement. (Huutoniemi & Willamo, 2014, p. 25)

As they argue: "operating at a systemic level increases the likelihood of finding 'leverage points' that enable radical intervention in problems instead of mere incremental improvement" (Huutoniemi & Willamo, 2014, p. 27). The difficulties encountered in searching for effective points of intervention are described by Meadows, who recognizes the limitations of systems approaches and how the actual consequences of an action may be counter-intuitive (Meadows, 1999). Considering systemic approaches to thinking about the environment, Huutoniemi and Willamo suggest that:

> Different approaches offer different heuristics for defining problems and finding solutions, but the richer our heuristic repertoire is, the higher our capacity to deal with complex problems is. […] Outward thinking might serve as a cognitive strategy for shifting across approaches, and particularly for environmental sciences to move closer to the humanities without losing sight of the causal accounts provided by the reductionist method. (Huutoniemi & Willamo, 2014, p. 28)

Searching for a more general level of meaning is interpreted here as looking for a set of goals that are not contaminated by controversy and scientific dispute but, instead, stands as innate and, to some degree, self-evident. Struck by the difficulties observed in defining environmental problems in a way that is independent of their social and political context, Huutoniemi and Willamo:

> Propose a heuristic tool for identifying and categorizing human-induced environmental changes. This tool uses ecological interaction at the interface between human systems and natural systems as its starting point and focuses on the direct influences of the former on the latter. The idea is that we can conceptualize all environmental problems as resulting from either a discharge from human systems to ecological systems or an intake from ecological systems to human systems. 'Discharges' and 'intakes' are anything that matter in ecological terms. […] Overall, the heuristics ensure that institutionalized categories and forms of analysis are not mechanically applied in sustainability problem solving, which clearly requires entirely new ways of thought and action. (Huutoniemi & Willamo, 2014, p. 45)

Varma provides an approach to practical and understandable high level ethics:

> In order to save the earth and natural environment, we should follow some guidelines at species, ecosystem and personal or individual levels. […] The eco-centric worldview states that the earth resources are limited and belong to all the species that exist in nature. Though humans have right to draw their requirements from the environment but certainly not the extent that degrades the environment and harms other species and living beings. No doubt, the success and healthy economy of mankind depends upon the healthy environment. It realizes that: 1. Existence of Nature is not only for humans but for all living beings. 2. Development should be inclusive incorporating the welfare of all living creatures. 3. Our economic growth should encourage the earthsustaining development. 4. The earth resources are limited and have to meet the needs of all. 5. A healthy economy depends upon healthy environment. (Varma, 2017, pp. 7–8)

In the light of concerns for resources and waste, Long: "proposes that a purposeful Design for Adaptability and Disassembly (DFAD) approach to the design of new buildings – which incorporates principles of Design for Future Adaptive Reuse (DFAR) and Design for Disassembly and Deconstruction (DfD) – is equally important to the reuse of existing buildings in achieving built environment sustainability" (Long, 2014, p. 1).

The reconciliation between environmental goals and economic growth continues to receive attention. While Regan and others have sought an intrinsic value basis for environmental actions, others like Beder have been comfortable describing how commercial enterprises have accommodated to the "green challenge" with varying degrees of cunning (Regan, 2013, Beder, 2013). Given the unresolved nature of these efforts to produce unchallenged guidance for environmental action, it may be necessary to pursue a course of axiological ethics that recognize that:

> It is through emotions and feelings that human beings discern values. The notion of right action is understood derivatively in terms of the values which emotions reveal. Axiology is the philosophical study of goodness, or value, in the widest sense of these terms. It may be used as the collective term for ethics and aesthetics – philosophical fields that depend crucially on notions of value – or the foundation for these fields, and thus similar to value theory and meta-ethics. (Axiology, 2021)

Significant contributions to the underlying philosophies supporting the pursuit of environmental principles include Permilovskiy (2012), Petersen (2007) and Curry (2011). Mosquin and Rowe establish an acceptable and persuasive position in their Earth Manifesto: "Beyond conscious experience, every person embodies an intelligence, an innate wisdom of the body that, without conscious thought, suits it to participate as a symbiotic part of terrestrial ecosystems. Comprehension of the ecological reality that people are Earthlings, shifts the centre of values away from the homocentric to the ecocentric, from *Homo sapiens* to Planet Earth" (Mosquin & Rowe, 2004, p. 5).

As Flyvbjerg has observed, there is no need to assume that natural science will or should provide logical answers to environmental problems. Once values, essentially human ethical propositions, are accepted as a basis for decisions, it is easier to see a way forward (Mendie & Eyo, 2016). From another perspective, the exploration of Double-Design suggests that its implementation will lead to achieving some politically stated goals. Yet, the consequences of Double-Design may also be shown to be generated and sanctioned by the underlying values espoused by an axiological ethical position on the environment.

3.1.7 Building Stock Data

The construction sector is important within the UK economy. The highly durable products that construction provides add significantly to the wealth of the nation. More than three-quarters of the nation's stock of its vital capital assets are the products of construction. These total £3,620 billion, about half of which are houses that provide shelter, security, and a sense of community for households and a critical source of wealth. (Clark & Johnston, 2013, p. 4). Measured by the economic value it adds (gross value added) for the National Accounts, construction's contribution to the UK economy in 2018 amounted to about £116.3 billion, equating to 6.1% of total gross domestic product (Clark & Johnston, 2013, p. 8).

The current stock of buildings reflects the distribution of power within society and as Kincaid reports, the rate of change is slow: "in any one year, no more than 4% of the national building stock will be in the process of physical change, the rest being subject to routine maintenance and minor modification" (Kincaid, 2002, p. 3). Changes in demand for space over time are indicated by changes in the economy shown in Figure 3.3.

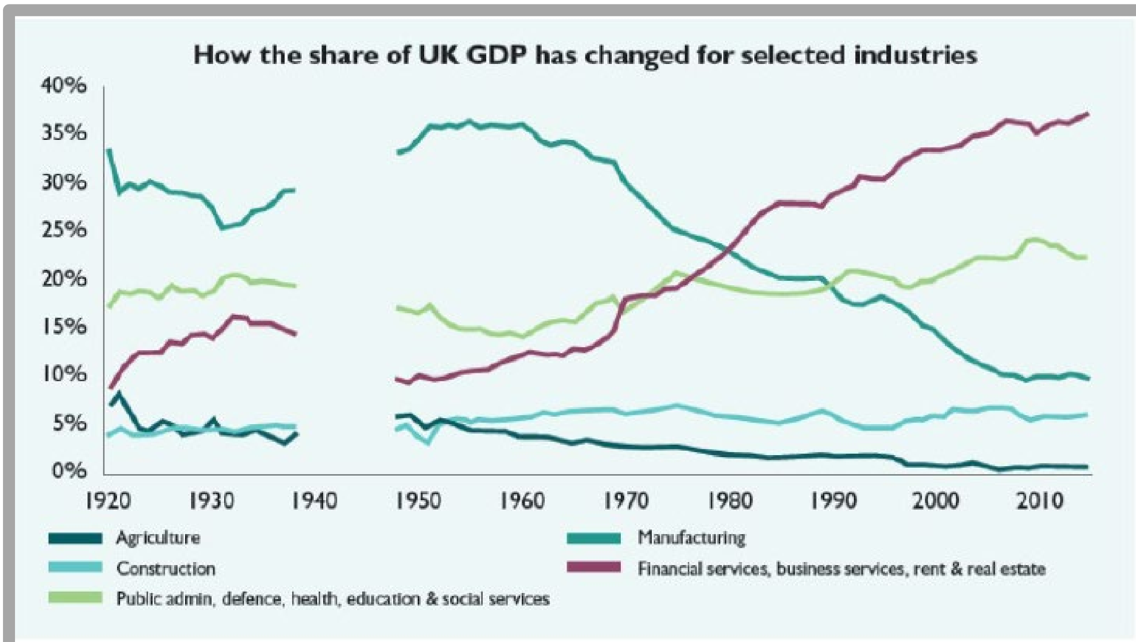

Figure 3.3 Changes in the contribution of different sectors to UK GDP illustrate the dramatic shifts to which the built environment must respond: from (Green,2020, p. 8).

The extent to which land-uses change to accommodate these shifts is also an important part of the context for this study. The dynamism of change is illustrated by the land-use change tables published by the government for England. For 2013–14, 13,387 Ha of developed uses changed to other developed uses. This represented nearly 50 per cent of the developed and non-developed land that change to developed uses. For 2014–15, the quantity increased to 14,721 Ha while the percentage dropped to 40. This suggests that there were changes of use amounting to 36.6 Ha per day in 2013–14 and 40.3 Ha per day in 2014–15. (*Live Tables on Land Use Change Statistics – GOV.UK*, 2015, table 350). The division between new-build and repair and between public and private sector investment is illustrated in Figure 3.4.

	PUBLIC SECTOR	PRIVATE SECTOR	REPAIR +MAINTENANCE	TOTAL
2006	13450	61863	51141	126454
2016	22255	77012	52808	152075

Figure 3.4 VALUE OF CONSTRUCTION, UK, 2016 £M: from (*Output in the Construction Industry*, 2018, Tables 2.4a, 2.4b)

Output from the global construction industry is expected to rise to $12.7 trillion in 2022, up from $10.6 trillion in 2017. However, despite this promising outlook, the industry has gained only 1% of productivity due to a lack of digitization in the last 20 years. This creates an opportunity to add $1.6 trillion by innovating in this area (Raconteur, 2019).

Further details of the background data are provided in Appendix Two.

3.2 DESIGN

3.2.1 Professionalism

The design process must be fully understood if it is to be improved as a mechanism for society to manage uncertainty. This is the case whether decision-making for design assumes rationality (Simon, 1972), acknowledges complexity (Webber & Rittel, 1973) or relies upon regulatory prescription (RIBA, 2013).

The relationship between a profession and the public it serves relies upon the acceptance by the public that the profession will base its design decisions upon predictable consequences. The architectural professions twin responsibilities are described by Spector, who says: "individual members of society require someone to construct buildings that presumably accord with their needs, and the public at large requires someone to protect it from the potentially devastating effects of poor and insensitive building practices" (Spector, 2001, p. 6). Architecture may play a comfortable part in a contractarian, cooperative model of society or simply serve an occupational elite asserting itself for its own gain (Larson, 1977). In either case, the position of architecture is undermined by its inability to deliver desired outcomes reliably. The adoption of Double-Design, seen as a response to uncertainty and therefore not with any particular expectation of accurately predicted outcomes, would reinforce architecture's contribution to the co-operative model by establishing a new balance between the interests of individual custodians and the wider interests of society at large.

Kaye observes that: "prior to the reformation, the professional occupations were concerned with the relationship between men and god: those that grew up before the industrial revolution with that between men and men and those that came after with that between men and machines" (Kaye, 1960, p. 12).

This prescient observation brings into play the question of what supports or sanctions professional conduct and activity and, hence, the role of science in society. Whitehead states that: "the culmination of science completely inverted the roles of custom and intelligence in the older professions. By this inversion professional institutions have acquired an international life. Each such institution practices within its own nation, but its sources of life are world-wide […] loyalties stretch beyond sovereign states" (Whitehead, 1933, p. 77).

Further, as Jones claims: "insofar as professionals can explain what they are doing they can transfer their responsibilities to information machines" (Jones, 1970, p. 25). Koolhaas observes that the Harvard Design School Project on the City began as a response to the 'pervasive' condition of architectural practice in which the architect is asked to intervene in but never to understand a given situation. As Chung et al. explain:

> An architect's interests are ultimately determined by a series of random encounters with projects and clients that do not allow an independent investigation of issues or conditions outside their field of vision. Thus architects

> operate with ulterior motives. The capacity for analysis, research or investigation is simply not within their repertoire. It is therefore, becoming increasingly important for architects to operate on a level independent of any architecture in order to understand the phenomena affecting the development of architecture and the city. (Chung et al., 2002)

A rare example in which architects were enabled to stand back and study before designing is provided by the work of the Nuffield Trust on hospital architecture in the 1950s (NUFFIELD TRUST, 1955). In 1975, in the skirmishing that led up to the abandonment of mandatory fee scales in the UK, Hillman observed that: "the professions have for too long shielded themselves behind the cloak of self or client interest" (Hillman, 1975, p. 129). Mandatory fee scales were changed in 1978 despite evidence that clients overwhelmingly supported them. The RIBA journal in 1977 had argued that "the public are now demanding higher design standards and insisting on greater regard for the environment and for the interest of users" (*RIBA Journal*, 1977, p. 821).

While sympathetic towards Massey and Harvey's political analyses, Double-Design is intended to achieve interventions that will be beneficial to future custodians and users, whoever they turn out to be Harvey, 1996). The long-term value of an increasing percentage of built space incorporating flexibility and adaptability cannot be overlooked.

The professionalism of architects encourages neutrality towards the custodians of new space. In the UK, the Architect's Code states: "You should, when acting between parties or giving advice, exercise impartial and independent professional judgment." (*The Architects Code: Standards of Professional Conduct and Practice*, 2017, Clause 6.4, p. 9). But the outcome of what architects do is very far from neutral. De Graaf has described recent changes to architecture's ideological aims: "The moment has arrived where architecture and marketing become indistinguishable […] Architecture is now a tool of capital, complicit in a purpose antithetical to its erstwhile ideological endeavour" (De Graaf, 2015, p. 10).[15]

In considering the advantages arising from the application of Double-Design, future spaces would be better matched with whoever was there needing them. The 'professional' ethic required a response to custodians of whatever kind turn out to be sanctioned by society. The difficulty with this position is that since the design is invariably for the future, there is an automatically established relationship between the 'now' team (custodians and designers) and the 'future' team (custodians and users). There is an implicit requirement to clarify the relationship between architect and custodian and how it will need to change with the implementation of Double-Design.

3.2.2 Design as System

Systems theory firmly establishes the connections between the purposes, stages and processes of human systems (Churchman, 1968). Commissioning, designing, and building are components of a complex human system (Rittel & Webber, 1973). Human sciences are not susceptible to the same kind of rules as the physical sciences, which makes it challenging to make confident predictions about the interaction of people with the spaces they use (Flyvbjerg, 2001). This, in turn, ensures that uncertainty is and

[15] An example will illustrate the contrast between an environmentally logical approach to architecture and the corruption of that logic brought about by the commodification of design and construction. The separation of layers advocated by Duffy and others suggests that building services should always be accessible to facilitate replacement, maintenance and repair. Designing a hotel for a major international company, the author proposed access panels to achieve the necessary separation between services and structure. The company, however, decided that it was cheaper not to provide any access panels but to rip out walls to get access to services if and only if there was a problem.

always must be a central feature of the context for design. Double-Design is envisaged as a valuable tool in helping to accommodate uncertainty. In the analogous fields of engineering design, where risks may be catastrophic, redundancy is an essential component in managing risk and uncertainty (Downer, 2009). Indeed, as Emery remarks, "redundancy is essential for adaptiveness" (Emery, 1977, p.23).

As Ciao observes:

> The nature of design, as a wicked problem, determines that it does not have an objectively persistent goal. Although the design process is a reasoning process of searching for solutions to meet given goals, the goals are evolving as the solutions are. It is not uncommon for designers to find themselves in a situation of a negotiation between goals and solutions and making changes to each site in order to meet the other. (Ciao, 2002, p. 3)

With application to the extended life of buildings discussed in this paper, the iterative nature of the design process can be seen to be stretched to incorporate significant changes of use over very long periods. Experience confirms that design solutions found for one problem are sometimes, with serendipity, found to solve others (Posen et al., 2018a).

In seeking to develop a social theory of architecture, McGuire and Schiffer suggest that: "architectural design is a process whereby social groups make choices concerning several recurrent sets of activities" (McGuire & Schiffer, 1983, p.278). This anthropological perspective highlights the differentiation of users from custodians and suggests that the symbolic attributes required of architecture, over and above the functional, increase with social differentiation. The analysis by Gero and Kannengiesser of the inner workings of the design process confirms the dynamism required to move from a static "situated" starting realm towards a preferred state. The information upon which the designer depends to help on this journey may be part of the situation, *given* by the constraints within the context, or *taken* by proactive importation. (This issue is covered in more detail in section 3.2.6 below). For Double-Design to be adopted within a design process, it must either be part of the context, imposed by regulations like health and safety requirements or imported by the custodian and the design team. To the extent that Double-Design may not be in the short term interests of the custodian, it may need to be imposed as representing the public interest (Gero & Kannengiesser, 2004).

3.2.3 Function and Form in Architectural Design

> *"I suppose a room is the summation of all that has happened inside it". "Yes, I think it is," agreed the Count. "And though I'm not exactly sure what has come of all the intermingling in this particular room, I am fairly certain that the world has been a better place because of it."* (Towles, 2016, p. 331)

Pursuing form ahead of function in much contemporary architecture ignores the importance of architecture as a servant of human activities**.** In particular, the value of flexibility and the capacity for growth has not been systematically incorporated into briefing processes or into the criteria used in testing alternative designs. Programming is a fundamental part of the design process and suggests a philosophical and professional position in which "form follows function" unambiguously. Factors that are important at the briefing stage will also appear in the evaluation of design alternatives at later stages of the process.

Traditionally, the production of architecture has been seen as a one-off event, as the creation of an object rather than an enabling container, with no follow-up or ongoing responsibility for the design team after completion. With increasing awareness of environmental concerns and faced with the design of complex institutional buildings like hospitals and universities, several innovative ideas were launched in the 1960s. The mantra of "long life, loose-fit, low energy" was promoted by the President of the RIBA (Gordon, 1972), supported by articles and examples by Weeks and Cowan (Weeks, 1960; Cowan, 1962). The issues raised included designing for growth and change, the life expectancy of buildings, the interactive nature of buildings in use, and building energy consumption. Whilst these ideas failed to find a permanent foothold in all design practices, they have renewed significance with current environmental concerns. It is an opportune time to revisit these ideas and see if new design guidance is needed (Lifschutz, 2017). In the context of sustainability, the *amount* of space "needed" as well as its *longevity* are essential factors for architectural design (Park, 2017). It can be argued that the pursuit of environmental goals could lead to a conflict between minimizing space to save resources and increasing space to provide robustness and contingency. The reconciliation of this dilemma seems likely to dominate spatial research for some time to come.

As Moffatt & Russell note:

> Part of the problem is that few buildings exist today that have been intentionally designed for adaptability, and put to the test of time. Traditionally many designers and owners have preferred to work from the assumption that their buildings will never experience significant change. But even when the inevitability of change is fully appreciated, the marketplace offers little incentive for developers and owners to invest in long-term adaptability. The initial developer who invests in a more adaptable building structure is unlikely to ever realize the economic benefits. For these reasons there are few older buildings purposefully designed for adaptability, and thus little evidence that adaptability is an effective design principle for improving environmental performance. (Moffatt & Russell, 2001, p. 3)

Architecture is nothing without people to commission it, use it, experience it, and manage it: each interested party brings to bear unique expectations and experiences. So it is small wonder that getting hold of reliable predictions of performance, and subsequent measures of achieved performance, is hard when the very notion of performance, let alone its measurement, may not be shared by any of these groups or by their architectural teams.

If Double-Design is to be fully implemented, the time dimension has to be central to the commissioning of buildings. As well as forming part of the evaluation/testing of new designs, the themes of change and growth and re-use must play a much more critical role in the briefing for new buildings and in evaluating the suitability for reusing existing buildings.

Communication between clients and design professionals needs to be improved if this future perspective is to be covered. This can be helped by articulating project goals and objectives and, simultaneously, protecting the uncertainty that is legitimately present when alternative design solutions are tested against future possibilities.

Whilst there are general recommendations and guidance on the need to incorporate change and growth in briefing and design, there is no coherent method available. There is not even a professionally agreed vocabulary for describing the steps in the interaction between buildings and users that might help clarify the key points at which decisions are made.

Building Information Modelling, while encouraging efficient coordination amongst the custodian players, does not address the more fundamental questions that have been raised in this research (Eastman et al., 2008). Hillier, pioneering the development of analytical tools, expresses shock that architectural discourse had become schismatic:

> There are, it seems, now two distinct traditions in architectural discourse: a critical tradition, which is concerned first and foremost with the changing form of buildings, sometimes confining itself to the superficies of style, but at its best attending carefully to the systematics of spatial and morphological form; and a research tradition which studiously avoids the issue of form, and addresses itself almost exclusively to matters of function, in the belief, it would appear, that function is scientifically tractable whereas form is not. […] But surely the schism is bizarre. How can there be a useful theory of building function unless it either incorporates or relates to a theory of the architectural malleability of form. Similarly, how can there be a theory of architectural form independent of a theory of the functional logistics of form. For both the scientist and the architect it is the essence of his discipline that the two issues are aspects of a single question: what is it about architectural form that works? (Hillier et al., 1984, p. 61)

Architectural media have focused almost exclusively upon architecture as object. Public attention is diverted away from buildings in use and away from their evaluation and re-evaluation over time. As Pallasmaa argues, full cultural appreciation of architecture requires experience rather than exposure to image alone: "buildings attempt to conquer the foreground rather than to create a supportive background for action and perception" (Pallasmaa, 2007, pp.102-103). Salama and Salingaros continue the argument:

> Architects still believe that they are eligible to use the act of building [...] for personal exploration and expression. Yet, it has produced fragmented and illegible urbanism. Therefore, one can argue that, in generic terms, while some architects manage individual buildings well enough, the overall built environment is increasingly mismanaged. (Salama & Salingaros, 2007, pp.114–31)

Millais also attacks the claims of some modern architecture and is especially damning about many of the attempts by architects to justify their work with specious philosophical references (Millais, 2009).

While an allowance for user participation may help to humanize the experience of architectural space, it may also be necessary to dramatize and symbolize the differentiation of urban forms. Hillier's important question is a reminder that the demands made of architecture go beyond the "purely functional" and must include other forms of satisfaction (de Botton, 2007). The application of "Double-Design" must not preclude the experienced pleasures that attend an architecture of variation (Spuybroek, 2009) as well as an architecture of eccentric intervention (Maudlin & Vellinga, 2014). As Vischer suggests, in seeking to develop a user-centred theory of the built environment, psychological comfort is included in the rating of how well the built environment performs as well as physical comfort and functional comfort (Vischer, 2008).

Theories about interaction with the physical environment are not comprehensive. Perhaps that is just as well. After all, if the effects of designs on human behaviour could be predicted reliably, it would amount to social engineering, and designers would be roundly criticized for exercising too much control. However, it is the very promise of predictability that makes it of interest to the social scientist. "What makes the interventions interesting is man's ability to predict the consequences. This places upon man a responsibility which is biologically unique" (Proshansky, 1970, p. 28). But caution is advised: "Valid conclusions about the direct influence of the inanimate environment upon human feeling, thought and action demand that very careful distinction be made between spontaneous and contrived or coerced behaviour" (Merleau-Ponty, 2002, p. 214). Indeed, the caution may need to extend to the very nature of perception itself. As Merleau-Ponty says: "in this transaction between the subject of sensation and the sensible, it cannot be held that one acts while the other suffers the action, or that one confers significance on the other. Apart from the probing of my eye or my hand, and before my body synchronizes with it, the sensible is nothing but a vague beckoning" (Seamon, 2010, 149). What is of significance here is the need to consider environmental experience as a whole. We experience spaces and their environment as a whole. The amount of space surrounding us, the amount of light and air are felt like one. In seeking measures for the environmental impact of new motorways in London, the combined impact of several factors was difficult to assess. Scientists were able to measure noise, visual intrusion and safety considerations but had no answer to the common sense view that it was the effect of these together that represented the real threat to wellbeing. In the 1970s, working on the environmental assessment of traffic impact, it was clear that there was no logical basis for assessing the *combined effect* of different impacts (Lassiere, 1974). As Langdon said: "If the environment is a total experience, does it make sense, for practical design purposes, to measure and analyze separate bits of it as they affect particular modes of perception? Ought we not to make some effort to integrate, to synthesize our studies so as to present the environment as a global whole?" (Langdon, 1968, 9).

A recent pioneering study by Lechner et al: highlights interactions and cross-modal effects between overall, thermal, and visual satisfaction and the important role of self-perceived control. As such, we recommend to carefully assess thermal, visual, and control scenarios jointly and not independently in future research studies and for future building design and operation strategies. Based on this, improvements in the design of the indoor environment can be made, for example, dynamic lighting adjusted to thermal conditions or vice versa to contribute to energy savings (Lechner et al., 2021, p. 18).

Groak argues:

> We may need to define different objectives at different scales of the built environment, recognizing that new technologies will allow us to provide the individual a much greater personal control of the local environment. […] Although we can control some aspects of behaviour through buildings, […] it is unclear how far we can [or even want to] control perception. The concept of comfort and the dimensions of perception provide a constant set of dilemmas of design. (Groak, 1992, p. 86)

The interaction does not take place in a vacuum. The context for environmental interaction must be considered. "Dynamic interaction between user, artefacts and their contextual environment is essential in order to understand how to design" (Popovic, 2002) (Popovic, 2000).

In this context, the modern movement did not help its cause. Rather than pursue functionalism and rationality that could have been grounded in human values, it sought to attack the symbols of the past by their replacement with new symbols. The new symbols did not generally emerge from inside a new architectural process but appear as indicators of technical rather than social functionality. As Botton has it:

> The widespread rejection of the modernist doctrine, with its emphasis on social morality, has inspired impressive aesthetic diversity, but it has also produced a climate of arrogance, cultural incoherence, and narcissism. […] the architects of the Modernist movement […] wanted their houses to speak. Only not of the nineteenth century. Or of privilege or aristocratic life. Or of the Middle Ages or Ancient Rome […] they wanted their houses to speak of the future, with its promise of speed and technology, democracy and science. (de Botton, 2006, p. 12)

It is encouraging to note the development of a radical and polemical movement by "anti-architects". As Salingaros and Masden say: "Architecture has become the exclusive domain of the so-called 'Star Architect' (starchitect in common usage), no longer operating as a conveyance, but as a usurper of culture and identity" (Salingaros & Masden, 2007, pp. 36–52).

The interactions of users with their spaces will play an essential part in either extending or limiting the useful life of the building. Although there has been much study of individual aspects of the interaction between buildings and their users, there has not been a convincing theory that would allow architects and designers to make better design decisions. If users are to be expected to contribute in a positive manner to help towards the extension of building life, it is necessary to understand the dimensions of that interaction. The consideration of "exposure time", that is, the period during which a person interacts with a building, is relevant when we ask: "How much control shall we give to the individual?" Institutional buildings are experienced simultaneously both as building and building-in-use. People feel the combined effect of building and regime. Sometimes, of course, the regime itself will go out of its way to avoid interaction. A medical superintendent of a Victorian hospital had a special corridor constructed, some 200 meters long, to avoid meeting patients and staff on his way to work in the morning. (Berrios & Freeman, 1991).

In 1970, the environmental psychologist David Canter said, "no attempt has yet been made to develop a theory of man/environment interaction that is of value during the design process" (Canter, 1970, p. 302). In the meantime, there is a "strong commitment within environmental psychology to try and study human–environment relationships within the full contextual framework in which they occur" (Evans, 1996)

Attempts have been made to model the man–environmental system in terms of the physiological factors in a stimulus–response mechanism (Wohlwill, 1966). Individuals vary considerably in their capacity to adapt and in their perception of the need to adapt. They "respond to both the real and symbolic features of their environment […] in addition to coping with the physical aspects of a change […] they must cope with the implications of the change" (Ruff, 1971). Lacan also refers to the Real, Imaginary and Symbolic as properties of a matrix, which make up part of every psychic function. (Bailly, 2009, pp. 76–91)

The phenomenological analysis of Norberg-Schulz develops the theory of architectural place and space: "it is practical to distinguish between space and character. Similar spatial organizations may possess very different characters according to the concrete treatment of the space-defining elements (the boundary) […] On the other hand it has to be pointed out that the spatial organization puts certain limits to characterization, and that the two concepts are interdependent" (Norberg-Schulz, 1976).

Echoing Merleau-Ponty, he asserts that: "Human identity presupposes the identity of place" (Norberg-Schulz, 1979, p. 35). Further, "man cannot be understood in isolation from his 'environment' […] our understanding of the world is always related to man" (Norberg-Schulz, 1979, p. 35). The significance of place and our interdependence with the physical environment must be recognized. Yet the transitional nature of the activities that occupy the spaces, coupled with the uncertainty and risk of everyday experience, go some way to explain the need for the symbolic certainty afforded, however misleadingly, by the solidity of architecture.

3.2.4 Design and Project Procurement Process

Professional experience of the process by which a building is procured and inhabited, together with the associated training and qualification, provides a common-sense appreciation of the sequence of steps that are required: briefing, design, construction, use (Bogers et al., 2008). In addition to contributing to sustainability, it is hoped that Double-Design will bring social and environmental benefits to both initial and later custodians (stakeholders, owners, professionals) and users (occupants). (Mulligan, 2014) (Baker, 2009) (Singh et al., 2009) (Rode et al., 2014) (Cotgrave & Riley, 2013) (Kates et al., 2005)

So that Double-Design can be implemented at the appropriate time in the decision-making cycle, the existing process needs to be understood. Figure 3.5 suggests the main connections between society, custodians and their professional teams, emphasizing flows of information and control.

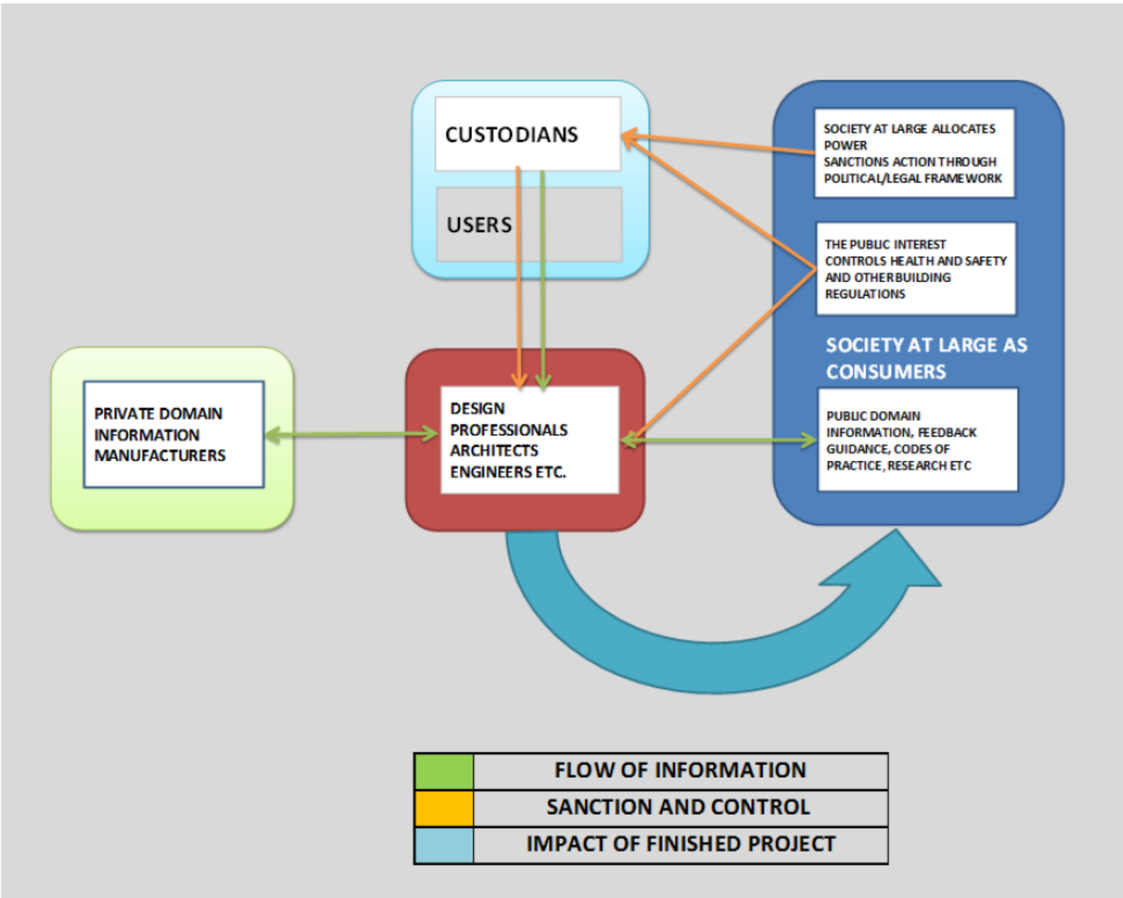

Figure 3.5 Showing the flows of information supporting the current relationships between society as a whole, the custodians empowered to develop and build projects and design professionals

Of particular importance is how society at large sanctions custodians through the political and legal framework while at the same time representing the public interest through the establishment and enforcement of laws protecting the health and safety interests of consumers, including the users of buildings. While the custodian will instruct the professional team, he may also *give* information upon which to base the project. The professional team will also, of necessity, *take* information from the public domain in the form of feedback, guidance, codes of practice and other research and from the private domain in the form of technical information held, for example, by specialist manufacturers. The concern here is to examine the basis for the relationship between custodian, users and design professionals and the "public interest".

3.2.5 Briefing

Many commentaries on the briefing process and their recommendations are focused solely upon the identifiable present requirements of the custodians and users. A notable exception is the work of Blyth and Worthington, who guide the achievement of adaptability during the briefing stage and through the evaluation of alternative designs (Blyth & Worthington 2010, pp. 50–58). As the WBDG (Whole Building Design Guide) website reports:

> In the 1980s and 1990s, some architectural schools began to drop architectural programming from their curricula. The emphasis of the Post-Modern and Deconstruction agendas was instead on form-making. Programming and its attention to the users of buildings was not a priority. Now, several generations of architects have little familiarity with architectural programming and the advantages it offers:
>
> - Involvement of interested parties in the definition of the scope of work prior to the design effort
> - Emphasis on gathering and analyzing data early in the process so that the design is based upon sound decisions
> - Efficiencies gained by avoiding redesign and more redesign as requirements emerge during architectural design. (Cherry, Edith & Petronis, John, 2016, p. 1)

The basic design process can be extended back in time to include the pre-project activities and forwards to include the post-construction phases when the building is in use. The same factors, together with new ones, modified and with varying priorities over time, will continue to be relevant as the building is used. It is not feasible to provide a specific brief for unknown possible future functions. However, it is possible to anticipate the future spatial and environmental requirements for a range of functions. The architect seeks to understand what his client, the custodian, is after and to get 'on the same wavelength'[16]. The response to those enquiries will cover 'objective' needs and 'subjective, underlying and psychological' wants (Curtis, 2002). The process goes to the heart of architectural activity.

Design teams are rarely, if ever, in a position to affect or even influence the scale of enterprise for which they are required to cater. The responsibility lies with the custodian. However, the value of Double-Design is not necessarily affected by the scale of the initial project. Yet, as observed earlier, it is legitimate for the design team to raise the issues of potential growth and change when determining the brief for any project. Research in this field has covered the optimum size of enterprises (Giancotti et al., 2017) (Kristensen, 2008) (Peters, 1994), the propensity of organizations to grow and the observed patterns of growth (Kemp & Verhoeven, 2002) and even the relationship between altruism within the firm and growth potential (Wickert et al., 2016). A custodian starting a project is free and encouraged to add some contingency in the form of spare spatial provision. A custodian occupying a building and needing to expand has several options, including:

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[16] In preparing a brief for a new university in Kuwait, the author arranged a series of meetings at which the custodian and the design team each presented ideas that were relevant to the project: the ensuing discussions were followed up by visits to projects in other countries. Through these dialogues a common language was established within the whole design and custodian team.

- Intensification of use (hot-desking, increasing density of occupancy, altered timetabling and the like)
- Adding space externally (land permitting) or internally (by the acquisition of adjacent property)[17]
- Adding non-contiguous space (retaining headquarters space and developing satellite spaces)[18]
- Moving altogether

3.2.6 Information Flow and Architectural Decision-Making

At different stages of the design process, design teams are GIVEN or are obliged to TAKE information from a wide variety of sources. It is helpful here to consider the comparison between the natural and social sciences. This distinction is made especially relevant because the natural sciences apply to the material behaviour of buildings while the social sciences deal, or at least are intended to cover, the use of buildings. As Flyvbjerg says: "Social science has set itself an impossible task when it attempts to emulate natural science and produce explanatory and predictive, that is, epistemic, theory" (Flyvbjerg, 2004, p. 3). Deriving his arguments from Aristotle, Flyvbjerg suggests that the social sciences cannot be compared for their epistemic qualities because social sciences require the introduction of values and context to make any sense. Such values and contexts are not subject to the same "laws" as natural science. "What principally separates the social and natural sciences is that the objects of study for the former, human beings, talk back to us" (Flyvbjerg, 2001, p. 6).

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[17] Robert Maxwell , then owner of the Daily Mirror building, famously tried to acquire a nearby office tower, owned by WH Smith because it would enable him to use its rooftop heliport. The author's firm was employed to design a direct bridge link between the two buildings.

[18] In developing the headquarters for the Kuwait Public Institution for Social Security, the custodian recognized a limit to the development of the HQ site and accordingly developed satellite buildings in each of the regions of the country served.

The dynamism of the interaction between the environment and its users characterizes the very purpose of buildings and, consequently, makes the interaction's predictability more important and more elusive. According to Flyvbjerg, Aristotle's three intellectual virtues are as follows:

> *Episteme*: Scientific knowledge. Universal, invariable, context-independent. Based on general analytical rationality. The original concept is known today in the terms 'epistemology' and 'epistemic'. Planning research practised as episteme would be concerned with uncovering universal truths and laws about planning.
>
> *Techne*: Craft/art. Pragmatic, variable, context-dependent. Oriented toward production. Based on practical instrumental rationality governed by a conscious goal. The original concept appears today in terms like 'technique', 'technical', and 'technology'. Planning research practised as *techne* would aim to arrive at better planning by means of instrumental rationality, where 'better' is defined in terms of the values and goals of those who employ the consultants, sometimes in negotiation with the latter.
>
> *Phronesis*: Ethics. Deliberation about values with reference to praxis: Pragmatic, variable, context-dependent. Oriented toward action. Based on practical value-rationality. The original concept is not to be found in an analogous contemporary term; it has disappeared from modern language. "Planning research practised as phronesis would be concerned with deliberation about (including questioning of) values and interests in planning." It is of particular relevance here that phronesis goes beyond "both analytical, scientific knowledge [episteme] and technical know-how [techne] and involves judgements and decisions". (Flyvbjerg, 2004, p. 287)

To make social science matter, Flyvbjerg argues, "social science should abandon those desires for technological and epistemological generalizability and certitude and turn to phronesis – prudence. Social science should proceed by refining our faculties of judgment through our careful study of, and our intelligent engagement with, individual cases" (Falk et al., 2009, p. 12). For design, phronesis certainly covers the values and power context but, as Falk et al. say: "it must stand next to and not in front of, episteme. There is still much value in social science simply aimed at understanding" (Falk et al., 2009, p. 10).

The architect must deploy the best social science understanding to serve his direct custodian better and serve his interpretation of the broader needs of society as future users of the building.

Rittel provides another useful classification of knowledge related to planning/design problems. Briefly summarized, there are five types:

- Factual knowledge: what is the case
- Deontic knowledge: what should be the case
- Explanatory knowledge: why what is there or should be there, is as it is or as it should be
- Instrumental knowledge: when x is done, then y is the consequence
- Conceptual knowledge: the meaning of words that facilitates communication

Rittel argues that "what is needed […] is that deontic knowledge should be much more explicit and externalized in the planning system" (Rittel, 2010, p. 174).

Determining the goals generates the deontic knowledge for a specific project: the more explicit this statement of intentions is, the more articulate the search for relevant information during the design process will be. In their critique of first-generation systems theory, Rittel and Webber recognize: "that one of the most intractable problems is that of defining problems [of knowing what distinguishes an observed condition from a desired condition] and of locating problems [finding where in the complex causal networks the trouble really lies]" (Rittel & Webber, 1973, p. 159).

For architects and other problem-solvers, there is a further classification of knowledge and advice:

- knowledge and advice that is *input* to the design process of necessity (including site-specific data, owner's requirements, statutory requirements etc.), the GIVEN

- knowledge and advice that is *imported* into the design process to enable the design to progress (including predictive knowledge, experience etc.), the TAKEN

Figure 3.6 sets these groups within the broad categories arising from the discussion above.

		EPISTEMIC	TECHNIC	PHRONETIC	
		natural science, universal knowledge, context-independent	pragmatic, instrumental application of technical knowledge	ethics, values, judgements, interpretations, wider context	social science, predictive/ understanding
GIVEN	contextual, site, instructions,statutory requirements,				
TAKEN	imported by design team in order to make decisions				

Figure 3.6 The relationship between Given and Taken information and Aristotle's categories of knowledge

The "truth" of architectural predictions cannot be expected to be like scientific truth. The architect cannot work in a way that is disassociated from issues of power and context: the custodian, working within a complex framework of procedures, regulations and laws, determines the context and exercises power within it. Nevertheless, an architect working in a context that provides values cannot remove from him the responsibility to use the best information available. Every decision an architect makes is predictive to some degree. Taken together, the sum ingredients of a building's physical structure are intended, that is to say, predicted, to last for a number of years: knowledge from natural science is imported to support this, for example, studies of how the strength of concrete in particular climates may reduce over time. Similarly, the shape, size and disposition of spaces are intended: predicted to support specific activities and provide scope for positive interaction between user and environment. Neither of these kinds of predictions can be expected to be perfect.

In considering the specific interactions between research and design, and here research is knowledge and information in a broad sense, Rittel distinguishes between:

1. Research on design: analyzing the design process

2. Research in design: research of the specific knowledge needed for a particular design problem

3. Research for design: research on generalizable knowledge which can be used by the designer (Rittel, 2010, p. 51)

Types 1 and 2 above would likely include both GIVEN and TAKEN information, while type 3 above would include TAKEN information.

The information given to or taken into the design process is critical to the performance of architecture. Yet, the relationship between architectural practice and knowledge remains problematic. Echoing Frayling (Frayling, 1993) in asking whether research is into, for or through, buildings, Till identifies the continuing distrust between academia and practice (Till, 2007, p. 3). He argues that:

> Architecture can, and should, be a research discipline in its own right, which both accords to the accepted criteria of research, but at the same time applies them in a manner appropriate to the issues at hand. […] The present state of architecture increasingly used to provide a velvet glove of aesthetics for the iron fist of the instrumental production of the capitalist built environment, is perhaps indicative that the state of marginality has been reached. (Till, 2007, p. 5)

But where does the information come from, what sanctions its use and integrity? In the overall framework, some of the goals for a project are covered by legislation: information under this heading is an instruction. Many building types are, in addition, the subject of published advice, Codes of Practice and the like, which, although not mandatory, is very strongly recommended. Then there is the generality of knowledge to which the designers have access. With the development of the internet, this could be seen as unlimited. A great deal of technical information can be imported directly, for example, from manufacturers and technical databases with a legitimate commercial interest. On the other hand, knowledge about building performance and the predictability of social effects of design are much more elusive.

To some degree, information that is given may be from the client direct, in the form of project-specific instructions, but may also be through the client referring to or recommending guidance produced by others and freely available. Information that is taken is thus sought out by the architect from sources that are neither directly from the client nor directly sanctioned by the client.

Figure 3.7 below offers a further clarification of the information world inhabited by the Architect. Some of the *given* information is subject to interpretation: the dialogue between Client and Architect is important in these areas. Some of the *given* information is mandatory: government regulations cannot be ignored, and, in certain countries, neither can Professional Codes. However, much of the information world is supplied by *taken* information, *taken*, indeed from an extensive range of sources, most of which are subject to open interpretation.

	GIVEN			TAKEN
	CLIENT INSTRUCTIONS	MANDATORY ADVICE	OTHER ADVICE	
			CUSTODIAN RECOMMENDATIONS OF ADVICE	
INTERPRETATION DIALOGUE AGREEMENTS	Instructions will cover project scope, budget and site and will be subject to discussion and clarification between custodian and architect		Guidance and non-mandatory Codes of Practice the use of which is sanctioned or requested by the Custodian	
COMPLIANCE		Government Regulations covering safety, health, materials and space standards: Professional Codes		
OPEN INTERPRETATION				Guidance, non-mandatory Codes, issue-specific advice (access, sustainability, design tests) commercial technical information (eg;curtain walling systems): general advice on design process. To these may be added the use of other examples of buildings with their relevant feedback and the influence of magaazine coverage and fashion. Sources of information thus TAKEN are subject to open interpretation with respect to their use and value.

Figure 3.7 Status of given and taken information as part of communication between architect and custodian

Rittel lists the primary ways of obtaining evidence:

- Introspection
- Analogy
- Observation of behaviour
- Experimental observation of behaviour
- Conclusions from general theories
- Symbolic communication

All of these would seem to fall within the TAKEN category. In an earlier paper, Rittel and Kunz had said:

> Through this counterplay of questioning and arguing, the participants form and exert their judgments incessantly, developing more structured pictures of the

> problem and its solutions. It is not possible to separate "understanding the problem" as a phase from "information" or "solution" since every formulation of the problem is also a statement about a potential solution. Four categories of information exchange occur during this process:
>
> - between the participants (opinions, expertise, reference to previous questions and decisions, similar questions, etc.);
> - with the experts about specific questions;
> - information from documentation systems (for literature support of a position, for factual reference, etc.);
> - in the case of dependent cooperatives: with the client or decision maker (directives, quest for decisions, reports, etc. (Kunz & Rittel, 1970, p. 2)

The acknowledgement of the importance of anecdotal evidence is refreshing. The direct experiences of those participating in a design process, as custodian, users or members of a design team, have always been meaningful. Applying the logical structure of knowledge upon which design decisions are made to the design process reveals the enterprise's complexity. Figure 3.8 shows how the given and taken information and advice comes from different categories of knowledge. It shows how complex the processes are, with multiple sources of information/advice for several activities. For example, the critical action of determining the needs that a building must fulfil, certainly a GIVEN, depends in fact upon techne and both subsets of phronesis.

	SUPPORTING INFORMATION/ADVICE GIVEN OR TAKEN?	EPISTEMIC	TECHNIC	PHRONETIC	
		natural science, universal knowledge, context-independent	pragmatic, instrumental application of technical knowledge	ethics, values, judgements, interpretations, wider context	social science, predictive/ understanding
	GIVEN				
	TAKEN				
STAGE 1					
STAGE 1A Site/constraints/opportunities	topography,				
	climate,				
	location,				
	urban context,				
	municipality zoning,				
	other physical and practical constraints,				
	mood of the site,				
	existing landscape...				
STAGE 1A Programme/function/activities/ organization/client/time	determine the needs that a building must fulfill.				
	must be rooted in a thorough understanding of the user's needs, the constraints and other goals of the project.				
	many needs and constraints may not be immediately obvious. Without a thorough exploration of the program, a significant need or constraint may not be discovered until later in the project, when it will be much more expensive and time-consuming to address.				
	examination of who the users of the building will be, what use they will make of the building, what rooms/spaces they need, what mood the building should create, and any other goals of the project.				
STAGE 1A Cost/budget/finance	Constraints arising from Owner approach to finance,				
	capital and running costs,				
	material availability,				
	construction industry resources..				

Figure 3.8 (part 1) Given and Taken information through the design process showing indicative categories of knowledge

	SUPPORTING INFORMATION/ADVICE GIVEN OR TAKEN?	EPISTEMIC	TECHNIC	PHRONETIC	
		natural science, universal knowledge, context-independent	pragmatic, instrumental application of technical knowledge	ethics, values, judgements, interpretations, wider context	social science, predictive/ understanding
	GIVEN				
	TAKEN				
STAGE 1A Statutory requirements	Take into account all statutory requirements that are relevant to the design				
	To the extent that statutory requirements fail to address all aspects of the public interest in health and safety, incorporate appropriate advice				
STAGE 1B Concept Design Alternatives: Design, Engineering, Cost	alternative concepts				
	generate a wide range of distinct solutions [with input on design, engineering and cost]				
	relationship between rooms and spaces: consider adjacencies and gradients of public vs private spaces				
	develop criteria for evaluating the alternatives				
	apply the criteria and select a short list of alternatives for further refinement				
	evaluate the shortlisted alternatives and select one for development in the next Stage				
STAGE 1C Selected Concept Development	develop the design/incorporate structure and services/materials				
STAGE 2					
STAGE 2A Concept Design	At this stage the interdependence of architecture with the supporting engineering systems, structure, building services engineering are fully resolved and cooordinated				
STAGE 2B Final Design and Working Drawings	the scheme is refined into the final design.				
	In previous phases, the focus has been on the project as a whole. During Final Design, it becomes important to give individual attention to each aspect, each space and each detail of the project.				
STAGE 3					
STAGE 3 Documentation and Tender Action	Stage 3 is concerned with the communication of information for the purpose of building and to provide legal documentation as the basis for agreement between owner and builder.				

Figure 3.8 (part 2) Given and Taken information through the design process showing indicative categories of knowledge

Another example will illustrate the richness of the framework: during the design, it will be necessary to establish the height of balustrades. In most countries, this will be covered by legislation, although it must be noted that there is a range of heights that are required in different places.[19] The derivation of such legislative standards is far from purely scientific and, as the height has crept upwards over the years to keep up with a population whose average height has increased, it can hardly be said to be context-independent. Beyond meeting the required height, the detailed design of the balustrade needs much broader consideration: the transparency of balustrades raises questions of privacy while allowing visual contact. The priority to be accorded these kinds of factors must be guided by information and advice from phronetic sources.The practical dependence of Double-Design upon the natural and social sciences is highlighted in Figure 3.9.

[19] Australia has 1m while Europe has 1.1m as the minimum. USA has standards that range from .864m to .965m, with Canada even lower: Are North Americans better-behaved than Europeans, or have a lower center of gravity that reduces the risk of falls?

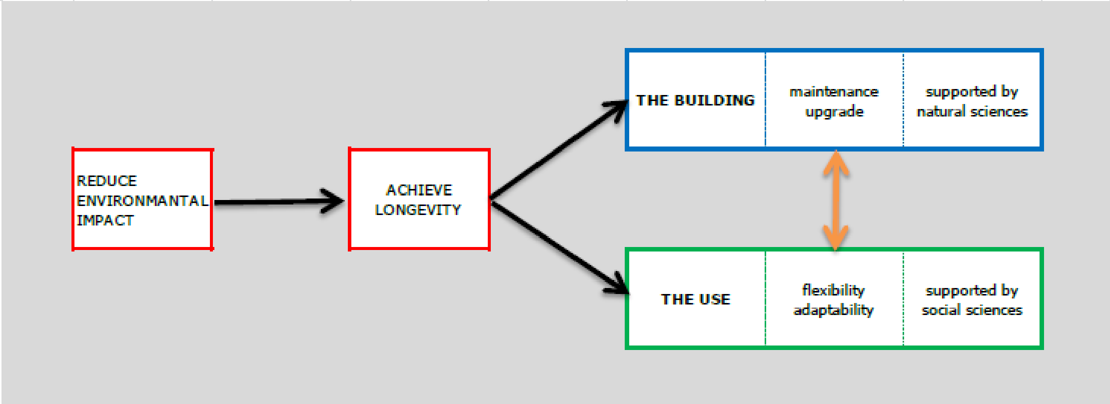


Figure 3.9 Social and natural sciences are seen to be complementary in supporting Double-Design

The design team is both a consumer of information as well as producing information with which to build. The building itself becomes a source of information during its use as post occupancy studies help custodians and users get the best out of it. For Double-Design to work, the instructions imported for the design team have to change from those related to short-term single function activities to instructions and guidance that anticipate long life and multiple uses.

Architectural design is not a linear process. During the time taken in the absorption and understanding of what is needed by the custodian, there is a requirement to develop, draw and articulate alternative design solutions, hypotheses by any other name. These must be subjected to evaluation and choice. The evaluation should cover anticipated performance over time and not just performance on the day of completion. Developing design technologies enable more sophisticated tests, which should make possible the testing of alternative sets of future requirements based on an imagined sequence of possible future uses. Such multi-future design strategies would be necessary to fulfil the design criteria of Double-Design.

The complexity of the relationships between the different actors, participants and processes, and products that are at work in building design is recognized by Schroeder:

> When exploring a completed building, all the struggles, negotiations, and compromises involved in bringing it into being remain hidden. Instead, I suggest attention should be shifted from buildings themselves to the practices that assemble buildings. Thus architecture should be explored as a "moving project", which emerges through "a series of transformations". I suggest we should open the typically black-boxed design process and follow architects, engineers, and clients at work as they enter their several construction sites of facts, forms, strategies, and technologies. Architectural studios and engineering offices are laboratories in which architecture is part of a contingent and unpredictable process, gradually assembled through diverse experiments. (Schroeder, 2018, p. 4)

The movement from each step to the next may be seen as one of Schroeder's 'transformations'. Although Schroeder's particular interest is with sustainability, his introduction of Callon's translation process applies to the design process generally and helps enhance the understanding of the elements that make up that process. Schroeder suggests:

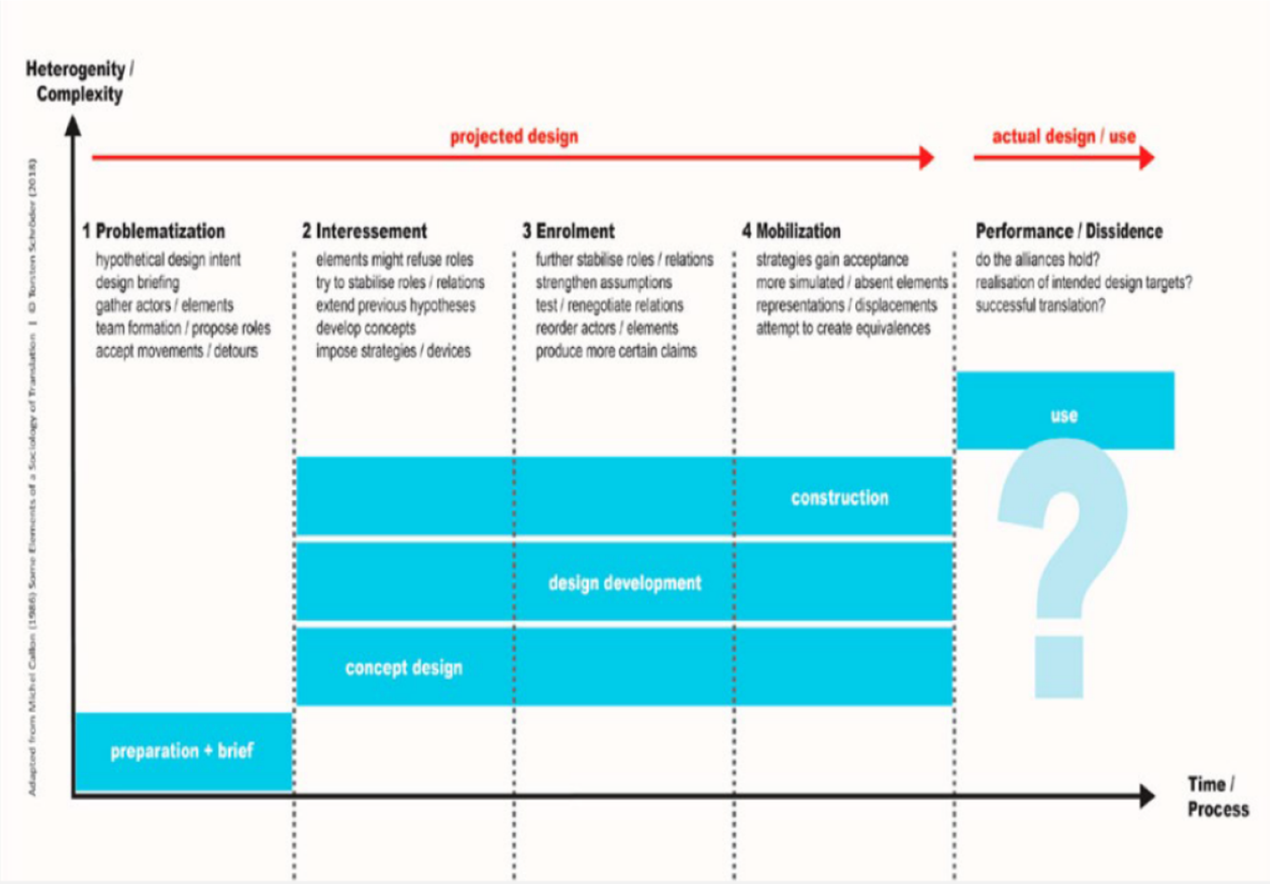
> Callon (Callon, 1984) describes the translation process through four specific phases (or moments) which in practice might overlap, and which mark a progression in the ongoing negotiations: 'problematization', 'interessement' (interposition), 'enrolment', and 'mobilization'. Crucially, the translation process is hypothetical during these four phases, success is never assured and in the end of these phases translation might fail: design teams might fall apart, buildings might not get built or buildings in operation might not perform as predicted during the design development. (Schroeder, 2018, p.7)

Applying the concept of translation makes it possible to open black-boxed design processes and understand how the concept of sustainability is continuously transformed within contingent, complex and dynamic architectural design practices as buildings materialize.

Schroeder continues: "Architectural design practices can be explored through different theoretical perspectives that contain profound differences in how they conceptualize the relationships between practices, society, materiality, and agency" (Schroeder, 2018, p. 5)

The analytical framework of translation adapted to architectural design processes.

Translation foregrounds the inseparable mechanisms of design knowledge production first; second, the construction of heterogeneous relationships; third, displacements and transformations; and fourth, controversies, choices, negotiations and adjustments, which are central in bringing buildings into being (Schröeder, 2018). In describing these 'stages' of design in more detail, it is necessary to acknowledge what is distinct at each stage and accept the fuzzy overlaps that speak of real-life activity and experience. In Figure 3.10, Schroeder's stages are compared with the generalized experience of the author, whose personal account of the process is given in the lower part of the diagram. The analytical framework of translation adapted to architectural design processes shows in an idealized form how Callon's four phases of translation relate to the typical architectural design stages.



ABSORPTION	IMAGINATION	EXPLANATION AND COMMUNICATION	EVALUATION AND SANCTION FOR EVALUATION	DECISION
During briefing, I try to get on the same wavelength as the custodian by a variety of means including getting information that is given (by the custodian and user...surveys and other relevant feedback here along with legislation and guidance) or taken (that is actively pursued from any other source, manufacturers, internet, and the like)	There comes a point, often muddy, at which I feel I have absorbed enough to begin sketching and doodling about relationships, scales, and flows. These ideagrams are reviewed almost as they are done, by which I mean, drawn. Only the survivors of this invisible and often unrecorded informal testing will be developed into more serious options. Iteration is already underway with the interplay between design idea and intended content and performance.	The remaining options or hypotheses need to be described in such a way that their essential characteristics can be understood. This is necessary because the process of evaluation and selection is not usually a private one. The custodian and users will often be involved with the design team so there needs to be some form of language common to all the players in order for the options to be understood.	Selection of design options may be effected by a variety of mechanisms ranging from discussion, exposition, surveys, polls with each process potentially enhance with the aid of more formal weighted scoring approaches. What is critical is where the sanction for decision-making really lies.	The choice of option always feels partial because it is nearly always incomplete in that there remains much still to be 'fleshed out' by way of design development

Figure 3.10 Comparison between Schroeder's stages, shown in the top half of the diagram, with an informal account by the author corresponding to those stages shown in the bottom half of the diagram (Schroeder, 2018)

Schroeder's recognition of the messy overlaps between theoretically discrete stages and the argumentative nature of design discussions is especially refreshing and helpful in revealing that Double-Design inputs must be made at every stage.

3.3 BUILDINGS IN USE

3.3.1 Structural Degeneration and Functional Obsolescence

Buildings are subject to physical degeneration and functional obsolescence. Whilst these forces act, to a large extent, independently, it is the combined impact of decisions made concerning both that determine the life of buildings. As Thomsen and van der Flier report: the most acknowledged and widely applied causal distinction is between physical factors, related to material processes, and behavioural factors, related to human actions and the interactions between them (Thomsen & van der Flier, 2011, p. 4).

This critical distinction is carried forward into the commonly accepted definitions of:

1. physical life (or real life) and
2. service life (the period of time during which a building or its parts meet or exceed performance requirements) (*ISO 15686-1:2011 Buildings and constructed assets□"Service life planning□"Part 1: General principles and framework*, 2011).

In 1992, in the multi-client research project Intelligent Buildings in Europe (IBE), DEGW and Teknibank proposed a model of building intelligence that sought to integrate *the user's needs* with *technological potential*. The IBE model focuses on the building's occupants and the tasks they are trying to carry out inside. The model states three main goals:

(i) Business management – the management of the organization's core business activities. Generally this can be characterized as a combination of the processing, storage, presentation and communication of information and knowledge.

(ii) Building management – managing the building's physical environment using both human systems (facility management) and computer systems (building automation systems)

> (iii) Space management – oversight of the building's internal spaces over time. The overall goals of effective space management are the management of change and the minimization of operating costs. (DEGW & Teknbank, 1992)

These three responsibilities lie with the custodians of buildings: all buildings require building management of the kind suggested above, and many of them either require or allow for space management. Building management and space management can be considered in more detail under two headings: **structural degeneration** (to be offset by preventative maintenance, structural repair, replacement and/or enhancement of mechanical/electrical services) and **functional obsolescence** (to be offset by modification of spaces within existing areas, replacement and enhancement of mechanical/electrical services, the introduction of new equipment/furniture, redecoration and/or adding space).

The suitability and availability of materials have always influenced the form that buildings have taken. Each new construction innovation enabled a new range of design choices. Perhaps now we should consider allowing the very form of buildings to be influenced by the nature of materials themselves. Studies of the longevity of building materials as well as of their 'green' credentials suggest that it is now possible to select materials for construction based upon criteria other than minimal cost (Bomberg & Kisilewicz, 2015) (Drochytka & Petránek, 2007) (Singh et al., 2017).

As Bomberg & Kisilewicz say:

> Structures and their components should be designed, constructed, operated, inspected, maintained and repaired in such a way that, under foreseeable environmental conditions, they maintain their required performance during their design lives with sufficient reliability for the safety and comfort of users and the intended use of the structure. To achieve this, the *service life* of the structure and its components shall meet or exceed the *design life*. (Bomberg & Kisilewicz, 2015, p. 176)

These and other studies encourage the reconsideration of which material to use in each situation. For example, highly durable but high energy-using materials like steel and concrete should be used only, and appropriately, for very long-life elements, while short-life but sustainable materials could be used for fit-out.

So that buildings can be used productively until the end of their physical life, they must incorporate both initial use flexibility and capacity to accommodate future uses. Uncertainty is not just an inconvenience encountered by every architect and custodian during the briefing process. It is a central feature informing every aspect of use and occupancy of space, undermining the reliability of assumptions and calculations made during briefing and design. A strong case can be made for uncertainty in all its forms to be embraced rather than feared. To regard unforeseeable or unforeseen events as a risk is disrespectful towards the open-endedness of human enterprise. Theoretical approaches to project management are turning away from risk management and towards uncertainty management. (Johansen et al., 2014; Ward & Chapman, 2003) (Nota & Aiello, 2014). Even in complex fields like space exploration, commentators have identified uncertainty as advantageous. As McManus and Hastings suggest: "Uncertainty is not always a negative to be mitigated; robust, versatile and flexible systems not only mitigate uncertainties, they can also create additional value for user" (McManus & Hastings, 2005, p. 1). In this context, design must be seen as capable of contributing to the management of uncertainty.

So that buildings last longer physically, they need to be designed and built to achieve a particular longevity target. As Celadyn notes: "Every building material and component is subject to gradual destruction as a result of entropy and the impacts exerted by external and internal destructive factors" (Celadyn, 2014, p. 18).[20] Figure 3.11 shows the process of structural degeneration.

[20] At a briefing meeting for a new fire station in east London, The author asked the custodian whether there was any problem in the area from vandalism; only from the firemen, he replied.

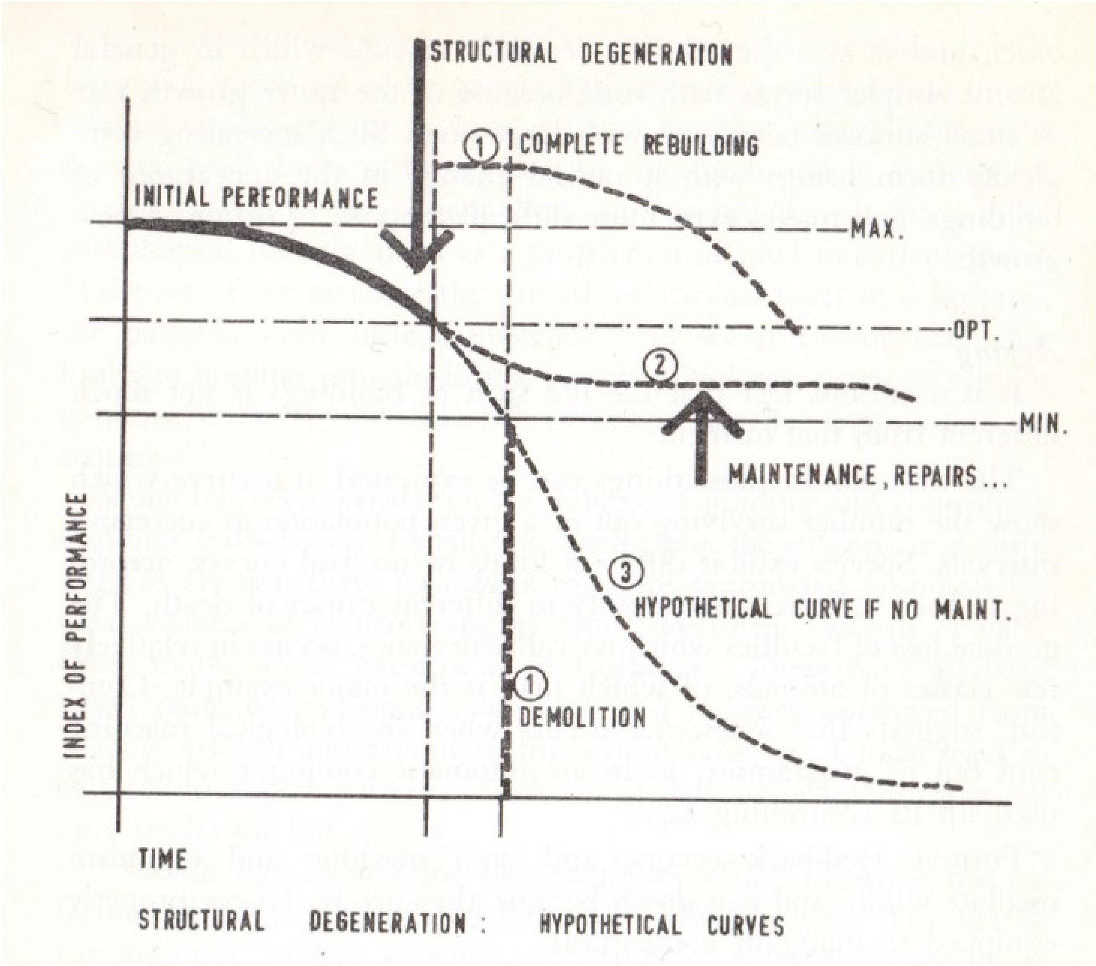


Figure 3.11 Structural Degeneration from (Cowan, Peter, 1962). Within the process of structural degeneration, the custodians may intervene to maintain or restore the material condition of a building. The diagram illustrates three scenarios:

1. Demolition and complete rebuilding: suggesting that the new building achieves higher performance than the original.
2. Maintenance and repair: keep the building going but at a lower level of performance than initially.
3. With no maintenance and repair: the building deteriorates to a point where it fails to meet minimum standards

Functional obsolescence, a term commonly used in real estate, reduces an object's usefulness or desirability because of an outdated design feature that cannot be easily changed (Asset Insights Glossary, n.d.). Functional obsolescence may incorporate economic, technological, legal and aesthetic aspects. In addition, functional obsolescence beyond the initial use can be slowed down by design that incorporates flexibility and adaptability and anticipates future changes in requirements (Kendall, 2015). The need to allow for future change is confirmed by the outcomes of post-occupancy evaluations (Bordass & Leaman, 2005).

Figure 3.12 suggests the main processes of functional obsolescence. [21]

[21] The diagrams of structural degeneration and functional obsolescence were originally drawn by the author when working with the Hospital Research Unit at UCL from 1962 to 1964.

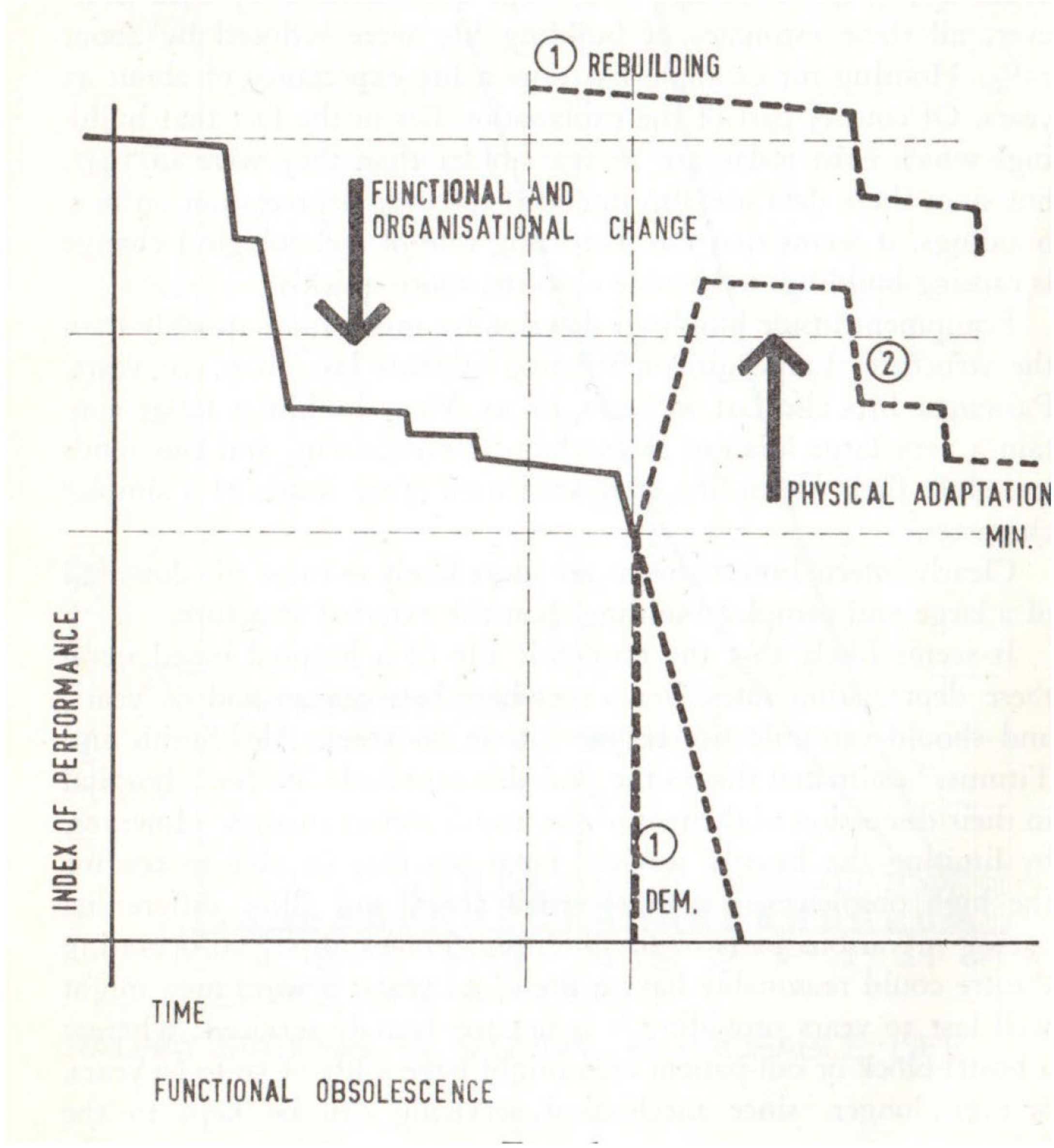


Figure 3.12 Functional Obsolescence from (Cowan, 1962). Within the process of functional obsolescence the custodian may intervene:

1. To rebuild, following by demolition
2. To adapt to ensure further acceptable use

The architect John Weeks first used the term indeterminacy to describe an approach to building design that arose from his experience with hospital planning. Weeks recognized that it was possible to design hospitals so that individual departments could expand as required if they were attached at one end to the main hospital communication street while being free to grow at the other end. This was planned to enable the expansion of departmental space within a context established by the communication system. This approach was influential in hospital and university planning in the 1960s and 1970s. Weeks' design for Northwick Park Hospital (Figure 3.13 refers) has a loosely linear form with the angle of growth for departments influenced by site conditions rather than *a priori* geometry.

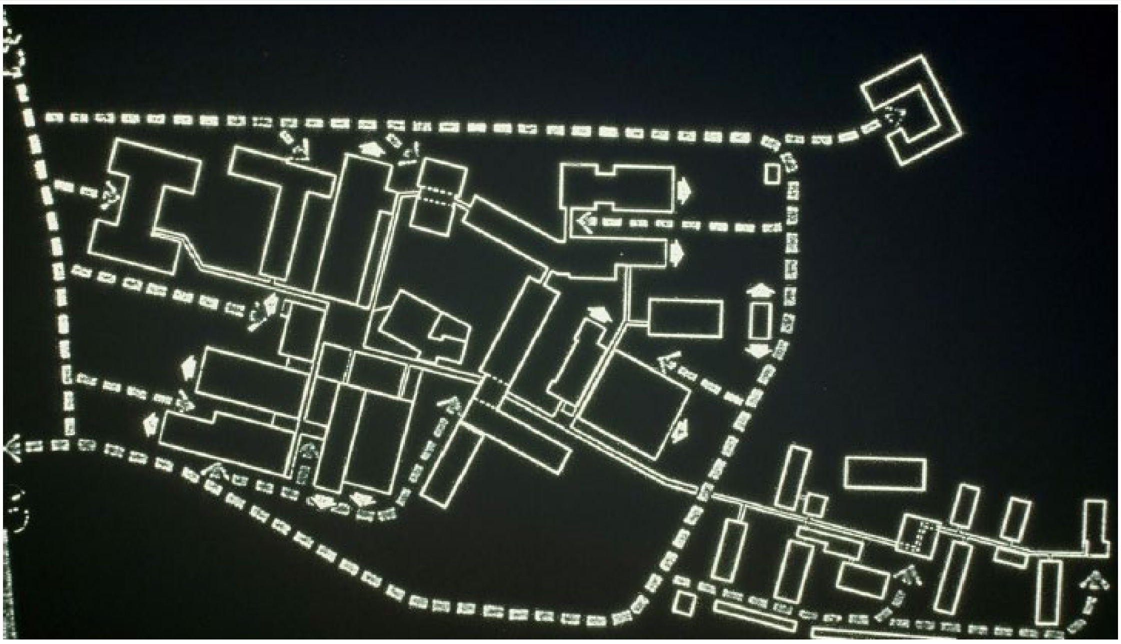


Figure 3.13 Indeterminacy: plan of Northwick Park hospital, London, Llewelyn Davies and Weeks, Architects

Architects produce blueprints, and the double meaning of blueprints is revealed by Bregman, who, in his treatment of utopias, contrasts the strict blueprint utopias, incidentally refuted by Popper and Arendt, with those that are more accommodating of change: "If the blueprint is a high-resolution photo, then this utopia is a vague outline […] Instead of forcing us into a straightjacket, it inspires us to change" (Bregman, 2017, p. 13).

How often has the intention of the architect, encouraged by the custodian, implied and expected 'high resolution' usage rather than more sympathetic and realistic openness? In planning terms, there is an analogous contrast between the end-state master plans of the Beaux-Arts and the indeterminacy of institutional planners like Weeks.

Returning to the purely physical deterioration, Remoy suggests a model in which regular maintenance and significant periodic investment will enhance performance. (Remøy, 2014).

Premature obsolescence can be avoided by ensuring that the building performs within acceptable limits for as long as its physical life allows.

> Obsolescence is a serious threat for built property. Most buildings are immobile, long lasting and capital intensive and have societal and cultural significance. The uncertainty about most buildings' future life is high. Therefore minimizing obsolescence is important for maintaining the physical, economic and societal investments involved. However, the available knowledge about the prevention and management of obsolescence is scarce. The available theoretical knowledge is limited, empirical data are scarce and evidence-based applicable expertise is hardly present or accessible. […] Obsolescence of building stocks is only partly a physical phenomenon. It is essentially a function of human action or disregard. Therefore a distinction should be made between actual and potential performance. Buildings are complex man-made artefacts and can only survive by means of regular reinvestments in maintenance and adaptation. (Thomsen & van der Flier, 2011, p. 4)

In developing explanatory models of building obsolescence, several scholars have used "performance" as the y-axis and "time" as the x-axis. This model facilitates recognizing a range of interventions whose general intention is to postpone the kind of obsolescence that leads to demolition. The historical origins of the concept of obsolescence as an inevitable consequence of nineteenth-century American capitalism are described by Abramson (Abramson, 2017).

In Cowan's diagram for functional obsolescence, there is a general reduction in "performance" in addition to significant steps down. There is no account of how interventions to enhance function could have the effect of improving performance.

In the work of Remoy and van der Voordt, conditions for successful transformation are discussed and the concept of "functionally neutral buildings" advanced (Remøy & van der Voordt, 2009, p. 8) (Mackay & Remøy, 2009).

Influenced perhaps by the many institutional projects, themes like growth and change were prominent during the 1970s. As Murray sets out clearly:

> In 1971 Alex Gordon became President of RIBA with the mantra; Long Life, Loose Fit, Low Energy. As a mission statement LL:LF:LE has never been bettered and certainly not by any subsequent RIBA policy document. The idea of building for permanence–optimising materials performance, yet being flexible enough to accommodate change and adaptability over a lifetime, whilst minimising energy consumption is surely the ultimate holistic objective for any architecture. The central problem, in my view: architects are by training, aesthetics and psychological predisposition, narrowly committed to the design of big permanent single structures and their efforts are directed merely to focusing big permanent human values as unrepeatable works of art. (Murray, 2011)

Research groups are considering the environmental benefits arising from extending the life of buildings. Conejos and Langston focus on developing an adaptive reuse rating tool targeted to new design (Conejos et al., 2014).

Langston sought a measure of good architecture in terms of durability, adaptability and sustainability. He argues that "good architecture cannot divorce itself from the financial implications of acquisition and maintenance else it will be rendered ineffective in the practical realm" (Langston, 2014, p. 164). Therefore, he seeks to use Life Cycle Costing (LCC) as a suitable predictor of good architecture and regards durability, adaptability and sustainability as equally essential and capable of objective measurement.

The construction of a physical life calculator for the durability of an existing building takes the form of assessment concerning three main factors: environmental context, occupational profile and structural integrity. This approach does not make the critical distinction between the physical characteristics of a building that determine durability, on the one hand, and the extent to which the building stays useful. On the other hand, adaptability is considered from the point of view of obsolescence–avoidance. Categories of obsolescence include; physical, economic, functional, technological, social, legal and political. The significance of these in contributing to adaptive reuse potential was assessed through expert interviews. The seven obsolescence categories were found in this work to have equal weight. Sustainability is assessed using the Australian green building council rating system (Green Star), considering eight environmental impact categories.

Although the principles upon which the work of Langston and his colleagues is based are consistent with those set out in this thesis, the objectivity of the scoring system is undermined by heavy reliance upon expert opinion. This would make it difficult for universal adoption of these approaches to be accepted. Furthermore, the practical guidance that might be expected from the research effort has not as yet materialized.

Schmidt and Austin provide a far-reaching analysis of adaptability that starts from a belief that: "a chasm remains between a perception of what architecture wants to be (in isolation as a finished and static sculpted work) and the reality of what architecture is (continually shifting in form and purpose to accommodate changing needs)" (Schmidt & Austin, 2016, p. xx).

They identify four themes that support adaptability:

1. The capacity for change is either physically responsive or a passive accommodation to an internal or external change. The object of the change might be structure, space or environment, but the most often cited is differing use or function.
2. Fitness for purpose describes the match between the building and its users. Staying 'fit' emphasises the human-building relationship and managing the constant performance slippage between the supply of space and the demand for it.
3. Value can be summarised as maximising productive use, to fit both the use and the stakeholders' desires, at a minimum cost. Hence minimising the effort (time and cost) of change is a defining facet of adaptability.
4. Time is described in two ways; to indicate the speed of change (e.g. quick transformations) and through-life changes (such as future changes or extensions of use). Thus, maximising the building's life, components or materials is a key feature. (Schmidt & Austin, 2016, p. 45)

The emerging definition of adaptability is given thus: "the capacity of a building to accommodate effectively the evolving demands of its context, thus maximising its value through life" (Schmidt & Austin, 2016, p. 45). Considering 'change drivers', they identify six categories;

- Physical
- Economic
- Functional
- Technological
- Social
- Legal

They develop the layers approach of Duffy and Brand as shown in figure 3.14.

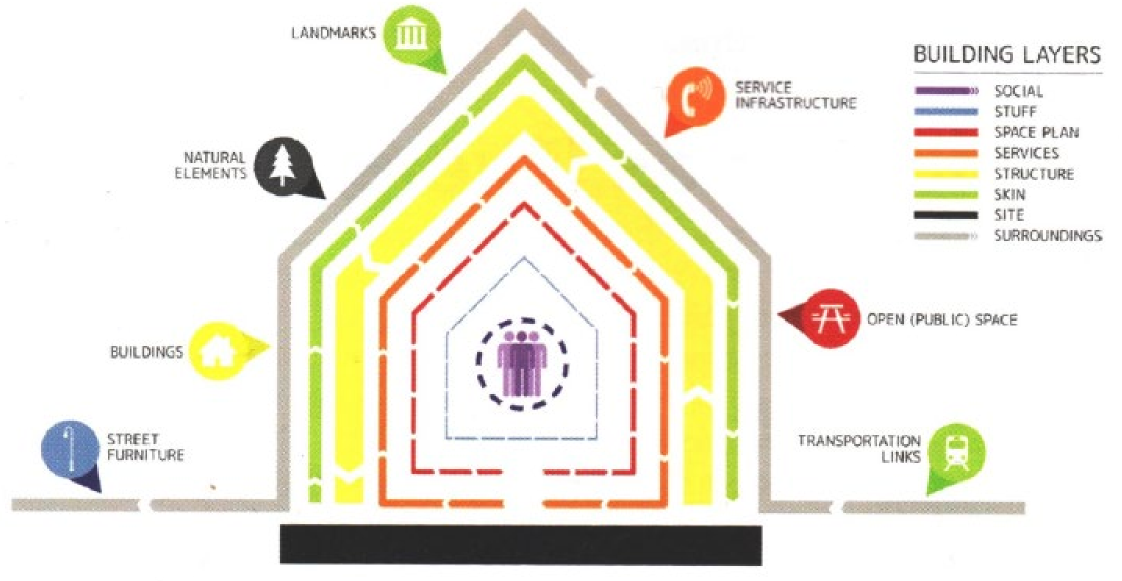


Figure 3.14 Building Layers: the layer of "surroundings" embeds a building more realistically in its context (Schmidt 111 & Austin, 2016, p. 56)

Reviewing several case studies, they conclude that the design strategies available to reduce the effects of change include:

1. Keeping elements outside the structural layer; that is avoiding load-bearing walls.
2. Separating the shortest (stuff and flexible space) from the longest (structure) lifespan elements helps the reconfiguration of space.
3. Movable solutions involving stuff and space plan are to be kept apart from services.
4. They also suggest a typology of adaptability:
    - Adjustable-change of task/user
    - Versatile-change of space
    - Refitable-change of performance
    - Convertible-change of use

- Scalable-change of size
- Movable-change of location

In moving towards the application of these principles, they observe that: "critical parameters are related to the longer lifespan components, re-emphasising the significance and controlling nature of the buildings more permanent layers" (Schmidt & Austin, 2016, p. 139).

The types of adaptability listed above may be set against the design parameters and design choices to articulate the implications for change and express priorities. Regarding the propensity of buildings to be subject to change, they argue that: "particular uses will be more prone to dynamic typologies given the complexity (healthcare), marketability (offices) and cyclical nature (schools) of a use". They state, without reference, that some 80–90 per cent of the built environment is 'dynamic' and that some 10–20 per cent (museums, libraries, monuments and the like) are presumed static (Schmidt & Austin, 2016, p. 145). The accurate assessment of how much built environment is, or can be regarded as, dynamic is a subject for future research (see Chapter Seven).

Figure 3.15 describes typical changes arising in six different building types.

Sector	Type of change	Type of adaptability	Design tactics	Motive/outcome
Retail	Configuration of space	Versatile, Refitable	Separation of tenant infill within landlord framework, combine retail units, grid coordination, planning grid, framed structure, intermediate component, reversible connection, standard product, general surplus capacity	Accommodate different tenants and changing tenant needs
Healthcare	Configuration of equipment	Adjustable	Equipment that can be moved or configured easily, adjustable furniture, fixtures, equipment	Accommodate different services for patients, different types of patients and user customisation
	Location of functions	Versatile	Move wards and departments around, movable partitions, spatial adjacencies, fixed versus flexible space	Accommodates market shifts (demographics, technologies)
	Building performance	Refitable	Easy separation of components, equipment	Accommodates new technologies
Office	Configuration of space	Versatile	Movable furniture, equipment and partitions, common space, hot-desking, undefined space, variety of finishes/ furniture, open space, wide circulation	Accommodate different activities (size, formality) and tenant customisation
	Configuration of plan	Versatile	Separate entrances, divisible services, rectangular plan, structural grid	Accommodate multiple tenants (subdivide floor space)
	Interior finish	Refitable	Market standard (e.g. Grade A), shell and core construction, custom finishes	Accommodate a range of tenants (different spatial demands)
	Building use	Convertible	Shallow plan depth, multiple cores, divisible services	Accommodate a shift in market (residential, hotel)
Education	Configuration of space	Adjustable, Versatile	Adjustable/movable furniture/equipment, close off/open up spaces, variety of room sizes, spatial adjacencies	Accommodate a variety of teaching environments
	Building use	Convertible	Secondary entrance, separable space (security, services)	Secondary uses during non-core hours (evening, weekends, summer)
Residential	Configuration of space	Versatile	Open plan, movable furniture, spatial adjacencies, fixed versus flexible space	Accommodate a variety of room layouts and activities
	Size of home	Scalable	General surplus capacity, extendable circulation, leftover/underused space, framed structure	Allow for expansion/shrinkage to accommodate changes in family demographics/lifestyles
	Interior finish	Refitable	Unfinished space, bare bones (infrastructure), custom finishes, market standard, shell and core construction	Accommodate a range of users and customisation (DIY)
Theatre	Configuration of space	Adjustable, Versatile	Movable furniture, equipment and partitions	Accommodates different performance configurations (set, audience, lighting, etc.)
	Building use	Convertible	Windows with shades (dark/light), additional doors (separate access), movable furniture, equipment, partitions, neutral colours	Accommodates uses (secondary uses), e.g. teaching or community events

Figure 3.15 typical changes mapped across six use types: from(Schmidt 111 & Austin, 2016, p. 147)

Schmidt and Austin summarize their analysis and recommendations in what they call pathways, shown in Figure 3.16, in which design strategies are broken down to show their relevance to particular kinds of adaptability. Although helpful in tracking the potential value of specific strategies, the model does not consider the consequences of needing to grant specific design strategies higher priority than others. Thus, for example, the achievement of Double-Design requires that the 'long-life' strategy is of overriding importance and must, as a different priority, be accompanied by other particular strategies concerned with continuing active and productive use (Schmidt & Austin, 2016, p. 161).

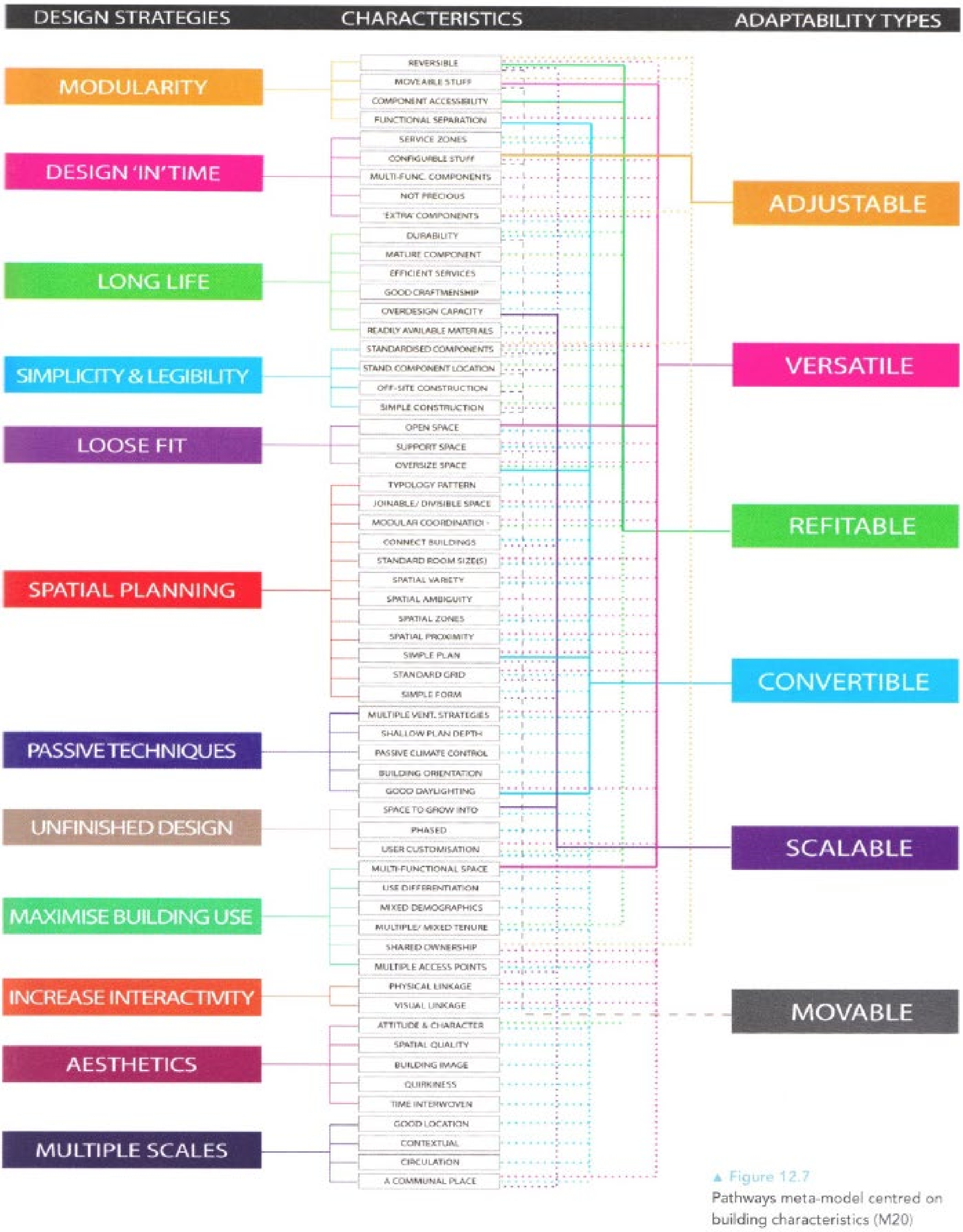


Figure 3.16 pathway connections between design strategies, building characteristics and types of adaptability; from (Schmidt 111 & Austin, 2016, p. 161)

Of particular interest, Schmidt and Austin include several examples of approaches to adaptability that are relevant to Double-Design. These include theoretical proposals for the transformation of building blocks, the development of an App for the increased control of buildings by their occupants and the development of a prototype school capable of becoming office, retail and residential. In developing the contribution to adaptability, Alison Brooks Architects suggests:

"Spacious, adaptable, sturdy and pragmatic, warehouses now accommodate everything from artists' studios, to tech companies, to restaurants, to hotels and apartments. They imply communities with shared interests and a sense of place that grows out of building for the long term" (Brooks, n.d.). The firm has designed examples of 'warehouses' used as student housing in Cambridge based upon the typology matrix presented in 2011 at the London Building Centre (Schmidt & Austin, 2016., p. 243).

The Loughborough University team also assesses several case studies illustrating aspects of adaptability (Fuster et al., 2009). Moffatt and Russell identify three ways in which adaptability can benefit environmental performance:

> Unless a building is capable of responding to changing circumstances it is vulnerable to becoming poorly utilized, prematurely obsolete and unable to accommodate new, more efficient technologies. The combined impact of such failures may be to increase resource use within the building sector by 20 to 30%. Depending upon the additional investment required to achieve adaptable designs and materials, it should be possible to significantly improve the environmental performance of the world's buildings in at least three ways, as outlined below.
>
> **1. More efficient use of space –** Adaptable buildings are likely to use the same amount of space and materials more efficiently, on average, over their entire life. For example, increased flexibility of spaces might mean that it is easy for occupants to use floor area more effectively as their needs change, or as their business (or family) expands. Convertibility may allow basements, attics, hallways, storage areas, roofs and entrances to be used for other purposes, as new needs arise. Expandability may allow the building to accommodate much higher densities with the same footprint and infrastructure. …For example, if the average lifetime space utilization is 10% improved, and all buildings are similarly designed for adaptability, then the world needs 10% fewer buildings.
>
> 2 **Increased Longevity –** Adaptability is also a strategy for extending the total lifetime of buildings. Most buildings are destroyed due to technological obsolesce, not structural deterioration. Adaptability can therefore extend lifetimes without imposing any of the significant environmental impacts associated with all the one

-time investments in the building structure and infrastructure. Consider, for example, the embodied energy in reinforced concrete – probably the single greatest pollutant source in a typical commercial building. Or consider the other long lasting elements of a building like wood, metal, glass and landscaping materials. Or consider the energy used in construction, demolition, and haulage and disposal of earth, materials and waste. If adaptable designs can extend the average lifetime of buildings by 10%, (and possibly much more), then we can similarly reduce the total world investment in replacing these long-lasting elements of the building stock. The most environmentally benign building is the one that does not have to be built.

> 3 **Improved Operating Performance –** Adaptability can also mean easier change overs as new technology becomes available. Thus adaptable buildings benefit from technological innovation sooner and at lower cost. The average efficiency of many doubled over the past 10 years. If a building has features that allow easier adoption of new, efficient technology, it is reasonable to assume an increase in average lifetime operating efficiency of 10% or more. This in turn would reduce the total environmental impact of operating the world's buildings by 10% – a very significant improvement. (Moffatt & Russell, 2001, p. 4)

At Loughborough University, the adaptability of buildings has been investigated by developing two design strategies, pre-configuration, dealing with initial design choices and re-configuration, looking at subsequent changes in use. A framework to describe adaptable buildings has been created as part of the research (Beadle et al., 2008).

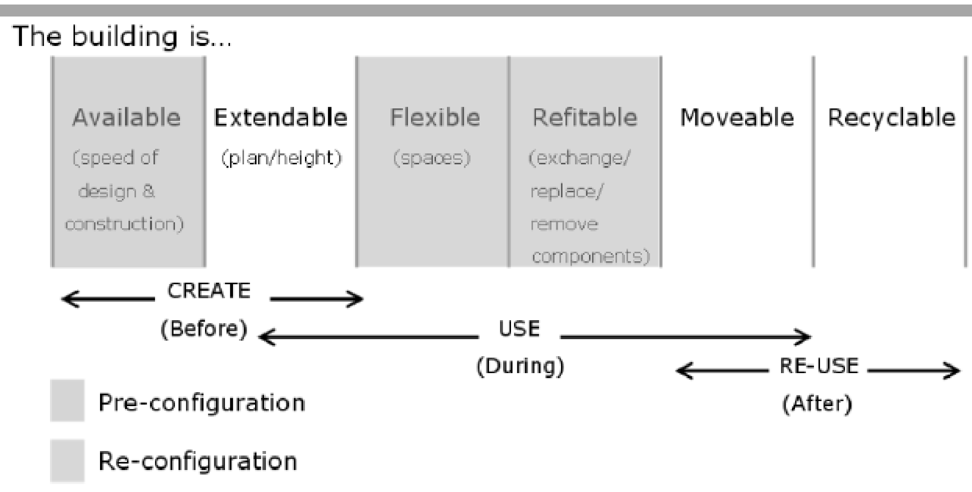


Figure 3.17 Adaptable Futures Framework: from (Beadle et al., 2008, p. 2)

Beadle et al. establish the context for change:

> Currently, the majority of buildings are bespoke creations to suit a particular use at a certain time, with little thought for the future or sustainability. […] The 21st century has seen changes in social, environmental and economic frameworks, the 'triple bottom line', which will change construction enormously (Elkington,

> 1994). These changes include: faster design and production to reduce client uncertainty and cost; much wider adoption of lean manufacturing approaches (including offsite); increasing demand for infrastructure reconfigurable to future needs that are usually unpredictable; a greater focus on sustainable procurement and development; the introduction of energy performance certificates; and an increasing focus on zero-carbon buildings. […] There is clearly both a business and sustainability case for extending the useable life of our building infrastructure. (Beadle et al., 2008)

3DReid, formerly Reid Architecture, conducted a concept study of reconfigurable adaptable buildings. The concept developed from this, Multispace, presents an adaptable, multi-use design that could form the basis of office, residential apartments, hotel and retail developments. Multispace offers the opportunity for mixed-use buildings to respond to market conditions by changing use without significant adjustments to the external envelope. This could have benefits that lead to more sustainable developments, including maximizing commercial return; reducing risks to landlords; reducing waste; extending the life of the building; enabling people to live closer to work; and creating buildings that can change with the needs of society. The aim of the study was to offer some potential solutions to the problems faced by creating multi-use buildings; these were addressed by identifying a set of design parameters. The technical requirements of these parameters were compared for each building use selected, enabling a generic specification for an adaptable building to be proposed. The design parameters included storey height; building proximity, form and plot density; plan depth; structural design; vertical circulation, servicing and core design; fire safety design; and cladding design. A summary of the proposed specification requirements from the Multispace concept is provided in Figure 3.18 (Beadle et al., 2008).

	Ground floor condition	Upper floor condition
Proximity of blocks	Determined by spread of fire regulations	18 to 21m min. between habitable rooms
Plan depth	13.5m (preferably 15m) to 45m	15 to 21m
Internal ceiling height	3.5m single storey 5 to 7m double height	Approx. 2.7m
Ceiling zone	0 to 500mm	0 to 500mm
Floor zone	Preferably 100 to 350mm	Preferably 100 to 350mm
Structural slab & spans	Min. 7.5m span 260mm slab @ 9x9m; 330mm slab @ 12x9m	Min. 7.5m span; max. 12m span 260mm slab @ 9x9m; 330mm slab @ 12x9m
Design occupancy for fire	1 person per 5sqm	1 person per 6sqm
Travel distances for fire	30m two way (12m one way)	30m two way (12m one way)
No. and size of lifts	N/A	Design for mixed use as the worst case and offices as worst case for single use
Cladding spec.	Maximise glazing within fire, noise and cost constraints	40 to 100% glazing, NR 20-30; 1.5m module & option for opening casements

Figure 3.18 Requirements for adaptable buildings: from (Reid Architecture et al. 2005)

Figure 3.19 shows the residential, office and hotel perspectives of the Multispace concept (Reid Architecture et al., 2005). This study is especially relevant to Double-Design as it considers designing for different future uses and not just adaptability and flexibility within the initial use.

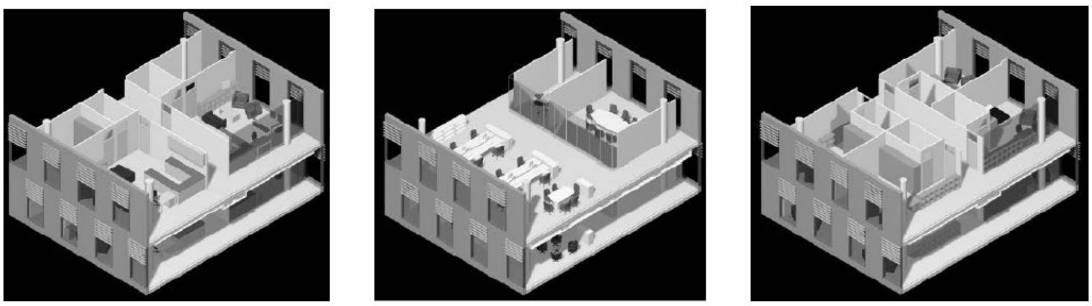


Figure 3.19 Residential, office and hotel perspectives of the Multispace concept (Reid Architecture et al. 2005)

One of the ideas suggested by John Weeks as a valuable guide to thinking about the challenges in hospital design in the 1960s was that of the duffel coat, and this has more recently been looked at by Fawcett. In his assessment of the "duffle-coat" theory of flexibility, Fawcett introduces his analysis:

> Hospitals experience constant change of use, so flexibility for activity change is an accepted objective in hospital design. By extending the useful life, flexibility enhances the sustainability of investment in hospital buildings. A widely accepted strategy for flexibility is to design hospitals with a small number of distinct space types, repeating these types as often as possible. By analogy with Royal Navy duffle coats, that were loosely tailored and supplied in a limited variety of sizes, this can be called the 'duffle coat' theory of room sizing. Standardisation of sizes may be desirable for the design, construction and maintenance of hospitals, but this study focuses on flexibility for activity change. In two mathematical simulations, the duffle coat theory of hospital flexibility is not validated. (Fawcett, 2012, p. 1)

Among the first to recognize the long-term and 'sustainability' value of flexibility, he continues: "Loose-fit design, providing flexible hospitals that work for the initial activities and can also cope with activity change over time, would increase the long-term usefulness of the financial, social and resource investment in hospital buildings, and would be highly sustainable" (Fawcett, 2012, p. 2).

Developing the ideas of Weeks and Cowan, Fawcett describes a model of activity-space interchangeability based upon floor area to test the duffle-coat theory. Figure 3.20 examines the analytical approach used.

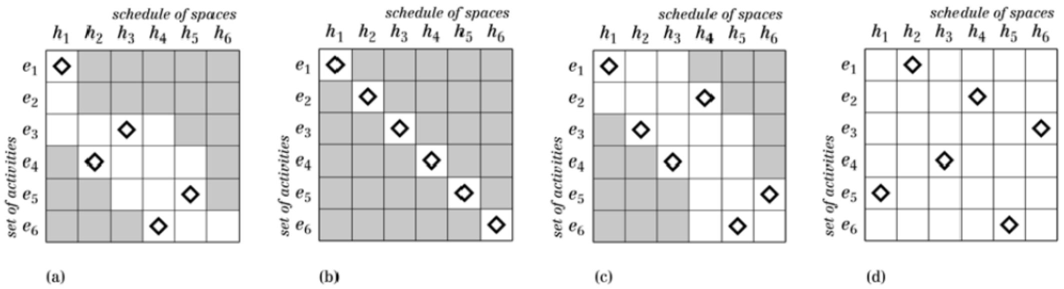


Figure 3.20 The feasibility matrix for a set of activities and a set of spaces. An activity can be allocated to any space for which there is a corresponding white cell in the matrix, but not to a space with a tinted cell. An allocation of activities to spaces is indicted by placing the diamond symbols in the relevant cells. In a feasible allocated all symbols are on white cells, and no row or column contains more than one symbol.

(a) A 'failing' feasibility matrix in which there is no feasible allocation of all the activities to the spaces. In the partial allocation shown there is no feasible space for activity *e*2.

(b) A 'tight fit' feasibility matrix for: there is only one way that the activities can be allocated to the spaces.

(c) An intermediate feasibility matrix, allowing some interchangeability: one allocation is shown; there are 26 feasible allocations with this feasibility matrix.

(d) The feasibility matrix allowing most interchangeability in the allocation of activities to spaces: one allocation is shown; there are 720 feasible allocations with this feasibility matrix.

(matrices and notes from Fawcett, (Fawcett, 2012, pp. 4–5))

Using these basic models, Fawcett's mathematical analysis concludes:

> The level of activity-space tolerance has a greater impact on flexibility than room-sizing, and this aspect should be prioritised in future research. Activity-space feasibility (and tolerance) is determined by many factors in addition to room sizing, which should be taken into account in studying hospital flexibility. Although there is no evidence that modular room sizing contributes to flexibility, modular hospital design may be valuable for other, practical reasons. Flexibility is quite rightly seen as a high priority for the long-term value and sustainability of hospital buildings, but it is poorly understood. Weeks's duffle coat theory was an intuitive response to a complex problem, but it should now be set aside in favour of better-researched strategies for flexible hospital design. (Fawcett, 2012, p. 15)

3.3.2 Feedback

The relationship of activity to space lies at the heart of all architectural design. Providing a space with certain geometrical and thermal/structural/aural performance characteristics allows for several different activities. The activities undertaken in a space are determined not only by the physical characteristics of the space but also by the applicable rules governing behaviour. These rules may be derived from the law of the land, from tenure agreements or by more informal undertakings. As the national and international significance of building performance has been recognized, the idea of learning from the experience of buildings in use has gained momentum.

The theoretical relationship between functional requirements and the extent to which buildings achieve those requirements has been described by several researchers and summarized by De Wilde (De Wilde, 2018, pp. 123–128). The models developed are, however, focused at a single point of time and do not take into account fully the need for performance to be assessed over the whole lifetime of a building. It is argued, for example, by Blyth and Worthington, that: "whether a building is successful will depend on the criteria used to judge success. The ability to measure the success of a building project relates to the yardsticks introduced in the brief, against which it can be measured" (Blyth & Worthington, 2010, p. 86).

Custodians and users' expectations of their buildings change over time, and the "starting" criteria may not remain valid beyond the initial use. Therefore, in the context of Double-Design, the criteria must be extended to encompass the life of the building and its continued use. The balance between the interests of the custodian and those of the wider public interest will vary over the life of the building.

In seeking to develop a universally applicable methodology for the assessment of building performance, the CREDIT Performance Indicator team recognized the need to incorporate indicators for buildings in use, including for adaptability, as well as for the more readily measurable aspects of environmental performance and comfort:

> The indicators have three different purposes depending on where and when in the building process they are addressed. In the initial phases, they serve as specifications or requirements in the briefing and programming phase. During the design and construction phase they serve as guidelines for the design and how to compare qualities and specifications of building and components in order to meet the requirements. After completion, they serve as tools for assessing the performance and the economic potential of the finished building, and as a

delivery to facility management and the users of the building (Bertelsen et al., 2010, p. 9).

The concept of building performance has a long history and is aligned with the protection of the public from the mistakes of builders and designers. As long ago as 1700 BC, the Code of Hammurabi specified the punishment for unsound work (*The Code of Hammurabi*, 1979, p. 38).

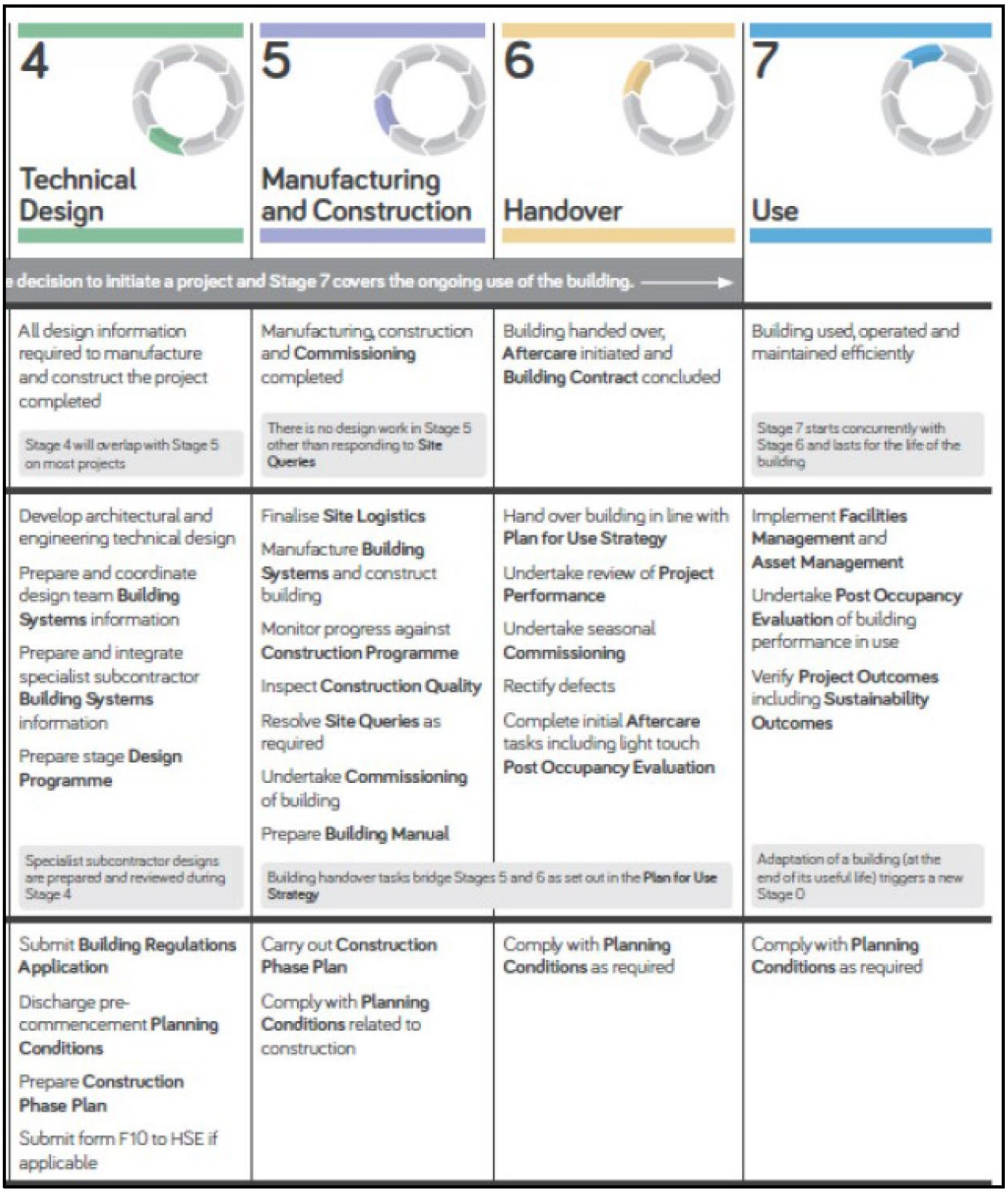
Post-Occupancy evaluation was pioneered in the UK by health care researchers, including those at the Medical Architecture Research Unit (Rawlinson, 1985). Institutions responsible for getting the best from their space promoted and published common sense guidance (Belshaw et al., 1993). Post-Occupancy Evaluation (POE) categorizes the approaches to building evaluation by describing the three levels of POE effort – indicative, investigative, and diagnostic – each differing in terms of time, resources, and personnel needed (Preiser et al., 1988).

Theoretical models of building performance developed by the Building Performance Research Unit at Strathclyde University suggest five systems as a basis for analysis:

- Building
- Environmental
- Activity
- Objectives
- Resources

(Markus, Thomas A, 1972b)

The importance attached now to POE confirms the interest in the ways in which buildings are used (Partington & Bradbury, 2017). Figure 3.21 shows how the influential RIBA plan of work now integrates post-occupancy evaluation as stage 7 in the design process and publishes advice on the conduct of POE (RIBA, 2016)



4 Technical Design	5 Manufacturing and Construction	6 Handover	7 Use
e decision to initiate a project and Stage 7 covers the ongoing use of the building.			
All design information required to manufacture and construct the project completed Stage 4 will overlap with Stage 5 on most projects	Manufacturing, construction and **Commissioning** completed There is no design work in Stage 5 other than responding to **Site Queries**	Building handed over, **Aftercare** initiated and **Building Contract** concluded	Building used, operated and maintained efficiently Stage 7 starts concurrently with Stage 6 and lasts for the life of the building
Develop architectural and engineering technical design Prepare and coordinate design team **Building Systems** information Prepare and integrate specialist subcontractor **Building Systems** information Prepare stage **Design Programme** Specialist subcontractor designs are prepared and reviewed during Stage 4	Finalise **Site Logistics** Manufacture **Building Systems** and construct building Monitor progress against **Construction Programme** Inspect **Construction Quality** Resolve **Site Queries** as required Undertake **Commissioning** of building Prepare **Building Manual** Building handover tasks bridge Stages 5 and 6 as set out in the **Plan for Use Strategy**	Hand over building in line with **Plan for Use Strategy** Undertake review of **Project Performance** Undertake seasonal **Commissioning** Rectify defects Complete initial **Aftercare** tasks including light touch **Post Occupancy Evaluation**	Implement **Facilities Management** and **Asset Management** Undertake **Post Occupancy Evaluation** of building performance in use Verify **Project Outcomes** including **Sustainability Outcomes** Adaptation of a building (at the end of its useful life) triggers a new Stage 0
Submit **Building Regulations Application** Discharge pre-commencement **Planning Conditions** Prepare **Construction Phase Plan** Submit form F10 to HSE if applicable	Carry out **Construction Phase Plan** Comply with **Planning Conditions** related to construction	Comply with **Planning Conditions** as required	Comply with **Planning Conditions** as required

Figure 3.21 RIBA plan of work showing Stage 7, the USE stage, integrated into the process. Earlier stages, not shown here, cover Strategic Definitions, Preparation and Briefing, Concept Design and Spatial Coordination.

The nature and quality of interaction between users and spaces are instrumental in determining how well a building performs over its lifetime. The interaction is two-way. Whilst the building must respond to changing needs, the organization can also respond to the building. There are points of decision at which the users must decide to intervene to modify or enlarge the space or accommodate somehow to the space they have.

In developing a model of property performance value, Oseland and Willis highlight three elements: quality, cost and time/use. Cost refers to the cost of "workplace facilities and services". Time/use refers to how efficiently the building space is being used over time. Quality refers to how well a space meets its intended purpose, usually assessed through surveys. (Oseland & Willis, 2000, pp. 157–163).

The guide published by Building Services Research and Information Association (BSRIA) lists some of the tests and methods that can be included when reviewing building performance:

- Building fabric
- Building services and operating strategies
- Energy use
- Handover and commissioning processes
- Occupant satisfaction
- Occupant comfort conditions (Agha-Hossein et al., 2015, p. 1)

The RIBA primer on POE/BPE covers:

- Occupant feedback
- Energy use
- System (how building regulates its environment)
- Environmental performance
- Benchmarking
- Case studies (RIBA, 2016, pp. 8–11)

While not taken for granted as an essential part of the architect's responsibility, post-occupancy evaluation and building performance evaluation have certainly become a more significant part of the design environment and an important source of information for design professionals. This move has been promoted by government concern over energy use, and overall building evaluation has benefited from the government initiatives including Building Use Studies, BUS, (managed by the Usable Building Trust and ARUP) (BUS methodology, 2017) and by the work of Innovate UK

(Palmer et al., 2016). The RIBA has recently proposed that POE should be mandatory for all buildings:

> The Royal Institute of British Architects (RIBA) believe that we would all benefit from an approach that made it easier to learn from both successful and more troubled projects via Post Occupancy Evaluation. To observers from other sectors, this sounds obvious. We need to embrace a culture of accountability and continuous improvement. Those that live in and use our buildings, as well as the environment, deserve and urgently need us to make these changes. (MacDonald, 2020, p. 3)

In 2000, the Construction Research and Innovation Strategy Panel commissioned three studies relevant to the effective use of feedback. They identified a feedback vacuum, with few linkages between those who occupy and run buildings and those who actually commission, design and make them. Key conclusions included:

- The relationship between buildings and occupiers is constantly changing, with frequent clashes between operational requirements and physical facilities.
- Designers seldom get feedback and only notice problems when asked to investigate a failure.
- Occupants' knowledge is not being used adequately to inform designers.
- Facilities managers are seldom involved in briefing, and there is no natural home for their experience.
- Very few POEs are undertaken.
- People don't want to pay; and aren't sure what to do, who should do it, or what value it will add.
- Designers fear the risks of liability and of voiding their insurance.
- In the few POEs that were done, the information usually stayed with the client and consultant group.
- We need a "keeper of information" of good and bad examples of products and processes.
- Building services are some of the most troublesome and least understood aspects. (Bordass et al., 2006, p.3)

Bordass and Leaman draw attention to the need to regularize the generation of feedback information from buildings in use and clarify the ownership of expert knowledge (Bordass & Leaman, 2013). Architectural design, encouraged by the outcomes of post-occupancy evaluations, should anticipate future changes in requirements (Markus, 1972) (RIBA, 2016) (Bordass et al., 2006) (De Wilde, 2018) (Partington & Bradbury, 2017).

The Egan report draws attention to the lack of concern in the construction industry for what the customer wants: "the construction industry tends not to think about the customer (either the client or the consumer) but more about the next employer in the contractual chain. Companies do little systematic research on what the end-user wants, nor do they seek to raise customers' aspirations and educate them to become more discerning" (Egan, 1998, p. 14).

The implementation of Double-Design would highlight a potentially enhanced professional role for architects and engineers who could take on a continuing responsibility through the life of a building.

3.3.3 Facilities Management

Responsibility for optimizing the outcome of the forces of degeneration and obsolescence lies within the scope of facilities management (FM). FM's subsidiary branches include building operation and maintenance, environmental management, IT and telecommunications, property management, and support services (Global FM, 2016). These have developed as separate specialities without theoretical or practical integration. Even the international standards organization seems keener to promote the market for integrated FM than to guide the integration itself (ISO, 2018). Although dedicated to recycling and reducing the environmental impact of commercial enterprises, Environmental Management Systems, supported by ISO documentation, fail to address issues of space and longevity (WRAP, 2015).

For the facilities management of both the physical and use aspects of building to be effective, clear initial performance statements are needed. These benchmarks may be used as a basis for monitoring the success of the building. While there are several factors to be considered, there is also a range of acceptable performance levels. The incentives for facility managers to avoid obsolescence have been understood:

> Avoiding obsolescence means following several courses of action: (1) planning and designing to avoid obsolescence and to provide the flexibility to respond to the early onset of obsolescence; (2) construction to assure that the facility has the required characteristics to enable the performance anticipated during planning and design; (3) operations and maintenance systems that monitor change and act (when possible) to increase performance or slow its degradation thereby deferring obsolescence; and (4) refurbishment and retrofitting to accommodate change. (Iselin and Lemer, 1993, p. 25)

Buildings may have a "designed" life concerning anticipated function and expected physical life. There are critical points in the design, construction and use process at which decisions must be made. Should provision be made for expansion of the initial function at the start? After the building has been used and all capacity for rearrangement within the building has been consumed, there may come a time at which the custodian needs to decide whether to expand or whether to demolish. If the building has been Double-Designed, the custodian will be able to hand it over to a new custodian and user with minimal additional capital, resource or time expenditure. The options at this crucial point are increased along with the life of the building.

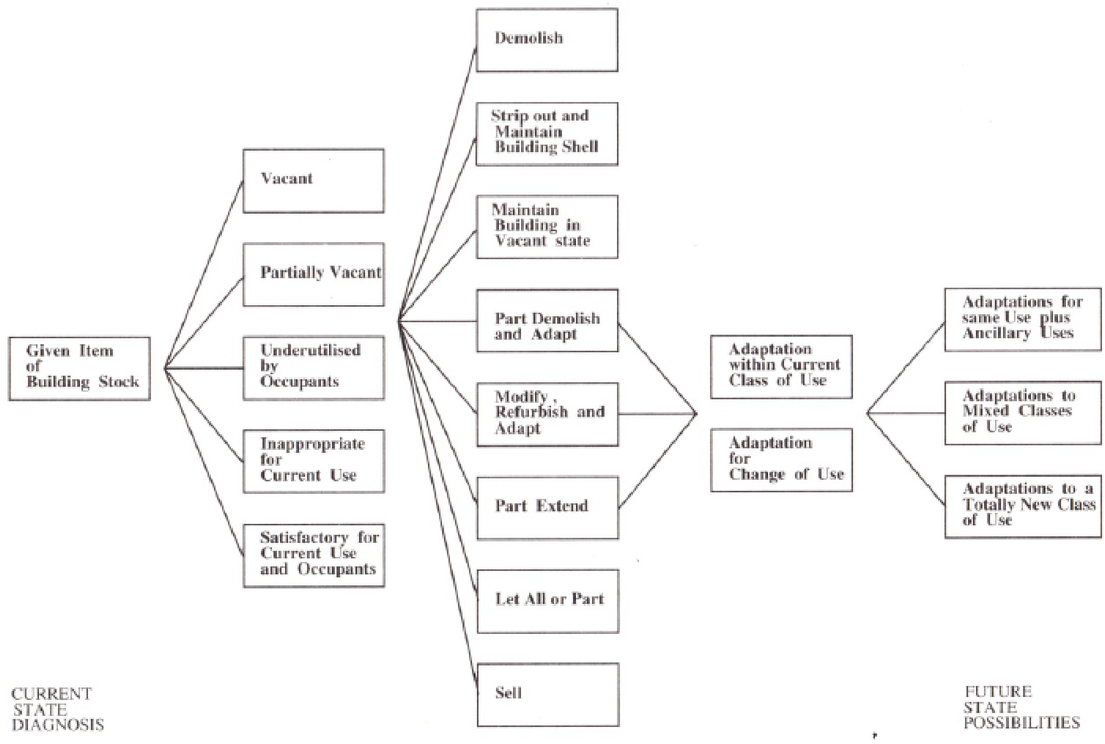


Figure 3.22 Options available to custodians as buildings are used: from (Kincaid, David, 2002, p. 12)

The options available to custodians as they use their buildings are described by Kincaid and are summarized in Figure 3.22.

3.3.4 Interventions

How custodians and users interact with their built environment is central to the concept of Double-Design. This is because the scope of intervention enabled and encouraged by Double-Design goes beyond the typical understanding of responsible "facilities management" behaviour expected of custodians and users in a single-function first use environment. Interventions also encompass the full range of responses to structural deterioration and functional obsolescence.

The scholars concerned with these issues come from such diverse academic and professional backgrounds that it seems hardly surprising that their lists and definitions for intervention should overlap and, overall, lack consistency in their application to research and analysis. Thus, for example, words like "adaptable" sometimes refer to an intention, at other times to a characteristic of the space itself, sometimes to an existing space and activity, and at others to the same space for a different activity. These lexicographic problems are elaborated by Charola reviewing Harris' book (Harris, 2001):

> One of the problems faced in architectural conservation is its interdisciplinary nature: architects, engineers, and material scientists (chemists, physicists, biologists, geologists) need to work together. Each discipline has developed its own lexicon, and, as the author points out, the borrowed medical analogy is not quite appropriate. The term "deterioration" is then used only when a special agent is in play, such as air pollution or rising damp, as it is currently used in the field of building conservation. Another point that could be misleading is the statement that "reconstitution is often more than the satisfaction of complying with standards of authenticity". Authenticity is one of those vague words introduced in the field of conservation theory that requires a defined framework. Is it material authenticity or building authenticity? And what standards are considered? (Charola, 2003, p.42)

A starting point towards clarification and consistency is provided by the development of a forensic architecture that is concerned primarily with the avoidance of decay and deterioration (Harris, 2001) (Richardson, 2001) (Ransom, 2002) (Douglas, 2006)

(Watt, 2007) and through the creative analysis of positive interventions to achieve reuse (Kincaid, 2002) (Wong, 2017). In addition, concern for the treatment of historic buildings provides a further, more specialized motivation (Grimmer, 2017)[23]. Focusing upon the avoidance of decay, Harris suggests six intervention approaches as illustrated in Figure 3.22 that represents a small sample of his intervention matrix.

INTERVENTION MATRIX (TABLE 2.1 FROM Harris)							
MECHANISM TITLE; TIMBER ROT							
necessary and sufficient conditions		Intervention approaches					
		ABSTENTION	**MITIGATION**	**RECONSTITUTION**	**SUBSTITUTION**	**CIRCUMVENTION**	**ACCELERATION**
	GENERAL MECHANISM	accept condition of rotted member and rate of continuing rot					demolish rotted member or members, and do not replace
1	TOXIN-FREE TIMBER		inject toxin into or on surface; apply toxin-bearing material onto timber	remove and replace timber in kind	remove and/or replace with another material; inject with epoxy or replace with steel	install parallel member for structural purposes, and relieve rotted member of load	
2	SELECT FUNGI		sterilize situs locus				
3	MOISTURE CONTENT 28-30%		reduce moisture available to the wood	dry timber to lower moisture content			
4	OXYGEN		reduce atmospheric oxygen content; store in oxygen-depleted vault			encapsulate member or element and evacuate volume	
5	TEMPERATURE NOT LESS THAN 40 NOR MORE THAN 120 degrees F		place member or element either in artificially high or low temperature				

Figure 3.23 Six approaches applied to one decay mechanism (timber rot) represents a small sample of an intervention matrix: from (Harris, 2001, p. Table 2.1)

To clarify the meaning of interventions, is it helpful to distinguish between those intended to restore the status quo ante or to achieve change? This distinction is used

[23] Revised by Grimmer from "The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings" by Kay D. Weeks and Anne E. Grimmer (1995).

to classify the main definitions of intervention. Further assessment will then address the remaining questions, namely:

- Whether an intervention is concerned with the fabric of the building, with the function of the building, or, as is occasionally the case, with both?

- Whether an intervention applies to a new building, to an existing building, or both?

- Whether an intervention is undertaken by the custodian, by the user, or by both?

Harris starts his list with "abstention", and, as this is not an intervention, it is omitted from the lists below.

It is helpful to list the interventions that have been identified, starting with those of Harris that all fall in the category of restoring the status quo. Appendix Three provides detailed definitions and references for the interventions listed.

As could be expected, there is a good deal of repetitive referencing at work as each generation of authors gets to grip with the complex technical content of the issues and seeks to pass on their extensive practical experience. In her more recent work, Wong provides a very comprehensive glossary without recommending particular definitions (Wong, 2017, pp. 13–28). Instead, her work includes many references of cultural and architectural relevance but which are less helpful in the search for unambiguous meaning. In cases in which Wong's terms add to the comprehensive list of interventions, they have been added. The purpose here is to develop a consolidated list to answer the remaining three questions.

The following three matrices address the questions raised above and are based upon the consolidated list of interventions. First: is the main impact of intervention upon the fabric or the function or both? Figure 3.24 refers.

INTERVENTIONS TO MAINTAIN STATUS QUO		MAIN IMPACT OF INTERVENTIONS		
CATEGORY	INTERVENTION	FABRIC	FUNCTION	FABRIC AND FUNCTION
1 ACTIVELY KEEPING A BUILDING THE SAME	1.1 PRESERVATION			
	1.2 MAINTENANCE			
2 ACTIVELY RESTORING A BUILDING TO A PREVIOUS (INITIAL) STATE	2.1 RESTORATION			
	2.2 REBUILDING			
	2.3 RENOVATION			
	2.4 RECONSTRUCTION			
	2.5 STABILIZATION			
	2.6 REPAIR			
	2.7 MITIGATION			
3 ACTIVELY RESTORE AFTER DAMAGE	3.1 REINSTATEMENT			
INTERVENTIONS TO ACHIEVE CHANGE				
4 CONSERVE FOR SAME USE	4.1 REFURBISHMENT			
	4.2 CONSOLIDATION			
	4.3 CONSERVATION			
	4.4 RECONSTITUTION			
5 CONSERVE FOR DIFFERENT USE	5.1 ADAPTATION			
	5.2 ADAPTIVE REUSE			
	5.3 ALTERATION			
	5.4 CONVERSION			
	5.5 REHABILITATION			
	5.6 RECYCLING			
6 CHANGES TO IMPROVE OR ENHANCE PERFORMANCE	6.1 RETROFITTING			
	6.2 IMPROVEMENT			
	6.3 UPGRADING			
	6.4 MODERNIZATION			
	6.5 REVITALIZATION			
	6.6 SUBSTITUTION/CIRCUMVENTION			
7 INTERVENTIONS THAT ENLARGE THE BUILDING	7.1 EXTENSION			
	7.2 REPLICATION			
	7.3 RELOCATION			
8 OVERALL MANAGEMENT	8.1 TEROTECHNOLOGY			
	8.2 ACCELERATION/DEMOLITION			
	8.3 NON-INVASIVE CHANGES			

Figure 3.24 Interventions: is the main impact of intervention upon the fabric or the function or both?

Second: is the main impact of interventions upon new buildings, upon existing buildings or both? Figure 3.25 refers.

INTERVENTIONS TO MAINTAIN STATUS QUO		MAIN IMPACT OF INTERVENTIONS		
CATEGORY	INTERVENTION	NEW BUILDING	EXISTING BUILDING	NEW AND EXISTING
1 ACTIVELY KEEPING A BUILDING THE SAME	1.1 PRESERVATION		■	
	1.2 MAINTENANCE	□	■	
2 ACTIVELY RESTORING A BUILDING TO A PREVIOUS (INITIAL) STATE	2.1 RESTORATION		■	
	2.2 REBUILDING		■	
	2.3 RENOVATION		■	
	2.4 RECONSTRUCTION		■	
	2.5 STABILIZATION		■	
	2.6 REPAIR		■	
	2.7 MITIGATION		■	
3 ACTIVELY RESTORE AFTER DAMAGE	3.1 REINSTATEMENT			■
INTERVENTIONS TO ACHIEVE CHANGE				
4 CONSERVE FOR SAME USE	4.1 REFURBISHMENT		■	
	4.2 CONSOLIDATION		■	
	4.3 CONSERVATION		■	
	4.4 RECONSTITUTION		■	
5 CONSERVE FOR DIFFERENT USE	5.1 ADAPTATION	□	■	
	5.2 ADAPTIVE REUSE	□	■	
	5.3 ALTERATION		■	
	5.4 CONVERSION		■	
	5.5 REHABILITATION		■	
	5.6 RECYCLING			
6 CHANGES TO IMPROVE OR ENHANCE PERFORMANCE	6.1 RETROFITTING		■	
	6.2 IMPROVEMENT		■	
	6.3 UPGRADING		■	
	6.4 MODERNIZATION		■	
	6.5 REVITALIZATION		■	
	6.6 SUBSTITUTION/CIRCUMVENTION		■	
7 INTERVENTIONS THAT ENLARGE THE BUILDING	7.1 EXTENSION			■
	7.2 REPLICATION			■
	7.3 RELOCATION			■
8 OVERALL MANAGEMENT	8.1 TEROTECHNOLOGY			■
	8.2 ACCELERATION/DEMOLITION			
	8.3 NON-INVASIVE CHANGES	■	■	■

Figure 3.25 Interventions: is the main impact of interventions upon new buildings, upon existing buildings or both?

Third: is the responsibility for interventions mainly with the custodians, users, or both? Figure 3.26 refers.

INTERVENTIONS TO MAINTAIN STATUS QUO		MAIN AGENCY FOR INTERVENTIONS		
CATEGORY	INTERVENTION	CUSTODIAN	USERS	BOTH CUSTODIAN AND USERS
1 ACTIVELY KEEPING A BUILDING THE SAME	1.1 PRESERVATION			
	1.2 MAINTENANCE			
2 ACTIVELY RESTORING A BUILDING TO A PREVIOUS (INITIAL) STATE	2.1 RESTORATION			
	2.2 REBUILDING			
	2.3 RENOVATION			
	2.4 RECONSTRUCTION			
	2.5 STABILIZATION			
	2.6 REPAIR			
	2.7 MITIGATION			
3 ACTIVELY RESTORE AFTER DAMAGE	3.1 REINSTATEMENT			
INTERVENTIONS TO ACHIEVE CHANGE				
4 CONSERVE FOR SAME USE	4.1 REFURBISHMENT			
	4.2 CONSOLIDATION			
	4.3 CONSERVATION			
	4.4 RECONSTITUTION			
5 CONSERVE FOR DIFFERENT USE	5.1 ADAPTATION			
	5.2 ADAPTIVE REUSE			
	5.3 ALTERATION			
	5.4 CONVERSION			
	5.5 REHABILITATION			
	5.6 RECYCLING			
6 CHANGES TO IMPROVE OR ENHANCE PERFORMANCE	6.1 RETROFITTING			
	6.2 IMPROVEMENT			
	6.3 UPGRADING			
	6.4 MODERNIZATION			
	6.5 REVITALIZATION			
	6.6 SUBSTITUTION/CIRCUMVENTION			
7 INTERVENTIONS THAT ENLARGE THE BUILDING	7.1 EXTENSION			
	7.2 REPLICATION			
	7.3 RELOCATION			
8 OVERALL MANAGEMENT	8.1 TEROTECHNOLOGY			
	8.2 ACCELERATION/DEMOLITION			
	8.3 NON-INVASIVE CHANGES			

Figure 3.26 Interventions: is the responsibility for interventions mainly with the custodians, users, or both?

Reviewing these diagrams and anticipating the implementation of Double-Design, it must be noted that categories 5, 6 and 7 would be activated. Building pathology becomes relevant at the point in the life of a building at which a decision has to be reached on its future.

Building custodians need to be aware of the two main streams of "agents acting outside and inside buildings" (Watt, 2007, pp. 97–98), namely:

- those acting outside the building: from the atmosphere or the ground, mechanical agents, electromagnetic agents, thermal agents, chemical agents, biological agents

- those acting inside the building: from occupancy, mechanical agents, electromagnetic agents, thermal agents, chemical agents, biological agents

Groak adds to the conceptual understanding of buildings as filters, distinguishing between three kinds of physical systems:

- Open systems, which allow flows of energy and matter to and from their domains
- Closed systems, which retain all matter but allow flows of energy across their boundaries
- Isolated systems, which have no flows of energy or matter across their boundaries

Groak further amplifies Watt's analysis:

> Taking buildings as open systems, we can describe buildings as affected by, receiving, filtering, storing, processing, dispatching, repelling or discarding, the following physical entities:
> - People
> - Machines
> - Information and communication
> - Electromagnetic energy
> - Kinetic energy and forces
> - Materials
> - Mixtures of materials (Groak, 1992, pp. 21–23).

Increased longevity is to be achieved by maintaining a level of performance. This level, or rather these levels, need to accommodate the spectrum of factors contributing to performance.

These naturally overlap with the established goals of the project and are going to include, in some form or other, health and safety (including environmental), efficiency, and happiness. The performance measures are applicable for the initial use of the building and any subsequent changes in use.

The factors within the control of the architect are space, structure, materials and services. The provision for these will affect the continuity of use throughout the life of the building. Further, the condition of these from the start will influence the capacity of the building to accommodate substantial changes of use without disruption.

Buildings are subject to functional obsolescence and structural degeneration. Structural degeneration can be delayed or accommodated by design that considers the different rates of decay appropriate for the building shell/structure, internal partitions, building services and furniture. Just as the selection of appropriate technology can delay structural degeneration, so too can functional obsolescence be delayed:

- by enabling the maximum participation of the users
- through the provision of flexible space, priority is given to *the nature of the space that is being provided*
- through the allowance for building expansion
- and to *the extent to which future generations of building users should be able to adapt the spaces to suit their priorities.*

Over the life of a building, the provided spaces and spatial arrangements should be capable of responding:

- to the initial needs,
- to the changing needs of the initial custodian/user (within the space provided initially)
- to the changing needs of the initial custodian/user (beyond the space provided initially) and, eventually,
- to the potential demands of quite different users, or
- to replacement

There are several approaches to design that can each contribute to the goal of robustness. Some of these approaches benefit both initial and future custodians and users as suggested in Figure 3.27.

		INITIAL USE		FUTURE USE	
		BENEFIT CUSTODIANS	BENEFIT USERS	BENEFIT CUSTODIANS	BENEFIT USERS
1	Providing spaces and furniture that encourage the users to modify furniture arrangements within the initial curtilage.	YES	YES	YES	YES
2	Providing spaces that incorporate some flexibility in terms of an ability to modify size, shape and services within and/or beyond the initial curtilage.	YES	YES	YES	YES
3	Providing spaces that, by their nature [size, shape, servicing potential and so on] will make it easier to re-use for different activities from those initially identified.	POSSIBLY: initial custodians may benefit from the extra value of a building with a longer life and with potentailly different future uses	NO	YES	YES

Figure 3.27 Initial and future benefits arising from provision of flexibility

In his pioneering work, Cowan begins to develop the idea that "human activities are adjustable to many different physical situations; and a single unit of space will often accommodate a wide variety of human activities" (Cowan, 1962, p. 58). Perhaps architecture works because spaces that can contain one set of human activities will often, just by their size and shape, be able to accommodate many others.

The characteristics that help to accommodate change include:

- The building's ability of meeting changing functional demands without changing characteristics, i.e. the ability to meet different functional needs without doing considerable changes in the building.
- The building's ability of meeting changing functional demands through changing characteristics, i.e. the possibility of doing changes in the building and technical structure at minimal costs and abruptions in operation, without increasing the area of the building.
- Beyond a response to change, buildings may have the possibility of growth (increasing usable area) or partition of the area in a building (decreasing area of use). (Jensø, 2003, p. 6)

Cowan further elaborated aspects of growth and advised: "that, if change becomes normal in society, the artefacts and structures which we build to house our various institutions and activities must themselves be adaptable. Since it is not possible to tear down and renew buildings each time they become obsolete because of changes in activities which they house, the only way that we can adjust our buildings to changing needs is by adapting them" (Cowan & Sears, 1966, p. 3).

Cowan's research traced the patterns of growth and change in six very different organizations (Cowan & Sears, 1966). It concluded that the factors that made a residential building suitable for modernization were: "First, they must be structurally sound. Second, the average cost per converted dwelling must be less than the cost of rebuilding. Third, there must be at least 40 years of potential life after conversion. Fourth, the dimensions and standards of new rooms created by modernization must as nearly as possible correspond to standards laid down for new buildings" (Cowan & Sears, 1966, p. 17).

The study emphasized the importance of estimating future needs and listed the following factors as affecting an organization's ability to retain buildings and find them satisfactory: "the most surprising fact to emerge from this study was the extent to which organizations moved entirely or in part because of dissatisfaction with a building, and the variety of reasons which caused the building to become, or seem to become, unsatisfactory" (Cowan & Sears, 1966, p. 3).

Designing for change brings organizational benefits if moves and disruption can be avoided. For some organizations working in exceptionally competitive environments, the speed at which a change can be affected may be critical to their survival. Looking at businesses, it may be imperative for them to introduce innovations quickly so as not to have to go through an elaborate change of use process. This accords with business models of decision making in dynamic organizations (Lyneis & Sterman, 2009). The case study described by Lyneis and Sterman raises another interesting issue. They describe the factors leading to reluctance by otherwise well-managed custodians to improve energy use. This suggests that Double-Design should always include an element of building services enhancement and some capacity to accommodate future services upgrading.

Activities needing to be accommodated and the spaces provided (demand and supply) will be affected by changes in legislation and changes in technology, leading to shifts in expectations concerning building performance.

Considering the extraordinary diversity of changes of use observed throughout the building stock and throughout the world, it is tempting to be overwhelmed by the uncertainty that inevitably attends the start of a project. But is it not a bounded uncertainty? While changes and the sequence of their occurrence cannot be forecast with accuracy, a range of possible changes in use could be suggested and, given that for each of those, there is a set of requirements that can be defined, an environment could be designed to accommodate activities throughout the physical life of the building.

Responsible stewardship of a finished and occupied building requires awareness of the factors that will, unless modified, shorten the life of the physical building and its productive use.

Groak suggests that adaptability means being capable of different social uses while flexibility means being capable of different physical arrangements (Groak, 1992, p. 15). Recognizing the importance of adaptability as a response to user interaction, Jensø suggests: "In accordance to Blakstad, adaptability is described as '*the ability to change as a result of internal or external influence, and is regarded as a strategic "from the top" approach'.* The term *physical adaptability* is used according to the structure and technical system of the building" (Blakstad, 2001). Brand[24] describes a model for stratification related to adaptability in buildings. Buildings are discussed as a set of layers functioning in a totality, where the layers are adjusted due to specific use and framework (Brand, 1997). Maximum adaptability is gained when the different layers can be changed independently or with few consequences for the other layers, due to technical lifetime, new claims and needs and so on" (Jensø, Monica & Getz, Alfred, 2003, p. 15). There have also been studies of the 'usability' of buildings especially as applied to hospitals (Jensø et al., 2004) (K. Alexander, 2008).

Adaptability can be regarded as a valuable characteristic of designers as well as of the spaces they design. Goodman offers advice to young designers, covering cognitive, emotional and situational adaptability (Goodman, 2018).[25]

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[24] Basing his analysis upon that of Duffy (Duffy, 1990). Brand is generous in his recognition of the innovative work of Duffy and his colleagues at DEGW.

[25] Embracing change and a future of infinite possibilities, though daunting, will inevitably strengthen your ability to adapt – and in turn, design. The ability to adapt can arguably lead to success in any field, but it has a multifaceted importance for designers. Beyond adapting to ever-changing tech specs, rotating team members, and the demands of clients and users, designers can set themselves up for success by learning to remain flexible cognitively, emotionally, and situationally.
Cognitive Adaptability In order to adapt well, it's important to understand the value of progress and react accordingly by making an effort to keep up with the changing world around you. We can't predict the future, but we can welcome it – and that makes all the difference.
Emotional Adaptability Creating a design that enriches the end user's experience necessitates putting yourself in the shoes of your client and their audience and learning to overcome your own confirmation bias. This can require a level of emotional intelligence that transcends everyday empathy. The more memorable and meaningful the design is, the more it will resonate with users.
Situational Adaptability Rather than letting challenging circumstances control you, a flexible worldview is fundamental for designers. Approaching change as an opportunity rather than a threat can positively influence both the way you work and your work itself. This kind of adaptability increases productivity and helps keep teams stable through times of change.

3.4 BUILDINGS IN USE: MATERIALS

3.4.1 Longevity

The selection of a longevity target needs to take account of both fabric and function. Given the importance now attributed to whole life-cycle costing, function and fabric, commodity and firmness should expire together (Gundes, 2016). How firmness is to be achieved is under the control of society.[26] It is the achievement of the sustainability benefits arising from longer-lasting buildings that must be the initial objective. As Kestner & Webster suggest: "given the difficulty of forecasting building life and the permanency of the structural system, it makes the most sense to design the structure for enough durability to ensure that it is not the weak link that results in a building's demise" (Kestner & Webster, 2010, p. 11).

Design must then ensure that the demand side, occupancy and potential occupancy last as long as the fabric. Structural degeneration can be slowed down by design that enables the replacement of separately layered components with different life expectancies, following the analysis of Duffy and Brand (Duffy, 1992; Brand, 1997) and by proactive maintenance (Gijsbers, 2006). The forces at work on the physical building will include deterioration, erosion and decay, and interventions made by custodians while the building is in use (Asset Insights Glossary, n.d.). But, as Costanza & Patten

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[26] **As the species succeeded, accommodation was expanded by excavating additional spaces; simple and effective with little environmental impact. Numbers have caused us now to operate in the built environment but we would be well advised to retain the same principles where shelter is more or less permanent and can be adapted to fulfil changing roles and requirements (Richard D'Arcy).**

remind us: "All systems are of limited longevity, so sustainability cannot mean "maintenance forever" (Costanza & Patten, 1995, p. 196).

But neither should systems be left to rot. There is a famous example in which a specific longevity target is set and achieved: Oliver Wendell Holmes' one-hoss shay lasted precisely one hundred years, and then all its components collapsed simultaneously, an extreme approach to ending function and fabric together (Holmes, 1858). The British historian, Sir John Glubb, wrote that the great empires – Assyria, Persia, Greece, the Roman, the Arab Empires, the Ottoman Empires, Spain, Russia, and Britain – flourished for about 250 years (Glubb, 1978). This seems to be the time allotted for imperial hegemony (Mamet, 2012). Further research may reveal a logical basis for establishing the optimal material longevity, perhaps for each building type. The pursuit of materials capable of self-repair, as reported by Tibbits, will affect this outcome (Tibbits, 2021).[27] However, a longevity target lying between Holmes's one hundred years and Glubb's two hundred and fifty will suffice for the present argument. Stewart Brand has also explored the concept that layers of culture may have appropriate time horizons without specifying individual targets (Brand, 1999). The Foundation of which Brand is a Director is trying to halt the slide towards short-term thinking: "The Long Now Foundation was established in 1996 to develop the Clock and Library projects, as well as to become the seed of a very long-term cultural institution. The Long Now Foundation hopes to provide a counterpoint to today's accelerating culture and help

[27] The author's architectural partner Brian Taggart mischievously published an account of an entirely fictional self-healing material in the AJ and was inundated with enquiries from those wanting to purchase it!

make long-term thinking more common. We hope to foster responsibility in the framework of the next 10,000 years" (About Long Now, 2021).

Henry Ford's approach to manufacturing epitomized the commodification of products[28] and is referred to here in recognition that making buildings last for a long time will challenge many of the assumptions embedded in current project commissioning practices.

To illustrate how far we have come from Ford's belligerent capitalism, the relationship between product design and sustainability has recently been brought into focus through product longevity studies. The proceedings of the first conference, held in 2015, argued that "product lifetimes have become an increasingly important element in the debate on the circular economy, resource efficiency, waste reduction and low carbon strategies for sustainability" (Salvia et al., 2016, p. 111) . Further consideration of the relevance of product design is given in Appendix Four.

Flager sets out to:

> Outline how buildings might be designed for improved life-cycle performance from a structural engineer's perspective. The argument goes as follows:
> 1 – How Buildings Change: A building can be thought of as a collection of components, which change at different rates according to the demands of the real estate market. The ultimate value and longevity of a building is often dependent on the ability of the structural system to accommodate the repair, replacement and renovation of individual components.
> 2 – Design For Change: By focusing on construction as a process rather than a result, there is an opportunity to improve a building's economy and efficiency. Since the construction process continues long after the original building is

[28] "Henry Ford, it is said, commissioned a survey of the car scrap-yards of America to find out if there were parts of the Model T Ford which never failed. His inspectors came back with reports of almost every kind of failure: axles, brakes, pistons – all were liable to go wrong. But they drew attention to one notable exception, the kingpins of the scrapped cars invariably had years of life left in them. With ruthless logic Ford concluded that the kingpins on the Model T were too good for their job and ordered that in future they should be made to an inferior specification" (Laird & Sherratt, 2010).

completed, engineers must consider the financial and environmental costs over the lifetime of the structure when assessing the performance of a design.
3 – Built For Change: There are a number of ancient and modem buildings that accommodate change quite well. (Flager, 2003, p. 9)

Of particular importance is Flager's assessment of the criteria to be applied to structural design to allow for change. These are summarized in Figure 3.28.

Module	Performance Requirements
Façade	- Separation of load-bearing and non-load bearing components
	- Demountable connections between facade and interior work
	- Demountable connections between prefabricated components
Partitions	- Ability to separate functional layers (finish, insulation, fire protection, etc.)
	- Demountable connections between partitions and building structure
	- Minimal use of insoluble composite constructions
Services	- Demountable connections between services and building structure
	- Separation of services modules by function
	- Accessibility and changeability of components
	- Minimal use of insoluble composite constructions

Figure 3.28 Criteria to be applied to structural design to allow for change: from (Flager, 2003, p. 9).

He continues with practical advice for the accommodation of change:

The future value of a building is mainly dependent on its ability to accommodate change over time economically. Obsolescence can result in an irreversible and major reduction in the market value of a building. The following design consideration significantly reduces the risk of obsolescence:

- Sufficient storey height to allow for building service upgrades
- Vertical load-bearing elements which do not prevent changes in use
- Space for staircases and vertical connections for building services
- Flexibility for changes in structural performance requirements
- Partitions that can be easily reconfigured
- Ease of maintenance, renovation and replacement of structural components
- Attention to building code requirements to anticipate alternative uses and maximize flexibility. (Flager, 2003, p. 28)

Flager draws attention to "one of the unique things about the Shinto shrine at Ise. […] it has a predetermined lifespan: the shrine buildings are dismantled every twenty years and then reconstructed in exactly the same manner using new materials. Due to the relatively short lifespan of the shrine buildings, their architecture is recognized as temporary" (Flager, 2003, p. 28).

Encouraged by the pursuit of sustainability, other aspects of building layers are increasingly subject to study to extend the life of building components and systems. Erkelens, for example, sets out the framework in which responsible design must operate:

> Resource conservation means that in the whole life span of the building, the use of resources (building materials, energy, etc.) should be such that the environmental impact is as low as possible and/or, better still, zero. Ideally, the combination of resources should have zero impact on the environment or even improve that environment, including its best quality and health. So far this is not yet feasible. A more realistic approach can be sketched as follows:
>
> - Minimisation of the use of resources, and where necessary
> - Use of renewable resources applying the ideas of biotecture**,** as well as
> - The extension of service life through re-use and recycling (at all levels from whole buildings down to materials).
>
> Environmental impact assessments are needed to check for the best combination of options, as it is not always the solution with the minimum use of resources that results in the minimum environmental impact. (Erkelens, 2002, p. 2)

In a case study, Erkelens reports that the option of renovating a building originally built in 1949 was less environmentally sound than simply maintaining it to the end of its useful life.

Considering methods to establish the life of building materials and components, Rejna says:

> The durability of a component expresses the propensity to supply during time the planned performances through the durability of materials, sections, and elements which compose it, i.e. through the durability of the relevant characteristics. There are two ways of building components' performances' loss: the first way is characterized by the sudden passage from the condition of good operation to a no operation condition: these components are called bistable. For them the damage or no operation can be univocally identified. The other way is characterized by a continuous loss of functioning, and so these elements are said not bistable. In this kind of decay there is the necessity to define the level of performance decay acceptable for the identification of the damage condition. (Rejna, 2002, p. 3)

3.4.2 Expected Life of Buildings

The establishment of target life for structures appears readily achievable, given that some categories of structures already have default life targets close to the 150 years mentioned above. For example, the UK modification of Eurocode for monumental structures (category 5) increases the expected life from 100 to 120 years (*Eurocode – Basis of Structural Design; Supersedes ENV 1991-1:1994 Incorporating Corrigenda December 2008 and April 2010*, 2005). A very long service life of even up to 500 years or more would be desired for monumental buildings such as temples and churches. Public buildings such as town halls and parliament buildings could be expected to last for 100 to 200 years, whereas private structures such as offices and dwellings for perhaps 50 to 60 years. BS 7543 (1992) defines the 'normal' life of a building as 60 years. The new Eurocodes, e.g. BS EN 1992-1-1 (2008), assume this period to be a lower one of 50 years (Dias, 2013).

Structural design to achieve desired life expectancies has been made easier by introducing parametric design software, which enables whole-model manipulation of design models with the rapid evaluation of results arising from varying input requirements (*Https://Www.Tekla.Com/Products/Tekla-Structures*, 2020).

The expected life of buildings is influenced, if not determined, by the financial decision-making of the custodian. But building is a field beset by risks and uncertainties. Custodians may do whatever calculations are needed to get a project started without guarantees of expected building life. In a way, the risks are transferred to the future custodians in terms of maintenance responsibility. Studies about the expected life of buildings initiated by the UK government and internationally cover definitions and predictive methodology rather than prescription and guidance (British Standards Institution, 2015). Much of the literature covers international efforts to standardize assessment methods and, at least in the field of buildings, there is a reluctance to establish targets and a reliance upon predicting service life based on qualitative and quantitative factors (Marteinsson, 2005, p. 49). Indeed, ISO 2394 refers ambiguously, in Figure 3.29, to *examples* of design service life rather than targets:

Category	Description	Building Life	Examples
1	Temporary	Up to 10 yrs	Site huts; temporary exhibition buildings
2	Short life	Min. 10 yrs	Temporary classrooms; warehouses
3	Medium Life	Min. 30 yrs	Industrial buildings; housing refurbishment
4	Normal life	Min. 60 yrs	Health, housing and educational buildings
5	Long life	Min. 120 yrs	Civic and high quality buildings

Figure 3.29 Examples of notional design working life: from (British Standards Institution, 2015, table 1)

Although BS EN 1990 suggests that the design working life should be specified, as shown in figure 3.30, design working lives are also consistently stated as examples rather than targets. Further, indicating the likely life of components and materials rather than specifying lifetime performance appears irrational and inconsistent with basic presumptions about design and specification.

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures (1)
2	10 to 25	Replaceable structural parts, e.g. gantry girders, bearings
3	15 to 30	Agricultural and similar structures
4	50	Building structures and other common structures
5	100	Monumental building structures, bridges, and other civil engineering structures
(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.		

Figure 3.30 examples of "design working life": from (*EN 1990 (2002) (English): Eurocode– Basis of Structural Design [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC]*, 2010, table 2.1)

According to the Building Research Establishment (BRE, 2006), design service life is the assessment of a structure, both as a complete building and individual components, which predicts potential lifetime based on design, workmanship, maintenance, and environment. Service life is the assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary. A factoring method for assessing the design service life of buildings and components has been developed by BRE for the Scottish Building Standards Agency (Kelly, 2007). However, the approach has been regarded as too dependent upon estimates to provide a reliable predictor of service life (Davies & Wyatt, 2004). Nevertheless, the fact that there is a developing methodology suggests that achieving a particular target design life could become a practical proposition (Frohnsdorff et al., 1999) (Edvardsen, 2010) (Helland, 2013). A way would need to be found to extend the scope of the methodology to cover unknown future uses, not just the initial use, as a factor in the calculation.

The interaction between users and spaces is two-way. Whilst the building must respond to changing needs, the organization can also respond to the building. The life expectancy of buildings is vital as a factor in building economics and relevant to architects and developers. Witold Rybczynski, a participant in a Getty Center colloquium on building preservation, observed that: "the life cycle of conventionally built (masonry and wood) buildings is about 120 years (before major repairs), whereas for modernist buildings it is only half that time – sixty years. It took several decades to discover that steel and concrete were precarious partners, and that porous, fragile concrete was a poor substitute for stone and brick as external cladding" (Rybczynski, 2015).

The analysis of building life expectancy plays an integral part in decision-making for capital investment.

Amortization usually refers to spreading an intangible asset's cost over that asset's useful life. For example, a patent on a piece of medical equipment usually has a life of 17 years. The cost involved with creating the medical equipment is spread out over the life of the patent, with each portion being recorded as an expense on the company's income statement. Depreciation, on the other hand, refers to prorating a tangible asset's cost over that asset's life. For example, an office building can be used for many years before it becomes run down and is sold. The economics of decision-making about re-use are being developed, especially in the field of housing (Crawford, 2014):

> The lifetime of a building is how long it lasts from when it is first built to when it is replaced. Within this there may be a shorter period of:
>
> - economic life: ends when the building is judged to no longer be the least expensive way of performing its function
> - service life: ends when the building is judged to no longer perform as intended
> - technological life: ends if the intended performance of a building is judged to be mismatched with what inhabitants or users expect
> - "effective lifetime" is the projected life of all our buildings given the total number of buildings in the UK and how many get built and demolished each year (not many are demolished so effective lifetime works out as about a thousand years)
> - design life is decided by a building owner/developer to guide engineers and assure investors and insurers about the quality that has been specified for the building and its equipment (UCL Engineering, 2017)

"The cost of the building is spread out over the predicted life of the building, with a portion of the cost being expensed each accounting year" (Ross, 2006,). In the UK, general guidance about design life for buildings is given in British Standards. It also provides guidance on presenting information on the service and design service life of buildings and their components when a detailed brief is being developed. There is important information which is required to determine the potential lifetime of a material or component:

- Time against which the durability is to be assessed.
- Conditions in which the material or component will have to perform.
- Performance level at which the material or component is not to the required standard.

In addition to these factors, issues such as maintenance levels and conditions of use should be estimated. Three levels of maintenance are described in BS 7543 (2003), shown in Figure 3.31.

Level	Description	Scope	Examples
1	Repair only	Maintenance restricted to restoring items to their original function after a failure	Replacement of jammed valves; reglazing of broken windows
2	Scheduled maintenance plus repair	Maintenance work carried out to a predetermined interval of time, number of operations, regular cycles etc. (see Note),	Five yearly external joinery painting cycle. Five yearly recoating of roof membrane with solar reflective paint
3	Condition based maintenance plus repair	Maintenance carried out as a result of knowledge of an item's condition. [The condition having been reported through a systematic inspection (procedure)]	Five yearly inspections of historic churches etc. leading to planned maintenance

NOTE The length of the regular maintenance cycle is an important factor. It may be stated in the brief or agreed while the design is being developed.

BS 8210 recommends systematic inspections as follows:

a) continuous, regular observation by the building user as part of the occupancy of the building; and

b) annual visual inspection of the main elements under supervision of suitably qualified personnel; and

c) full inspection of the building fabric by suitably qualified personnel at least every 5 years.

There may be statutory requirements for more frequent inspections.

Figure 3.31 Maintenance levels other than daily and routine cleaning: from (British Standards Institution, 2003, table 1)

This Standard also includes detailed information relating to factors that can cause deterioration. Many examples of premature deterioration are also listed in addition to agents that can affect the service life of building components and materials (British Standards Institution, 2015).

Braungart and McDonough develop a more radical concept in which the inevitable production of waste is replaced by a system in which "cradle-to-cradle design relies on reconnecting this waste-producing "technosphere" with the "biosphere" (Braungart & McDonough, 2002).[29]

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[29] **Buildings that 'last' should positively contribute to optimising embodied energy – why constrain to 150 years! Despite their 'lasting' nature – buildings, and their materials have organic degradation characteristics – so I think the devil will be in the detail in relation to maintenance and incremental renewal/component/system replacement strategies. After 150**

Within mainstream architectural advice, there is recognition that the life expectancy of buildings has something essential to do with serving clients well. For example, Maria Lorena Lehman says:

> Your design solution may become outdated, as someone else comes up with a better way to solve for a problem or need later on down the line. The answer here is to design your building for change and growth. To ensure that your building's lifespan is long (and valuable to people), make sure that it stands not only because of the strength of its materials, but also because of the adaptability of its composition. (Maria Lorena Lehman, 2020)

In their book, "Buildings Must Die", Cairns and Jacob explore the metaphor of building "life" to the limit, rightly describing the overlapping states of the last phases of a building's use. There is no doubting the fascination with which abandoned buildings are pursued and archived (Cairns & Jacobs, 2014). Yet neither can the irresponsibility of leaving a building 'unattended' be ignored.

The simplicity of the choices for future adaptability or expansion that are open to a custodian at the beginning of a project is well described by Becker. However, Becker's options highlight the likelihood that designing for future adaptation, including Double-Design, may require additional costs that would not have been incurred with a simple, non-adaptable building. Approaching the subject from the viewpoint of reducing environmental impact and, hence, seeking to choose structural solutions with minimal embedded energy, the approaches are summarized as follows:

> Option 1: Design for structural efficiency based on today's requirements for program and codes. This option would require the existing substructure and superstructure to be demolished and a new structure built when expansion is required. Because the foundation of a building is the most difficult to replace or retrofit and therefore most expensive portion of the structure to remove or retrofit for additional levels, options 2 and 3 focus on the design of the

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years – how much of the original building will be evident – structure (spatial organisation)/ fabric (skin/cladding/insulation)/systems – Cabling/HVAC/sanitary? (Rod Bond).

> foundation only for future expansion while the superstructure is designed for immediate programmatic needs. In the future, the superstructure would require either retrofitting or demolition. These options are advantageous in that the embedded energy in the foundation is not wasted and the expense of concrete removal, earthwork, formwork and new concrete placement is spared.
> Option 2: Design the substructure for future expansion but demolish and rebuild the superstructure.
> Option 3: Design the substructure for future expansion and retrofit the superstructure to meet expansion demands.
> Options 4: A comprehensive future design strategy – Design the substructure and superstructure to support future loads consistent with projected increase in urban density for a given area. This option can be subdivided into two categories: one accommodating continued use of the building during expansion and the other requiring the building to be vacated during construction. (ARCC2015_Perkins-Will-Conference-Proceedings, 2015, p. 57)[30]

Nevertheless, Douglas and Ransom maintain the need for innovations in the building industry to help avoid obsolescence and create greater adaptability. (Douglas and Ransom, 2013, p. 276). The Athena Institute conducted a three-year study in Minneapolis/St. Paul (Athena 2004) and found that of the 227 structures demolished during the three and one half-year period from 2000 to mid-2003, only 31% were demolished due to the physical condition of the building and 7% from fire damage, while 57% were demolished because of area redevelopment or because the structure was not suitable for anticipated use. Only one-third of the demolished structures were made of concrete and steel, but of those, 63% of concrete structures and 80% of steel structures demolished were under 50 years old. (Athena Institute, 2004)

It is interesting to note that consideration of the reasons for failure in buildings generally focuses upon their physical failure rather than their lack of fitness for purpose. This may well be influenced by the fact that the users, who directly interact

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[30] A high-rise project in Kuwait was modified during construction with the addition of eight floors, without redesign, to take advantage of a change in planning laws!

with the building, are often disconnected from the custodians. However, a team of Cambridge researchers are making a case for flexible buildings that can be easily reused and recycled. They explain the benefits:

> Supermarkets in the UK are typically refurbished after 10 years and replaced after 20. The replacement is generally opened on a different site to allow a change of size, and the old store demolished. What if, instead, we built supermarkets out of a prefabricated kit of parts that could be quickly constructed, would be flexible in use and could be dismantled and reused after 20 years?
>
> This ideal of flexible, deconstructable buildings could be extended across many other segments of the building stock. It would require some changes in design with existing building components, particularly related to the floor slab or foundations, and could be achieved if adaptability and deconstructability were incorporated into project briefs and embedded at an early design stage. The result would be buildings with longer lives and far greater material reuse than is currently possible. The benefits include a significant reduction in embodied emissions, reduced waste, increased adaptability and faster construction times. If buildings were designed with future users in mind, incorporating flexibility and adaptability into their designs to allow subsequent alteration and upgrade, their useful life could be increased from an average of 40 years to 100 years. When these two measures are combined for commercial buildings we could reduce embodied emissions by 80%, meeting the target from the 2008 Climate Change Act with no technology innovation or loss of value to users.
>
> The strategies of design for adaptability are largely parallel to those when designing for deconstruction. This has an additional benefit of being a built-in fail safe: if the building is no longer required then it can be deconstructed and either moved to a new suitable location or the individual components reused within new construction. This thus preserves the value of the materials and the embodied carbon already expended in creating them.
>
> To be most effective, these strategies must be applied at an early design stage and will be successful with a coordinated approach from the design team. Our researchers are tracking projects through the design stages to highlight opportunities, gain a better understanding of current barriers and estimate the impact on building costs (Allward & Tingley, 2014).

The interdependence of building life and finance is revealed in studies of Chicago:

CHART 2.
AVERAGE LIFE OF BUILDINGS EXISTING EACH YEAR

Year	No. of Bldgs.	Years Av. Life
1885	8	1 1/2
1886	11	2
1887	11	3
1888	13	3 4/7
1889	14	4 3/7
1890	16	4 3/4
1891	19	5
1892	26	4 2/3
1893	33	4 2/3
1894	38	5
1895	42	5 4/7
1896	45	6 1/4
1897	48	6 5/6
1898	49	7 3/4
1899	49	8 3/4
1900	50	9 1/2
1901	50	10 1/2
1902	53	10 3/5
1903	54	11 2/5
1904	57	11 4/5
1905	60	12 1/6
1906	66	12 1/6
1907	70	12 4/7
1908	72	13 2/9
1909	72	14 2/9
1910	78	14 1/6
1911	84	14 2/7
1912	87	14
1913	94	13 7/8
1914	100	14
1915	102	14 2/3
1916	107	15
1917	108	15 4/5
1918	109	16 2/3
1919	110	17 1/2
1920	111	17 3/4
1921	111	18 3/4
1922	115	19 1/4
1923	124	19
1924	131	19
1925	135	19 1/2
1926	141	19 4/7
1927	159	18 1/3
1928	167	18 1/8
1929	178	17 1/2
1930	186	17 5/6

It took 16 years (1901) for the average life of existing buildings to reach 10 years; 31 years (1916) to reach an average of 15 years; 37 years (1922) to reach 19 years; and in the entire 45 years, the maximum average age has not reached 20 years.

Figure 3.32 average life of buildings in Chicago in each year, 1885–1930: from (Abramson, 2017, p. 28)

Figure 3.32 shows the average life of Chicago office buildings and formed part of the research effort aimed at achieving tax advantages for owners, at the time, due to obsolescence (Abramson, 2017, p. 29).

3.5 BUILDINGS IN USE: SPACE

3.5.1 Extending the Life of Existing Buildings

A substantial percentage of buildings experience a change of use (Barej, 2017) (*Construction Statistics Annual Tables – Office for National Statistics*, n.d.) (Gause, 1996) (Houghton, 1994)

It has been suggested by Addis that the future of construction will show a distinction between highly specialized buildings with a short life and buildings with a much longer life that are designed for unknown changes and re-use (Addis, 2007). The pursuit of environmental goals suggests that the first category, with architecture as commodity, is no longer relevant.[31] In the city of New York, half the building permits issued are for conversions, often of unlikely and apparently specialized buildings, (Hughes, 2014). In support of Addis' assertion, Celadyn begins to develop a different argument, suggesting that buildings designed with a short life (shopping malls seem to be chosen as the example of this category despite their observed longevity and resilience) should conform to a deconstruction strategy in which components can be readily dismantled and re-used elsewhere (Celadyn, 2014, p. 24).

[31] The possible reconciliation between long and short-term architecture is considered later in Chapter Seven.

Wong points out that the first use of the term 'adaptive reuse' in 1973 coincided with the global oil crisis, triggering awareness of natural resources (Wong, 2017, p. 30). She reviews early examples of reuse and describes recent 'violent' interventions intended to deconstruct the aesthetics of architecture. She also charts the progress over time towards the formalization of preservation of historic buildings (Wong, 2017, p. 90). She concludes: "the practice of adaptive reuse is much like playing the second violin to the melody of the host building. It is a song of redaction in which the minor keys humbly and sweetly negotiate between existing context and new context" (Wong, 2017, p 246).[32] Latham explores and records the variety of successful reuses of existing buildings, providing twenty case studies to illustrate the diversity achieved. He identifies six keys to change: rescue/restoration of a derelict building, internal intervention, partial demolition, external intervention, minimal alteration, and major extension (Latham, 2015).

Since building reuse has become so commonplace, indeed, the characteristics that enable successful reuse should arguably be required in all new designs. The continued focus upon the first-day novelty of architecture, rather than the long-term value of effective use and reuse, continues to deflect architecture from its proper path.

Kincaid developed an origin-destination approach to the analysis of changes of use. The broad categories of changes of use for a group of London boroughs are shown in Figure 3.33. The dominant changes of use were: Office to Residential, Other (public

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[32] Perhaps with Double-Design from the start the whole orchestra will be engaged.

buildings, education and hospitals) to Residential, Office to Other and Industrial to Residential.

Original Uses \ Destination Uses	Residential	Retail	Industrial	Office	Other	
Residential	3.5%	1.2%	0.0%	3.2%	0.6%	8.5%
Retail	1.1%	1.2%	0.3%	2.6%	0.6%	5.8%
Industrial	7.6%	0.5%	1.5%	3.5%	2.3%	15.4%
Office	**33.7%**	4.7%	0.2%	1.2%	9.6%	49.4%
Other	10.8%	0.8%	0.3%	5.5%	3.5%	20.9%
	56.7%	8.4%	2.3%	16.0%	16.6%	100%

Figure 3.33 Origin and destination use of planning applications involving 'change of use'. Source; APR database for January 1993–November 1994 for seven London boroughs: from (Kincaid, 2002, p. 4).

As Kincaid concludes: "There are no operational methods for the identification of the strategic options for refurbishment to new uses; neither are there established techniques for testing and comparing the relative value of options" (Kincaid, 2002, p. 5). What are the factors that lead to change? Kincaid discusses the comprehensive refurbishment of buildings to enable them to be used for purposes different from those originally intended. Kincaid's work used surveys of key players to highlight the factors considered most important in deciding whether to reuse an existing building: "users' preferences were remarkably consistent with the marketing and developer groups, with positive external factors including building character, period features, size of windows, car parking and transport access being of paramount importance. Within the building, floor to ceiling height, floor plate size and the configuration of core areas were seen as the more important features" (Kincaid, 2002, p. 26).

The "Use Comparator" compared the physical and locational characteristics of a building with the characteristics best suited to various types of use. As a result, 77 targeted types of use are evaluated, in contrast to the 17 uses usually considered by regulatory planners in the UK.[33]

Kincaid identifies changes in demand (1985–1995):

- Reduced manufacturing (-18%)
- IT impact
- Organizational needs
- Flexible employment practices
- Space sharing
- User expectations
- Regulatory context
- Facilities management

and in supply:

- Vacancies
- Redundancy of specialized buildings
- Under-provision (housing)
- Premature obsolescence

[33] The "Use Comparator" is referred to in Kincaid's book as being available from UCL but unfortunately is no longer usable.

Kincaid asserts that it is now "no longer reasonable to assume that most new-build stock will remain within its original class of use" (Kincaid, 2002, p. 3).

The exercise of ingenuity in changing from one use to another must consider the building stock's characteristics. This is a vital part of charting the potential compatibility of an "inherited" building with a new use. Hence, if compatibility assessment can work for changes of use, it may also work for new-build, and for Double-Design.

According to Gause (The Urban Land Institute), the advantages of adaptive reuse include:

1. Timing: reusing an existing building can speed up the predevelopment process and enable an enterprise to open earlier, especially when the zoning of the proposed new use is compatible with the existing use.
2. Price: since the cost is a major factor in determining project feasibility, there will be many cases in which reuse will save money.
3. Marketing appeal: old buildings may have unusual or unique features that may add to the appeal of the refurbished building; high ceilings, old materials.

The examples of change of use included in Gause are shown in Figure 3.34:

FROM	COMMERCIAL	INDUSTRIAL	PUBLIC	CULTURAL	HOUSING/HOTELS
TO					
COMMERCIAL	1,2,3,4,6,8,13, 16	17, 20, 22,24, 26,27,29, 32,36,38,39,40,41,42,48 ,50,	53,57,61,62,64,67,	69,70,71,	73,76,78,79,
INDUSTRIAL		19,			
PUBLIC	5,7,	23,25, 31, 35,50,	56,66,		
CULTURAL	10, 11,	18, 28, 33,	54,58,59,60,68,	72,	
HOUSING/HOTELS	9,12, 14, 15,	21,30,34,37,43,44,45,46 ,47, 48,51,52	55,63,65,		74,75,77,80,81,82,83

Figure 3.34 Examples of adaptive reuse representing a broad range of old and new uses and a diversity in use, cost and size: numbers refer to specific illustrated examples, from (Gause, 1996, pp. 134–170).

The spectrum of successfully reused buildings is so great that it would be wrong to rule out a new design, with the benefit of "Double-Design", being suitable for almost any future use (Ogbu, 2010).

There are many examples in which an unlikely beneficial second use has been established. A theatre turned into a library in Buenos Aries, and a water tower becomes a penthouse dwelling. The BBC recording studios at Maida Vale, the largest in Britain, started life as an 'American roller-skating palace' and may now be in line for a further manifestation as apartments (BBC, 2020). The website of a German/Chinese architecture practice records:

> Today adaptive reuse is a worldwide practised mode of architecture. Any building can be reutilized, and adaptive reuse takes many forms: Churches are turned into restaurants, old train wagons and disused silos are reused as homes, factories are converted into concert halls, and former hospitals are turned into hotels or office buildings. […] We will explore this special connection by investigating two of the most popular adaptive projects:
>
> TATE MODERN ART GALLEY Tate Modern Art Gallery on the south bank of the Thames in London, just across St Paul's Cathedral, might be the most famous adaptive reuse project in the world. Adaptive reuse can be considered the entry point of a unique form of architecture into the urban sphere.
>
> ZECHE ZOLLVEREIN Adaptive reuse projects can be of social and cultural significance, as the following example, the revitalization of the former coal mine industrial complex Zeche Zollverein in Germany, will demonstrate. Zeche Zollverein is located within the Ruhr area, Germany's traditional industrial belt; the site began operation in 1847. Zeche Zollverein is comprised of many buildings, widespread over an extensive area of 100 hectares. Today Zeche Zollverein is a multifunctional culture park with museums, event halls, restaurants, schools, offices, open air fairs, sport facilities, galleries, exhibition areas, and so on. […] It is noteworthy, that such integration of the past into the present with a signal effect for a whole region can only be achieved by revitalizing old buildings. (Hartmann et al., 2017)

It is unusual for a second, different, use to be taken into account seriously from the start of a project. The design of the London Olympic village may be exceptional, anticipating that athletes housing would convert to general housing after the games in 2012. The designers made a distinction between "games" mode and "legacy" mode (Moore, 2012). Another, perhaps more surprising, example is provided by Smith and illustrated in Figure 3.35: "a proposal for a deployable wall and roof panel system for the U.S. military operations in Iraq. The system contains integral gabion mesh to be filled with local stone for ballistics and relate to the vernacular housing. Once vacated, the building is a dwelling for local residents" (Smith, 2010, p. 233).

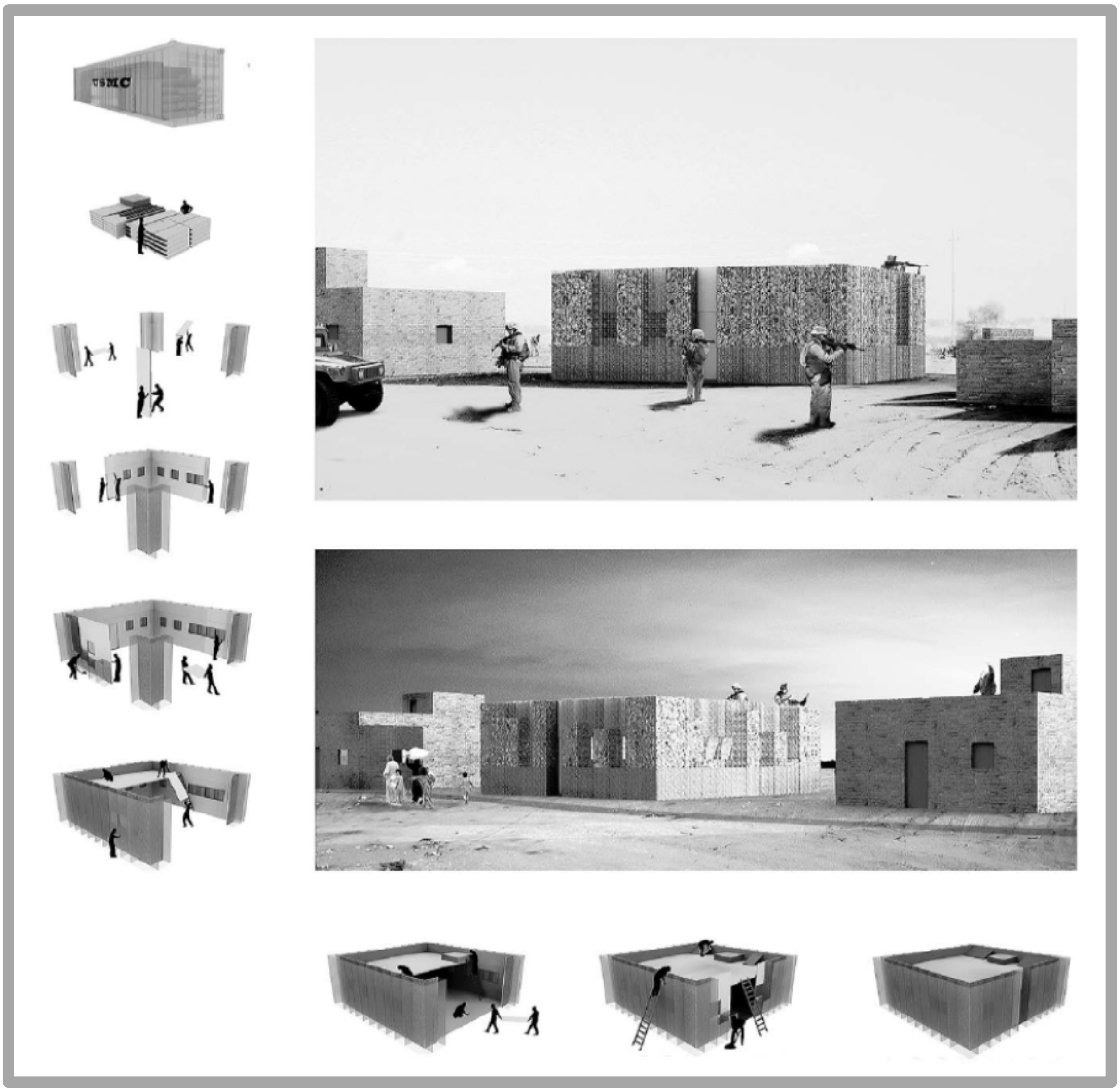


Figure 3.35 US military wall and roof system becomes dwelling for local residents: from (Smith, 2010, p. 233)

Having set my architecture students, in 1963, the task of designing packaging, we visited the warehouse of a famous north London company specializing in international freight. The owner, TE Dingwall, told us that, on finding his large wooden crates used for housing in Peru, he had arranged for doors and windows to be pre-cut in the crates to facilitate their reuse after their initial load emptied. His extraordinary altruism has stayed fresh throughout my career. The local history website reports: "in 1946 T.E. Dingwall took over. They were packing case manufacturers, bringing in timber by barge, converting it into packing cases and shipping them out again by barge. Most of the wood moved only a couple of hundred feet on land".(*Post-War Camden Town*, n.d., pp. 121–122)

The conversion of the warehouse into a thriving music and live events venue in 1973 is another example of reuse.

Ross et al. sought to quantify the effectiveness of design-based enablers of building adaptability. They included participants with experience in the construction field:

> Based on the survey responses the four most effective enablers are: accurate information about the building (Plans), reserve capacity in the building systems (Reserve), separation of building systems according to their rate of replacement (Layer), and interior spaces that are free of structural and other elements that cannot be easily removed (Open). Respectively, these enablers account for 11.8%, 11.8%, 11.7%, and 11.3% of overall adaptability. Statistical analysis indicates that these four enablers were ranked significantly (within 95% confidence) higher than the other seven enablers considered in the survey. (Ross et al., 2016, pp. 424–427)

It is interesting to note that from the point of view of organizations looking for space, in this case, gymnastic clubs, the approach is very straightforward: "It is expected the most cost-effective and efficient way for a Club to expand will be to make use of and move into existing building premises. It is anticipated the most likely sources that would be vacant are industrial or commercial buildings as these are likely to have suitable clear height and clear floor area already available" (British Gymnastics, 2015, p. 1).

The available statistics do not reveal the degrees of difficulty, costs or time taken in securing changes of use. There is, nonetheless, an argument for enabling such changes to be easier, cheaper and faster. Contributing to the Building chapter of the Intergovernmental Panel on Climate Change (IPCC) report on climate change, Lacon et al. have no doubt concerning the value of retrofitting to achieve environmental goals:

> As buildings are very long-lived and a large proportion of the total building stock existing today will still exist in 2050 in developed countries, retrofitting the existing stock is key to a low-emission building sector […] a few broad generalizations are: (1) For detached single-family homes, the most comprehensive retrofit packages have achieved reductions in total energy use by 50–75%; (2) in multi-family housing (such as apartment blocks), a number of projects have achieved reductions in space heating requirements by 80–90%, approaching, in many cases, the Passive House standard for new buildings; (3) relatively modest envelope upgrades to multi-family housing in developing countries such as China have achieved reductions in cooling energy use by about one-third to one-half, and reductions in heating energy use by two-thirds; (4) in commercial buildings, savings in total HVAC energy use achieved through upgrades to equipment and control systems, but without changing the building envelope, are typically on the order of 25–50%; (5) eventual re-cladding of building façades – especially when the existing façade is largely glass with a high solar heat gain coefficient, no external shading, and no provision for passive ventilation, and cooling – offers an opportunity for yet further significant savings in HVAC energy use; and (6) lighting retrofits of commercial buildings in the early 2000s typically achieved a 30–60% energy savings.
>
> (Lacon et al., 2014, p. 690)
>
> Costs of deep retrofits studies have repeatedly indicated the important distinction between conventional 'shallow' retrofits, often reducing energy use by only 10–30%, and aggressive 'deep' retrofits (i.e., 50% or more relative to baseline conditions, especially when considering the lock-in effect. […] there is sufficient evidence that deep retrofits can be cost-effective in many climates, building types, and cultures. Retrofits getting closer to 100% savings start to get more expensive, mainly due to the introduction of presently more expensive PV and other building-integrated renewable energy generation technologies. (Lacon et al., 2014, p. 704)

The ingenuity employed in making the best of inherited spaces never ceases to astonish (*Use of Historic Buildings for Residential Purposes SCOPING REPORT – DRAFT 3*, 2015).

However, some feel, perversely, that the friction caused by a mismatch between space and function is somehow beneficial (*Contrasting Concepts of Harmony in Architecture: The 1982 Debate Between Christopher Alexander and Peter Eisenman, An Early Discussion of the "New Sciences" of Organised Complexity in Architecture*, 1982) (Alexander & Eisenman, 1982).

Blyth and Worthington also suggest the potential positive effect of constraints. "Why have old buildings lasted? Generally, they were not built with change in mind, yet often they have been able to accept new uses. […] research shows that many buildings have survived because they have become loved and stimulate innovation in use" (Blyth & Worthington, 2010, p. 48). Vidler has traced some of the intentionally provocative architects, their philosophical influences and the feeling of unease arising from their efforts (Vidler, 1994). However, at a time of dramatic social, economic and technological change and uncertainty, is it possible to make it easier to manage the future relationship of space with activities?

This discussion confirms that many buildings are capable of reuse and that physical characteristics help towards a successful transition. Therefore, the identification and advocacy of those characteristics could lead to significant benefits.[34]

3.5.2 Extending the Life of New Buildings

While locational and other contextual constraints will still be present for new-build, a fundamentally different approach is required.

Functional obsolescence related to the initial building use (housing, commercial and so on) can be avoided by allowing for internal flexibility and adaptability and by encouraging the active engagement of users and custodians in the ongoing use and management of buildings. (Popovic, 2000) The challenge for the design of new buildings is to allow for different, unknown and unknowable uses.

---

[34] In connection with converting buildings to housing, Private Eye notes that the Inland Revenue headquarters in Nottingham were sold off to a developer who now seeks to sell them with permission to convert to housing. The architects, Hopkins Architects, have reported that, although not impossible, this would be difficult to achieve while ensuring the building's special features are preserved. Estate agents marketing the site suggest it could continue as offices, or be converted for medical or educational uses as well as residential ('Nooks and Corners,' 2021, p. 23).

The useful life of buildings may be prolonged by designing them to:

- respond more readily to change,
- respond to the demands of growth
- respond to the unanticipated needs of future, perhaps different, users

Over time, the effect of such design would be to reduce the extent that the inherited estate inhibits what society seeks to achieve. This approach to design would not be intended to make architecture easier. The first custodians and users will have to be satisfied as well as future custodians and users.

The effects of extending the useful life of new buildings are likely to include:

- Minimizing resource use over the life of the building. Even allowing for the extra cost of building to last, Double-Design should realize very substantial resource savings. Several authors have pointed out that the additional costs of incorporating adaptability in new buildings are marginal (Vimpari & Junnila, 2016) and that, given accurate information about environmental targets, custodians should be prepared to pay more for longer-lasting projects (Loftness et al., 2011).
- Reducing the production of construction and demolition waste. (33% of the total generated waste in Europe) (Mastrucci et al., 2017)
- Minimizing transaction (change of use) costs in money and time.
- Responding more rapidly to changing needs. It may be essential for some organizations to introduce innovations quickly to avoid an elaborate change of use process. The significance of this advantage is confirmed with business models of decision making in dynamic organizations (Lyneis & Sterman, 2016).
- Improving the fit between future space needs and future available space. Architectural space is an indicator of the distribution of power (Massey, 2005).

The responsibility for commissioning new space, or refurbishing and re-using existing space, reflects a particular distribution of economic and social power that happens to obtain at a specific time. As this distribution of power changes, the physical environment will need to respond. Such a response will be more readily achieved if all new buildings incorporate "Double-Design".

Several of the advantages identified above are also highlighted in the arguments favouring high-performance buildings that have been advocated by Loftness et al. They refer to mortgage cost savings, FM cost savings, positive impacts on staff performance and morale, faster implementation of organizational and technological change as well as waste reduction (Loftness et al., 2011, p. 15).

Loftness and her colleagues are working within the existing economic framework, simply trying to persuade developers of sustainability's 'intrinsic' merits. It seems likely, however, that the application of Double-Design will require legislation rather than persuasion.

By way of contrast, Cairns and Jacobs think hard about the end of a building's life: "In a cradle-to-cradle architectural design, the way a building ends should be a consideration on the drawing board. Designing a building would include designing its end. Designing for deconstruction is a pragmatic industry approach to the cradle-to-cradle idea" (Cairns & Jacobs, 2014, p. 225). Yet, without asking what kind of end to plan for, this approach is inappropriate. The end could be heroic after long life and long usefulness or trivial if designed and built for just one function.

3.6 UNDERSTANDING COMPATIBILITY

Several of the forensic pioneers have progressed far beyond the technical analysis of material failure observed in buildings. Instead, they have offered practical advice on the reuse of buildings. This has been built up from practical experience rather than theory and has often suggested suitable second uses for each first use. Douglas, for example, lists the problems associated with converting housing to commercial/industrial uses:

- Technical
- Legal
- Economic
- Environmental
- Functional

He then lists possible new uses for:

- Farm buildings

- Church buildings
- Industrial buildings
- Office buildings
- Public buildings

He then considers the implications of lateral and vertical extensions and structural alterations (Douglas, 2006, pp. 156–171).

Watt, having dealt in detail with the problems arising with the deterioration of specific materials, also gives some overall advice on reuse:

> Finding the right use for a building […] successful utilisation of a building relies on a variety of factors, and is as much to do with finding the right user as it is with altering the structure, fabric and services of the building. It is therefore necessary to understand both the building and the potential market (including supply, demand and investment potential) when assessing the feasibility of a particular course of action. (Watt, 2007, p. 244)

These forensic approaches are important in recognizing both the desirability and feasibility of reuse. As Douglas argues:

> The pressure for more adaptation of existing buildings will probably increase in the developed part of the world owing to the growing need for more efficient and sustainable construction. Innovations in information technology, new working practices and stricter environmental controls are all causing a significant transformation in the type and extent of demand for property generally. Existing properties also have to respond to this shift in demand, from being tight fit, purpose-built facilities to flexible, 'greener' buildings.
>
> Adapting buildings is an important component of any sustainability strategy. Along with adequate maintenance it is essential for ensuring the long-term prosperity of our built assets. Moreover, adaptation entails less energy and waste than new build, and can offer social benefits by retaining familiar landmarks and giving them a new lease of life.
>
> The growth in adaptation schemes in recent years is having a major impact on the total output of the construction industry. It is now reckoned that along with maintenance it will soon match that of new build in many developed countries. (Douglas, 2006, p. 73)

He continues:

> The adaptive reuse of buildings is a key strategy of sustainable construction. It provides an economic and socially advantageous way of giving otherwise disused buildings a new lease of life. It minimizes the need for wasteful and disruptive demolition, which is almost irreversible. […] It did not emerge as a viable alternative to the redevelopment of existing property until around the second half of the 20th century. Other interventions such as extensions, alterations and refurbishment work are frequently included in many adaptive reuse schemes nowadays. (Douglas, 2006,, p. 195)

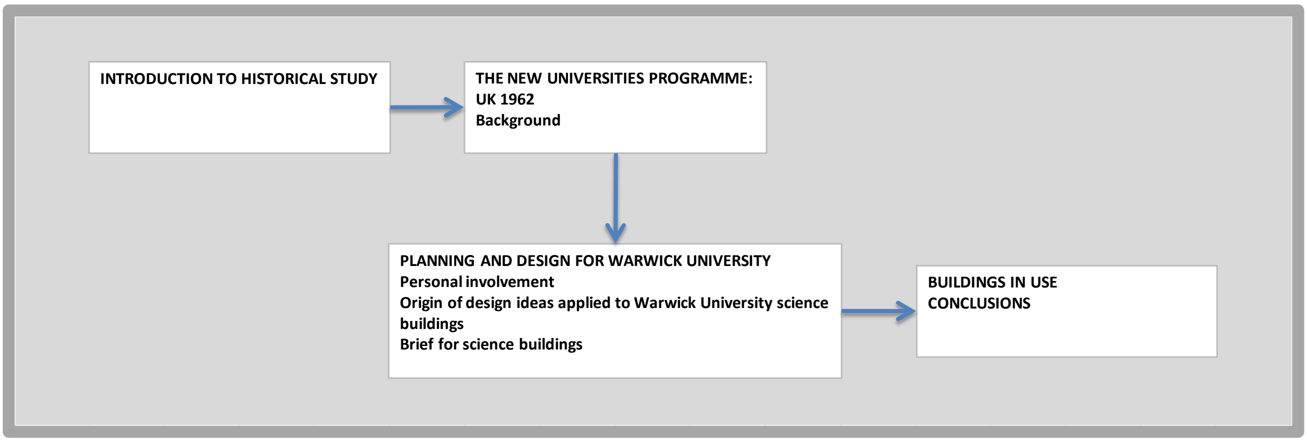
These authors begin to hint at the morphological parameters that play a significant part in determining compatibility between first and second uses. Yet, none has suggested that the initial design should accommodate a second or later use. However, in recommending design provisions anticipating the future, Douglas does suggest that to maximize a building's sustainability, it is essential to allow for future adaptations in its original design. This can be achieved by considering the following:

- Location and orientation of the original building: Lateral extensions will be heavily determined by the position of boundaries in relation to the existing building.
- Space around the building: Access (e.g. footpath and carriageway) and car parking space for the new or upgraded use.
- Selection and availability of products: Matching the new with the old to achieve an architecturally appropriate design.
- Foundation and basement design: Robust substructure capable of taking additional loadings involved when adding a vertical or lateral extension.
- Location and capacity of services: Suitability of existing drainage and supply pipelines to cope with additional or modified demand.
- Means of access and egress in respect of the site and the building: Ease of entry and exit for contractors when undertaking major works to the building to minimize disruption and inconvenience.
- Size and layout of the structural grid: This will impact on the design and construction of the extension.
- Legal restraints – planning, easements, covenants: May restrict extent and form of external changes – particularly if the building is listed or in a conservation area. (Douglas, 2006, p. 63)

These wise and practical remarks contrast with the short-term mind-set of many custodians and their financiers who, without regulatory guidance to do otherwise, continue to build wastefully.

This Chapter has sought to establish the context for architecture covering the philosophical and political basis for understanding space. It has also outlined the nature of design and the information flows upon which it is dependent as well as the forces affecting the expected life of buildings. Examining the compatibility of existing buildings to accommodate some changes of use has introduced the search for the more general spatial compatibilities that are covered below in Chapters Four, Five and Six.

CHAPTER FOUR: CASE STUDY



4.1 INTRODUCTION TO HISTORICAL STUDY

Aware of the complexity of any institutional story, it is tempting to simplify the framework within which to arrange the narrative. A historical perspective would require either reliance upon facts, building a story from the bottom-up, or reliance upon a starting hypothesis with facts sought out to confirm or refute it, as if history were like Popper's view of science (K. Popper, 2002). The case study illustrates the processes of interaction between the custodians and users and their buildings and spaces. The interest is in the life of a building after it is built and while it is in use. The pre-project is influential but, being specific to the particular project, may not be a necessary determinant of the categories of interventions that may be undertaken during the use of the building.

In telling the story of a particular project, especially one for which the author was partly responsible, it is necessary to seek guidance upon what can be expected. Ultimately, the historian's task is to shed light on the what, why, and how of the past, based on inferences from the present evidence. Two preliminary issues are relevant to almost all discussions of history and the philosophy of history. These are issues having to do with the constitution of history and the levels at which we choose to characterize historical events and processes. The first issue concerns the relationship between actors and causes in history: is history a sequence of causal relations, or is it the outcome of an interlocking series of human actions? The second issue concerns the scale of historical processes in space and time: how should historians seek to reconcile micro-, meso-, and macro-perspectives on history? (Little & Zalta, 2017).

Walsh hopes to propose a framework within which the main questions about history can be addressed, including major traditions. He advances the view that the historian is presented with several events, actions, and developments during a period. How do they hang together? The process of cognition through which the historian makes sense of a set of separate historical events Walsh refers to as "colligation" – "to locate a historical event in a larger historical process in terms of which it makes sense" (Walsh, 1960, p23). As Little sets out:

> Walsh fundamentally accepts Collingwood's most basic premise: that history concerns conscious human action. Collingwood's slogan was that "history is the science of the mind" (Collingwood, 1946), and Walsh appears to accept much of this perspective. The critical intellectual task for the historian, applying this approach, is to reconstruct the reasons or motives that actors had at various points in history (and perhaps the conditions that led them to have these reasons and motives). This means that the tools of interpretation of meanings and reasons are crucial for the historian. (Little, 2011, p. I)

Walsh suggests that the philosophical content of the philosophy of history falls naturally into two different sorts of inquiry, parallel to the distinction between philosophy of nature and philosophy of science. The first has to do with metaphysical questions about the reality of history as a whole; the latter has to do with the epistemic issues that arise in the pursuit and formulation of knowledge of history. He refers to these approaches as "speculative" and "critical" aspects of the philosophy of history. He attempts to formulate a view of the key questions for each approach. Speculative philosophy of history asks about the meaning and purpose of the historical process. Critical philosophy of history is what we now refer to as "analytic" philosophy; it is the equivalent for history of science's philosophy for nature. The set of epistemic values that we impart to scientists and historians include the value of intellectual discipline and a willingness to subject their hypotheses to the test of uncomfortable facts. Once again, a review of the history of science and historical writing makes it apparent that this intellectual value has an effect. There are plentiful examples of scientists and historians whose conclusions are guided by their interrogation of the evidence rather than ideological presuppositions. Objectivity in pursuit of truth is itself a value that can be followed (Walsh, 1960). Even allowing for the author's involvement, it is possible to be clear why certain design decisions were made concerning the science buildings that were not made concerning other aspects of the university requirements.

Analysis of a fifty-year-old education institution illustrates the factors leading to decisions about fabric and space during the phases of design and use.[35] In presenting the longitudinal case study, the steps recommended by the Critical Incident Technique have been followed:

1. ascertaining the general aims of the activity being studied;
2. making plans and setting specifications;
3. collecting the data;
4. analysing the data; and
5. interpreting the data and reporting the results. (Butterfield et al., 2005, p. 477)

4.2 THE NEW UNIVERSITIES PROGRAMME: UK 1962–

Perkin provides an insider's assessment of the pressures leading to the expansion of university education in the UK:

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[35] The author was granted access to records covering the life of the institution in the form of minutes of meetings held on a regular basis over fifty years. The summary notes recorded here are based upon estate decisions covering fabric and function.

> The 1960s were so obviously the "Robbins era" that most of the credit – or blame – is usually given to the Robbins Committee. But the Robbins Report did not come out until October 1963, when all the key decisions had already been taken, and in fact the Committee was, as we shall see, more an effect than a cause of the explosion of student numbers. […] So we have to look back before Robbins for the real origins of the last wave of growth. How far back? It was commonly assumed by those who were agitating for expansion in the early 1960s […] that the increased demand for student places was not foreseen by their predecessors. This is not strictly true. The University Grants Committee in the early 1950s clearly forecast the effect of the "bulge" (in the age cohorts) and the possibility at least of the "trend" (to stay on at school). Their 1953 Report forecast that, to accommodate the post-war bulge in the birthrate whose peak of 1947 would hit the universities in 1965, "a marked increase in student numbers will be required from about 1960 onwards if the proportion of each age group which reaches the universities is to be maintained.
>
> I do hope that as a condition of the strength and welfare of the country and almost of its survival as a great power, we shall immediately set to work on a great building programme for the universities and on achieving a steady and rapid increase both in total students and, more especially, in technologists. Lord Simon was followed by speaker after speaker supporting him and demanding more realistic plans for university expansion. (Perkin, 1972, p. 113)

Perkin gives a blow by blow account of the Byzantine decision-making that influenced the location, the political support and funding for the new universities, as well as the background of fear and animosity from those institutions unwilling to change and to grow in the face of pressure from what Perkins calls the "facts" of student demand.

4.2.1 Background

The University of Warwick website gives a proud account of the establishment and growth of the institution:

> History of the University
>
> ---
>
> The establishment of the University of Warwick was given approval by the government in 1961 and received its Royal Charter of Incorporation in 1965.
>
> The idea for a university in Coventry was mooted shortly after the conclusion of the Second World War but it was a bold and imaginative partnership of the City and the County which brought the University into being on a 400-acre site jointly granted by the two authorities. Since then, the University has incorporated the former Coventry College of Education in 1978 and has extended its land holdings by the purchase of adjoining farm land.
>
> The University initially admitted a small intake of graduate students in 1964 and took its first 450 undergraduates in October 1965. In October 2013, the student population was over 23,000 of which 9,775 are postgraduates. Around a third of the student body comes from overseas and over 120 countries are represented on the campus.

The University's founding Vice-Chancellor was Mr J.B. Butterworth (Lord Butterworth), who guided the University through its formative years and provided much of the vision for the University's future growth and success. His achievement was to establish Warwick firmly on the national stage, to set a basic strategy and culture for the University which still obtains today and to oversee the building of a university on what was a greenfield site.

The Campus

1960s

The main campus of the University is situated on land granted by Coventry City Council and Warwickshire County Council in the early 1960s. The first buildings were completed in 1965 (and now house Biological Sciences); by 1970 the Library, Science and Arts Buildings and Rootes Residences had been built on central campus.

1970s

During the 1970s, further academic and residential accommodation was built on campus, including the Social Sciences building in 1977, Senate House and the Arts Centre (1974) and the Students' Union Building (1975). In 1979, the former Coventry College of Education merged with the University to form what is now the Institute of Education on the Westwood site.

1980s

The 1980s saw the further expansion of the Arts Centre, the construction of the Jack Martin Halls of Residence and of the purpose built post experience training centre, Radcliffe House (1986) referred to above. In 1989, in partnership with Rover and Rolls Royce plc, the University extended the new Advanced Technology Centre to provide extensive new research facilities.

1990s

During the 1990s, the built campus continued to develop. Between 1993 and 2000 over £100m of new buildings were erected, notably the construction of the Arthur Vick, Claycroft and Lakeside Residences, the International Manufacturing Centre (1994), the Ramphal Building (1996), and the new Medical School Building and associated Biomedical Research facilities generously funded by the Wolfson Trust and through a successful appeal (2001).

Other notable developments have been a joint Students Union and Retail building (1998), Sports Pavilion (1998), the first two phases of a new building for the Warwick Business School (1999 and 2001) and a new building for Computer Science (2000). Since 2000 plans for further building have amounted to a programme of c. £50m.

2000s

A new Mathematics and Statistics building was opened in 2004 and a major investment in developing the Sports Centre has provided high-class sports facilities, amongst the best of any British university. Warwick's Institute of Advanced Studies launched in 2007 and the Institute of Advanced Teaching and Learning was launched in 2010.

The Warwick Digital Laboratory was opened by Prime Minister Gordon Brown in July 2008. In 2009, the Arts Centre's Butterworth Hall underwent a £8million development, and we made extensive improvements to the Students' Union, building extra retail space, cafes, bars and performance areas.

2010s

Two new student residences, Bluebell and Sherbourne, were opened in 2011 and 2012 respectively, and new science academic buildings are currently under development along with a new extension to Warwick Business School. (*University of Warwick*, 2020)

4.3 PLANNING AND DESIGN FOR WARWICK UNIVERSITY

4.3.1 Personal Involvement

Yorke, Rosenberg and Mardall were appointed Architects and master planners for the university in late 1963. The author joined the firm as a junior architect (not quite qualified) in early 1964. The university had acquired planning permission using a plan by Arthur Ling and Howard Goodman. This plan was adhered to in the location of the first phase of buildings. Figure 4.1 shows the Master Plan prepared by Yorke, Rosenberg and Mardall.

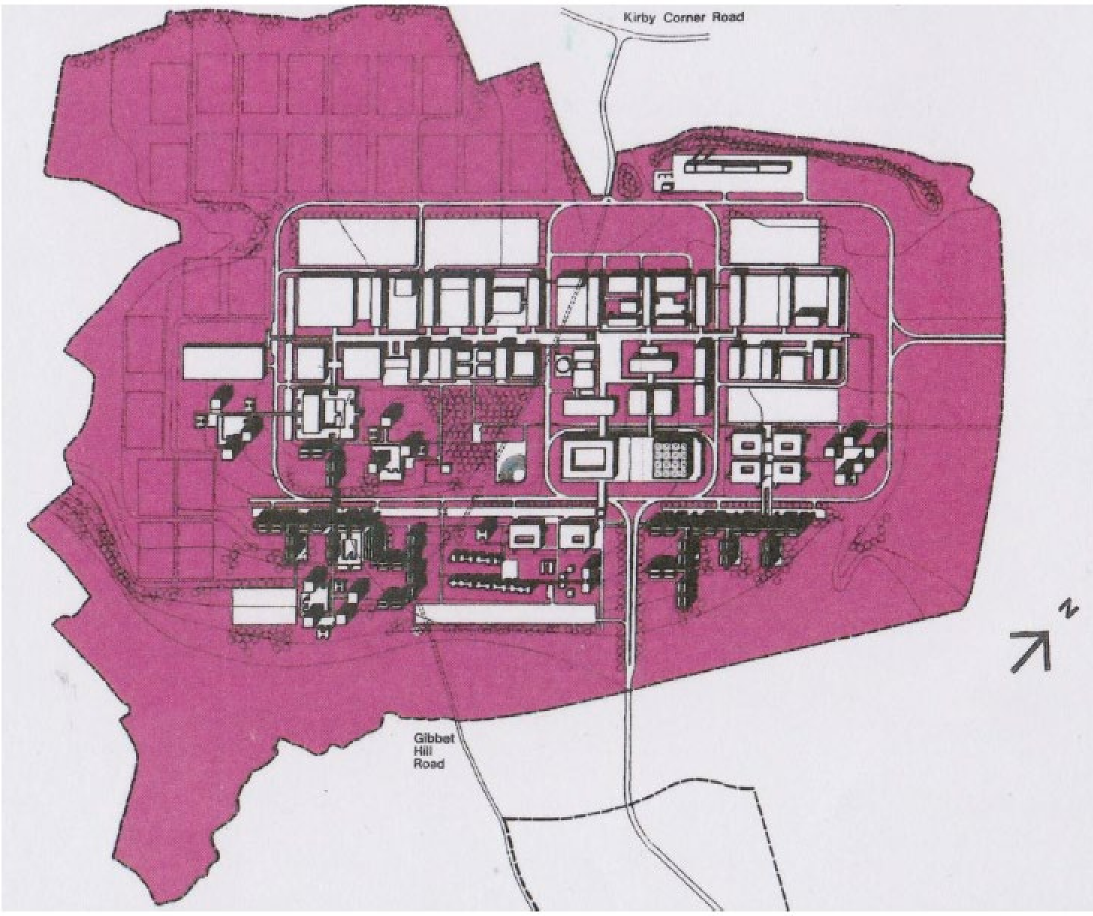


Figure 4.1 Master Plan for University of Warwick, prepared by Yorke, Rosenberg and Mardall, 1963-64

4.3.2 Origin of Design Ideas

The ideas that led to the grid pattern plan for the University of Warwick arose directly from a design thesis undertaken at UCL for a new university (Cassidy et al., 1962). This was undertaken when both theoretical and practical planning ideas for institutions undergoing change were receiving professional and academic attention. The thesis project had proposed a simple linear plan based loosely upon the proposals by Arturo Soria y Mata (1844–1920) for the city planning of Madrid (Figure 4.2 refers).

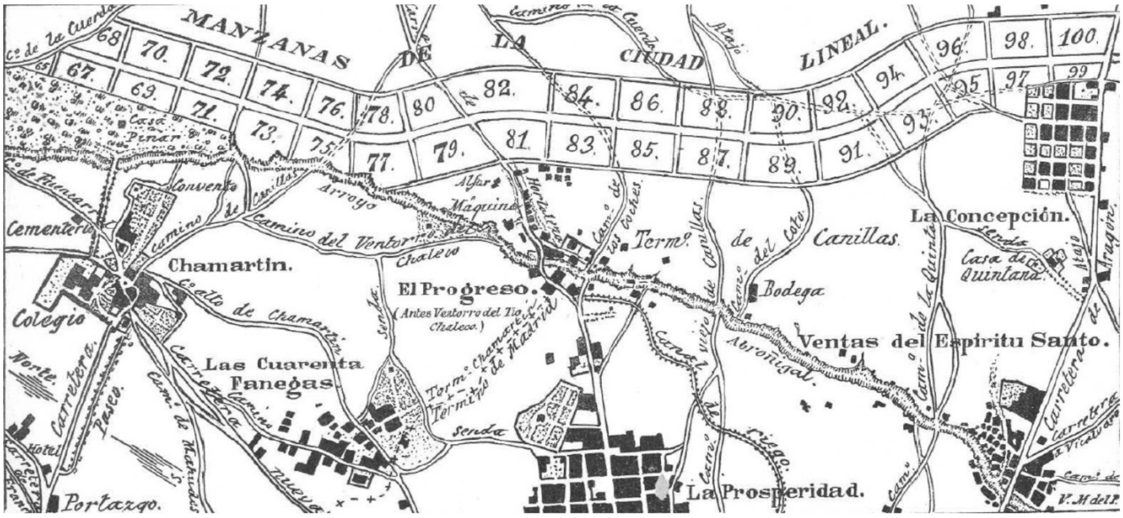


Figure 4.2 Arturo Soria y Mata's idea of the Linear City (1882) replaced the traditional idea of the city as a centre and a periphery with the idea of constructing linear sections of infrastructure - roads, railways, gas, water, etc.- along an optimal line and then attaching the other components of the city along the length of this line. "The **linear city** was an urban plan for an elongated urban formation. The city would consist of a series of functionally specialized parallel sectors. Generally, the city would run parallel to a river and be built so that the dominant wind would blow from the residential areas to the industrial strip. The sectors of a linear city would be: 1. a purely segregated zone for railway lines, 2. a zone of production and communal enterprises, with related scientific, technical and educational institutions, 3. a green belt or buffer zone with major highway, 4. a residential zone, including a band of social institutions, a band of residential buildings and a "children's band", 5. a park zone, and 6. an agricultural zone with gardens and state-run farms (*sovkhozy* in the Soviet Union). As the city expanded, additional sectors would be added to the end of each band, so that the city would become ever longer, without growing wider. The linear city design was first developed by Arturo Soria y Mata in Madrid, Spain during the 19th century, but was promoted by the Soviet planner Nikolai Alexander Milyutin in the late 1920s. (Milyutin justified placing production enterprises and schools in the same band with Engels' statement that "education and labour will be united".) Ernst May, a famous German functionalist architect, formulated his initial plan for Magnitogorsk, a new city in the Soviet Union, primarily following the model that he had established with his Frankfurt settlements: identical, equidistant five-story communal apartment buildings and an extensive network of dining halls and other public services" (Tufek-Memisevic & Stachura, 2015) (Burgoo, 2021.)

The thesis envisaged a covered linear street that could be extended and with academic units able to be located along it and grow at right angles to the street. (Figures 4.3, 4.4 and 4.5 refer).

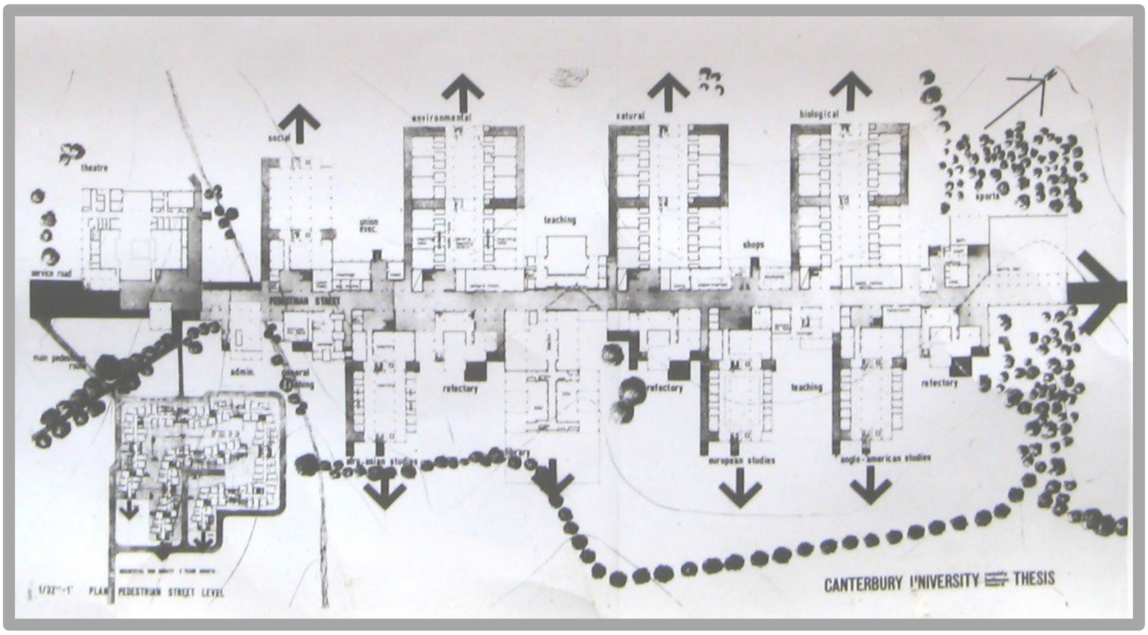


Figure 4.3 Canterbury University Thesis, UCL, 1962, Michael Cassidy, Louis Hellman, Robin Moore. Plan of proposed campus showing main street and directions of growth.

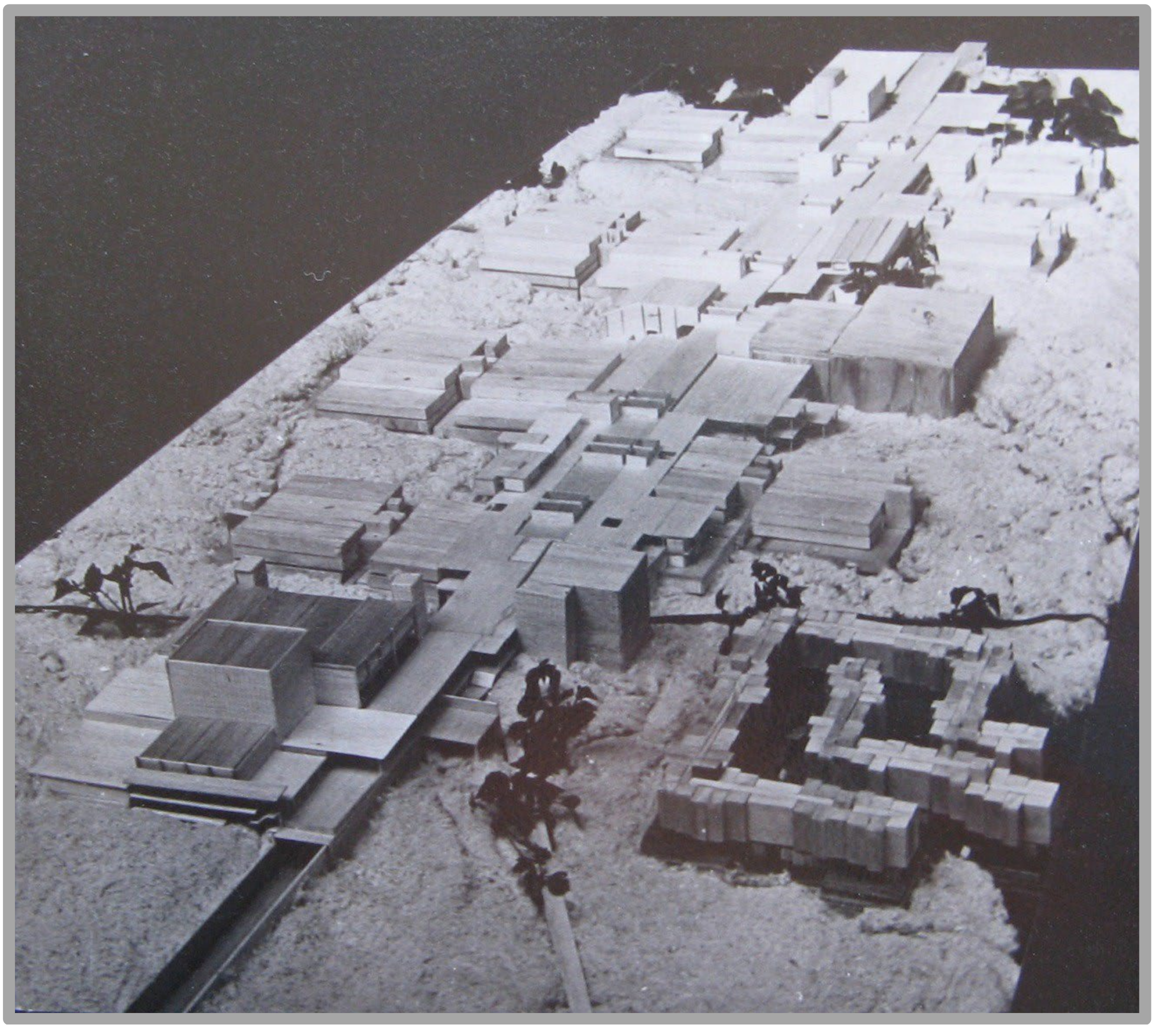


Figure 4.4 Canterbury University Thesis, UCL, 1962, Michael Cassidy, Louis Hellman, Robin Moore. Model of proposed campus showing main covered street.

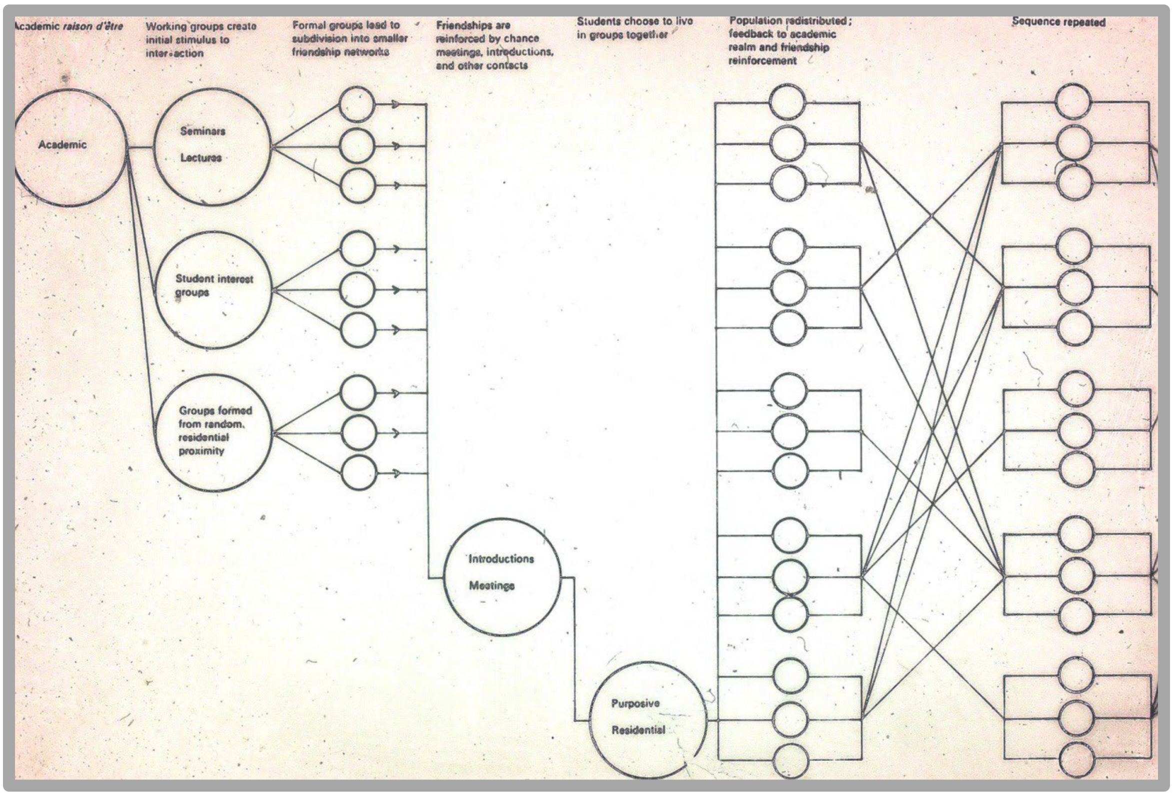


Figure 4.5 Canterbury University Thesis, UCL, 1962, Michael Cassidy, Louis Hellman, Robin Moore. The diagram shows how social groups are formed and reinforced through contacts in the university environment, emphasizing meeting places and circulation routes.

The thesis assumed a particular organizational structure and would have proved to be inflexible if the faculty structure changed. Weeks' plan for Northwick park hospital, illustrating his idea of indeterminacy, was being developed in parallel with the thesis work at UCL and shares the limitations of fixed starting points for the independent growth of departments. (Figure 4.6 refers)

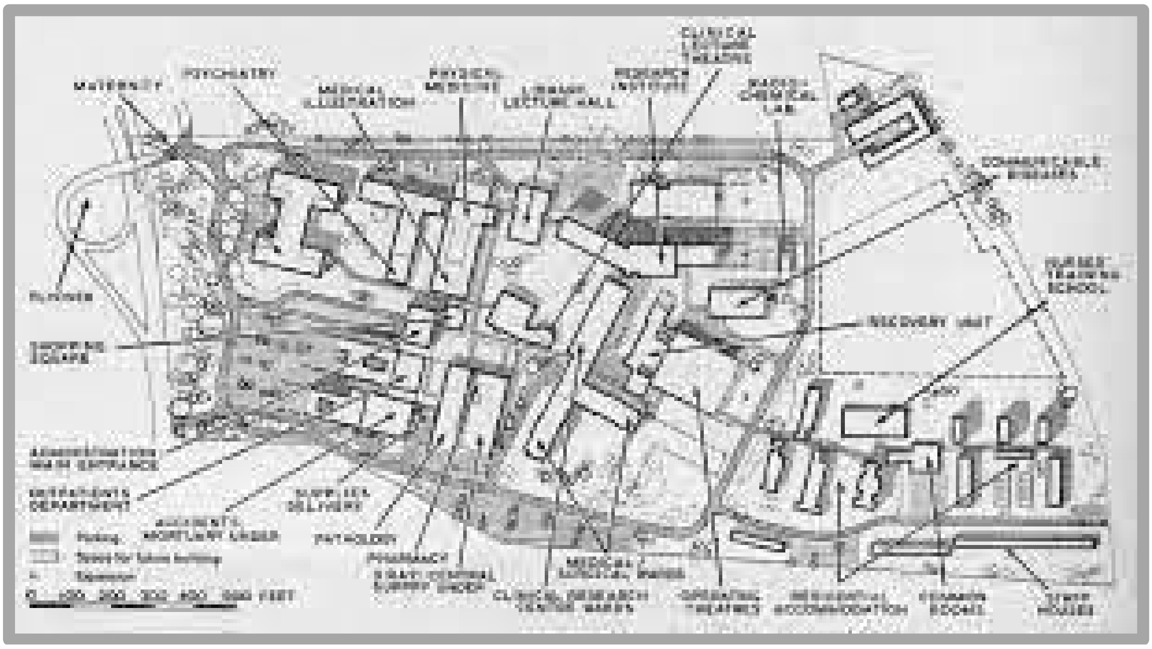


Figure 4.6 Northwick Park Hospital Master Plan, 1962–63, Llewelyn Davies and Weeks, Architects.

The open grid arrangement adopted for the science development for Warwick sought to overcome this weakness and provide a favourable structure that could respond to fundamental organizational change. At the time, this seemed a logical progression from the thesis, and it occurred in parallel with several other institutional plans. These include the plan for the Free University of Berlin, Lancaster University and Bath University.

At the time work started on the University of Warwick, the design team were not aware of the radical design of Candilis, Josic Woods for the Free University of Berlin and only aware through direct personal contact with other teams of architects in the UK addressing the problems of planning new university campuses and, in the case of Weeks, hospitals. These included specifically the thinking behind the Universities of Bath and Lancaster, which followed the linear model of the UCL thesis and sought simple ways to overcome the limitations in that model. Thus, for example, for Bath, while the central “street” idea is retained, called a parade, subsidiary grids are established to accommodate different departments with different space requirements.

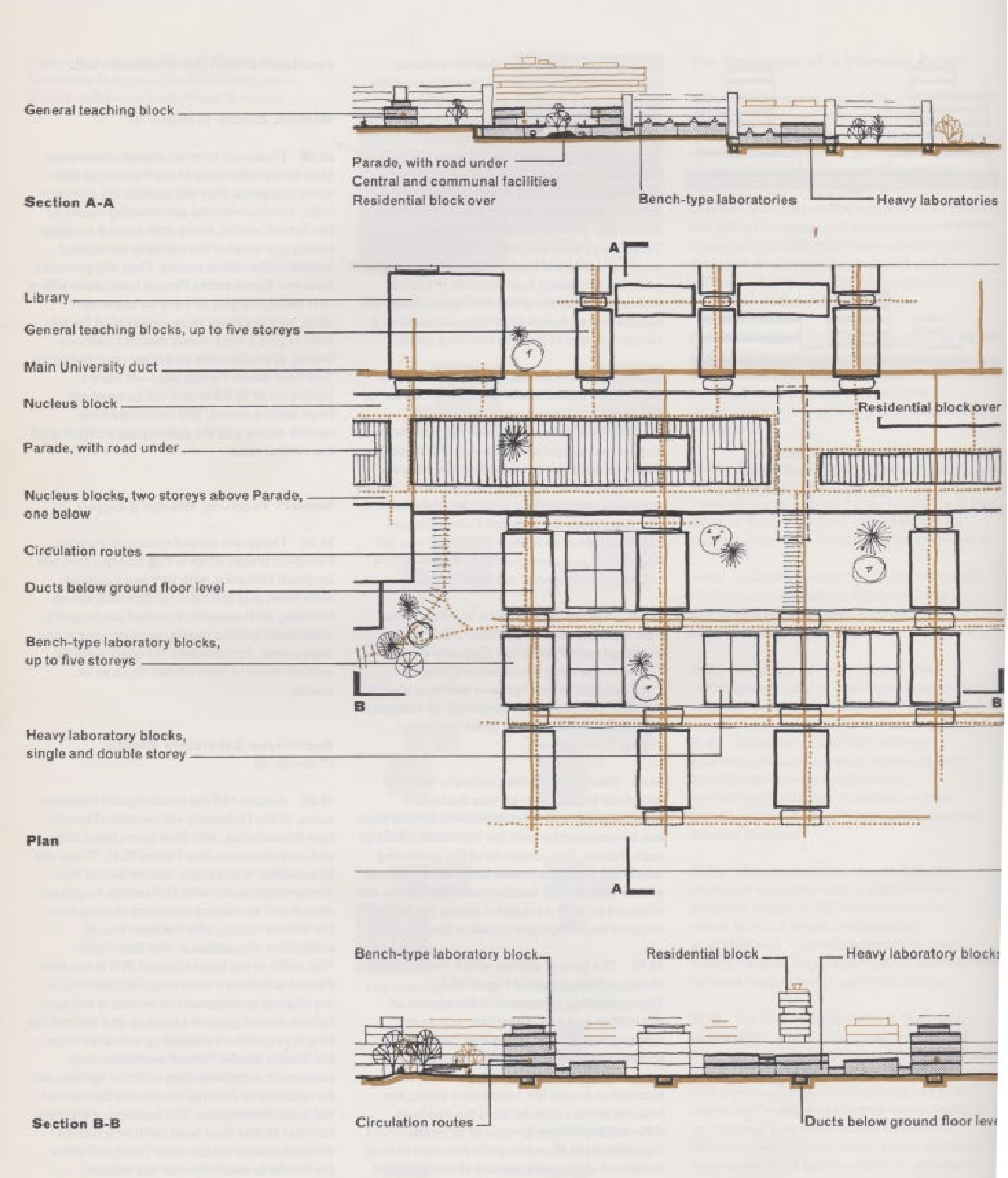


Figure 4.7 University of Bath Master Plan, Teaching and Research Areas: Schematic Plan and Sections (RMJM, 1965, p. 86)

Lancaster University was awarded to the architects Shepheard and Epstein because, it was rumoured at the time, of a linear sketch produced or drawn at the interview. The plan that emerged was developed and implemented.

Figure 4.8 **Lancaster University Masterplan**, 2017-2027, 2017, pp. 22–23

With the benefit of hindsight, it is possible to view the struggles with planning Warwick as part of a process of importing ideas from urban planning that has overlaps with the themes of megastructures (Banham, 1976) and mats (Forés, 2006) (Smithson, 1974) (Calabuig et al., 2013).

Banham's comprehensive coverage of the themes leading to megastructures includes reference to the English new towns movement as well as the new universities:

> One finds that concepts like that of the pure pedestrian street as a good human environment in its own right inform both campus plans and urban-design schemes, associated in both cases with the idea of adaptable linear planning, built that they get built on the campus, not in the city. \`Street campuses\` were much discussed and much projected, but some of those that were built contrived, in their final forms, to conceal this urban intention almost entirely. Thus Warwick University in England, which one must now perceive as a number of rectangular buildings strung tidily across a long site, was originally conceived, in a student research project by Michael Cassidy, as a bustling multi-level pedestrian street with subsidiary buildings 'clipped on' along its length as need dictated. (Banham, 1976, p. 131)

Calabuig et al. set out the story as follows:

> Mat-building seemed to use new tools that dismantled the compositional principles of the early modern period. In the last quarter of 1963, Georges Candilis, Alexis Josic and Shadrach Woods worked in conjunction with the German architect Manfred Schiedhelm in two competitions, the results of which took critics by surprise. Although the design for the reconstruction of the centre of Frankfurt-Römerberg was not retained, it triggered a heated debate that culminated in the announcement of the winning design for the Free University of Berlin.

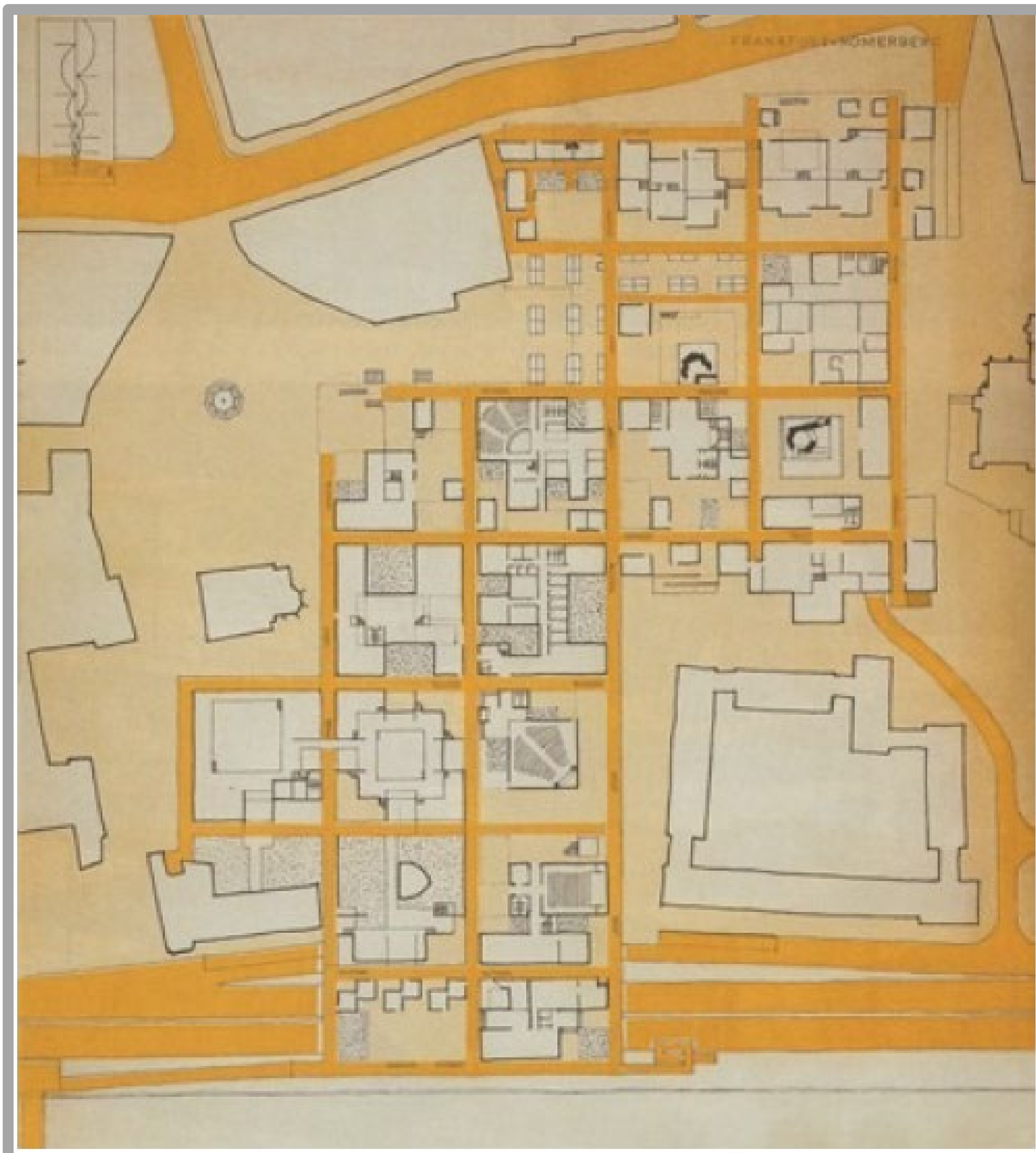


Figure 4.9 1963 competition drawing for the reconstruction of the centre of Frankfurt-Römerberg, by Candilis, Josic, Woods and Scheidhelm (from Calabuig et al., 2013).

> Many of Candilis, Josic and Woods' aspirations finally materialised in the paradigmatic Free University of Berlin whose open-plan design – typical of the universities in the 1960s – matched the characteristics of mat-building perfectly. This university is an exceptional example: its construction involved the French engineer Jean Prouvé and was overseen by the Berlin studio run by Manfred Schiedhelm, in collaboration with the American architect Shadrach Woods. (Calabuig et al., 2013)

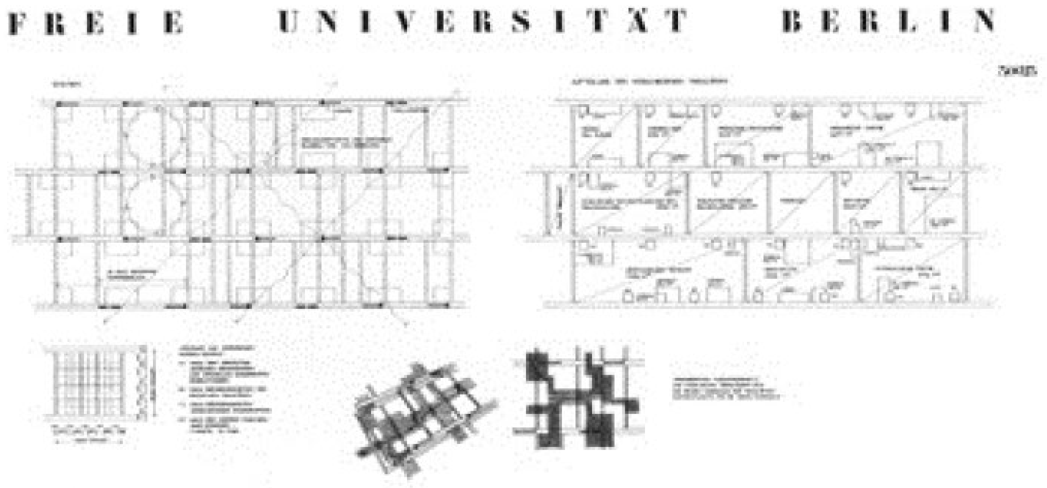


Figure 4.10 Original competition drawings illustrating the Free University of Berlin by Candilis, Josic, Woods and Scheidhelm. From (Calabuig et al., 2013)

The Free University exhibited several characteristics common to university plans of the "open-ended" kind;

- Open circulation grid
- Capacity to accommodate different shapes and types of buildings within the grid
- Vertical separation of circulation systems for different traffic (typically pedestrian above ground level with service and motor traffic at ground)

Arising from the post-war period of social optimism, architects and some of their enlightened clients were influenced by the theoretical thinking of Umberto Eco, who is credited with influencing a generation of designers. In introducing the 1989 translation of Opera Aperta, David Robey suggests:

> The idea of the open work serves to explain and justify the apparently radical difference in character between modern and traditional art. The idea is illustrated in its most extreme form by what Eco calls "works in motion" (*opere in movimento*). What such works have in common is the artist's decision to leave the arrangement of some of their constituents either to the public or to chance, thus giving them not a single definitive order but a multiplicity of possible orders;

> if Mallarme had ever finished his Livre, for instance, the reader would have been left, at least up to a point, to arrange its pages for him- or herself in a variety of different sequences. (Eco, 1989)

Neither the student project at UCL nor the slightly later design work for Warwick was directly influenced by the theories of Eco. Still, a societal shift towards the positive accommodation of openness and embracing of uncertainty can be discerned. Introducing a summary paper on university planning, Cassidy identified the need for "a balance between an environment which will last, be capable of effective use for many decades and which will meet the requirements of initial users" (Cassidy, 1968, p. 496).

4.3.3 Brief for Science Buildings

Pre-building notes relevant to science planning concept.

> *The university should be one large building – covered circulation should be provided for all parts. (August 1963 Promotion Committee)*
>
> *Fundamental that the plan should, both in respect of the Humanities as well as the Sciences, be based on the concept of a unitary rather than a collegiate university […] the plan appeared to make adequate provision for further development on the science side as need arose. (23 December 1963 Building and Development sub-committee)*
>
> *To facilitate staged growth up to 20,000 students […] to allow for growth in the accommodation requirements of each subject as well as the development of new or associated subjects by means of a flexible plan while determining the main dispositions of uses. (31 December 1963 Building and Development sub-committee)*
>
> *From a planning point of view […] the need to combine compactness with the potentialities for growth in ways which cannot yet be foreseen, and the fact that it will not be possible to give physical recognition to individual Schools of study in the plan. (31 December 1963 Building and Development sub-committee)*

Alan Powers provides some insight into the architecture of the early campus and the parallel development of the campus and the university art collection (Shalgosky & Tooby, 2015).

The design for a brand new university required the phased growth of student numbers at an unknowable rate. Nevertheless, it was possible to assess possible growth scenarios and base physical plans on those numbers.

There was an added theme for the science buildings: the relationship between traditionally discrete departments was changing. Faculty structures were replacing departmental structures. "Life Science" was replacing Biology and Chemistry. This suggested that the buildings that housed science should have the capacity to be connected to match the intellectual connections that were being made. Figure 4.11 shows an article from the Guardian newspaper referring to Warwick's approach to science.

Dons' delight at Warwick by Peter Preston

Here, perhaps, the radical intent is clearest of all, for Professor Malcolm Clark has little patience with "compartmentalised" science. He looks sharply at the last four British Nobel prizewinners and he looks sharply at university divisions which artificially channel effort away from the areas of research where the greatest challenges lie.

His School of Molecular Sciences abolishes the old, increasingly irrelevant compartments—chemical physics, theoretical, physical, inorganic, organic, biochemistry. It maintains that the study of phenomena at the molecular level is a wide, single discipline stretching from biology, on one hand, to physics, on the other. His fundamental contention is that modern advances in science are being made increasingly in the old twilight regions between disciplines, the fringes where one specialisation needs applying to another.

It is this concept, more than anything, which imbues Warwick with its special personality. In the sciences it, theoretically, gives scope for fruitful research and simultaneously binds practical science to industrial need. In the arts — because employers still fail to differentiate between the general fact that an applicant has a degree and the particular fact that his speciality is, say, modern languages—it allows the evolution of courses which flourish on their own intrinsic merit. In the university as a whole, it provides a common approach, a situation in which arts and sciences come together through link subjects like economics and form a continuous circle of learning.

Figure 4.11 Article in The Guardian by Peter Preston (who edited **the Guardian** for 20 years, from 1975 to 1995) October 1965. The article highlights the radical approach to the changing structure of the sciences that influenced the initial plans for Warwick Science.

Figure 4.12 illustrates the initial diagram responding to the new requirements for connectivity between the emerging scientific and engineering disciplines.

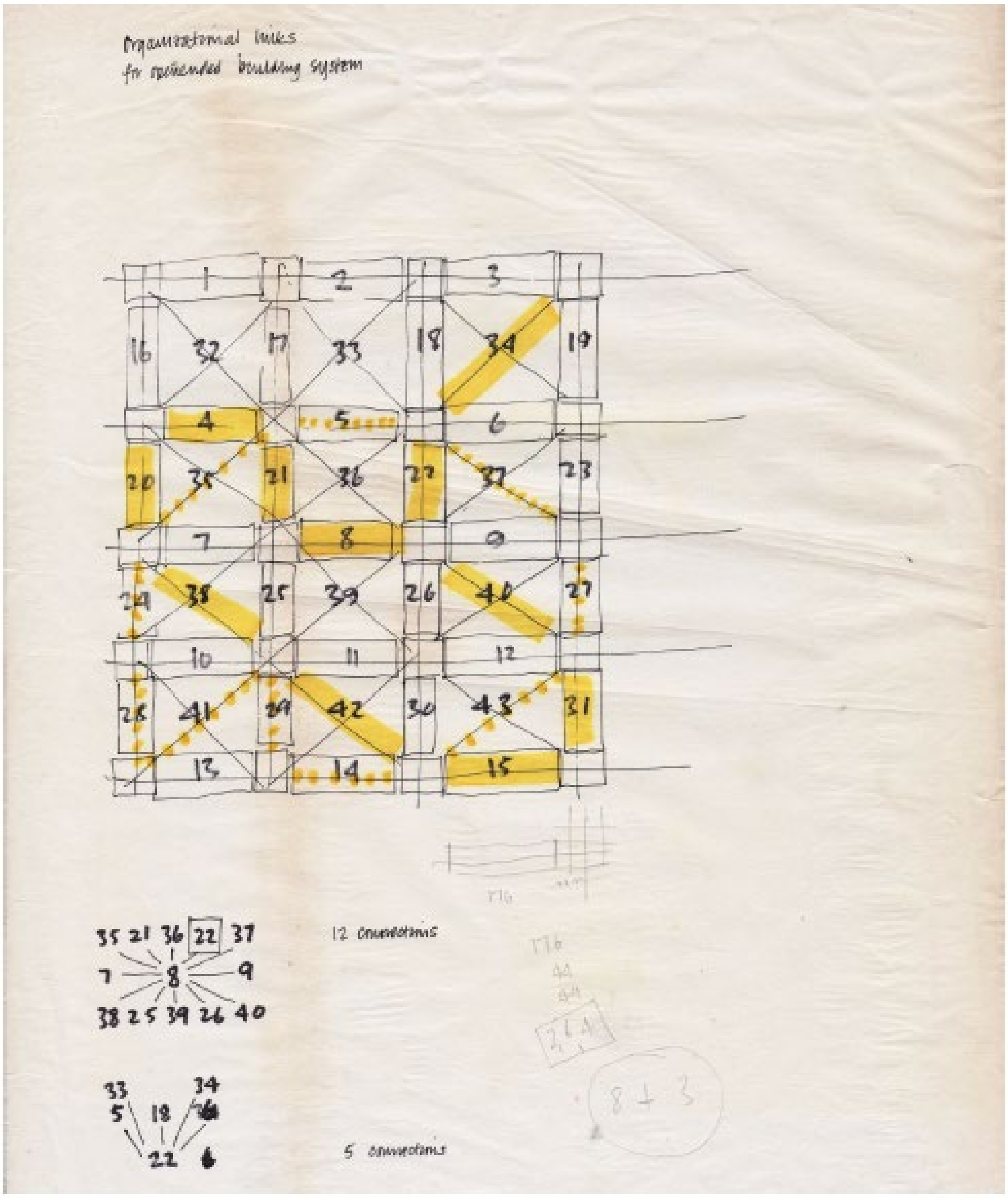


Figure 4.12 Suggested potential organizational links for planning the University of Warwick Science Complex, 1964, Yorke, Rosenberg and Mardall, Architects.

The analysis illustrated in Figure 4.12 led directly to the layout for the first stage of science buildings shown in plan form in Figure 4.13 and as part of the master plan, highlighted in Figure 4.14.

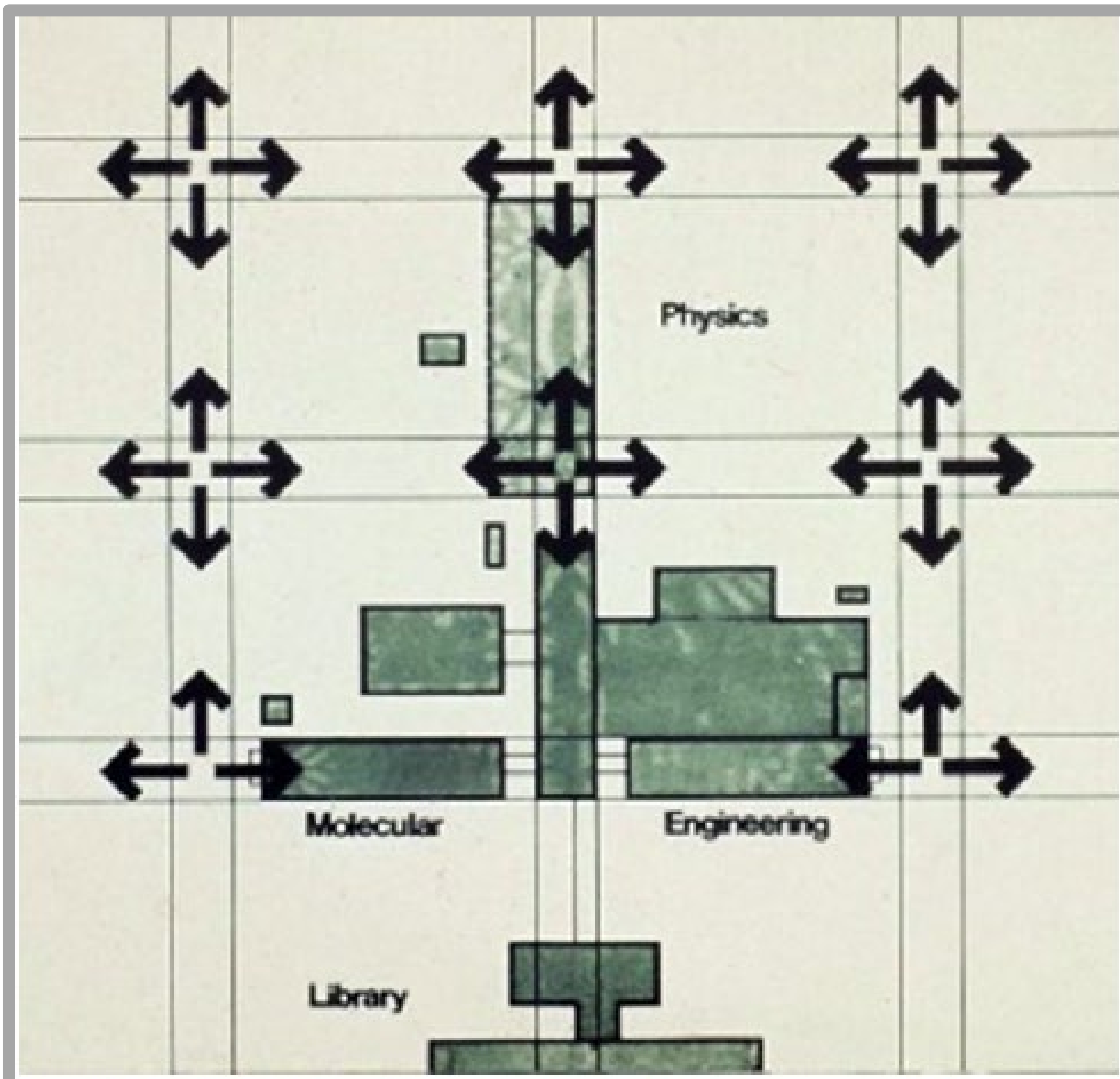


Figure 4.13 Tartan grid shows nodes of growth and distinction between thin buildings containing "regular" spaces and "lumpy" spaces requiring additional height and/or ground floor location, 1964, Yorke, Rosenberg and Mardall, Architects

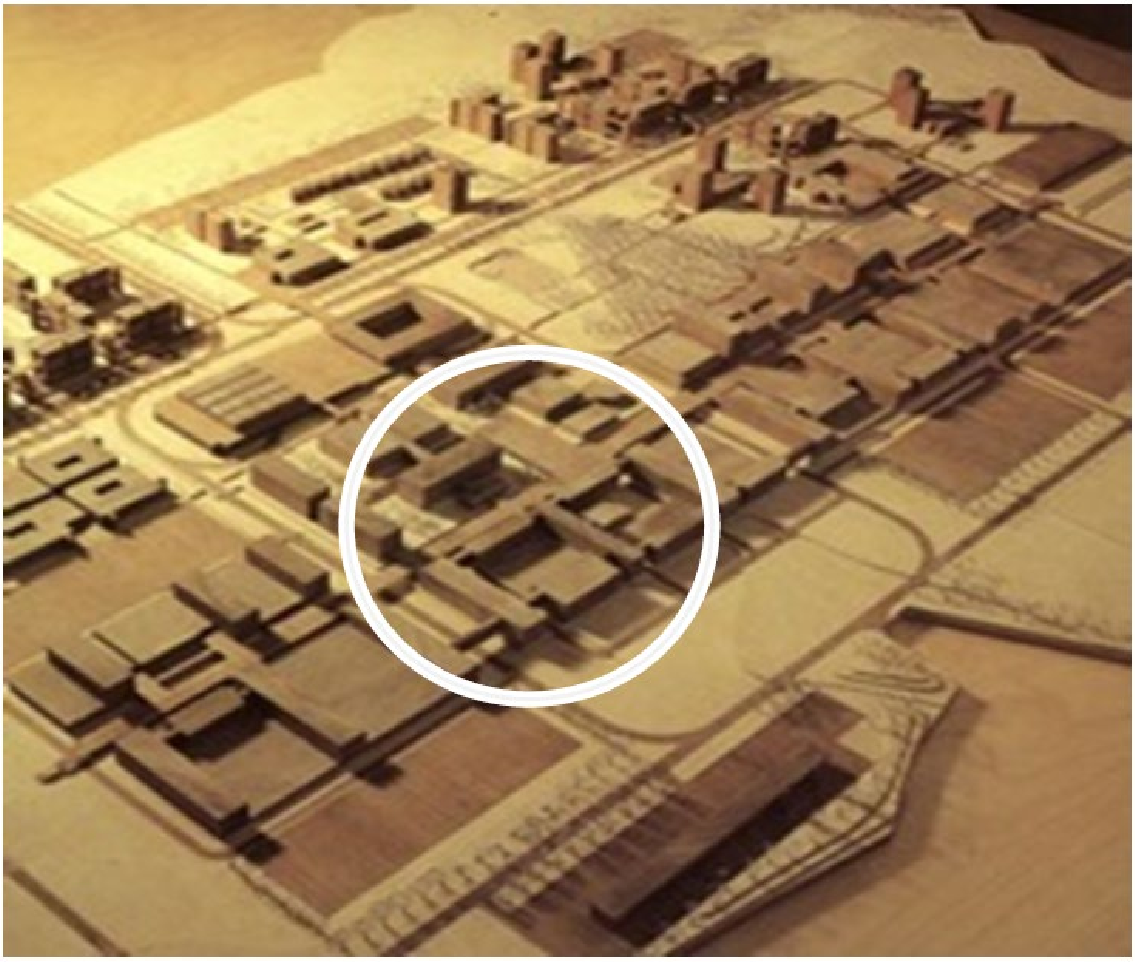


Figure 4.14, Model of initial master plan that was required for planning reasons, to be consistent with previous approved plans, 1964, Yorke, Rosenberg and Mardall, Architects

The geometry that emerged to guide the initial development and placement of spaces and the growth of the science complex had a feature additional to the idea of connectivity. Looking at the space requirements of the sciences, it was clear that they could be divided into two quite distinct categories: first, there were spaces capable of being housed in a building floor of regular width suitable for stacking vertically; second, there were spaces that were "lumpy", that would not fit within a standard width or, because of equipment loads, needed, logically, to be on the ground floor. (Figure 4.13 refers).

The first category included bench laboratories and offices, and small teaching spaces, and the second category included large lecture theatres, heavy engineering workshops, and the like. Figure 4.15 illustrates one of the ‘lumpy’ elements: the science lecture theatre block.

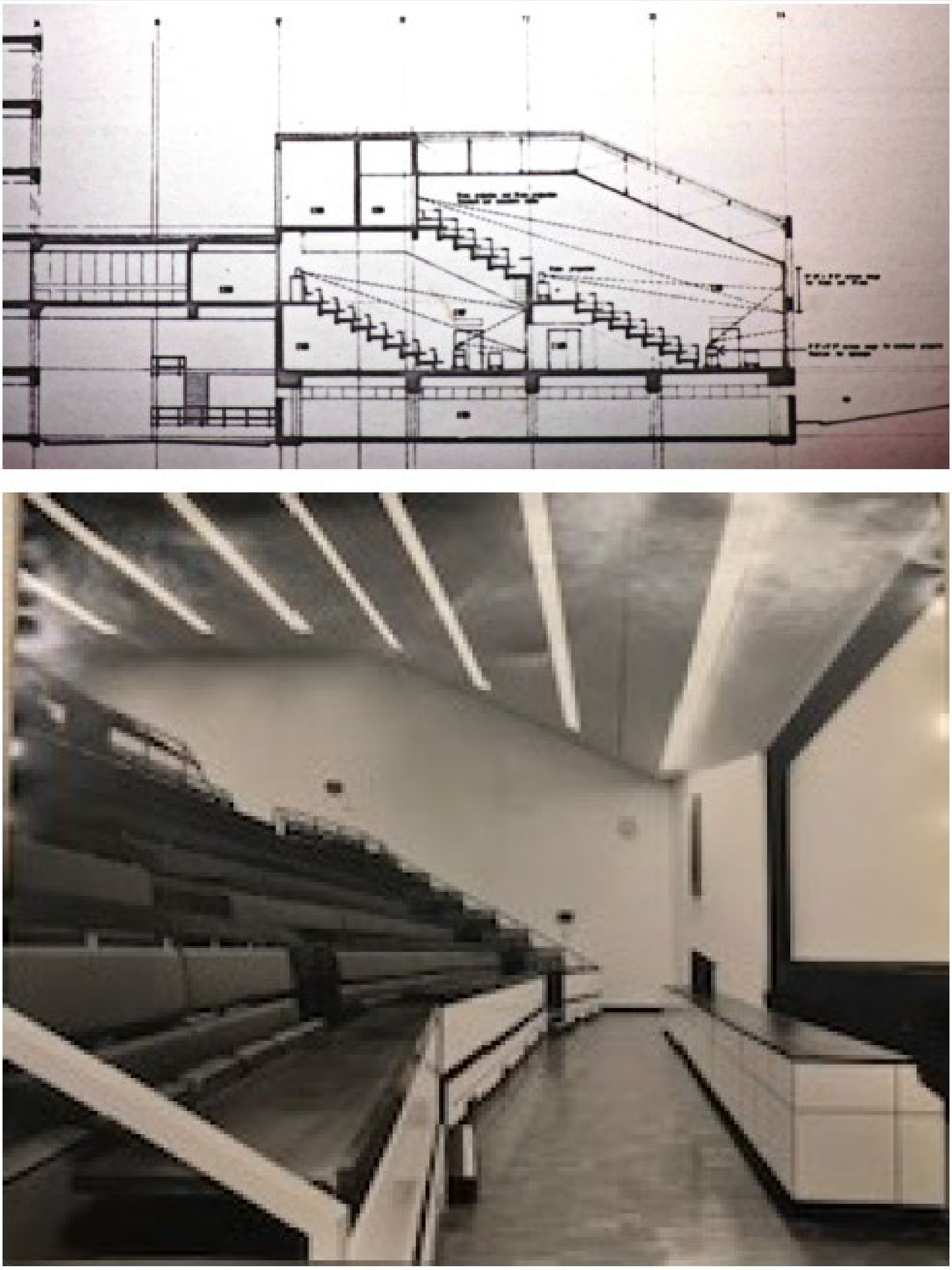


Figure 4.15 Cross section and recent photograph of interior of Science lecture theatre block. Access to the theatres is by means of a bridge linking the main concourse through the Science buildings. In the context of changes of use it can be noted that the space below the theatres was intended for car parking but was, during the design, reallocated to the central telephone exchange and this, in turn, was changed to other uses as telephone technology changed.

The first category spaces were ideally suited to a modular approach in which structure and services were coordinated using a geometrical grid based upon the optimum bench spacing. Figure 4.16 shows the planning grid used for the ‘thin’ buildings arranged with an asymmetrical corridor along which were placed a regular row of vertical ducts for building and laboratory services.

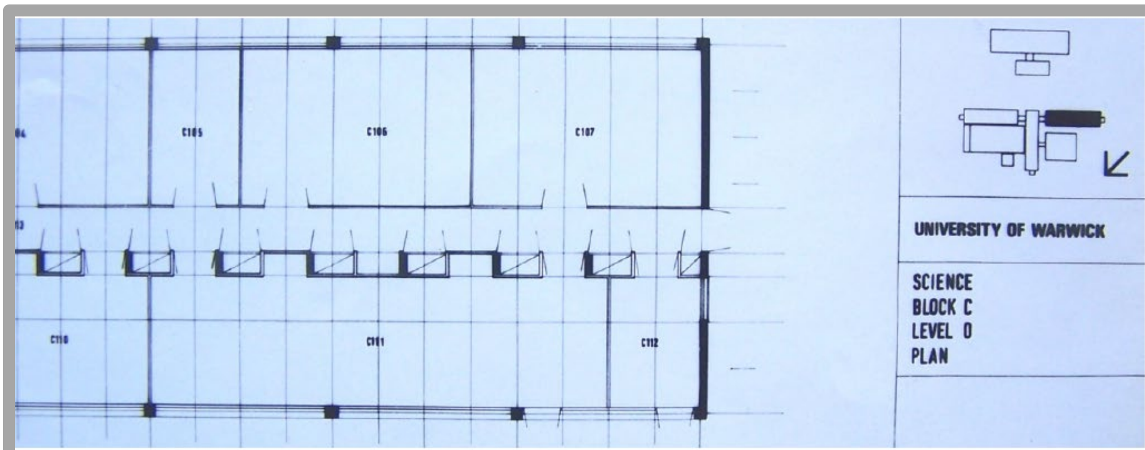


Figure 4.16 plan of science building, University of Warwick

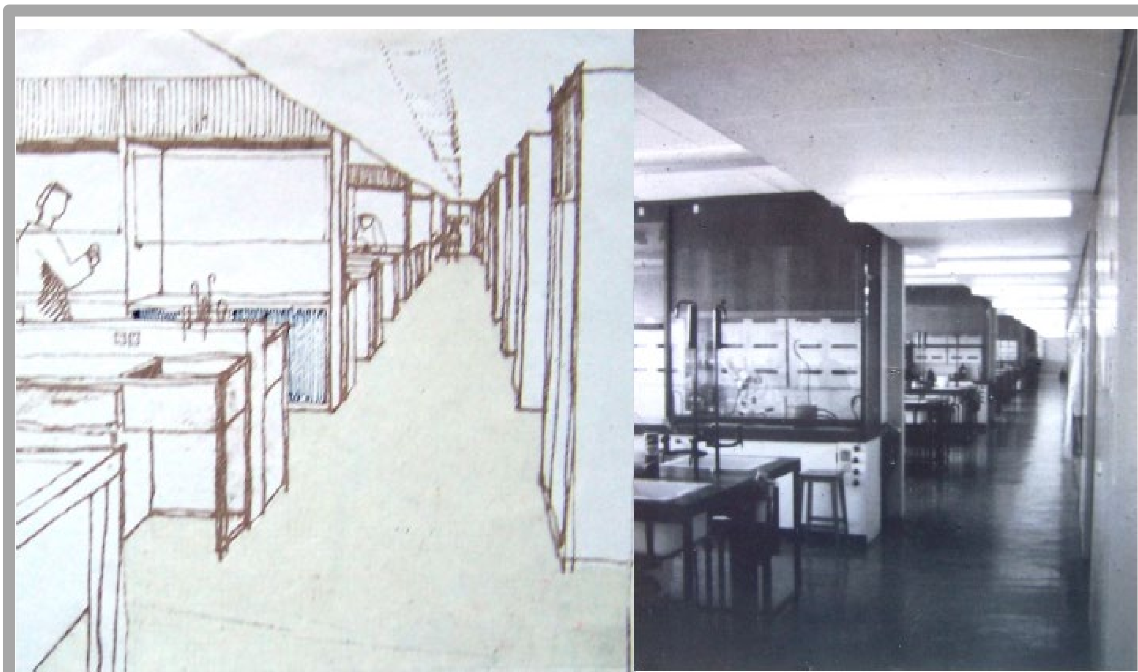


Figure 4.17 Sketch (1964, by the author) of the expected appearance of science laboratories showing row of service ducts to the right: photograph of finished building from 1967

Armed with this conceptual framework, a diagram emerged that provided corridor connections at the first-floor level, essentially a public route, with private connections at all other levels. Thus, there was a balance between the public connectivity serving the complex as a whole and the local connections, building to building, that were available at all the other levels. The first phase of science buildings followed this diagram as shown in Figure 4.18.

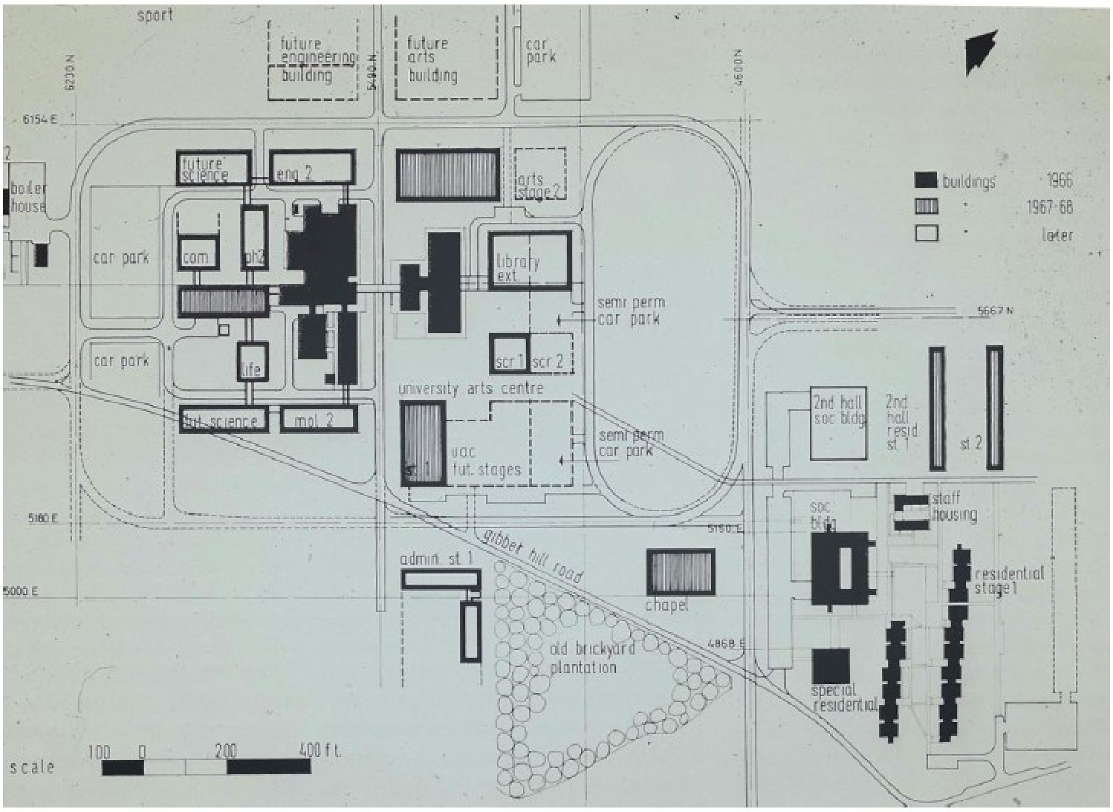


Figure 4.18 Central campus plan from 1964-1965 shows rapid development of flexible grid shown in Figure 4.12 to practical Phase 1 layout: science and library Phase 1 buildings shown in black.

Confident that the diagram would be followed in Phase two, the fire escape stairs at the end of the thin buildings were designed to be unbolted and moved to the end of the next building. The diagram and the principles embodied in it were enthusiastically embraced by the first academics, themselves chosen for their ambition and innovation.

The next phase of science buildings followed the diagram, and it was with some satisfaction that the author saw the fire escape staircase being moved to its new home at the end of the next thin building. However, by the time the following phase was being developed, the new academic appointments were demanding their own front doors, their own departmental identity, and the spirit of the diagram was, to some degree, eroded (Figure 4.19 refers).

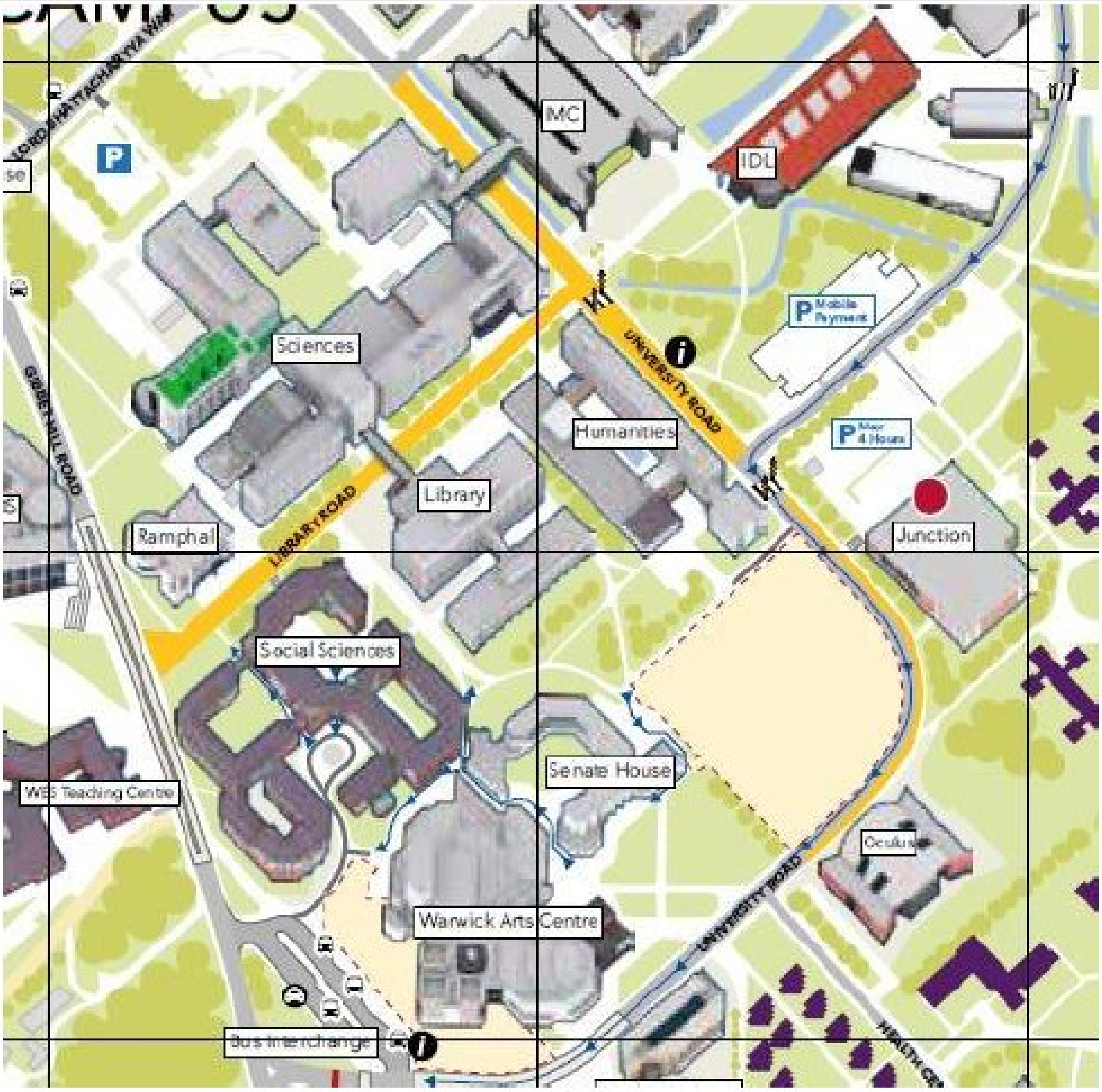


Figure 4.19 Central area of campus today showing how the original diagram for science was modified to accommodate particular opportunities for growth and, across the road, how the library was able to expand only by means of an additional building

The involvement of the users of the science buildings was addressed through the flexibility inherent in the module of the laboratory buildings. The distance between laboratory benches with a pathway wide enough to allow two people to pass in comfort, as recommended by the then current best practice and contemporary research by the Nuffield Foundation, was adopted as the module, or planning grid, for all the thin buildings. Vertical ducts at every module further provided flexibility in providing laboratory services, including drainage, power, water and gases. The furniture, too, was modular and, hence, interchangeable.

Looking back at the discussions with the University academics, the ideas that led to the physical diagrams and the science building designs were fully aired. The client accepted the strategies proposed and the reasons for them. The team was not challenged to prove they were right, only that they were acceptable. This is the common sense, the soft test for architectural approval. The building spaces worked, changes were made and the connectivity concept lasted for some time but not forever.

Figure 4.20 shows the entrance to the Science complex.

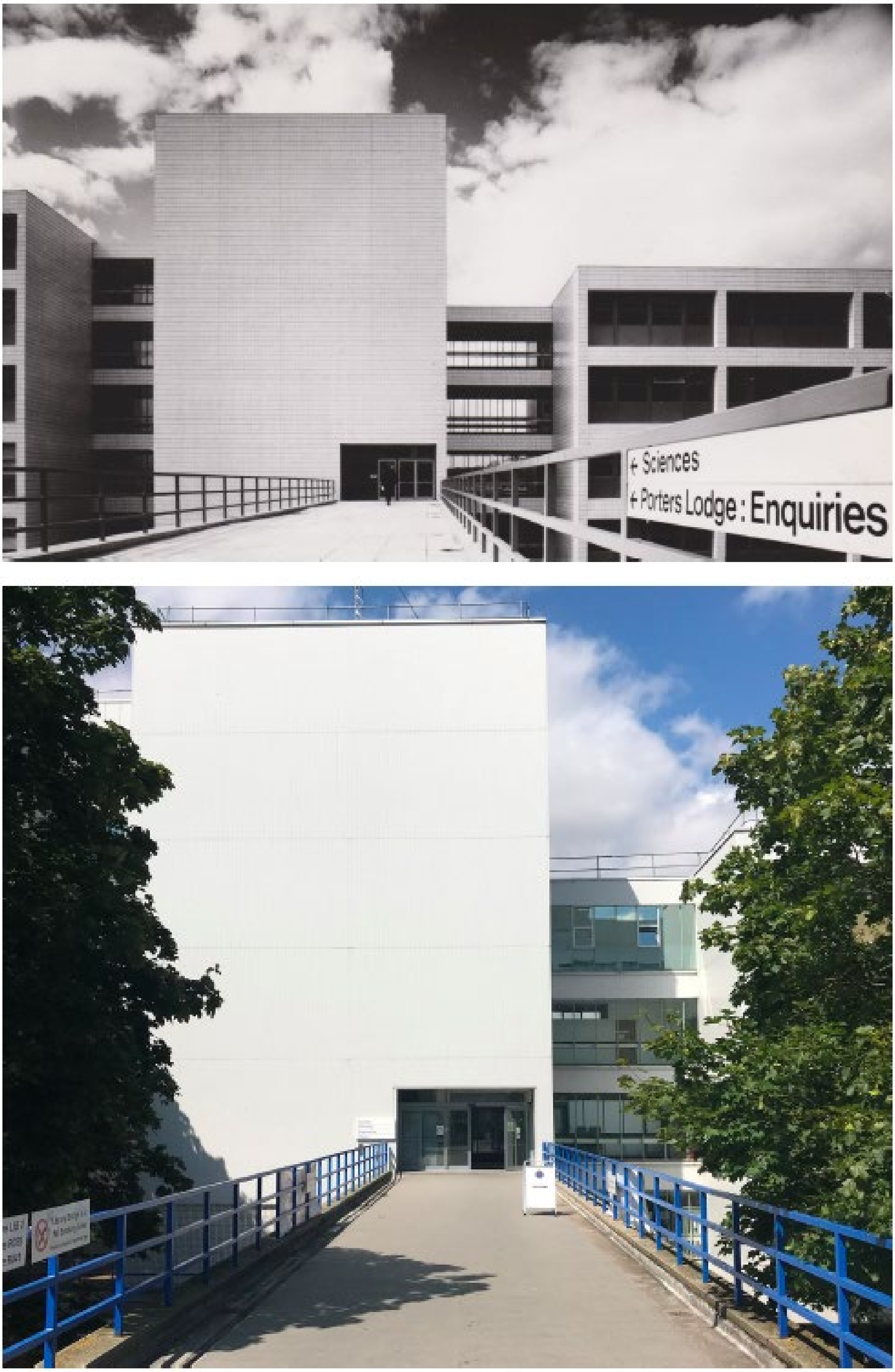


Figure 4.20 Entrance to science buildings; above shows original appearance with austere tiled facades: below shows same entrance with composite panel replacement facade

Figure 21 shows a current photograph of the Warwick campus.

Figure 4.21 Current photograph of Warwick campus

At almost the same time as Warwick University was starting, Arup Associates were developing a plan for the engineering department at Loughborough University. As this offered a similar approach to institutional growth, an account of the proposals and their consequences is included here:

Arup Associates set out their proposals for the campus:

In Loughborough we have tried to design buildings to meet the needs of both growth and change. The lack of a definite brief at the outs – an intelligent refusal to hazard a guess at future developments in teaching disciplines by the client – made the development of such a building the only viable solution was to propose a series of dimensional relationships realised as grid networks, giving a discipline within which the various parts can be related to each other and to the whole. (Thomas, 1967, p. 7) (Figures 4.22 and 4.23 refer).

Based on a common grid, the master plan of Loughborough University was established in 1966, to ensure order and continuity in the development of the campus, as well as allowing flexibility to meet future requirements. Each building was planned as a universal adaptable design, able to change to varying teaching categories of use, including workshops, research laboratories, specialist and non-specialist teaching spaces and staff offices. The whole scheme was coordinated at campus and building level, by standardizing the structure, partitions & services pathways dimensions. These dimensions, used throughout the campus and building design, meshed together to form a tartan grid.

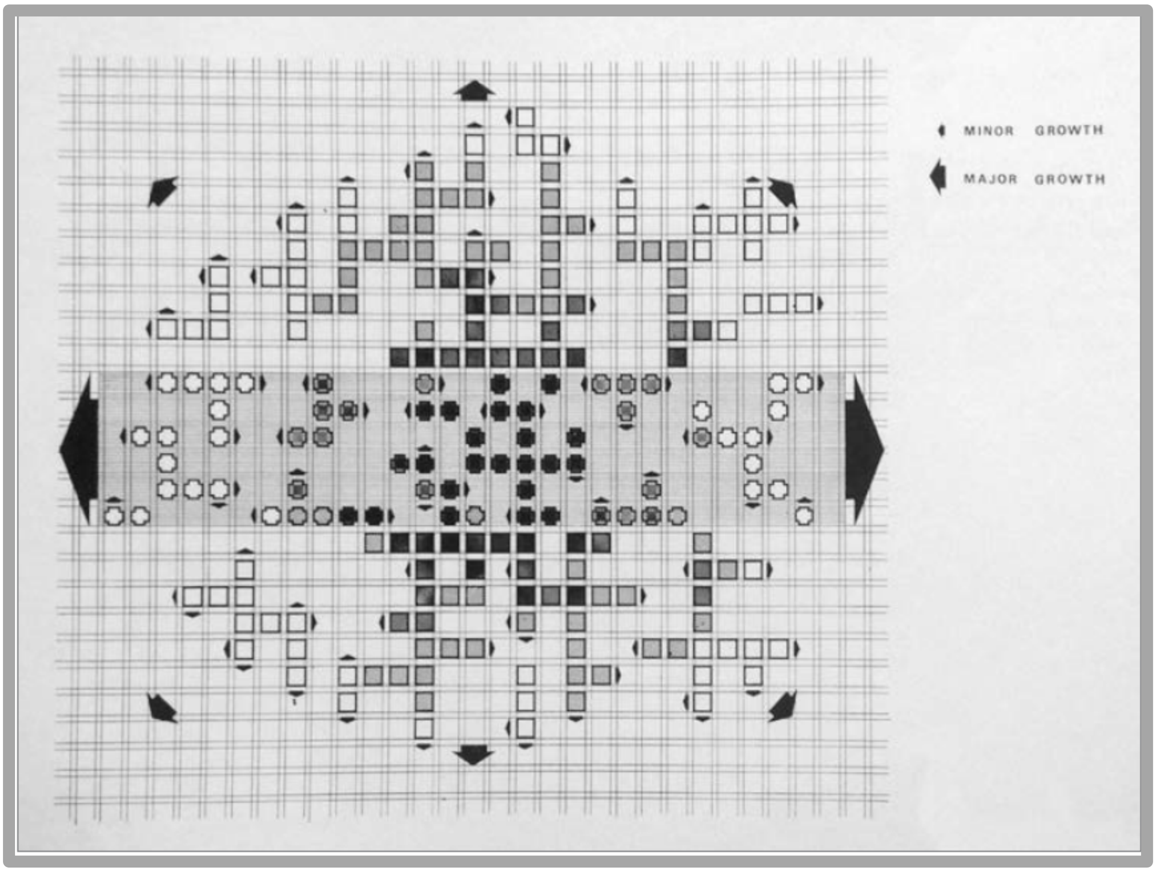


Figure 4.22 Loughborough University of Technology growth pattern, Arup Associates (1966)

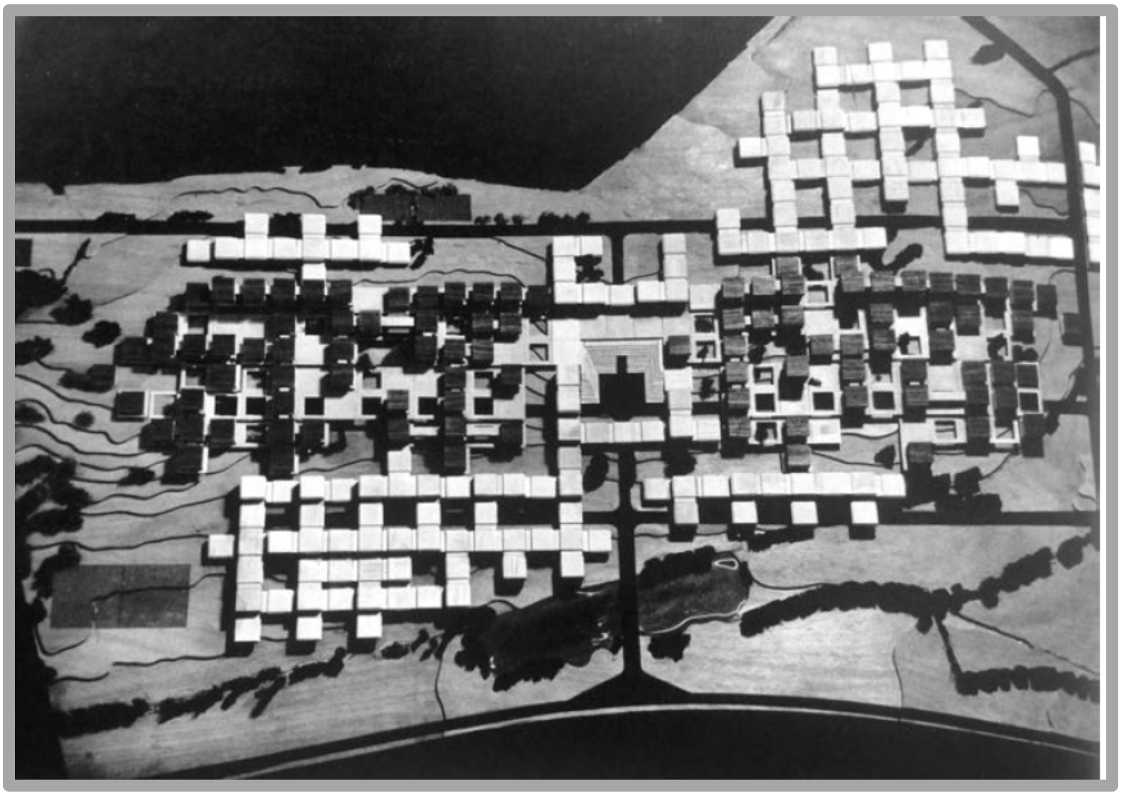


Figure 4.23 Model of master plan for Loughborough University of Technology, Arup Journal 6 (1967) p. 14

> Arup Associates designed a square block as universal adaptable volume, linked by modular connections. The size of units was chosen to maximise natural lighting, while allowing maximum open space for various plan arrangements. The shape enabled extension of similar units on any of the four sides. A partition system was developed to facilitate easy changes and the buildings included all services requirements thanks to the deep structural floors. Vertical rising ducts could be accommodated in nearly any position, to suit unknown changes in technology and needs. The Civil Engineering Building was the first to be designed and constructed in 1969, using four square units of two floors. (Fuster et al., 2009, p.6)

Domingo-Calabuig reviews the Loughborough diagrams and plans starting with an approach to activities and spaces. Rather than the binary approach taken at Warwick, Arup Associates uses: "three types. First, there are heavy or industrial laboratories, then specialized spaces or research laboratories and, finally, generic teaching spaces, such as classrooms and seminars. The goal is to find, for the first two space types, a universal and useful relationship for the partition's position, the structural elements and the service routes" (Domingo-Calabuig, 2020, p. 7).

Her exploration of the way in which the grid is almost assumed to have supernatural powers is especially valuable in the light of events at both Warwick and Loughborough in which the "discipline" of the grid broke down: "Thus, the grid is both a pattern organization of lines that work as communication channels and a homogenous surface that feeds a utopian picture. However, when defining the 'discipline', the Arup Associates firm uses the grid as a succession of limitations" (Domingo-Calabuig, 2020., p. 10).

Exploring the possible psychological dependence that architects display towards their grids, their graticule, as described by Lucan (Lucan, 2009) and explored more fully by Fischbach (Fischbach, 2010), is beyond the scope of this thesis. However, Domingo-Calabuig tantalizingly concludes her review of the Loughborough plan as follows:

> The time limitation is never expressly defined, but there is an insistence on compositional rules that will guarantee a procedural unity forever. Hence, all these design operations refer us to a sort of cheating or visual illusion. Background and figure are confused in both the near and distant gaze – from the first of the grids to the master plot – and finally, the proposal looks like a complex cage that can only be opened with a limited combinatorial series. (Domingo-Calabuig, 2020, p. 14)

While the 'open-ended grids' of Warwick and Loughborough appeared to their authors as providing sufficient flexibility to accommodate growth, neither diagram survived intact for very long. Perhaps the pattern laid down initially would have been followed for a longer period if the architects had themselves lasted longer contractually working with the custodians. The potential value of such an extended professional role is explored elsewhere in this thesis and in Appendix Five. Hence, if uncertainty is to be accommodated, it needs more than simple grids at its heart together with a mechanism that ensures continuity.

4.4 BUILDINGS IN USE

The only certainty at the commencement of the Warwick University Science project was that nothing was capable of accurate prediction within a general goal of institutional ambition. Although the major factors can be recorded separately, their impact was experienced together. Factors were either within the institution or part of the context within which the institution operates. The decision-making process of the custodians has been tracked. Figure 4.24 tracks the interventions to the Science buildings. Note that interventions to the fabric are shown in red, while those driven by functional considerations are shown in blue.

RANGE OF INTERVENTIONS based on Watt (2009)		UNIVERSITY OF WARWICK CENTRAL CAMPUS: SCIENCE 1964-2000				
		INTERVENTIONS WITH INITIAL USE			INTERVENTIONS FOR NEW USE	
		BY USERS	BY CUSTODIAN		BY CUSTODIAN	
		WITHIN SPACE	WITHIN SPACE	WITHIN AND OUTSIDE SPACE	WITHIN SPACE	WITHIN AND OUTSIDE SPACE
1	Rearrangement- moving furniture and fittings to suit activities					
2	Replacement- acquiring new furniture and fittings		1971:additional furniture for Molecular Science 1975: added fume cupboards....a/c modifications to computer centre. Conversion to office and lab. 1986: additional fume cupboards and services for Molecular science			
3	Maintenance- achieving and maintaining a satisfactory level of building performance		1969: catastrophic defects in external tiling; high court case leading to contractor, sub-contractor and architects paying for repairs. 1974: tiles replaced with aluminium cladding. 1974: planned maintenance and redecoration cycle introduced 1979: renewal of roofing and additional coping to all buildings 1981: review and repair of some Omnia slabs 1983: resurfacing science concourse 1986: replace all vinyl tiles 1990: extensive floor repairs		1975: conversion of offices and added fume cupboards	
4	Adaptation-accommodating a change in the use of a building, which can include alterations and extensions		1977;amalgamation of laboratories 1979 insert darkroom in Molecular Science 1979: remove all offices from laboratories and build offices in links 1979: convert office in Molecular Science to electronic lab 1979: Engineering covert office to store and enlarge office 1982: provision of computer terminals on concourse 1988: multple changes of use arising from removal of Environmental sciences to elsewhere 1988: convert staircase lobby to store 1990: canopy over substation and spectrometer (flooding problem)		1982: Engineering gets its space back (from Psychology)	1964; design use car park changed to telephone exchange. 1980 changed to computer science. 2000 change to chemistry. 1974: Law, History of Art and Psychology move into Engineering! (Due to pressure from government on funding). 1976:severe pressure on space leads to conversion of staircase landing to offices, conversion of lavatory to lab and office to cold room. attempt by engineering to get space occupied by psychology back fails
5	Alteration-changing or improving the function of a building to meet new requirements		1971: additional furniture. 1973; sinks and services added, partitions, improved lighting, 1973: new door openings, repositioned equipment and fume cupboards. Add dark room in computer centre 1975; relocation of compressors in Engineering lab. Adapting room for tea-making 1998: comprehensive refurbishment of Chemistry research labs			

Figure 4.24 (part 1) tracks the interventions to the Science buildings. Note that interventions to the fabric are shown in red, while those driven by functional considerations are shown in blue.

6	Conversion-making a building of one particular type fit for the purposes of another type of usage				1975: temporary use by Psychology requires added observation rooms	
7	Extension-increasing the floor area of a building, whether vertically by increasing height or horizontally by increasing plan area		1986: additional mezzanine floor for Engineering added	1988: accommodation report suggests centrally timetabling space used by Engineering and Physics for large scale experiemnts in order to improve efficient use of space		1966: siting of new physics building: agreed to connect to concourse but ONLY at one level. Prof wanted his own front door. 1967:computer centre located centrally in courtyard as proximity to served departments considered critical to function (200 yards maximum distance). computer centre moves out to be replaced by computer science and, in 1990, to be replacede again by physical sciences1967:Engineering 2 connected to Engineering 1. 1972: Biological science located 1975: waterproofing new plant room for Physics
8	Improvement- bringing a building and/or its facilities up to an acceptable standard, possibly including alterations, extensions or some degree of adaptation		1973: add a/c for for electron microscope, add gas services for research labs. 1976: added sound-proofing. Extension to crane rail. 1978: extend gas supplies to Environmental Science	1976: add concrete walls and shelves in external solvent store. 1980: add foil to windows to reduce solar gain 1987: external cladding overcloaked (due to tiling problems)		
9	Modernisation- bringing a building up to a standard laid down by society and/or statutory requirements		1973: added fire alarms, added pressure reducing valves to water mains 1975: new partitions and CO2 fire extinguishers added. 1976: safety screens added for lab benches. Waterproof cover over HV substation. Add a/c for new sigma computer. 1979: responsibility for fire protection changes leads to inspection	1986: removal of asbestos ceiling tiles 1987: review of roofing insulation due to uncertain future energy costs 1987: all toilets mofified for disabled access		1980; changes to temporary Psychology Department rooms in Engineering
10	Refurbishment-overhauling a building and bringing it up to current acceptable functional conditions		2001: comprehensive changes to lighting, a/c, heating, flooring. Roof replaced. Toilets refurbished.			
11	Rehabilitation-work beyond the scope of planned maintenance, to extend the life of a building, which is socially desirable and economically viable					

Figure 4.24 (part 2) tracks the interventions to the Science buildings. Note that interventions to the fabric are shown in red, while those driven by functional considerations are shown in blue.

4.5 CONCLUSIONS

The provision, maintenance and allocation of space emerge from the case study as critical activities. The case study illustrates the range of uncertainties to which custodians and users of buildings need to respond. These include changes generated by human activity (often associated with equipment) and changes arising from the nature of building fabric (held in check to some degree by maintenance). While architects have usually been trained to find out precisely what their custodians needed, it seems necessary now that they must avoid designing too tightly around those requirements. At the same time, the building must work for the initial custodian and user. The provision of initially redundant space may contribute to the long-term value for the custodian. It may also facilitate greater flexibility and adaptability for the initial and later users. From the post-occupancy evaluation literature, several possible interventions have been identified. The University of Warwick is especially interesting because, from the start in 1964, there is a contrast between the science complex, which is open-ended and allowed for future connectivity[36], and the library building which could only expand by means of a new separate building.

By reviewing the stages of change and growth, analysing the reasons influencing or determining the decisions about change, the factors that enabled or prevented changes can be identified. The estate custodians of buildings need to be aware of the influences that may necessitate change. The custodians will make changes as a result of:

- a pro-active review by the custodian, (on a regular timed basis or as required by legislation).
- information or "pressure" from elsewhere in the organization.

The case study examined decisions affecting space and fabric over fifty years. A decision to move furniture around within existing spaces is not of interest here and

[36] essentially an early urban mat as well as an example of Steadman's *archetypal building* (Steadman & Marshall, 2005a) (Steadman, 1998).

may well not be recorded anyway. But a change that requires expenditure, a works order or the like provides a reasonable starting point. How change is undertaken and how buildings have been observed to grow provides a context for developing ways to make these responses easier to achieve without disruption. By studying the decision-making of custodians of buildings in use, it is possible to show the points in the overall design and building process at which the advice and techniques developed will benefit. Unexpected events, requiring a response from building managers, may arise within the organization or in the context within which the organization operates. The unexpected events may arise from:

Within the institution

Recruitment. The quality, effectiveness and ambition of employees are influential. The need to respond, sometimes very rapidly, to opportunities arising from the availability of special people and special money (research funds, etc.) has a significant impact on campus development. There was a regular assessment of the academic marketplace regarding national and regional interests, which inevitably informed decisions about priorities. Opportunities for merging with other existing institutions arose when the momentum of the new institution was recognized.

The outcome of disputes. The refusal of newly appointed senior staff to respect the provisions for growth that were already part of the campus plan significantly impacted the connectivity of departments as the university expanded.

Changes in the administrative setup and decision-making machinery influenced changing priorities through patronage and funding. With campus growth, the mechanisms by which functional requirements are identified and communicated were divided into two parallel processes with separate teams responsible for space allocation and space procurement. This sophistication is matched by a changing balance between centrally timetabled space and locally controlled space. The allocation of space to solve short-term problems leads to complications when the temporary occupants demand changes to the fabric and service provision of their "temporary" home. The "host" is forced sometimes to struggle to get back their lost territory over decades. There were several examples in which changes of use took place in response to unexpected demands.

Technical decisions were made in light of the best available knowledge at the time. The central computer facility was initially located less than 200 yards (183 m) from places it served. As soon as technical advances outgrew this constraint, the space occupied was re-allocated to a succession of other uses. Space and environmental services needed to be updated as equipment was replaced.

Context: Aspects of the external environment outside the control of the institution include:

Finance. To a large extent, the development of the campus reflects the timing of funding and the control exercised by the funding authority. Since the funding authority is itself subject to national financial allocation, the campus development was frequently at the mercy of what seemed to be arbitrary investment cuts and delays. The lack of funds at critical times led, in extreme instances, to staircases and toilets being converted to offices and laboratories. The change from being wholly publicly financed to being reliant upon diverse sources of finance affected every aspect of campus growth. Opportunities for private investment in campus buildings could not be overlooked.

Land and town planning. The need to assemble land from different donors and achieve development approved by local planning authorities influenced campus growth and traffic and pedestrian movement patterns.

Implementation. Many factors may influence the implementation of projects. These include design issues, contractor performance and financial stability, strikes, material availability and so on.

Regulations. The retrospective application of improved standards of health and safety affected both space and services provision.

Despite the institutional turbulence, the buildings at Warwick have continued to work. This success may owe something to the fact that, as Cowan says, "the majority of human activities occur in spaces of under 200 sq. ft. (18.6 m^2)" (Cowan, 1962, p. 59). Whilst the above factors have been identified in an institutional context, it is not difficult to see that the unpredictability experienced would apply in some measure to many other projects, public and private, residential and commercial. It is essential to recognize the interdependent impact of these factors. The changes in university funding during the 1980s, already referred to by Troiani and Carless (Troiani & Carless, 2021), encouraged an opportunistic approach to campus planning that was not consistent with continuing support for an established planned pattern, however rationally that was based upon a sensible appreciation of needs.

The conflict between a logical layout and an opportunistic financial context can be seen at Loughborough as well as Warwick. The use of a tartan planning grid has continued elsewhere since its deployment at Warwick. Weeks and Best proposed a version of the concept, very similar to the original Warwick sketches, for the health sciences complex at Memorial University of Newfoundland (Weeks & Best, 1970, p. 278). Figure 4.25 illustrates their approach to the three-dimensional communication pathways similar to those originally set out for Warwick while figure 4.26 shows the plan.

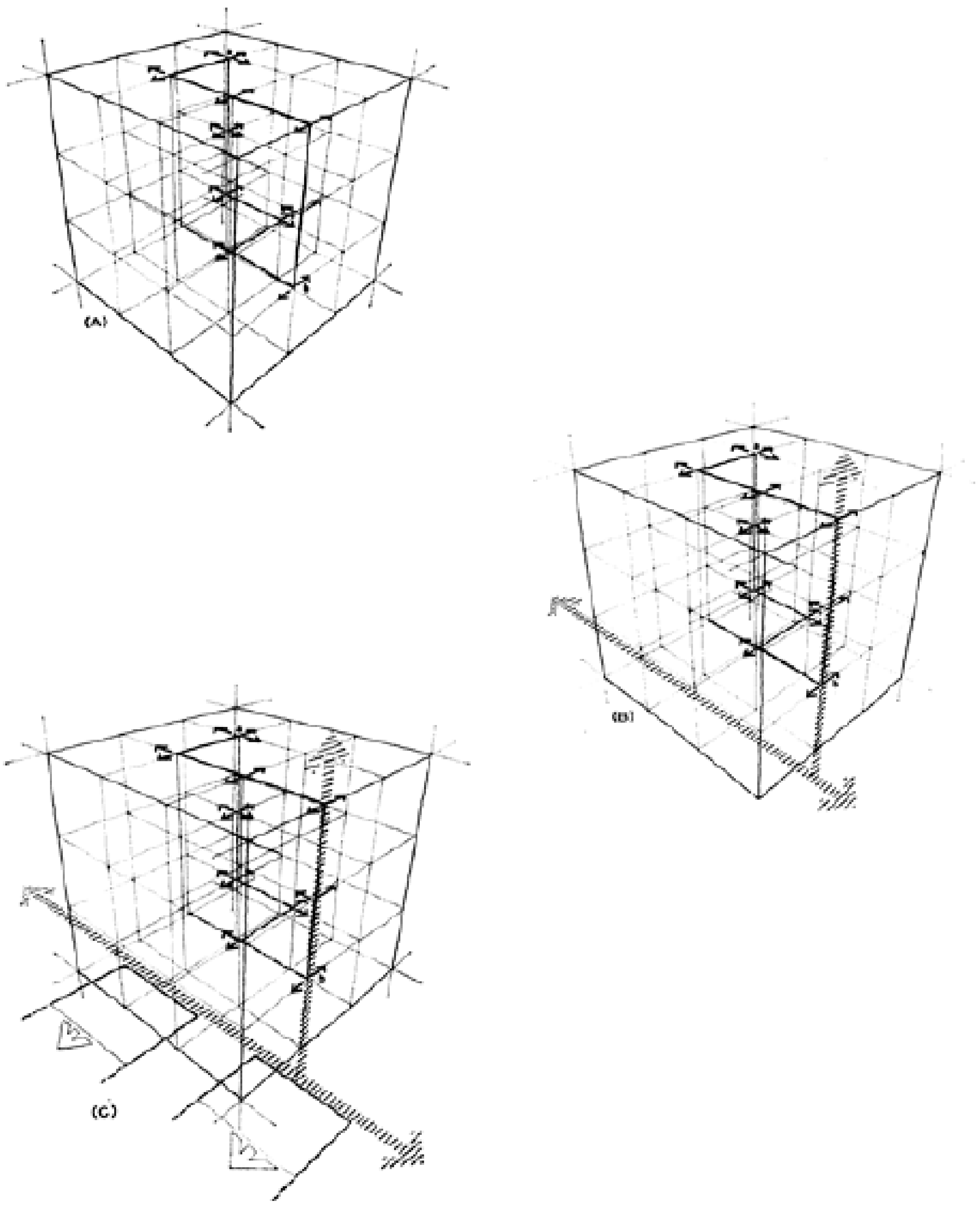


Figure 4.25 Communication lattice in health sciences facility. Each strand in lattice represents a communication path. A. Two points a and b can be connected by many paths, each finding different node points in complex. B. Addition of through communication spine provides users with bypass system. This would connect to each of the vertical strands in the lattice, here symbolizing elevator banks. C. Subsystems may have independent lives and independent extension requirements. These are attached to main system in such a way that its chief characteristics are not affected, from (Weeks & Best, 1970, p. 278)

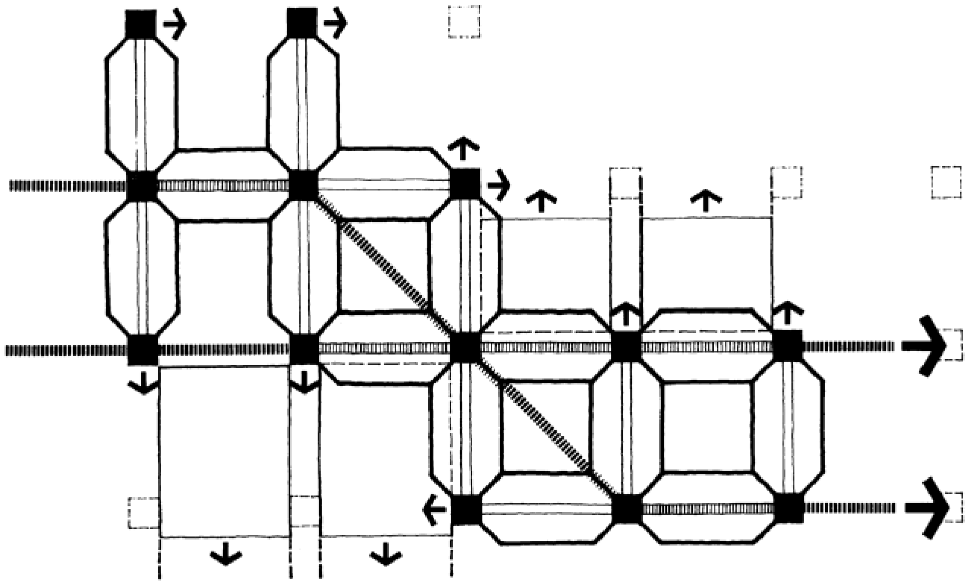


Figure 4.26 Black squares are nodes at which various stages of construction may join. Independently extendible elements are at ground level and may extend between nodes. Two through communication lines are shown; these connect at right of diagram to nonmedical campus and may extend to left. Complex may be built of small units, constructed in any order and starting at any point within complex. Each node contains vertical communications sufficient for the construction that abuts it, from (Weeks & Best, 1970, p. 278).

Steadman describes the Warwick style grid as an archetype (Steadman & Marshall, 2005b, p. 6). Figure 4.27 refers.

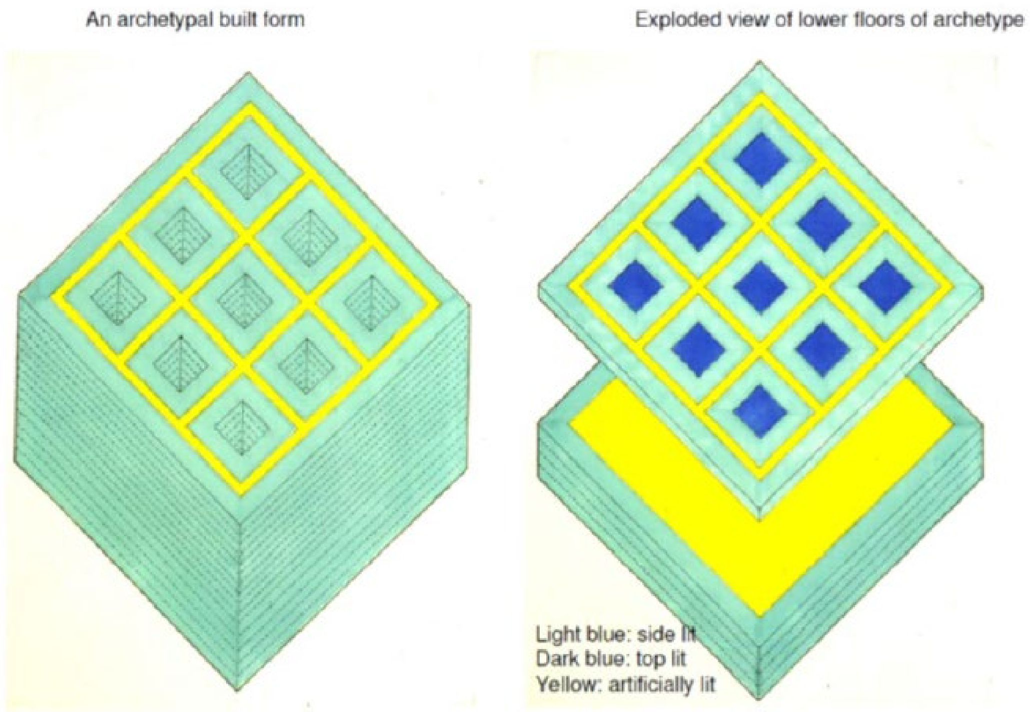
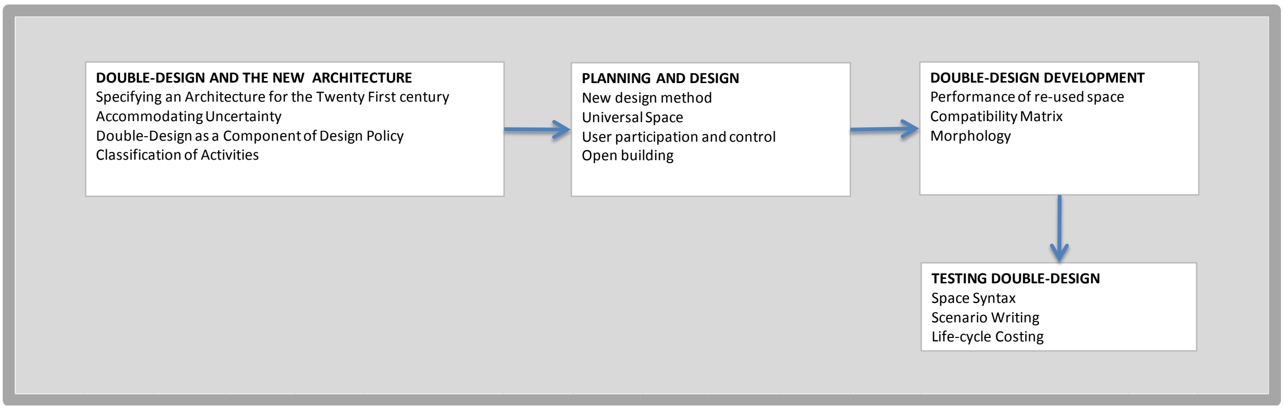


Figure 4.27 Archetypal building form, from (Steadman & Marshall, 2005b, p. 6)

Fukao concludes his assessment of the value of grids in adaptable buildings: "good architectural design, it is effective to achieve dimensional coordination using multiple grids of various levels superimposed on one other. The suitable grid system differs depending on the nature of the building components. An adaptable building system can be obtained through the use of a sophisticated grid system" (Fukao, 2006, p. 5). Yunitsyna has explored the use of grids in generating plans for a range of flexible housing projects (Yunitsyna, 2012b).

CHAPTER FIVE: MOVING FORWARD



5.1 DOUBLE-DESIGN AND THE NEW ARCHITECTURE

5.1.1 Specifying an Architecture for the Twenty-First Century

Based upon the consideration of the current place of architecture in society, as covered in Chapters Two and Three above, together with the analysis of the case study with the emphasis upon design for uncertainty, the characteristics of a successful architecture must include regard for:

- function
- custodian and user participation and control with adaptability and flexibility
- uncertainty with provision for growth and change through the agency of Double-Design
- environmental considerations
- imageability
- improvement of building performance

5.1.2 Accommodating Uncertainty

> *Le doute n'est pas un état bien agréable, mais l'assurance est un état ridicule.*
> Doubt is not a pleasant condition, but certainty is an absurd one. (Voltaire, 1770)

Uncertainty is a condition confronting organizations and institutions, yet awareness and perception of the condition are experienced, communicated, and reacted to by individuals. Therefore, it is a surprise to find very little understanding of the interdependence of individual and institutional uncertainty. Anderson et al. address this question, suggesting that:

> Uncertainty is fundamentally a mental state, a subjective, cognitive experience of human beings rather than a feature of the objective, material world. The specific focus of this experience, furthermore, is ignorance – i.e., the lack of knowledge. Importantly, uncertainty is not equivalent to mere ignorance; rather, uncertainty is the conscious awareness, or subjective *experience* of ignorance. It is a higher-order metacognition representing a particular kind of explicit knowledge – an acknowledgment of *what* one does not know, but also *that* one does not know. (Anderson et al., 2019, p. 2)

As Anderson et al. observe: "most past empirical and theoretical work has focused on negative or undesirable affective responses to uncertainty. Nevertheless, intuitively there are life situations in which affective responses to uncertainty are positive. A small set of studies currently provide initial empirical support for the notion that uncertainty can, at times, produce positive affect" (Anderson et al., 2019, p. 7). From a spiritual point of view, Kelly suggests that it is:

> Impossible to be certain of anything except that everyone suffers as a consequence of being born. What is usually overlooked is that uncertainty, when consciously faced and perceived in the context of life's totality, is the creative aspect of being […] Then, the challenges and stresses of everyday life can be scrutinised with a developing spiritual perception which reveals new insights and the appropriate action for any situation […] The process can last for many years, even a lifetime, but with the knowledge that the uncertainty of living is gradually being transformed to a higher octave of truth. (Kelly, 2018)

Uncertainty is not just an inconvenience encountered by every architect and custodian during the briefing process. It is a central feature informing every aspect of use and occupancy of space, undermining the reliability of assumptions and calculations made during briefing and design. A strong case can be made for uncertainty in all its forms to be embraced rather than feared. To regard unforeseeable or unforeseen events as a risk is disrespectful towards the open-endedness of human enterprise. It is reassuring to note that theoretical approaches to project management are turning away from risk management and towards uncertainty management (Johansen et al., 2014; Ward & Chapman, 2003) (Nota & Aiello, 2014). Even in complex fields like space exploration, commentators have identified uncertainty as advantageous. As McManus and Hastings suggest: "Uncertainty is not always a negative to be mitigated; robust, versatile and flexible systems not only mitigate uncertainties, they can also create additional value for user" (McManus & Hastings, 2005, p. 1). In this context, design must be seen as capable of contributing to the management of uncertainty.[37]

The essential characteristic of uncertainty pertains to an inability to predict the consequences of actions. As Zinn suggests: "the experience of uncertainty has to be accepted as a fundamental modern experience and the view on problems of uncertainty needs to be changed. Consequently newer research focuses on uncertainties (still foremost technical, medical, or scientific limits of producing certainty) and how they are managed or how they could be managed best (not as a final transformation of uncertainty into certainty but as a process of managing unpreventable uncertainties)" (Zinn, 2005, p. 2). Socio-cultural approaches to risk and uncertainty recognize the positive aspects of risk reflecting a "multidimensional" appreciation of risk-knowledge: Zinn continues: "this approach seems to accept that living in late modernity implies the acceptance of some degree of uncertainty and instability" (Zinn, 2005, p. 4). In the broader context of society and government, O'Malley argues that there should be less focus upon the transformation of uncertainty into risk but more on the management of uncertainties as government strategies: "accordingly we need to develop a more nuanced analysis of the ways in which, almost

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[37] **I entirely agree with your approach, In fact since the mid 60's [sic] I have always been designing for adaptability and change. I was first introduced to this approach by the architect John Weeks for the design of Northwick Park Hospital. The philosophy we followed was that for hospital design the only constant was to design for change, for adaptability and extendibility. Since that time I have always designed for adaptability but I accept it is not common practice but as you suggest I agree that it should be (Sir Nigel Thompson).**

everywhere, that risk appears, it is assembled into complex configurations with other technologies, particularly – if not only – with uncertainty. Moreover, while risk and uncertainty, and the politics they generate, are diverse in origin and form, they also are connected to variations in the forms and genealogy of political liberalism" (O'Malley, 2012, p. 27). The contribution of Beck to a more widely felt impression of societal uncertainty is described by Burgess et al:

> Central to Beck's thinking about risk is the proposition that the major threats that society faces are no longer primarily external, coming from without – most obviously as natural hazards. Instead they are produced as unintended consequences of modernisation itself, most palpably in the form of climate change produced by human activity.(…). What makes matters worse in Beck's reading is that the very institutions and instruments responsible for risk management are now part of the problem, wedded as they are to the frames of reference and types of solutions that produced the problems in the first place. […] It is not only the nature and scale of the risks themselves, but the inadequacy of primarily national institutions to cope with global problems that Beck sought to illuminate. He identified a burgeoning culture of public distrust in expert systems, which further limited the capability of regulatory institutions to respond to emergent threats. (Burgess et al., 2018, p. 1)

The political implications of uncertainty are amplified further, in apocalyptic terms, by Lorey:

> Precarization means more than insecure jobs, more than the lack of security given by waged employment. By way of insecurity and danger it embraces the whole of existence, the body, modes of subjectivation. Precarization means living with the unforeseeable, with contingency […] The way that precarization has become an instrument of government also means that its extent must not pass a certain threshold such that it seriously endangers the existing order: in particular, it must not lead to insurrection. […] The question is rather where, within these governing mechanisms, cracks and potentials for resistance are to be found. (Lorey, 2015, p. 11)

The universality of the threats arising from uncertainty help to explain the prevalence of approaches like risk analysis that attempt to mitigate or exploit uncertainty analysis. Robustness is seen as one of several positive outcomes contributing to the management of uncertainty (McManus & Hastings, 2005). Change and adaptations are important concepts in ecology, and the interdependences between different levels of ecological systems find expression in the "panarchy" of Gunderson and Holling

(Gunderson & Holling, 2002) (Figure 5.1 refers). This concept, albeit with very different time parameters, echoes the nested skins or layers of Brand and Duffy.

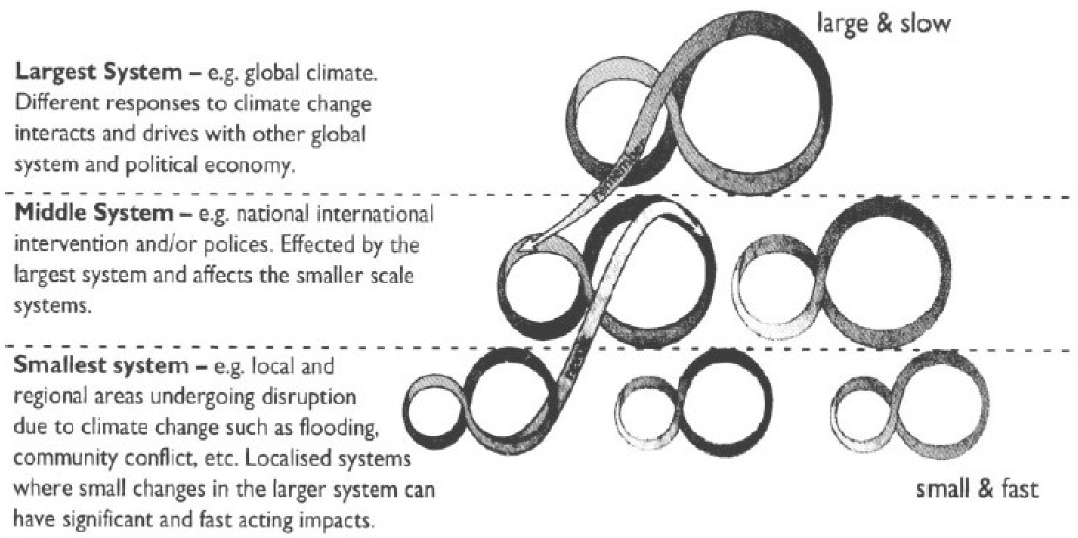


Figure 5.1 The Panarchy from (Gunderson & Holling, 2002)

The interdependence of building space with space in the city as a whole is recognized by Coaffee and Lee, whose work follows the responses to natural and institutional crises that have threatened the sustainability of the city: "As the majority of the infrastructure that will serve cities for the next 100 years is yet to be built [...] planning to deliver urban resilience in the context of increasing complexity will become ever more pertinent to the way in which we view cities and think about their creation and adaptation" (Coaffee & Lee, 2016, pp. 4–5). Their work supports the idea that design must be seen as helping to manage uncertainty.[38] As Fisher suggests: "we need to [...]

[38] **It is a very long period for predicting what technology, new science and energy needs as well as building materials and systems. If total flexibility of change of use is to be considered for a very long building life, this will be more challenging (Maysoon Jamali).**

understand how design thinking provides us with a way to anticipate unintended failures and increase the resiliency of the world in which we live" (Fisher, 2012, p. ix). Working primarily at a local community level, the Transition Movement:

> Envisions a resilient system as one that is diverse (making its constituent elements and connections interchangeable) and with built-in redundancy, modularization (so parts of the system can reorganize in the event of shock, thus making the system less vulnerable to disruption in wider networks), and with tight feedback loops (so that one part of the system can respond to changes in another part). In this vision, increasingly localised systems are seen as the most resilient and better able to respond in a self-organised way to disruption, allowing the community to be increasingly responsible for its own environment. (Coaffee & Lee, 2016, p. 8) (Hopkins, 2011)

The design ideas proposed in this thesis, Double-Design plus adaptability and long-life, complement those implemented at a local level by the Totnes Community Development Society. This charity has recently acquired funding for re-using an old milk factory and provides a valuable example of the interdependence of planning and community engagement (*Totnes Community Development Society*, n.d.) (Figure 5.2 refers).

Figure 5.2 Totnes Community Development Society has been awarded a £2,576,400 grant from The National Lottery Heritage Fund to restore the Brunel Building. New facilities will also be added to make it a vibrant space for community enterprise, events and local services. The Brunel Building is a well-loved entrance to Atmos Totnes and for many visitors to Totnes it is the first building they see as they step off the train . (Totnes Community Development Society, n.d.)

Coaffee and Lee are clear that planners have vital responsibilities in enhancing urban resilience, and the role of government in establishing and monitoring their implementation is emphasized. The weakness of planning institutions in the UK is contrasted with those in more authoritarian countries. As they say: "we are living in an age of more visible risk, where individuals and governments have ever more knowledge about the possibility of a seemingly growing number of undesirable events occurring, such as flu pandemics, economic crashes, terrorism or flooding. As we have highlighted, it is imperative to learn from the past and to plan and design out maladaptation in the built environment and associated government processes" (Coaffee & Lee, 2016, p. 259).

However, uncertainty within the construction industry has been approached from a different and much more limited perspective. For example, an AIA study assessed some factors encountered during the design and commissioning process that contributed to project uncertainty:

> As the first phase of this research, over 1,500 owners, architects and contractors were presented with a list of factors and asked to select the one that causes the greatest uncertainty on building projects. Listed below are the top seven causes of uncertainty identified by these respondents.
>
> - Accelerated Schedule
> - Owner-Driven Program or Design Changes
> - Design Errors
> - Design Omissions
> - Construction Coordination Issues
> - Contractor-Caused Delays
> - Unforeseen Site or Construction Conditions
>
> Interestingly, responsibility for all but one of these seven disruptive factors can be said to align closely with a particular project team member. (*Managing Uncertainty and Expectations in Building Design and Construction*, 2014, p. 11)

The AIA study is based upon a very limited definition of uncertainty, focused upon technical and practical concerns rather than the long term value of a project: "Perspectives vary between owners, architects and contractors on the relative importance of key drivers of uncertainty on building projects. However, unforeseen site conditions are among the top three factors cited by all parties"[39] (*Managing Uncertainty and Expectations in Building Design and Construction*, 2014, p. 5). In a similar way, the UK Cabinet Office has published guidance on some policies that are intended to help the UK construction industry. This guidance is focused almost exclusively upon efficiency and has little to say about longevity or building performance while making passing references to waste avoidance and sustainability (UK Cabinet Office, 2020).

The clear implication for design is that uncertainty about the short and long term effect of particular designs on occupants, custodians, and users must be considered. The accommodation of the individual occurrences of uncertainty needs to be an essential part of the design process. Architecture must contribute to the kind of "technical" uncertainties outlined in the AIA study. Still, a more comprehensive response, like Double-Design, embedded in all architectural work could significantly contribute to the technical aspects of project uncertainty and to the more social and psychological experiences of uncertainty referenced by disenfranchisement, climate change inequality and the like. In suggesting an approach to the management of uncertainty in the development of innovative enterprises, Rice et al. identify four categories of uncertainty:

> **Technical Uncertainties** These relate to the completeness and correctness of the underlying scientific knowledge, the extent to which the technical specifications of the product can be implemented, the reliability of the manufacturing processes, maintainability and so forth.
> **Market Uncertainties** These include the degree to which customer needs and wants are clear and well understood, the extent to which conventional forms of

[39] A serious problem was encountered on a project in Kuwait when the ground survey team, unable to get access to the right site, surveyed a nearby but quite different site to which they could gain access.

> interaction between the customer and the product can be used, the appropriateness of conventional methods of sales/distribution and revenue models and the project team's understanding of the breakthrough innovation's relationship to competitors' products.
> **Organizational Uncertainties** Given the length of the breakthrough innovation life cycle – often 10 years or more – organizational dynamism creates another category of uncertainty. […] The uncertainties related to organizational context stemmed from a fundamental conflict between the mainstream organization and the unit engaged in breakthrough innovation, the difficulty of managing the relationship between them and the challenge of managing the transition from breakthrough innovation project to operating entity.
> **Resource Uncertainties** This emerged as the fourth category of uncertainty, as project teams continually struggled to attract the resources they required. […] Even when a breakthrough project is formally established, its funding is generally unstable over time..... Because the breakthrough innovation life cycle typically lasts a decade or longer, a project can expect to see its supporters and sources of funds change multiple times. Consequently, project champions must be prepared to continually pursue funding from a variety of potential sources. (Rice et al., 2008).

This analysis confirms the wide range of uncertainties to which the Warwick Science buildings were required to respond as described in Chapter Four.

While unwelcome in its origin, there can be few better or more dramatic demonstrations of the value of "spare space" than the conversions of convention centres and other suitable spaces worldwide to hospitals for coronavirus patients. The flexibility inherent in such spaces further illustrates their value in responding quickly to unanticipated requirements (Figure 5.3 refers). As Dezeen reported:

> Converting convention centres into coronavirus hospitals is the most efficient way to increase intensive-care capacity, according to James Hepburn of architecture and engineering firm BDP, which helped convert London's ExCel centre into the 4,000-bed NHS Nightingale. To create a functioning hospital so quickly required using the building's existing elements efficiently. In Italy, Carlo Ratti and Italo Rota designed an intensive-care pod within a shipping container, while flat-pack startup Jupe has created the "world's first standalone intensive care unit" and Opposite Office has proposed creating a temporary superhospital within Berlin's unfinished Brandenburg airport. (Ravenscroft, 2020)

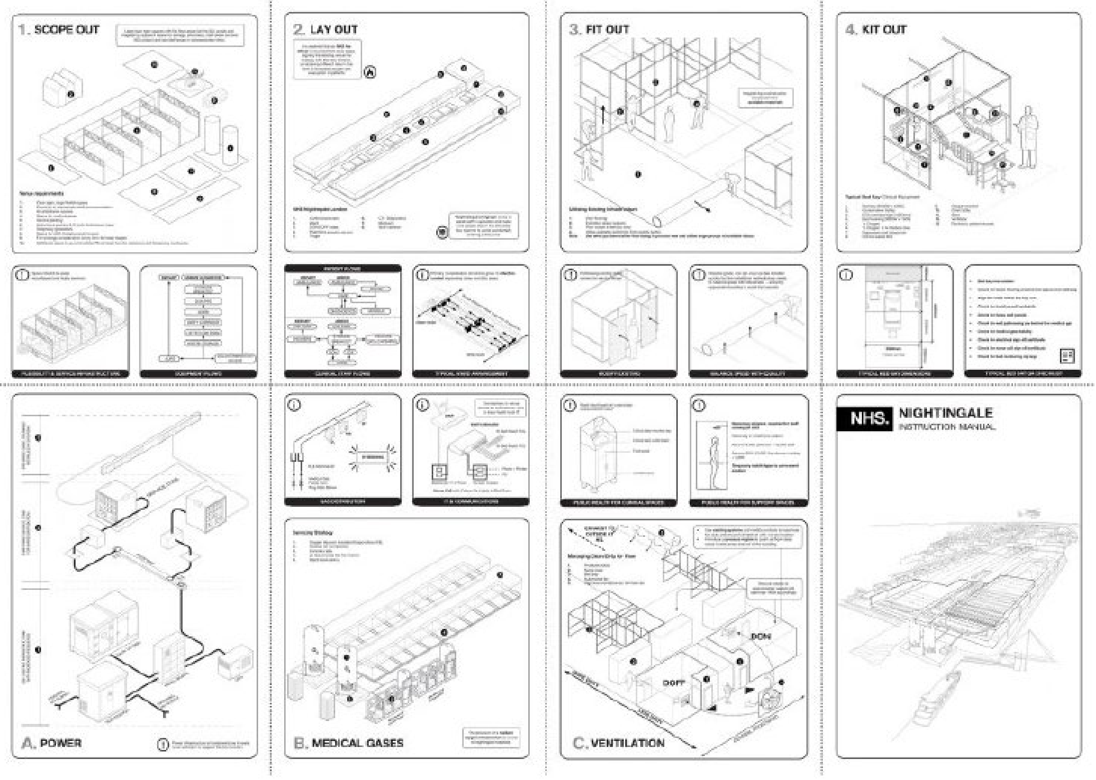


Figure 5.3 Convertion of London's ExCel centre into the 4,000-bed NHS Nightingale hospital illustrates the value of spare space (Ravenscroft, 2020)

We have seen the ingenious ways in which the reuse of existing buildings has been achieved. However, as noted earlier, there are fewer examples in which future, even unknown, uses have been anticipated. Jensø and Getz provide an insight into the problems associated with designing hospitals for the future:

> The Norwegian Parliament repeatedly approved expansions and changes in the project, some of them so late in the building period that completed buildings were torn down, and new planning and design started. Flexibility in buildings, concepts, technical solutions and organization was emphasized as criteria for success in the initiating phase of the project, and the project was developed with intentions of accommodating different organizational models. According to the director of Rikshospitalet, the new buildings are designed for future changes in size and organization. The hospital can be rebuilt and adjusted for different patient categories and new technical equipment without affecting the activity and the patient treatment too much. …The authors of the concept emphasize flexibility and adaptability in this way: "*The future hospital consists of simple, general and flexible buildings in a 'suitable size', with a story height suitable to varying claims for technical constructions. The buildings are situated at own sites of a generous size. (...) The future hospital building is not bound to a specific use during the life time. The general design of the story plan, makes different kinds of future use possible. The block concept, with homogenous, general buildings, permits large flexibility at a possible future internal move.*" (Jensø & Getz, 2003, p. 8)

5.1.3 Classification of Activities

A comprehensive theoretical framework within which to consider human activities is provided by Ekholm (Ekholm, 2001) (Ekholm & Fridqvist, 1996). A basic concept in a description of reality is that of system. A system is a complex thing with bonding relations among its parts; it has composition, environment and structure, both intrinsic and extrinsic (Bunge, 1979, p. 8). A process is a sequence of events in a system. An activity is a goal-directed process. The terms 'process' or 'activity' may also be used to designate the system itself since it is a characteristic feature. An artefact is a man-made or man-controlled system; it is made with a purpose to make certain activities possible. A human activity system that involves the use of artefacts is also called a sociotechnical system. Work is a specific kind of activity; it is a useful activity (Bunge, 1979, p. 179). A sociotechnical system engaged in some work activity is in management science called an "organization", "human activity system" or "enterprise". The organizations of modern society are complex sociotechnical systems organized in functional units composed of human individuals and equipment, including tools and machinery. An organization has a spatial extension traditionally called activity space. The activity spaces are of different scale from the smallest, defined by the human body, tools and materials, to the space determined by the organization as a whole. To adopt a view, or aspect, on a system is to observe a specific set of properties. Of specific interest to design are the functional and compositional views. A functional view focuses on the system's relations to the environment and on parts that contribute to the system's function (Ekholm, 2001, p. 3). This framework introduces the idea of modelling activities and spaces in the application of CAD and is seen as part of the shift from two-dimensional to three-dimensional modelling. Recognizing that an understanding of human activities is central to both the design and use of space:

> The process of acquiring a suitable building starts with a description of the organisation and its activities. The activity description is used as a basis for developing a space function program which defines requirements on the building's spaces. The following step includes development of a building program. The building program together with the activity description and the space program are used as a background for building design, but can also be used for building performance analysis during the facility management stage. (Ekholm, 2001, p. 5)

This understanding of the design process is crucial as it reinforces a central theme of this thesis; as Ekholm concludes:

> The versatility of space is a measurement for its capacity to accommodate different activities. Further program development should be made to allow the user to develop space function programs as an important part of the problem definition work. Information about activities and required building properties are stated in the space function program, which is used both as a starting point for the building design process, and as a background for performance studies during facility management. (Ekholm, 2001, p. 13)

Architecture is a discipline requiring action: decisions have to be made, outcomes predicted, or at least suggested, and communicated. Therefore, it is helpful to look at the philosophical underpinning of action., Basic action theory typically describes action as behaviour caused by an *agent* in a particular *situation*. The agent's *desires* and *beliefs* lead to bodily behaviour (Meusburger et al., 2017) In the simple theory, the desire and belief jointly cause the action. Michael Bratman has raised problems for such a view and argued that we should take the concept of intention as fundamental, and not analyzable, into beliefs and desires (Bratman, 1999). However, applied to architectural decisions, and supporting Davidson's position, the desire to achieve a particular outcome is backed up by a belief that it will occur (Davidson, 1963). In some theories a desire plus a belief about the means of satisfying that desire are always what is behind an action. Agents aim, in acting, to maximize the satisfaction of their desires. Such a theory of prospective rationality underlies much of economics and other social sciences. While causal laws must be strict and deterministic, explanation in terms of reasons need not. The value of Davidson's ideas here is that he loosened the relationship between intention/reason and outcome, perhaps paving the way to deal with architectural decisions that are often observed to be intended solutions to many problems/opportunities simultaneously. To achieve an early start to construction for a government conference centre in Kuwait, it was determined that an allowance of 15 cm between the structural concrete and the outside face of the building would accommodate ANY subsequent design for the insulation, granite cladding and its fixation; this was an enabling design decision of a kind common in the design process. Many architectural decisions are of this type, and, often, it is not expected that a decision will have a perfect score on all fronts. The variability of the success across the spectrum of outcomes does not, and cannot, inhibit the making of the decision. As Alain de Botton says, "Architecture is perplexing, too, in how inconsistent is its capacity to generate the happiness on which its claim to our attention is founded" (de Botton, 2006, p. 17). If reliable forecasting of the consequences for users of design decisions is not available, does something else replace it? What else is it that may provide confidence in the making of design decisions? Perhaps architecture works because it is impossible to predict its consequences accurately. Spaces that can contain one set of human activities will often, just by their size and shape, accommodate many others. The presumption by architects that design has clear causal or deterministic powers is not supported by evidence. Robust design requires the provision of spaces that can accommodate many activities and that are arranged so that the layout can accommodate many different organizational requirements over time. Developing tests for robustness as part of the evaluation of designs before they are built is thus an essential element of an architectural philosophy. Architectural design must address the activities of custodians and users. Important questions of classification are raised. Can "types" of activity be classified in terms that are objectively related to their space and environmental requirements and not to conventional common sense grouping? We are familiar with: Education, Health, Residential, Commercial, Industrial, and the like, but these broad groups may be much less useful than physical categories. A starting point for assessing the potentiality of a space to accommodate a range of activities is to classify or codify what is meant by an activity. It would be helpful to array first uses (and their constituent activities) against possible second uses to assess the direct physical compatibility. The claim arising from such analysis would take the form: "by designing in such a way (using the Double-Design approach) for first uses, automatic provision is made for some or all specified second and subsequent uses." The intention is to extend the possibilities for second uses by modifying the provision for first uses. Architects and many others will be familiar with anthropometric data that sets guidelines for basic space needs: table heights, door widths for wheelchairs and the like. However, it seems ironic that the most sophisticated classification of human activities has come from the need to mimic human activities to design robots. (Knoop et al., 2006). Human activities are often clustered together as "uses": housing, offices and the like. UK planning law identifies the following categories: Class A – shops (including some services), Class B – further business and industrial activities, Class C – hotels, hostels and dwelling houses, Class D – non-residential institutions, and *sui generis*. The International Building Code has Group A for assembly, Group B for business, Group E for education, Group F for factory and industrial, Group H for Hazardous, Group I for Institutional, Group M for mercantile, Group R for Residential, Group S for Storage and Group U for Utility and Miscellaneous (Thornburg & Henry, 2015). Part of the search for compatible spaces must decide whether it can break down a "use" into its constituent physical or geometrically defined activities. This could take the form of identifying the lowest common denominator for space-consuming activities rather than relying upon conventional groups of activities (Knoop et al., 2006; Sangelkar et al., 2012; US Bureau of Census, 2017). For Vacek et al., activities are classified by structure and by function. Figure 5.4 and 5.5 refer.

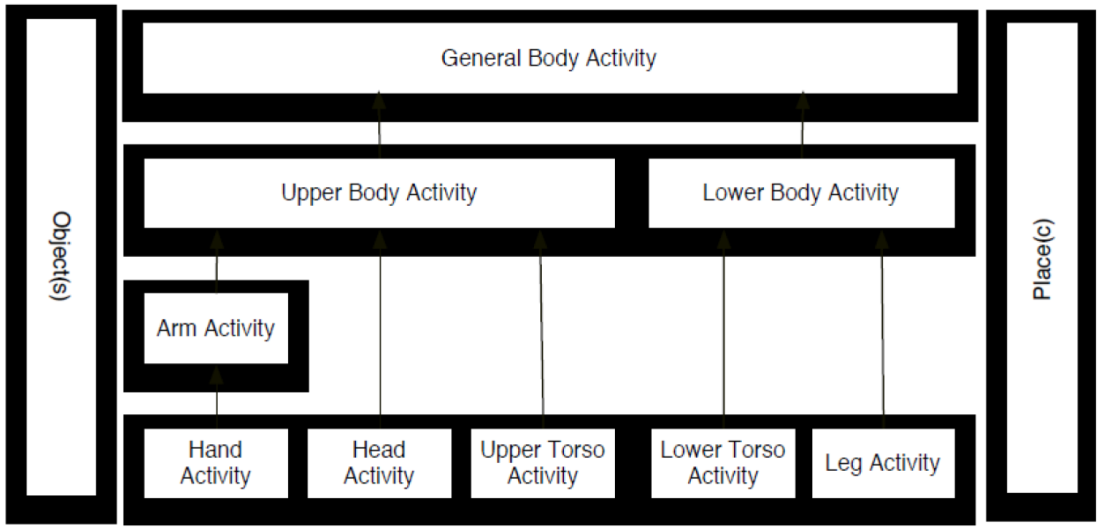


Figure 5.4 Overview of human activities classified by structure from (Vacek et al, 2005)

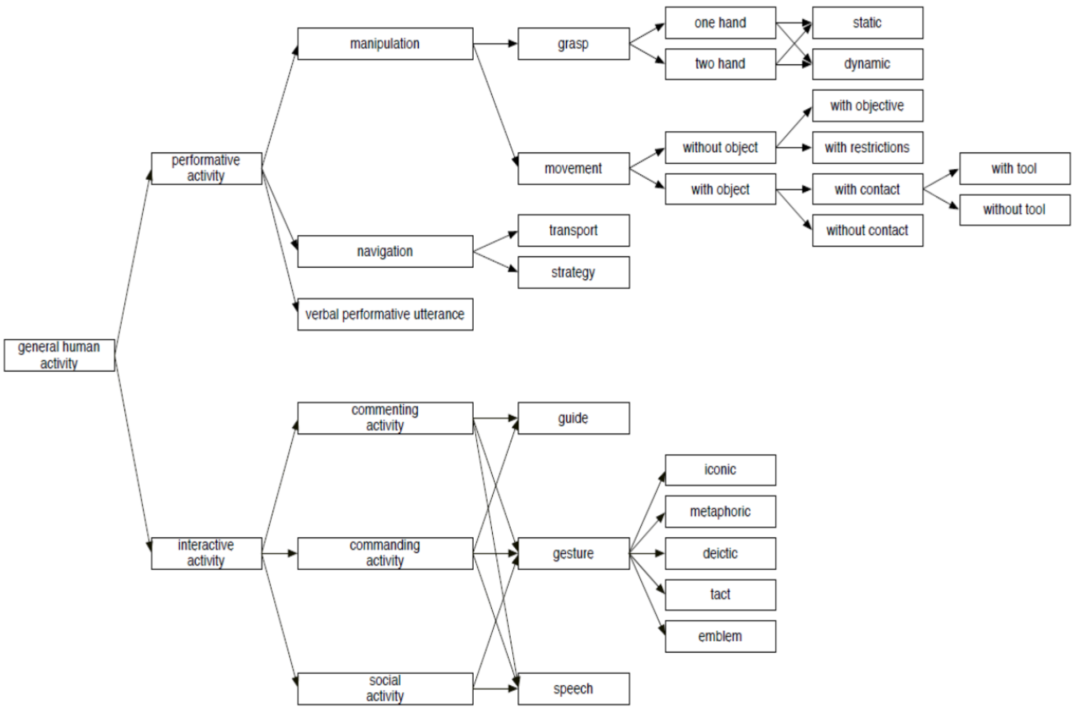


Figure 5.5 Overview of human activities classified by function from (Vacek et al., 2005)

In contrast to structural classification, the classification by function is guided by the purpose or aim of an activity. It remains to be seen whether the combination of these activity classifications can lead to a better understanding of the space needed to do things. There are many different "lists" of activities that have been developed for widely varying reasons. (*Standard and other national and international classifications*, 2015). To establish which activities may be accommodated in particular environments (the compatibility approach), it would be helpful to identify activities or units of activity in a way that will help in the communication and implementation process of Double-Design. While design advice concentrates upon the physical need for space for practical reasons, social and psychological aspects must also be accommodated. The classification of human activities has been a preoccupation of social scientists. Stinson cautiously proposed some changes in the accepted definitions and codes, as shown below in Figure 5.6 (Stinson, 1999, p. 22).

Proposed Classification System (Stinson, 1999,p22)		
Time Type	**Major Group (1 digit codes)**	**2 digit codes**
Necessary Time	1. Personal care activities	11 Sleeping
		12 Sleeplessness
		13 Personal hygiene and grooming
		14 Non-professional health care
		15 Eating / drinking
		16 Waiting related to personal care
		17 Communication about per.care
		18 Travel about personal care
		19 Personal care NEC
Contracted Time	2 Employment activities	21 Work for pay at main job
		22 Work for pay at other job(s)
		23 Primary production and services for income not for establishments
		24 Work breaks
		25 Job search and related activity
		26 Waiting /delays related to work or job search
		27 Communication about work or job search
		28 Travel/commuting to/from work or job search
		29 Employment activities NEC
	3. Education activities	31 Gen education: school/ university
		32 Job related training
		33 Homework/study/research
		36 Waiting related to education
		37 Communication about education
		38 Travel related to education
		39 Educational activities NEC
Committed Time	4. Domestic activities	41 Food/drink preparation/cleanup
		42 Laundry, care of textiles
		43 Other housework
		44 Grounds / animal care
		45 Home maintenance, construction, and repair
		46 Household management
		47 Communication rel. to dom. act.
		48 Travel related to domestic act.
		49 Domestic activity NEC

Figure 5.6 (part 1) Changes proposed in the accepted definitions and codes, (Stinson, 1999, p. 22)

	5. Care for "dependent" household members (children, sick/disabled or elderly)	51 Physical or emotional care of "dependent" household members
		52 Teaching/ helping/reprimanding "dependent" household members
		53 Playing, reading, talking with "dependent" household members
		54 Minding (supervising) dependent household members
		55 Visiting care related establishments / schools
		56 Waiting associated with care of "dependent" household members
		57 Communication associated with care of "dependent" hh members
		58 Travel associated with care of "dependent" household members
		59 Care of "dependent" household members NEC
	6. Purchasing activities	61 Purchasing or returning goods
		62 Purchasing services
		66 Waiting associated with purchases (5 minutes or more?)
		67 Communication associated with purchases
		68 Travel associated with purchases
		69 Purchasing goods or services NEC
	7. Voluntary work & care	72 Unpaid helping / doing favors (for households)
		73 Unpaid voluntary work (with org.)
		76 Waiting associated with voluntary work or care
		77 Communication associated with voluntary work or care
		78 Travel associated with voluntary work or care
		Voluntary work or care NEC
Free Time	8. Social & Community interaction	81 Socializing
		82 Entertainment
		83 Attendance at sports events
		84 Religious / ritual activities
		85 Community participation
		86 Waiting related to social & community interaction
		87 Communication related to social & community interaction
		88 Travel related to social & community interaction
		89 Social & community interaction NEC
	9. Recreation and leisure	91 Sport and outdoor activity
		92 Games, hobbies, arts, crafts
		93 Reading / writing
		94 Audio/visual media
		95 Attendance at courses (except school or university)
		96 Other free time
		97 Communication associated with free time
		98 Travel associated with free time
		99 Leisure and recreation NEC
	0. No activity	00 No activity

Figure 5.6 (part 2) Changes proposed in the accepted definitions and codes, (Stinson, 1999, p. 22)

Two fields of thought have contributed to the deeper understanding of human activity and they provide a framework within which the dynamics of design and change can be explored. These theories help to identify the complexity and richness of human activity. Hashim & Jones suggest that:

> Activity theory uses the whole work activity as the unit of analysis, where the activity is broken into the analytical components of *subject*, *tool* and *object*, where the *subject* is the person being studied, the *object* is the intended activity, and the *tool* is the mediating device by which the action is executed […] two additional units of analysis, which have an implicit effect on work activities. The first is *rules*, these are sets of conditions that help to determine how and why individuals may act, and are a result of social conditioning. The second is *division of labour*, this provides for the distribution of actions and operations among a community of workers. (Hashim & Jones, 2014, p. 5)

In the case of spatial requirements, the mediating artefact, the tool, can be regarded as the building, the physical environment. Just as the study of the tools, the artefacts, illuminates the nature of activities, so the nature of space can be seen to influence and constrain as well as to protect the activities of those for whom it is provided. Thus activity is not viewed as a simple individual action but as being culturally and historically located: "In other words, activity theory stems from its fundamental view of purposeful activity in a cultural historical context as the fundamental unit for the study of human behaviour. Activity Theory is an approach which underpins the complex and dynamic human problems of research and practices" (Hashim & Jones, 2014).

The functional origins of human activity are further emphasized by Leontiev:

> Separate concrete types of activity may differ among themselves according to various characteristics: according to their form, according to the methods of carrying them out, according to their emotional intensity, according to their time and space requirements, according to their physiological mechanisms, etc. The main thing that distinguishes one activity from another, however, is the difference of their objects. It is exactly the object of an activity that gives it a determined direction. […] Thus the concept of activity is necessarily connected with the concept of motive. Activity does not exist without a motive; 'non-motivated' activity is not activity without a motive but activity with a subjectively and objectively hidden motive. […] Their needs are satisfied not by these "intermediate" results but by a share of the product of their collective activity, obtained by each of them through forms of the relationships binding them one to another, which develop in the process of work, that is, social relationships. (Leontiev, 1977, p. 99)

It is possible to imagine an architecture that was obliged to respect and respond to the *intention of activities* rather than to the space they take up. The emphasis upon the efficacy of design rather than its shape and aesthetic would dramatically alter the relationship between designer and custodian. Moreover, it would contribute to the redefinition of professional responsibility. Instead of focusing upon the simple interaction of people with their environment, Hägerstrand and his followers provide a framework in which the intentionality of human activity is the starting point for a notation seeking to describe the subtlety and richness of individual and social activities in space and time. Successful performance of activities to achieve goals creates couplings in time and space between the involved persons on one hand, and these persons and the tools and other resources needed on the other. Then, the time-space location of people and resources is essential. When considering couplings in time and space, the individual's dependence on other individuals is underlined, which helps reveal what might hinder, or facilitate, the achievement of individual and organizational goals. The two seemingly simple dimensions of time and space help sort out things that otherwise might be perceived as entangled and not subject to a coherent logic (Ellegård, 2019, p. 4). The recognition that it is not individuals who should be the focus of design but their capacity for choice and interaction has profound implications for design. The contributory processes of movement, recognition, coupling and de-coupling require appropriate environments (Ellegård, 2019, p. 43). Hägerstrand introduced several related concepts (Shaw, 2010).

> The concept of path (or trajectory) was introduced in order to help us to appreciate the significance of continuity in the succession of situations. […] concept of project was introduced in order to help us to do two things. We need to rise up from the flat map with its static patterns and think in terms of a world on the move […] We need to have concepts which are able to relate events that happen to the strivings for purpose and meaning […] The word project then, […] was meant to tie together into a whole all those 'cuts' in evolving situations that an actor must secure in order to reach a goal. (Hägerstrand, 1982, p, 324)

Hägerstrand identifies three types of constraints: "*Capability constraints* are those which limit the activities of the individual because of his biological construction and/or the tools he can command"; *Coupling constraints* "define where, when, and for how long, the individual has to join other individuals, tools, and materials in order to produce, consume, and transact"; *Authority constraints* refer to "control areas" or "domains". A domain is a time-space entity within which things and events are under the control of a given individual or a given group. (Hägerstrand, 1970, pp. 12–16). It is essential to understand the relationship between human activities and the physical environments designed to accommodate them. Space, time, movement and human perception have been seen as critical aspects in the search for comprehensive theories. Sometimes the concern for the architect's position in this drama appears to inhibit the search. For example, Hillier and Leaman say that the:

> Man-environment paradigm lies in two mutually exclusive epistemological positions – that of the organism looking out into the environment, and that of the environment bearing in on the individual. It moves us from a problem definition in which a building is an object whose spatial form is a form of social ordering, into one in which the physical environment has no social content and society has no spatial content, the former being reduced to mere inert material, the latter to mere abstraction […] Intentions are a favourite theme in architectural discourse. Not only are they said to be the starting points for design, but also that which distinguishes architecture as an art from architecture as a science. Since science deals with how things are, not how they should be, architectural 'intentions' are said to be the responsibility of the individual designer, or the bodies who instruct (the design), and architectural science is asked to concern itself with the perfectibility of a process, a methodology for the realisation of pure intentions. (Hillier & Leaman, 1973, p. 8)

The variable way in which people spend time in different activities and in different countries confirms the need for a responsive built environment. Figure 5.7 shows how people use their time.

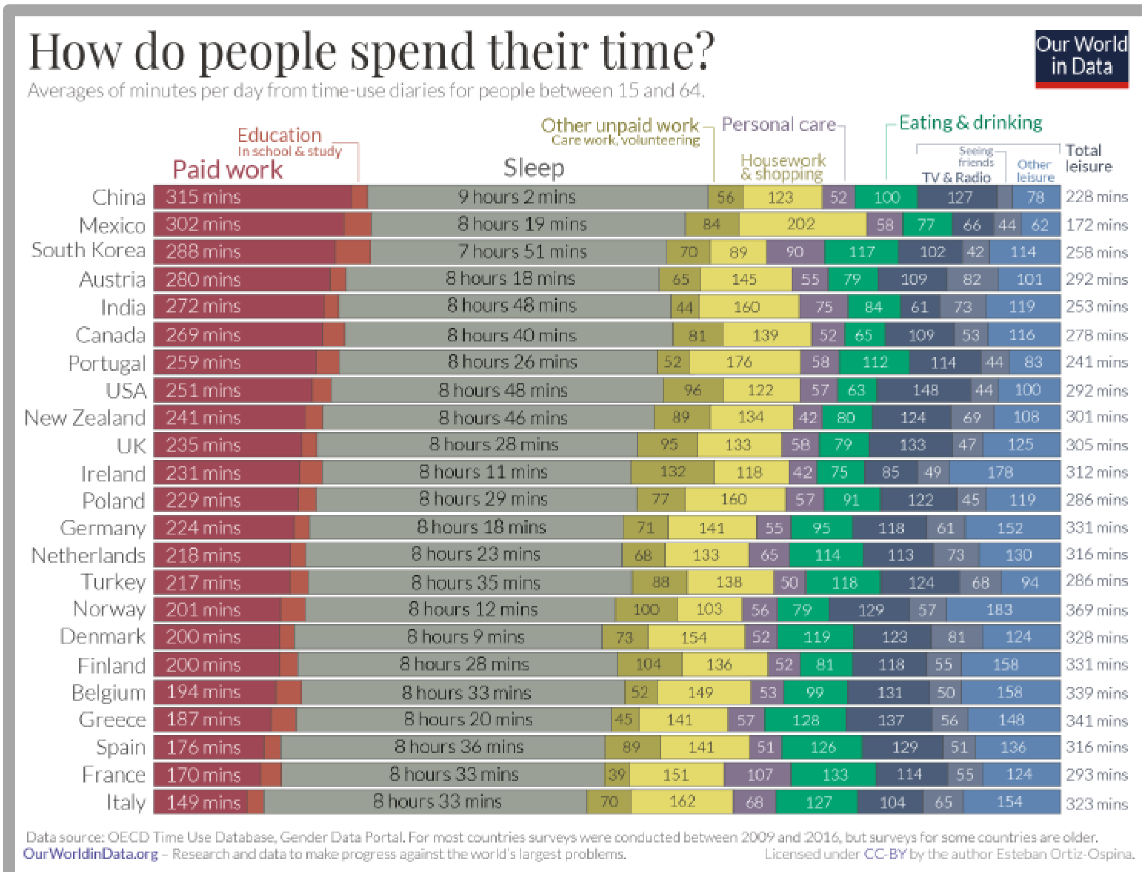


Figure 5.7 How people use their time (from: https://ourworldindata.org/time-use-living-conditions)

What is needed is a morphology of activity to complement the morphology of space. A single activity can be seen to generate a particular space in the over-simplified world of anthropometric guidance. That single activity has to be seen as the generator or the propagator of an unknown number of other related activities. It is, after all, the space needed by a cluster of contiguous activities that drives towards a particular shape of the enclosure. For example, a work-station in an office or a laboratory or a classroom does not generate the need for space. It is only the starting point (or volume) of a spatial continuum that must logically include the space needed to attend meetings, the cafeteria, the bathrooms, the access ways and the escape routes. These together make up a contiguous whole for each individual and, taking into account the overlap of space utilization, it is the aggregation of such volumes that ultimately requires enclosure and determines the spatial limits. The building briefing process requires the custodians and users with their design teams to anticipate all the extended contiguities of space that the stated starting positions may generate. Perhaps by focusing upon "all the activities that might be related to a given activity, over time", it will become possible to address Hägerstrand's concern for the quality as well as the quantity of interaction. Activity theory and time-geography are essential for architectural design because they suggest that the scope of design must encompass the complete spectrum of human activities and not just those easily identified. For example, conventional design guidance incorporates the amount of space typically required for specific activities – sleeping, typing, cooking and the like. Activity theory and time geography draw attention to the critical activities of movement and perception, without which activities would remain incomplete or, at best, a series of disconnected events. The common features of the two theories are;

- Time is seen as continuous. Actions are seen as intended. Intermediate tools are seen as instrumental in the pursuit of intended actions.
- Actions are undertaken within a framework of control and societal sanction. The morphology of built space starts with establishing how much space is needed to accommodate human activities and the equipment necessary to augment and complement those activities.

Figure 5.8 below shows the link between disaggregated human motions [1], individual recognizable activities [2], and the functional lists based upon Use Classes and standard industrial classification [3] and building types [4, 5].

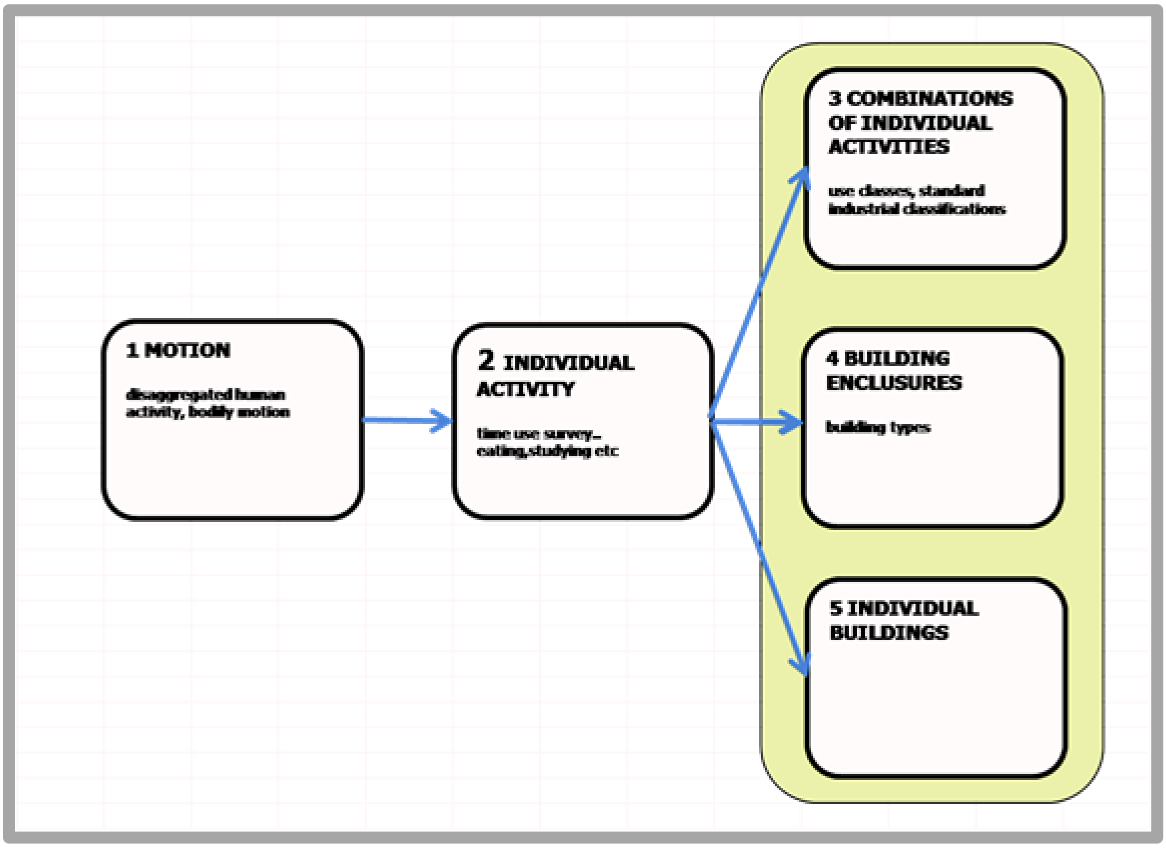


Figure 5.8 The link between disaggregated human motions [1], individual recognizable activities [2], and the functional lists based upon Use Classes and standard industrial classification [3] and building types [4,5].

The derivation of this morphology has its own narrative, as follows:

1 MOTION

There are disaggregated human activities like physical movements of the arms, legs and head. For example, health services use a simple chart to record the capacity of an individual to undertake movements of limbs (*Range of Joint Motion Evaluation Chart*, 2014). On the other hand, disaggregated equipment-based activities have been studied for purposes of robotic design. To improve human-machine interface (interaction) (Aggarwal & Ryoo, 2011) (Vacek et al., 2005.) (Bodker, 1987) (Yu & Shaw, 2008), Vacek et al. sought to develop an analysis of activities that would facilitate the development of robots able to understand and be understood by humans. They suggest that for designing the classification, some important issues have to be considered:

> The classification should not depend on any existing algorithm doing activity recognition, but it must also be possible to use this classification for the development of future recognition algorithms. It should be open ended in a way that new categories could be added in the future and also previously unconsidered activities should be categorised later on. It should have a clear structure for the ease of usage. It should be usable for different disciplines, like computer vision, dialogues or task learning. (Vacek et al., 2005, p. 3)

They consider two approaches to the classification of human activities. Firstly, there is an approach based upon the structure of the human body (how is the activity performed?), and the second is guided by the functional meaning of the activity (what is the aim of the activity?). The latter classification is elaborated to distinguish between performative and interactive activities. Research efforts continue to improve the reliability of activity recognition from video images (Kuehne et al., 2011).

2 INDIVIDUAL ACTIVITY

A range of purposeful activities can be listed that bring together components of motion to describe individual activities and individual combinations of human-equipment interaction. Design guidance that covers the spatial requirements of specific activities are included (Dreyfuss & Tilley, 2002) (Neufert & Jones, 1998) (Pheasant & Haslegrave, 2005) (*Ergonomics and Human Factors at Work A Brief Guide*, 2013). Other lists have been developed to satisfy the needs of research that records activities in time-use studies. Examples include sleeping, reading, cooking, working at a pc, etc. (European Commission & Statistical Office of the European Union, 2019)

3 COMBINATIONS OF INDIVIDUAL ACTIVITIES

Groups of purposeful individual activities are brought together to form socially purposeful and conventionally recognizable activities. The forces leading to the clustering of individual activities include political, social and economic. The resultant activities include those undertaken by families, companies, institutions and businesses. For example, the use class orders that form an essential part of UK planning legislation list activities (*The Town and Country Planning (Use Classes) Order 1987 UK Statutory Instruments 1987 No. 764*, 1987). The international building code used in the USA provides a comparable list (*International Building Code.*, 2006). Commercially oriented versions of these lists have also been prepared (*NAIOP Terms and Definitions: North American Office and Industrial Market*, 2012). In addition to these, there are economic activities for the UK (Prosser, 2008) and internationally (United Nations, 2008).

4 BUILDING ENCLOSURES

Enclosure types (building types) are generated by custodians acting on behalf of the interests of socially purposeful groups in a way sanctioned by society at large. Lists of building types reflect national and regional variation, climatic and economic factors. Lists of building types have been used in many design guidance documents (*WBDG Whole building Design Guide*, 2019) (Neufert & Jones, 1998). Historians have also used lists, including Pevsner (Pevsner, 1976). For Pevsner, the functional story behind his history is one of the diversification of building types driven by rapid urbanization in the nineteenth century. Double-Design would have the effect of reversing this trend towards specialization and, over time, producing more generalized spaces.

5 INDIVIDUAL BUILDINGS

Individual buildings are subject to physical and functional interventions involving custodians and users. Of particular interest is the increasing evidence that buildings are accommodating multiple uses: there is an implication here that Double-Design is already partially at work. Figure 5.9 summarizes the main characteristics of common activity lists.

ACTIVITY LIST	CHARACTERISTICS					NOTES
	disaggregated motions only	individual activities	aggregated activities with function	aggregated activities with economic purpose	comprehensive activities	
MOTION	■					basic lists of human bodily motion are contained or included within all oher lists
TIME/USE ACTIVITIES		■				while essential in undertaking survey work, time use analysis does not help when establishing space requirements
USE CLASSES			■		■	The use classes are familiar within the UK planning system
UNIFORM BUILDING CODE			■		■	based upon broad occupancy groups with sub-groups
SIC [UK]				■		relevance limited to economic activity
SIC [UN]				■		relevance limited to economic activity
WBDG space/building type			■			lists of the space types and building types are incomplete
NEUFERT			■		■	the listing is derived from this standard reference work
PEVSNER						The historical work inevitably focuses upon significant non-housing building types
WIKIPAEDIA			■		■	A common-sense listing based upon broad categories of function

Figure 5.9 Summarizes the main characteristics of common activity lists

The physical spaces covered by the above lists provide a neutral backdrop to human activity, the understanding of which must be fundamental to any attempt to improve the longevity of building use. In moving forward to set up the compatibility matrix, the choice of activity list must be determined by the likely audience for implementation. This suggests that the UK Use-Classes should be the starting point for reviewing the prospects for and extent of compatibility. For example, suppose compatibility between an initial use and a future use is to be achieved. In that case, the physical characteristics of the initial environment will need to be enhanced, and the mechanism for achieving this could be through planning laws and building regulations. The latter are not aligned with the Use Classes but are related to specific areas of risk. This means that at least two independent sets of documents must be referred to in the implementation of Double-Design; the Use-Classes and the building regulations. The long term effects of increased compatibility between uses could lead to and require a comprehensive reappraisal of the categories by which planning control is exercised in the UK. Changing social, political and economic circumstances give rise to constantly evolving requirements for space. There will be many cases in which a combination of activities will form the brief for a project. As a result, there are fewer single-function buildings. This could be supported by the end of the single-function space/room. The end of the single function space should perhaps be recognized within a new framework for the city in which cosmopolitan activities are more readily accommodated (Weber, Max, 1969). Melvin Webber examined how geographic propinquity no longer limited human activities and connectivity between groups with shared interests (Webber, 1964). Cultural public buildings have become extensions of public space. However, many of these transformations demonstrate compatibility in terms of spatial requirements between the initial and later uses. The effect of not having a complete set of user requirements at the beginning of a project has traditionally felt uncomfortable for the professionals involved. However, this particular situation requires a creative understanding of flexibility and adaptability that can only be beneficial in the context of Double-Design. Figure 5.10 illustrates a project for which uncertainty had to be overcome.

Figure 5.10 BRIT School in Croydon: the curriculum was being worked out while the project was being built, Cassidy Taggart Partnership, Architects

Shopping facilities invade airports and hospital entrances. Gift shops turn up in cathedrals. Homes become offices and playgrounds. Offices become homes. Automatic dispensing machines are to be found everywhere, reducing the width of planned escape routes. Jukeboxes and one-armed bandits are to be found in pubs and restaurants. Smart industrial sheds change from factory to office to salesroom. Train stations are transformed from single-function places to multiple-function emporia with shopping, sales displays and market stalls infiltrating the hallowed clarity of Victorian engineering. Benedikt sees this shift in requirements as part of broader and more far-reaching societal change:

> The focus of more and more of our creativity, then, is not things, really, nor services as 'parcels' of useful labour, but information fields, treated as private property, in which memorable and entertaining experiences can be had. Restaurants compete in atmosphere and service, with the food becoming more like art on a plate, and waiters more like actors. Climate-controlled shopping streets become 'Roman marketplaces'; gigantic suburban bookstores imitate old-time intimate ones with living room furniture, readings, and espresso bars; movie houses become movie 'palaces' again (but, much more economically, set off of freeways), and so it goes. At children's hospitals, patients become explorers, 'embarking on a journey to recovery,' while new housing developments imitate historic or imagined small-town life (if at quadruple the density). In short, every place, every product, every service and event in the experience economy becomes themed, as though it were part of an endless carnival. (Benedikt, Michael, 2001, pp. 1–2)

While this account offered by Benedikt may be exaggerated, it is undoubtedly the case that the imageability of spaces is subject to intense promotion by those wishing to gain from the commodification of the new and novel.

5.1.4 Notation

In his pioneering work in developing a notation to classify the perceived space-defining elements encountered in primarily public spaces, Thiel focused upon the physical characteristics and the time an observer was exposed to them. Although he sought to understand the meaning of spaces under the acknowledged influence of Kepes, he did not address the activities being undertaken at the time of observation. As Thiel suggests:

> The spaces, surfaces, objects, events and their meanings which are associated in such varied combinations to constitute our natural and man-made landscapes cannot be seen simultaneously, but must be experienced in some temporal sequence. From one space we move to another, and then on to the next: subway car, station platform, escalator shaft, station lobby, square, bus shelter, bus, avenue, street, building lobby, elevator, corridor, ante-room, office. […] This discursive or sequential quality of our visual experience has been recognized, to

> varying degrees, in all periods of history; and has served as a determinate for some notable architectural and urban works. (Thiel, 1961, p. 33)

Thiel proposed a system of graphic notation for the continuous representation of architectural and urban-sequence experiences. In their later development of similar ideas, Hillier and Leaman recognize some of the internal factors affecting experience: "With regard to the observer, they may be grouped into the two categories of the external and the internal. The former includes the path chosen, and the direction and rate of travel along it; and the field of vision as well as its possible restrictions. The internal conditioners are the observer's age, preoccupations, culture (or value system), and familiarity or previous experience with the space" (Hillier & Leaman, 1973, p. 2). The purpose of the activity, the reason behind the movement, does not feature in this analysis of space perception. The lack of consideration for the activity that underlies the movement is carried forward into the approaches of space syntax, which focuses upon physical movement and connectivity in describing the characteristics of different building configurations rather than upon the differences in activities that determine appropriate or inappropriate patterns of movement and connection (Dursun, 2007). As Bafna says:

> Socio-cultural factors, in space syntax theory, are like the injunction against handling the ball in football; they are constraints that determine the very nature of buildings and without them the buildings would cease to exist as particular types. Constraints from physical factors, […] on the other hand, would only modify the form, or restrict possible variations of it. It follows that whatever else may lead, in practice, to modify or even form particular patterns of access in a working building, the patterns of access cannot themselves be so distorted as to go against the basic sociological functioning of the building. (Bafna, 2003, p. 1)

Hillier and Leaman introduce the ideas behind space syntax: "The notion of function as a creator of form, in a suitable environment led to a new understanding of the importance of time, resulting eventually in the vast new perspective of evolution theory. Architecture, in spite of its predilection for organic analogies, has not passed through a parallel emancipation" (Hillier & Leaman, 1973, p. 2). According to several space syntax slide shows presenting an overview of the subject, space syntax is aimed at simulating the likely effects of designs on the people who occupy and move around them (Sailer, 2017). The difficulty architects have in saying whether their designs will "work" is an important input to the discussion and not quickly resolved. As Hillier suggests:

> There is a widespread belief that architecture can cause social malaise, either by directly bringing about anti-social behaviour, or by inducing stress and depression in individuals, or by creating vulnerability to crime. Little is known about these effects. We cannot even be sure if any of them genuinely exist. The long-term and large-scale studies that would be necessary to settle the questions have not been done. From a research point of view, there are good grounds for scepticism, at least on the basis of current evidence. There is a problem of method in establishing any kind of link between architecture and social outcomes, which studies have not usually convincingly broached. (Hillier, 2007, p. 138)

Hillier & Leaman suggest:

> That buildings are 'functional' and 'meaningful' is self-evident, but it is equally self-evident through the morphogenetic analysis; that 'function' and 'meaning' exist and are intelligible by the evolution of a morphology of built forms. This requires us to make a further fundamental distinction in the study of artificial systems, which is familiar in linguistics but not in sociology or architecture. This is the distinction between the morphology itself, as it exists at any point in time, and the individual or corporate appropriation and use of that morphology. A conceptual difficulty arises with architecture because the morphology of forms exhibits what we might call 'negative redundancy' in relation to function: that is, nearly everything functions in more than one sense…But this duality is not strange. In fact it is normal. All systems by which mankind changes its relation to nature, are also elaborated into systems of social signification. (Hillier & Leaman, 1973, p. 9)

This observation reinforces the significance of Hägerstrand's view of activities, referred to earlier, and the conceptual difficulty of addressing their implications for design. There can be little doubt that space syntax has a place in evaluating alternative architectural plans at the stage at which alternative designs are being reviewed. Future organizational options are being identified to ensure that the chosen design can accommodate the anticipated options. Yet, if flexibility and adaptability are firmly embedded in the design anyway, the scope of the evaluation process is limited by the very flexibility built in. It is the fit-out, the variability of internal layouts that may benefit from the kind of building analysis undertaken by, for example, Marcus (Marcus,

1993) and Hanson (Hanson, 1999, pp. 109–134). The latter, in particular, seems determined to be helpful to designers in their full appreciation of how people behave in houses:

> Real houses are a complex expression of the social and individual worlds of their occupants, in which social structure and convention seems inextricably bound up with the idiosyncratic, whimsical, arbitrary or even chaotic circumstances of people's everyday lives. That this is so nearly always poses problems in understanding and interpreting the hidden order in houses and homes, for all too often what is different about a set of houses seems to be as important in expressing significant aspects of everyday life as what they have in common. Increasingly, analysis will seek to pinpoint the typical ways in which different room functions and domestic activities are configured in people's homes, the importance of furniture and object arrays in providing the scenery and props for social encounter and interaction, how domestic space and its fixtures and fittings relate to explicit and tacit household practices, inter-personal behaviours, domestic habits and routines, the postures and gestures which people make in haptic space and even the language and concepts which people use when talking about what their homes mean to them. Increasingly, a configurational approach will reach out to related disciplines such as sociology, anthropology and psychology in addressing the social and personal interpretation of domestic space. (Hanson, 1999, p. 276)

Hanson's profound intellectual modesty illustrated especially in her approach to housing is refreshing in developing new approaches to design. Ratti has voiced concerns about the scope of space syntax: However, despite the growing (and glowing) success of space syntax and the fascinating questions on the use of space that it has raised, some of its findings remain controversial in the academic community. The discussion focuses mostly on the support used for simulations:

> A simplified representation of urban texture in just two dimensions, which does not take into account the dimensional property of streets (later referred to as `metric') but only the way they connect to each other. How is it possible to tell so many things about the urban environment with such a limited amount of information that is, after having dismissed data such as the height of buildings and the size of streets? (Ratti, 2016, p. 2)

Nevertheless, the intention and importance of theory are undeniable: "by giving shape and form to our material world, architecture structures the system of space in which we live and move. In that it does so, it has a direct relation – rather than a merely symbolic one – to social life, since it provides the material preconditions for the patterns of movement, encounter and avoidance which are the material realisation –

as well as sometimes the generator – of social relations" (Hillier and Hanson, 1984, p. ix). The personal and academic interactions between the development of space syntax and the advances in the morphological understanding of architecture have been described by Gil and Coelho (Gil & Coelho, 2017). Suffice it to mention here that, however inconvenient for theoreticians, it is the functional and social needs and activities of individuals, groups and organizations, that determine an *appropriate* morphology. Thus, the shape of spaces and buildings generated by human needs must be examined to identify opportunities for compatibility. Working differently, Alexander et al. conflate activities into events that lie at the heart of the perceived patterns that make up the environment, accepting that: "we do not have a picture of a building or a town which shows us how it's obvious outward structure – the way it looks, its physical geometry – is interlocked with these events" (Alexander, 1979, p. 81). He goes on to describe what he calls the timeless way of building:

> As a process through which the order of a building or a town grows out directly from the inner nature of the people, and the animals, and plants, and matter which are in it. It is a process which allows the life inside a person, or a family, or a town, to flourish, openly, in freedom, so vividly that it gives birth, of its own accord, to the natural order which is needed to sustain this life. (Alexander, 1979, p. 7)

Despite the manifestly humanitarian basis for Alexander's patterns (Alexander et al., 1977, p. x), the precision with which an activity or group of activities must be matched with a very particular spatial solution must be seen as delimiting the freedom of human endeavour that the deployment of the approach seeks to encourage. As Hillier and Hanson note: "Alexander's notion of a pattern is too bound to the contingent properties of configurations to be useful for us. […] his preoccupations with hierarchical forms of spatial arrangement […] would hinder the formation of non-hierarchical, abstract notions of spatial relations which, in our view, are essential to giving a proper account of spatial organization" (Hillier & Hanson,1984, p. xi). Dawes and Ostwald have provided a thorough review of the reception and use of the pattern language: "many perceived problems with Alexander's theory are directly or indirectly connected to high level conceptual issues. The thematic grouping of these issues indicates that Alexander's theory [...] embraces an ontology that confuses objective and subjective phenomena, rejects pluralistic values and alternate experiences, ignores political and social realities, and accepts only one 'right' way of building" (Dawes & Ostwald, 2017, p. 12). However, if the patterns are regarded as examples rather than as mandatory templates, the humanity would be allowed to flourish. As long ago as 1961, Cowan and Watson were focusing upon the ingredient so singularly missing from the approaches described above:

> Buildings begin with people. Architecture should not be a formal or production-derived solution imposed upon the users, but a growing together of human needs and the industrial equation. Somewhere a synthesis occurs; at this point stands someone – call him architect or what you will – reconciling not leading – creating not directing – not an amateur of other disciplines, but a profession in this task. As our knowledge of human physiological requirements deepens, creative design becomes easier. The multi-disciplinary team is the organisation, research is the tool, and science the discipline which will push our vocation forward in the second half of this century. Buildings end with people. (Cowan & Watson, 1961, p. 744)

Yet, the last fifty years of architectural research have neither offered a comprehensive theory nor led to better architecture. What are missing are the people, the activities themselves. As Wacquant points out, in his review of books about urban policy:

> But moral munificence is no guarantee for rigorous social analysis, and even less so a substitute for it. And the task of social science, ethnography included, is not to exonerate the character of dishonoured social figures and dispossessed groups by "documenting" their everyday world in an effort to attract sympathy for their plight. It is to dissect the social mechanisms and meanings that govern their practices, ground their morality (if such be the question), and explain their strategies and trajectories, as one would do for any social category, high or low, noble or ignoble (Wacquant, 2002, p. 1470).

The users of buildings, like the minorities 'dishonoured' by social analysis mentioned above, have to have a voice in the design process. We see an emerging consensus that time is a critical component in understanding architectural space. We see a notation, Thiel (1961), that tracks movement and perception over time. We see an analytic method, space syntax, that enables an understanding of movement and spatial transition and allows comparisons between different design options regarding movement and organizational structure. We see mathematical analysis of enclosed space in the morphology of March and Steadman. Nevertheless, despite the occurrence of 'real-world' conditions in the descriptive notation, the relations with use, with human activities, remain remote and theoretical. Steadman suggests that: "geometry can indicate performance independent of human occupancy" (Steadman, 2014, p. 30). But despite this confident assertion, there is much to be done if the fourth dimension, that of time, critical to understanding the actual performance of space, is to be integrated into the analytical vocabulary. As Steadman and others noted, computers were not initially used to generate designs but to support the design process by searching for optimal solutions based upon selected criteria. Approaches to the design of hospitals to minimize nurses walking time, for example, (Whitehead & Eldars, 1965), gave rise to several problems: There were questionable assumptions made about trips and the 'value' thereof. Deep spaces were inevitable. The over-reliance upon a single criterion was recognized as an oversimplification. Steadman suggests that these kinds of limitations led to the development of the 'archetype building' that embodies, or contains within it, multiple building solutions. In seeking to review the assumptions made by Steadman and by Steadman and March regarding the efficiency of certain types of building form in the urban context, Ratti et al. raise important questions about the dangers of oversimplification in the choice of parameters. They introduce their case study: "moreover, when a large number of environmental variables is taken into account, it is likely that conflicts amongst them will emerge and so terms such as 'best' and 'optimum' embody value judgements that resolve conflicts. Despite this, predominant urban types are associated with certain climate types, such as the courtyard type and the hot-arid climate" (Ratti et al., 2003, p. 54). Any perspective on architectural space that does not incorporate the use to which space is put is undoubtedly bound to fail. As Gudkova and Gudkov point out:

> Morphological representations meant that architectural space is formed not only by fixed structural masses, spatial fencing structures, but also by dynamic processes of human activity, that are developing in them and between them. At the same time, the internal architectural space is a void between constructive masses protecting it from the outside. And it can be interpreted as an analog of "emptiness" in two different conceptual ways – as a static space formed with the help of constructive masses that cover it from the outside and as a dynamic space of human movement and activity taking place inside. The latter became very significant for modern architects. (Gudkova & Gudkov, 2017, p. 2)

They conclude their assessment of the spatial mission of modern architecture:

> A common modernist concept of space, masters of architecture embodied it in different ways. So the space-time concept of Le Corbusier was based on movement and tempo-rhythmics of the architectural space "from inside to outside." The concept of integral space of Frank Lloyd Wright is that inner and outer spaces are parts of the same whole. The concept of universal space of Mies van der Rohe summarized the whole process. The master managed to realize the idea of a minimum maximized – he "dissolved" the inner in the outer and made the whole space unified. These concepts have allowed to gradually form the common features inherent to the architecture of modernism. (Gudkova & Gudkov, 2017, p. 6)

Double-Design can be seen as a logical extension of the simplified spatial concepts referred to above as the spatial mission of modern architecture.

5.2 PLANNING AND DESIGN

5.2.1 New Design Method

In 1963, the author taught a course for architecture students with George Coulouris, a physicist (and son of the famous British actor[40]). He believed it was possible to teach architects to write computer programmes (using ALGOL) to perform tasks of

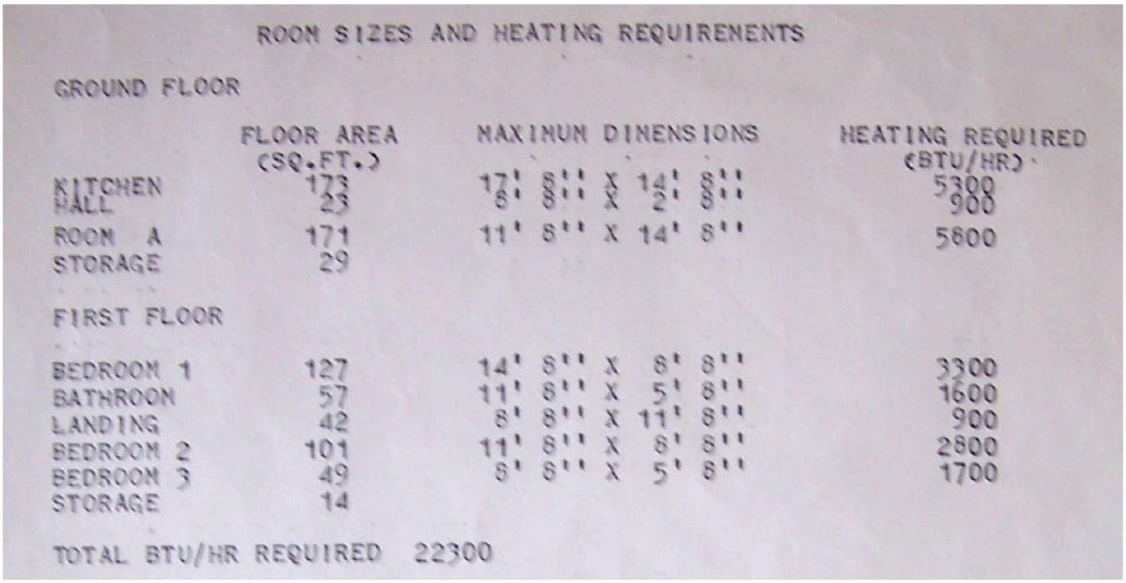
[40] George Coulouris, most famous for his role in Citizen Kane.

architectural relevance. The task set was to optimize the arrangement of cells in a three-dimensional lattice taking into account various "costs" reflecting, for example, unused edges of circulation space and desired clustering of like cells. The results had a profound effect on my subsequent thinking about the nature of design. There was an infinite number of solutions. With the computer fire-power available at the time (Atlas, the best in England, occupied four adjoining houses in a nearby Georgian Square, see Figure 5.11[41]), it was impossible to find a single optimum solution. The author interpreted this to mean that, to make practical decisions related to design alternatives, designers needed to suggest sensible solutions that were "likely" to work and to test these. It turned out that this "satisficing" approach already had an important place in decision theory (Simon, 1947).

[41] Atlas was delivered in 1963: The computer was delivered a month before it was paid for. Shell ran a program on it which optimized their shipping and decided to implement the output for a month. The author was told that one quarter of one per cent was shaved off the shipping bill and that was enough to pay for the whole computer. The lorry driver delivering the computer to Gordon Square fainted when told the value of his load!

Figure 5.11 Four Georgian houses in Gordon Square, London, were converted to accommodate Atlas: another example of reuse.

Later applications of computers for design and construction incorporated the idea of testing designs. For example, in 1963, the nationalized steel company in the UK, Richard Thomas and Baldwin, began developing a prefabricated steel house (IBIS) to seek a share of the housing market in the UK. Their approach to the design and marketing of their building system was innovative. Architecture traditionally had been seriously tested only when finished. Figure 5.12 illustrates a sample of the computer printout from the testing process.



ROOM SIZES AND HEATING REQUIREMENTS

GROUND FLOOR

	FLOOR AREA (SQ.FT.)	MAXIMUM DIMENSIONS	HEATING REQUIRED (BTU/HR)
KITCHEN	173	17' 8'' X 14' 8''	5300
HALL	23	8' 8'' X 2' 8''	900
ROOM A	171	11' 8'' X 14' 8''	5600
STORAGE	29		
FIRST FLOOR			
BEDROOM 1	127	14' 8'' X 8' 8''	3300
BATHROOM	57	11' 8'' X 5' 8''	1600
LANDING	42	8' 8'' X 11' 8''	900
BEDROOM 2	101	11' 8'' X 8' 8''	2800
BEDROOM 3	49	8' 8'' X 5' 8''	1700
STORAGE	14		

TOTAL BTU/HR REQUIRED 22300

Figure 5.12 Testing designs: Each of the IBIS plans was tested with respect to: The ratio of the external wall to the floor area; Structural integrity; Space adequacy; Sound insulation; Heat-loss through the fabric; Lighting adequacy; Compliance with regulations; Cost: Example of printout

The publicity associated with IBIS stated: "the computer can be of considerable help to the architect. […] contributions to all phases of design will become possible. The computer will not only relieve the architect of essential but laborious tasks it will undertake analyses in depth and in quantity, at a speed and with a degree of accuracy that can hardly be envisaged at the present time" (Fair et al., 1966). The application of computers in architectural design has progressed from IBIS through the Oxford Method of hospital design (with whole-building modelling) (Richens & Hoskins, 2013) and to BIM. Developing integrated design and testing processes has been a recent phenomenon. Until recently, architects could be sustained in their design methodology by the theoretical underpinning of Karl Popper (Popper, 2002), who showed that scientific advancement was achieved through the generation and testing (or falsification) of hypotheses. In the same way, the architect generates alternative solutions and tests them, using more or less sophisticated evaluation criteria.[42] The integration of design generation with instant evaluation was a fond dream. In Popper's view, the advance of scientific knowledge is an *evolutionary* process characterised by his formula: **PS1----TT1----EE1----PS2.** In response to a given problem situation (PS1), a number of competing conjectures, or tentative theories (TT1), are systematically subjected to the most rigorous attempts at falsification possible. This process, error elimination (EE1), performs a similar function for science that natural selection performs for biological evolution. Theories that better survive the process of refutation are not more true, but rather, more "fit" – in other words, more applicable to the problem situation at hand (PS1). For Popper, it is in the interplay between the tentative theories (conjectures) and error elimination (refutation) that scientific knowledge advances toward greater and greater problems; in a process very much akin to the interplay between genetic variation and natural selection (Popper, 1968)

To implement Double-Design, it is necessary to achieve a significant shift in the information environment within which architectural decisions are made. As a result, the scope of the GIVEN information, primarily covering the spatial and material aspects of robustness and longevity, will increase significantly, affecting many of the critical decisions in the new design process. Architects cannot offer any degree of certainty as to the outcome of their design decisions, either to their direct custodians or to society at large. The management of the consequent uncertainty after the building is designed

[42] The author worked for many years in Kuwait, a country whose law required the development of at least six distinct architectural options at the design stage of public projects. This was both demanding and rewarding, despite on occasion failing to give rise to the best solution!

and in use must undoubtedly be located within the domain of the building use. It is the responsibility of custodians and users to understand and respond to their changing needs and the responsibility of architects to provide the appropriate tools with which to secure a robust future. These are essential elements in the ability of custodians and users to maintain the usefulness of buildings for as long as they will last physically. Although the interaction between users and their environment cannot always be predicted, it is clear that the provision of flexibility within a structural system that does not get in the way of rearrangement should be taken for granted in design. The distinction proposed by Groak between adaptability (capable of different social uses) and flexibility (capable of other physical arrangements) is helpful. Both play a part in helping to enable buildings to last longer in productive use (Groak, 1992, p. 5). Allowing for and encouraging intervention and participation by the people who will use the building is intrinsically a good idea. There is the kind of flexibility that enables designers to generate many configurations of design using the same elements. Architects have been intrigued by notions of flexibility, and these have, on occasion, started from simple geometrical premises and developed with repetitive technological solutions. Often, however, the idea of flexibility for the users in the occupation of their space has not been a dominant factor. Instead, a kit of parts has been devised from which a variety of solutions can be assembled. This produces flexibility for the designer but not necessarily for the custodian or user. Thus the flexibility is of particular value to the original designers in choosing the starting configuration of the space and to the benefit of builders through the economies of scale arising from repetitive building elements. The starting point of Finnish wooden house-building systems in the 1960s:

> was to divide the building into parts that were as small as possible, thus each part was specialized for a particular building task. These components could be assembled, like Meccano or Lego, into an infinite number of different configurations. The ideology included, of course, the potential to later dismantle or extend the building. It was […] a structural issue, which perhaps only momentarily had congealed in the form seen" (Heikkinen and MacKeith, 2004, p. 54).

Research groups are considering the environmental benefits arising from extending the life of buildings. Conejos and Langston focus on developing an adaptive reuse rating tool targeted to the new design (Conejos et al., 2014). Langston sought a measure of good architecture in terms of durability, adaptability and sustainability and derived a combined rating. He argues that: "good architecture cannot divorce itself from the financial implications of acquisition and maintenance else it will be rendered ineffective in the practical realm" (Langston, 2014, p. 164). Therefore, he seeks to use LCC as a suitable predictor of good architecture. He regards durability, adaptability and sustainability as equally important and capable of objective measurement. The construction of a physical life calculator for the durability of an existing building takes the form of assessment for three main factors: environmental context, occupational profile and structural integrity. This approach does not make the critical distinction between the physical characteristics of a building that determine durability, on the one hand, and the extent to which the building stays useful. On the other hand, adaptability is considered from the point of view of obsolescence-avoidance. Categories of obsolescence include; physical, economic, functional, technological, social, legal and political. The significance of these in contributing to adaptive reuse potential was assessed through expert interviews. The seven obsolescence categories were found in this work to have equal weight. Sustainability is assessed using the Australian green building council rating system (Green Star), considering eight environmental impact categories. Although the principles upon which the work of Langston and his colleagues is based are consistent with those set out in this thesis, the objectivity of the scoring system is undermined by heavy reliance upon expert opinion. This would make it difficult for universal adoption of these approaches to be accepted. Furthermore, the practical guidance that might be expected from the research effort has not materialized. Russell and Moffatt noted that, in addition to adaptability, two further design strategies could help to achieve long-term environmental performance:

> *Durability*: selecting materials, assemblies and systems that require less maintenance, repair and replacement. Since durability extends the useful lifetime of materials and technology in a building, it is complimentary to adaptability. *Design for Disassembly*: making it easier to take products and assemblies apart so that their constituent elements can more easily be reused or recycled. Designing for disassembly can reduce the costs and environmental impact associated with adapting buildings to new uses. (Moffatt & Russell, 2001, p. 2)

They also point out that designing for a shorter life can reduce costs; providing design allows for the reuse of all materials and components. In building up a specification for new approaches to architectural design, articulating critical criteria becomes essential. Geraedts describes an approach to the assessment of flexibility in seeking a methodology for matching supply and demand for existing as well as new buildings:

> Thus, Flexis forms a means of communication on both the supply and the demand side of the building market. Flexis distinguishes four aspects of the flexibility of installations in buildings: partitionability, adaptability, extendibility and multifunctionality. *Partitionability* is the possibility of splitting up, rearranging or combining installation systems into different spatial units in a simple way. The *adaptability* of an installation is the possibility of altering installation systems in a simple way to meet changes in the user's demands (the installation function required). *Extendibility* is the possibility of adapting installation systems in a simple way to additional user demands, for instance by the addition of more or new installation components called for by structural or functional extensions, both inside and outside the existing building. *Multifunctionality* is the possibility of using or deploying installation systems or components for several functions. This allows of a more efficient use of space and permits clustering and concentration of installation components. This concept is sometimes also called integration. (Geraedts, 1998, p. 6)

Of particular interest in the context of this thesis, the concept of multifunctionality, illustrated in Figure 5.13, suggests a step towards Double-Design.

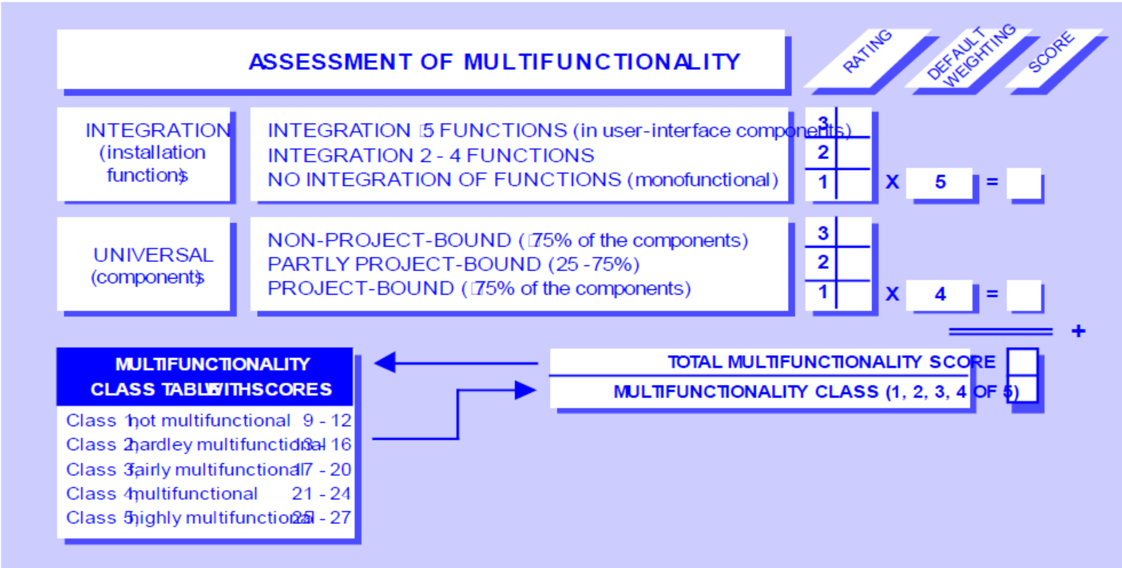


Figure 5.13 Criteria and weighting factors used in judging multifunctionality: from (Geraedts,1998, p. 10)

Geraedts concludes his description of Flexis: "a multifunctional installation or component can be used for several purposes. It permits a more efficient utilization of the available space and enlarges the ductless area through clustering and concentration. Another aspect that plays a role in the assessment of multifunctionality is the extent to which a system is universal" (Geraedts,1998, p. 10).

Studies by Tingley point the way towards the new design criteria that need to be incorporated into the design process: Construction 2025, a partnership between industry and government, has published four ambitions to transform the UK construction industry, one of which is a 50% reduction in emissions:

> Minimisation of operation carbon is already underway, driven by building regulations. But halving the emissions associated with the construction project itself – known as embodied or capital carbon emissions – requires a different approach. One sixth of the world's CO_2 emissions, or equivalently half of all industrial emissions, arise from producing steel and cement. Half of this steel and all of the cement is used in construction, but the industries that make these two key materials are the most energy efficient in the world. It is unlikely that there will be any significant break-through technologies for producing these materials, and because we use them in such great volumes (currently 200 kg of steel and 550 kg of cement per person per year for everyone alive on the planet) currently we have no substitutes. This means that halving capital carbon emissions to meet one of the ambitions of Construction 2025 – means halving the amount of new material purchased by the sector. Technically it is feasible to achieve this.

For example, by avoiding over-design, we could halve the structural mass in new multi-storey steel buildings – it is currently cheaper to use excess material if it allows a saving in labour, so we use more than necessary. We're also using commercial buildings for a fraction of their potential lifetime. Even at the end of life, we could re-use modules, components and materials directly, rather than dumping or recycling them. Using half the material for twice as long is a realistic ambition for the construction sector, and would significantly reduce its capital carbon emissions. This approach could also reduce delivery times – for example with offsite fabrication of components, or design for adaptability, upgrade and eventual deconstruction. And, with anticipated growth of construction worldwide in the next 10–30 years, the UK could become a global leader in the export of the systems, interfaces and design expertise to produce materially efficient construction. Capital carbon is significant, and the sector's Low Carbon Roadmap targets a 39% reduction by 2050, material efficiency will be required to meet this.... As we understand these costs better, we'll be able to identify where UK innovation could lead to lower cost, material efficient construction. This document presents a summary of evidence about three core strategies for reducing material demand in construction, and concludes with suggestions about how UK leadership in the area could grow" (Tingley, 2014)

The outlines of these three core strategies are aligned with the intentions of this thesis: Tingley continues:

1 Designing For Purpose Not Surplus
When building designs use only the materials required, in the right place and without excess, then demand for materials and energy is reduced. However, in a detailed study of 23 commercial buildings, we found that multi-storey steel structures could, on average, be built with half the amount of steel and still meet the Eurocodes. The increasing use of offsite fabrication also creates a wider opportunity to optimise composite floor panels, and reducing the material in the superstructure decreases the loads to the foundations, creating further opportunities for material savings. Designers can facilitate both on-site and off-site waste reduction, for example, by specifying that excavated material is used as fill elsewhere on the same site, and clients can support good practice through specification in the project brief.
2 Building Life Extension
Buildings in the UK could last for at least 100 years but are generally replaced decades before that: if instead we facilitated adaptability, and maintained the value of buildings for over 80 years, we could save long-term costs and emissions by significantly reducing material use.
3 Material Options
Most construction depends on four key structural materials: steel, reinforced concrete, timber and masonry. Material reuse allows the embodied carbon already expended to be valued over a longer time and avoids the need for new material production. Material reuse can occur either on an individual element level or on a component level. Steel is particularly suited for reuse due to its durability and robustness during deconstruction. New buildings could be designed for deconstruction to reduce future salvage times. There is a substantial overlap between deconstruction strategies and those required to facilitate adaptability. Deconstruction tactics focus particularly on the reversibility of connections and the separation of building layers and individual components. Provision of a

> deconstruction plan and storing building information are also key elements for this strategy. (Tingley, 2014)).

IDEA+ is an integrated design environment for architecture. It requires the development of an architecture-oriented data structure and a prototype application. In the research project, the focus lies on transitions between different design phases and scale levels, and at the same time, integrating evaluation tools in the design environment. The IDEA+ project aims at: "developing an Integrated Design Environment for Architecture, allowing the modelling and testing of a design with access for all professionals"(Hendricx & Neuckermans, 2001b, p. 195). A gradually refined design representation takes a central position in this environment. At the appropriate time, additional software tools that are in tune with the precision of the design at that moment can be plugged in and use/complement the design data (Hendricx & Neuckermans, 2001, p. 73). Design modelling that simultaneously generates multiple design solutions and tests them is now available, and this approach could lead to a practical approach to Double-Design.[43] Bringing the design process development further up-to-date, Autodesk has applied for a patent from the US authorities for its "Generative Design for Architecture". The invention claimed is:

> A computer – implemented method for optimizing a set of design options for a structure, the method comprising: generating a first design option for the structure based on a plurality of design criteria, wherein the first design option delineates a first geometry for the structure; generating a first grid for the first geometry based on the first design option, wherein the first grid includes a first set of routes traversing the first geometry; generating a first metric based on the first grid quantifying at least one characteristic of the first design option that is

[43] Your idea of Double-Design seems highly appropriate for today's post-pandemic world where redundant office towers are being converted to housing or permitted design planning allows roof extensions and so on, not to mention the use of parametric models in computer design where such built-in flexibility could easily be incorporated into the programmes' software (Louis Hellman).

> associated with the first set of routes; generating a second design option based on the first design option and the first metric, wherein a second metric generated for the second design option exceeds the first metric, thereby indicating that the second design option meets more design criteria included in the plurality of design criteria than the first design option. (Nagy & Benjamin, 2018, p. 34).

This latter description sounds very much like the specification of a programme that would help towards multiple-function testing. Autodesk continues to pioneer the integration of design generation and simultaneous evaluation (Villaggi, 2017) (Kallioras & Lagaros, 2020). In addition, researchers elsewhere are contributing innovative approaches to the application (Khan & Awan, 2018). The further development of the software should facilitate Double-Design. The input would incorporate the physical performance characteristics of all the uses to be 'allowed for' in the initial design. Autodesk is already claiming successful applications on their website. (*Autodesk: Industry Experts on the Benefits of Generative Design*, 2020) The Autodesk REVIT blog introduces generative design as follows:

> What if you could explore more design alternatives in fewer steps? What if you could rank, filter, sort, and select based on parameters and constraints that you and your teams define? What if you could focus on the viable alternatives and filter out the noise? Now you can. With this new feature you can generate and explore more options directly in Revit – helping you back good design intuition with data, run more rigorous experiments, and satisfy clients and project teams through more informed decision-making. To explore results, the generative design capability offers scatter and point coordinate results managers, so you can adjust parameters with the simplicity of sliders or compare different clusters of results. Dial in on balance across all design factors, or optimize for a single factor, and bring to your team and client meetings the depth, breadth, and rigor of data well done (Smolker, 2020).

Software pioneers suggest that developing design technologies will address many opportunities for designing for multiple uses:

> Through the integration of new paradigms of material and structural analysis and simulation, business management, parametrically driven design analysis and automated generative computer design, construction projects will be more efficient and will take advantage of forms of innovation that are only possible through the use of these new media and tools. The syntaxes of architecture and construction will manifest a higher level of artificially conceived and functionally driven elements and systems that result from this enhanced process. (Riese, 2009, p. 197).

The sophistication of design technology suggested, however optimistically, by Riese and others, could surely be applied to Double-Design in the strategic service of society and not just used to improve the suboptimal efficiency of the construction industry.

5.2.2 Universal Space[44]

Approaches to the idea of universal space, in which the principal driver is the provision of space capable of accommodating many, if not an infinite number, of different activities, have tended to be either at a huge scale or the scale of the domestic dwelling. Reviewing the development of the understanding of universal space at a large scale, the UK practice of Wilkinson Eyre report as follows:

> Architects and astronauts share a preoccupation with the exploration of space, but for architects it is limited to the design of contained space. To envisage and design spaces is a fundamental part of our job and convention has made it easy for us by limiting the size and shape of rooms to what people can readily understand. Most buildings are made up of essentially rectangular spaces with modest headroom related to human proportions… The term supersheds can be applied to the buildings which enclose universal space and can be defined as 'buildings enclosing a large single volume of space with relatively long spans and without major subdivision'.. It is here, however, that the skills of architecture and engineering converge. Universal space implies a kind of 'loose-fit flexibility', which is not specific to a single user, and there are many examples of redundant industrial structures being transformed with considerable success for an entirely different use. Fewer people go to church regularly nowadays but perhaps other forms of building can provide this need for spiritually uplifting space. Perhaps it is now the turn of the huge regional shopping malls or the massive sports stadia – in which case let us all try to raise the quality of their architecture so that these buildings not only fulfil a practical function but also a spiritual need. (Wilkinson, 2001)

Figure 5.14 illustrates Mies van der Rohe's vision for universal space (Wilkinson,2001).

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[44] Having considered the development of universal space, it is necessary to note that the concept has been 'usurped' in current architectural language by the movement supporting the idea of universal *accessibility*. The way in which this transformation took place, its origins and motivations, must be a study for another time. Suffice it to say here that the validity of the movement, led as it was by Goldsmith and others in the UK, has never been in doubt (Goldsmith, 2000).

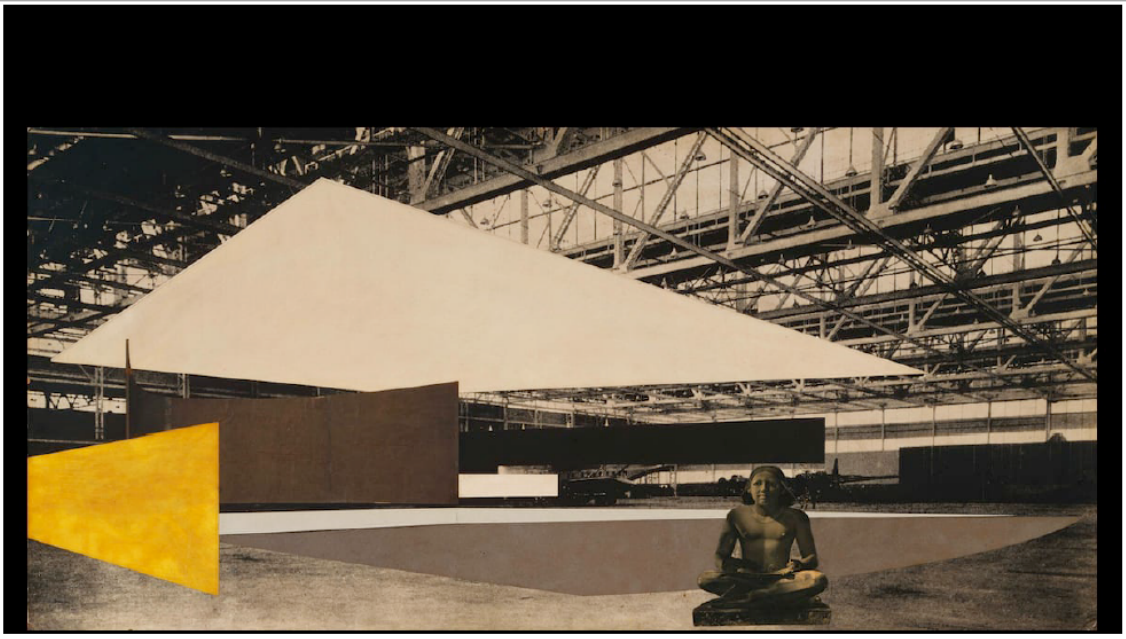


Figure 5.14 The term 'universal space' was first proposed by Mies van der Rohe to describe a kind of long-span single-volume flexible enclosure. In order to explain the concept, he used an interior photograph of the Glenn Martin Aircraft Assembly Building, designed by Albert Kahn in 1937, as a backdrop for a montage onto which he superimposed a number of free standing planes to represent walls and ceilings that could be moved to suit changing requirements. It's a wonderfully descriptive image with which to identify the kind of space that can house a wide variety of uses, ranging from industrial to transport, sports and leisure activities. Moreover, the big single-volume enclosure is the ultimate flexible space, which can be modelled or adapted to suit almost any user requirement.

With a more cautious and practical approach, again from a current practitioner, Allford argues:

> The essential urban building of the near future is flexible, memorable, and allows a mix of programmes to flourish. And it offers universal use! I think what has changed now is that people have realised that the longevity of the city is not brought about by endless clearing. It's about buildings that allow change to occur within them. If you look at the history of architecture, structures have been endlessly recycled. So our position is only a reversion to history. (Allford, 2016).

At the domestic end of the universal space spectrum, Yunitsyna observes:

> Universality in housing deals with possibility of dwelling to be adapted to the changing living activities without touching the inner structure of unit. In universal dwelling any space potentially should host all possible actions, therefore it is important to define primarily all range of them. Universality of dwelling means, that there are several spaces in living unit, which can be inhabited in different way. Universality of the whole is a combination of universalities of several or even just of one unit. According to Leupen minimal dimensions for the social space in house are 4 x 4 m, which gives a certain degree of universality – every space with such size can potentially have this function, and if there are more than one of such spaces in unit, that means, that the functions can be

> exchanged between those spaces. Spaces can be analysed also from social and cultural positions. (Yunitsyna, 2012a, p.3).

Li seeks to develop the universal space concept for housing through the idea of "versatile space, which is multi-functional, is the opposite of unitary space. Versatile space accommodates diverse functions, while unitary space is only suitable for a particular one" (Li, 2003, p. 68). Li goes on to suggest that:

> Adaptability is the potential of a system to harmonize with the environment. The adaptability of a space can change or adjust the elements constructing the space to respond to the changing environment. Unitary space could not accommodate new functions by maintaining its characters, and it could not provide the possibility to change or adjust some part of it. A unitary space loses its value when the function changes. Versatile space, more adaptable than unitary space, could accommodate new functions with or without changing. Various functions could take place in a versatile space simultaneously or successively. No extra spaces are required. This is a way to save resources. (Li, 2003, p. 70)

Li begins to outline the specification for versatile space as follows:

> Size: to contain certain function, a space requires a certain size. And to contain various functions, the size of a space should be proper for all of the functions. Shape: A space also needs to have some certain shape to contain certain function. Quality: Quality is another important factor of space-function relation. The quality of a space concerns lighting, ventilation, sunshine, temperature and so on. Linkage: Some function occurs in a single space, while some needs a series of spaces. (Li, 2003, p. 71)

Having referred to examples from traditional Chinese domestic architecture and the work of Hertzberger, Li concludes:

> The implications of versatile space are significant. Versatile space makes a solution to design building and structure adaptable to respond the rapid change of social and economic circumstances in high-density areas. The theory of versatile space is originated from the doubt of some principles of modernism, such as function-zoning and *form follows function.* And it is also originated from commercialization and digitization. Commercialization requires timely changing of the spaces according to the market, and digitization makes function more adaptable to the space. (Li, 2003, p. 74)

When asked to consider the importance of possible housing design options in their own home in the event of developing a disability or need for assistance, Judd reports in Australia that: "the most favoured option was that 'the home you are living in can be modified easily and at low cost to meet your needs'; the Adaptable Design approach (85 per cent important or very important). This was followed by the Universal Design approach (78%) of having the home designed to meet needs from the start so 'the home you are living in will meet your needs without any modification being required" (Judd, 2010, p. 284). The value of universal space presumes a universality of activities and functions that will make demands upon it. It may be that, at the domestic scale, this continuity can be assumed, given that the size of people and their families are more or less predictable within an established range for different cultures and societies. However, the size of families and their changing space needs over time will continue to represent an aspect of uncertainty to which design must respond.

In an interesting exploration of the potential value of universal space, Macht describes the work of architectural firm *utile* (https://www.utiledesign.com/). In the context of the limitations arising from single-use zoning, Macht describes how a major public client sought to explore the value of universal structures as long-term sustainable assets. Although focused upon a single project, the adopted approach follows much of the logic this thesis follows and confirms the importance of issues reviewed.

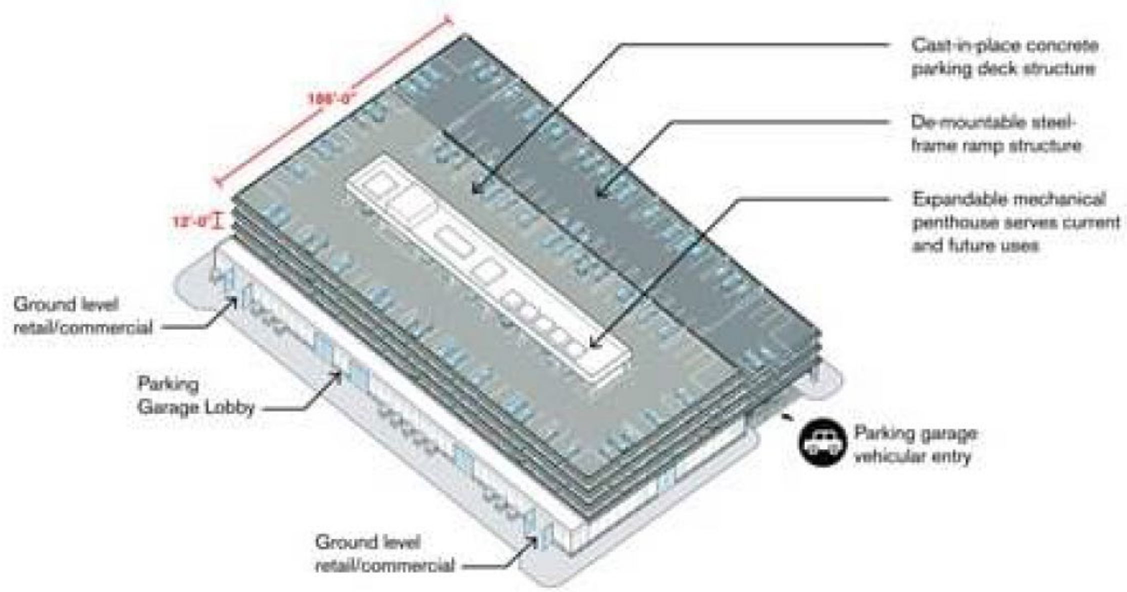


Figure 5.15 Boston Convention & Exhibition Centre (BCEC); proposals by *utile* Architects (https://www.utiledesign.com/)

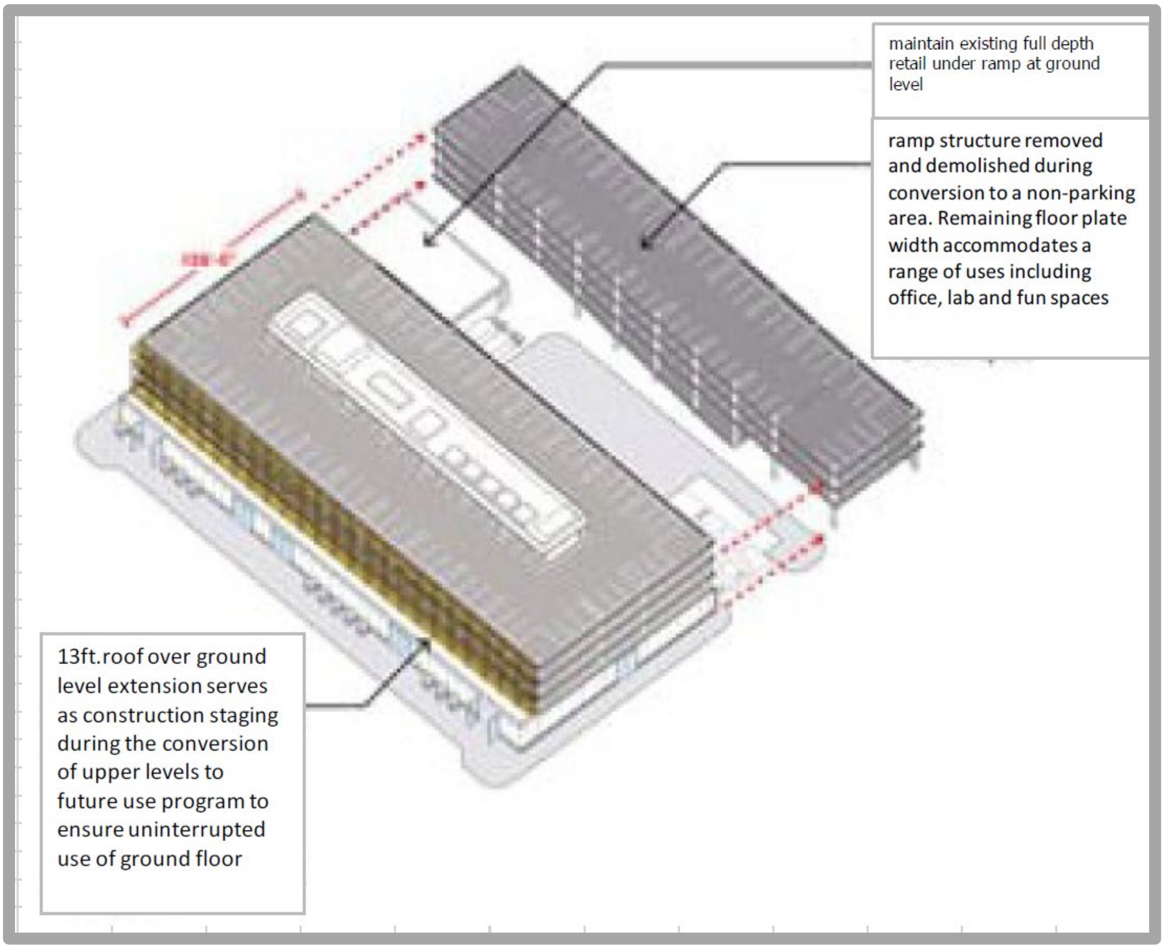


Figure 5.16 Boston Convention & Exhibition Centre (BCEC): proposals by *utile* Architects (https://www.utiledesign.com/)

Figures 5.15 and 5.16 illustrate the approach adopted which is described below. Macht traces how single-use zoning has forced developers to value-engineer urban carparks to become deep plate structures with low floor-to-floor heights and sloped floors with no capacity to convert to other uses:

> As development capital has become more securitized and investment appetites favour shorter-term returns, developers increasingly act as merchant developers, rarely able to hold onto projects for long-term investment. This trend reinforces many developers' need to undertake less-sustainable short-term, single-use development. Now, an institutional developer with substantial landholdings, large-volume parking needs, and long-term objectives is pursuing a very different approach as it plans to replace a 1,350-space surface parking lot with parking garages. The Massachusetts Convention Centre Authority (MCCA), a state-chartered public authority, is proceeding with a 1.3 million-square-foot (121,000 sq. m) expansion of the Boston Convention & Exhibition Centre (BCEC). The expansion will displace the BCEC's existing parking lot, but rather than design the

garages as conventional single-use parking structures, the MCCA has chosen to design them as universal structures that can be used not only for parking but also for a variety of denser, higher-value uses But for a long-term developer – particularly for a public institution like the MCCA – sustainability can be viewed over an extended time horizon. When assets are owned for decades, investment decisions can take into account long-term factors like life-cycle costs and adaptability, not just short-term returns on investment. (Macht, 2015, p. 2)

The time horizon for developers is critical for specific projects and an essential factor in the implementation of innovations like Double-Design.

However, by 2019, the flexibility actually provided in what was eventually built was limited to very conventional room configuration options (*BCEC Expansion 2019 Project Report*, 2019).

The design by Grimshaw Architects for the Igus factory near Cologne illustrated an approach to internal flexibility and external growth, responding to a demanding and innovative brief. Figure 5.17 illustrates the growth pattern proposed.

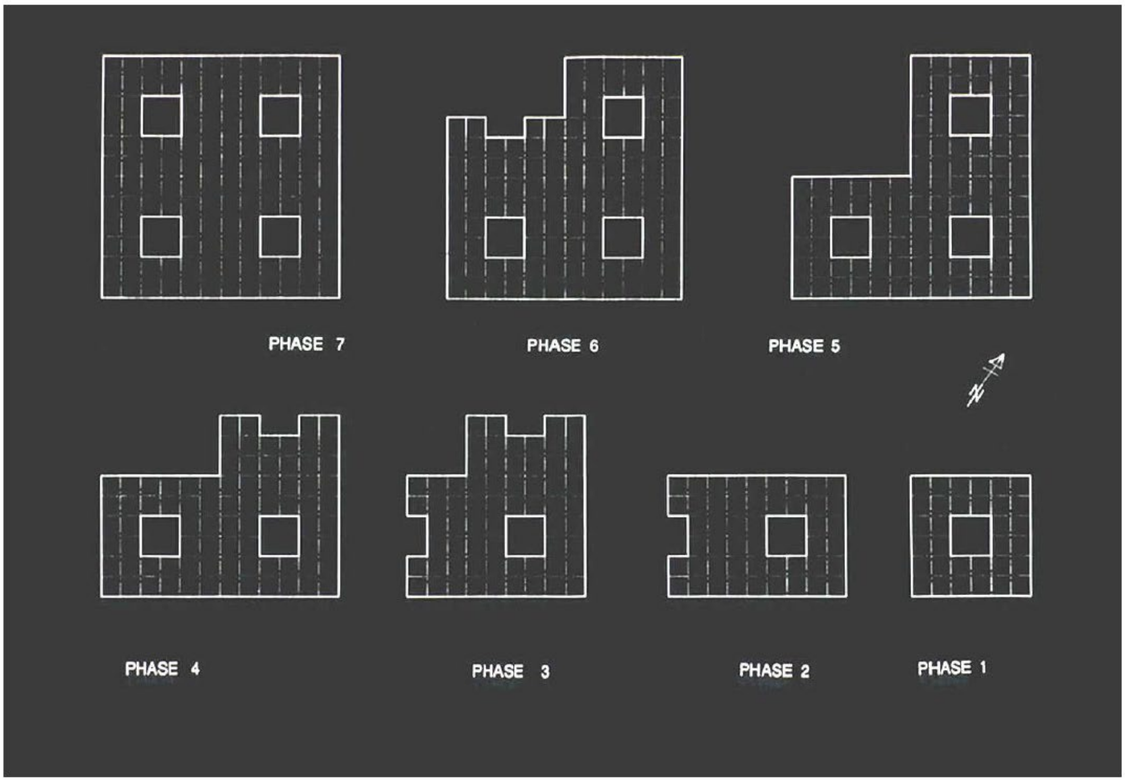


Figure 5.17 Phased growth plan for Igus factory: Grimshaw Architects from (Fuster et al., 2009a, p. 5).

Grimshaw's website introduces the project:

> In October 1988, igus® acquired a plot of about 40,000 square metres in the Porz-Lind district of Cologne. This will be the future site of development, production, sales, administration and planning. All activities should have their core here, where igus® will have its headquarters. igus® has made preparations for fast growth, fast change and flexible response in all areas, accompanied by steady consolidation of the enterprise's overall position. Offering the necessary facilities and technology, the new "igus® factory" will also be designed to promote staff performance. The interior and exterior will be designed to reflect the enterprise's products and key philosophy: innovation – service – reliability, the customer being comparable to a solar system's centre orbited by all igus® staff and igus® entities dedicated to solving the customer's problems. (Grimshaw, 2000)

The external cladding, shown in Figure 5.18, is designed as interchangeable components so that nothing is wasted at each growth stage or change.

Figure 5.18 Igus factory showing interchangeable cladding units: Grimshaw Architects

A review of the performance of the project concludes:

> The building has facilitated the clients' long term plans, thanks to the adaptable design approach, by allowing all the changes and providing the ability to grow in different phases. The grid adopted coordinates the abundance of moving, portable, changeable and repeatable parts, which has a clear value in giving flexibility to the whole scheme. It also has enabled a neater appearance of the

> internal space and prevented from the chaos of such a changing, busy and noisy factory. The repetition of parts has also helped through all the process and the extensions have been easier due to the previous experience. The scheme has allowed the frequent changes to the manufacturing processes, production lines and machinery, to suit the variant demand without big disturbance or major cost. It has also facilitated the expansion of the business and growth of the factory over the 17 years, from 4.500 to 20.000 sq. […]The pods – designed to change from place to place, to remain close to the ongoing operations in the factory – have almost never been moved and remain now static, as the space is completely full of machinery. In fact a new extension is actually undergoing and a factory building of more than half the actual will be linked to the existing four squares. There will not be any more pods and the offices are going to be fixed. At this new stage, some areas could have been improved, but finally not radical changes have happen as the new building must keep the ability to interchange its parts with the existing one. The biggest constraint has been again the fire regulations to enable big open spaces, solved by means of sprinklers, water curtains, automatic shutters and a big deal of discussion between the company and the planning responsible. The cost of constructing the building has not been cheap however; it has been a very good investment and given the company a significant value by allowing them to accommodate the ever changing business needs and grow when necessary (Fuster et al., 2009a, p. 5).

5.2.3 User Participation and Control

The participation by users, enabled and encouraged by flexibility, is bounded by spatial and tenure-based constraints. While participation has been seen and supported in serving an overtly political agenda by some commentators (De Carlo, 2005, pp. 3–22), others have seen the encouragement of participation as intended to achieve change in attitudes towards architecture itself (Till, 2005, pp. 23–63). In his review of flexibility and adaptability in housing design, Estaji gives international examples of past attempts to provide housing designs that respond to changes required by users (Estaji, 2017). The role of institutional constraints in inhibiting full user participation is referred to by Marris: "In their choice of accommodation, students were influenced by three desires: to be as free as possible from regulations, formalities, or community pressures; to make friends and enjoy their social opportunities; and to provide for their physical comfort with the greatest economy of time and money" (Marris, 1964). Communication lies at the heart of the briefing process: the professional team seeks to understand the requirements of the custodian in quantitative as well as qualitative terms. The custodian representatives will, in turn, seek to represent or at least describe the interests of the users. Yet, the individual sovereignty of the users with their implicit contract with society at large rarely forms a significant part in the process. Their informed consent is rarely sought; their true interests are rarely established or embedded in the design process. Although some primary interests of health and safety may be protected by the action of regulatory authority, through design guidance and, ultimately, the law of the land, the scope for empowering the individual with respect to each environment is rarely developed into a central element of design. As Seddone concludes: "a creation has to satisfy the demand of an entire community that is represented by that organism that brings together its spirit, identity and personality. Understanding this fact is the reason, I believe, why successful creations are approved and acknowledged by the entire community and not only by a part of it" (Seddone, 2013, p. 12). Ilievski outlines the concept of individual sovereignty as a relatively new concept, narrowly connected with some political theories and philosophies, focusing on the individual liberty at most. In that sense, the individual sovereignty would be analysed through the theoretical framework of the theories of *libertarianism*, *individualist anarchism* and *classical liberalism*. Libertarianism represents a political theory and political philosophy which puts the individual as the central actor in social relations, and the individual liberty as the highest value in its axiological system. The idea of individual liberty express the concept of *self-ownership*, which, "asserts the absolute right of each man, by virtue of his (or her) being, to 'own' his or her own body; that is, to control the body free of coercive interference" (Rothbard, 2002, p. 28) (Ilievski, 2015, p. 7). This discussion, the importance of which is amplified by governmental reactions to the recent pandemic, provides the context for exploring how space users could manage, control and influence their local environment, whether institutional or familial. There needs to be a clear distinction between flexibility *for the designer* and flexibility *for the custodian and user*. For the designer, a kit of parts has sometimes been devised from which a variety of solutions can be assembled. This is of particular value to the original designers in choosing the starting configuration of the space and the benefit of builders through the economies of scale arising from repetitive building elements. Often, however, the idea of flexibility *for the users* in the occupation of their space has not featured in the implemented design. There is evidence that offering users more control over their local environmental conditions brings a wide variety of benefits, not least in the current context of concerns about energy consumption. However, it would be ironic if the ready availability of control devices gave rise to the sacrifice of personal autonomy and the handing over of absolute control to the manufacturers of the devices. Studies are already identifying the public concerns and lack of trust in such technologies. As Wilson et al. say, in their analysis of the benefits and risks of smart home technologies: "Both prospective users and actual early adopters also express caution towards ceding autonomy and independence in the home for increased technological control. These broader sociotechnical risks are perceived more strongly than the privacy and data security concerns that have affected smart meter rollouts in the EU" (Wilson et al., 2017, p. 82). In an informative online advertisement for smart control devices, illustrated in Figure 5.19, the risks are addressed as follows:

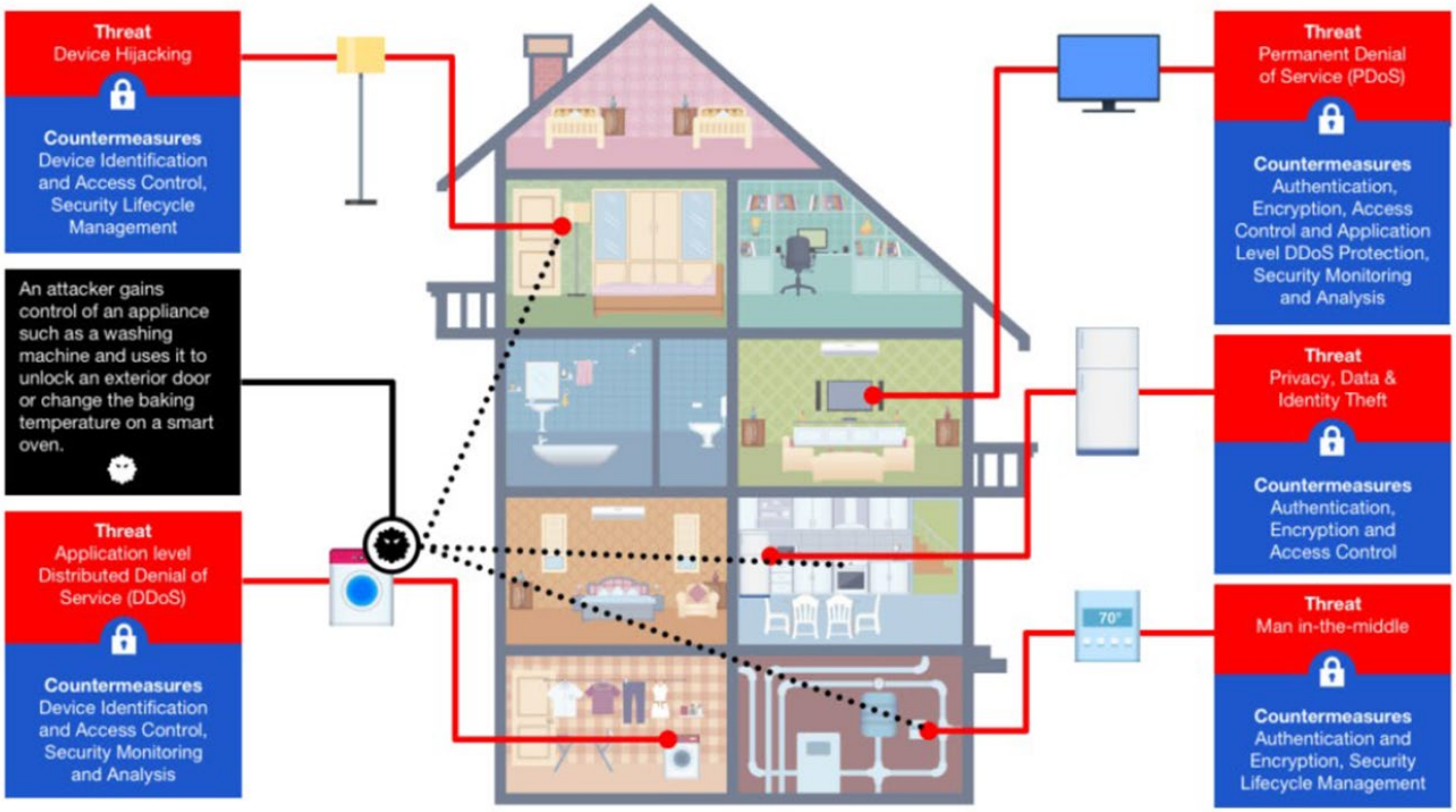


Figure 5.19 Range of threats to personal privacy arising from "smart" technology: from (*Smart Home: Threats and Countermeasures*, 2019)

An estimated 80% of IoT devices are vulnerable to a wide range of attacks. Clearly, connecting traditionally 'stand-alone' smart devices such as lights, appliances and locks introduces numerous cyber security risks. Even connected baby monitors are vulnerable to digital intruders, as a number of horrified parents belatedly discovered when hackers spoke to their young children via compromised devicesThe attacker hijacks and effectively assumes control of a device. These attacks are quite difficult to detect because the attacker does not change the basic functionality of the device. Moreover, it only takes one device to potentially re-infect all smart devices in the home. For example, an attacker who initially compromises a thermostat can theoretically gain access to an entire network and remotely unlock a door or change the keypad PIN code to restrict entry. (*Smart Home: Threats and Countermeasures*, 2019)

Considering the central importance of interaction in any understanding of what architecture is about, it seems surprising that little attention has been paid to the active encouragement of "user participation" concerning completed buildings. If we are to listen to the interests and wishes of building users, perhaps there need to be limits to the decisions left to the architects. Gone are the days when the great architects would design everything in a building down to the door handles and the curtain rails. The architect Candilis put it well: "It is impossible for each man to construct his house for himself. But the architect must make it possible for each man to make his house his home. We must design the habitat only to the point at which man can take over" (Candilis, 1962, pp. 559–602). But how to establish exactly where that point is? A starting point is to assess the potentiality for participation for different building types. We need to consider the various ways in which individual users can contribute to and control their own "local" environment within the context of the management of space by or on behalf of the custodians. The interaction between building managers and individual users can be seen as continuing the dialogue between custodian and architect. Indeed, the managers may call in professional advice to modify or tune the building. The provision for individual intervention and environmental control varies with building type. Any attempt to increase such personal customization must start with some awareness of the range of potentiality for each kind of building and a fundamental understanding of the difference between structural degeneration and functional obsolescence. Maintenance will address some of the problems of physical ageing. At the same time, a wide range of responses may be deployed to deal with functional obsolescence, subject to the robustness of the design and including individual customization. Focusing upon the office environment, Duffy has suggested a timescale for some of these responses to change. The main elements of the office building are:

(i) Building shell: long-life elements including structure, external skin, core, etc. *expected to last for fifty years or more*
(ii) Services: basic infrastructure of heating, air-conditioning, electrical power, elevators, etc. *expected to last for fifteen to twenty years and needing to be maintained and replaced.*
(iii) Scenery: interior elements including partitions, ceilings, wall coverings, lighting, local systems for the distribution of services, fitted and loose furniture and equipment. *Expected to last some five to seven years, often related to the length of the lease.*
(iv) Sets: particular arrangements of scenery to meet specific layout requirements of users. *Expected to be subject to facilities management changes to allow for the introduction of new technology and internal management rearrangements* (Duffy, 1992) (Brand, 2007) (SLA, 2007).

The significance of this classification lies in establishing a time dimension for the architect that reflects the way the building will be used and how the support systems will need to be maintained and renewed. Cowan's previous work had assessed the obsolescence rates for mechanical equipment and the need to allow for its replacement without closing down the building. (Cowan, 1970).[45] The circumstances that will make provision for individual customization useful include:

- Where people have suffered loss (of place, family or friend) or significant change: for example, older people moving away from their own home into care

[45] The author remembers a story about the design of Senate House in London, headquarters of London University. The architect, even in the 1930s, was still skeptical about the use of structural steel and made it possible to replace the steel lintols over each of the windows!

will value their possessions; students moving away from home to college will want to take with them their posters, computers and music.

- Where efficiency may be improved: commercial managers can encourage loyalty and commitment; teachers who can control their classroom environment (temperature, lighting, furniture layouts, communication media and so on) will teach better.

- Where individuals are better at understanding their own comfort parameters than architects and engineers: this suggests that the length of time an individual is located in one place may have a bearing on the value of customization; workstations, office furniture arrangements, classrooms, as well as housing of all kinds, are prominent examples.

- Where the effect of intervention/control/participation will bring growth and increased well-being to the individual: the scope of intervention and control may thus include, at the least, control of environmental comfort, furniture arrangements, and interior design.

As there are overriding reasons why personal customization is something worthwhile to pursue and allow for wherever possible, then the above circumstances could be significantly extended. Recent arguments concerning the importance of natural ventilation in promoting human comfort have been reinforced by the need to design to avoid the impact of any future 'pandemics'. Roaf argues forcibly that there needs to be more generous floor-to-floor heights as well as openable windows. Her assessment of the responsibility of the air-conditioning industry has parallels with analogous analyses of the role of big pharma in the recent episode of Covid-19 (Roaf, 2021; Perronne, 2021).

In a spirited attack upon "gray" architecture, Salingaros says:

> We see an infatuation with drab, gray surfaces of raw concrete. Everyone I ask (with the notable exception of some architects) finds such surfaces morbid and depressing; and yet architects keep building them. Even worse, they go to great lengths to prevent their users from painting them with color so as to stop the deadening effect. Where paint is allowed to be used, again it is often restricted to depressing shades of gray. This is in stark contrast to historical and vernacular architectures around the world. The greatest buildings of the past are very colorful (or were before their color faded from weathering). Owner-built dwellings employ all the color they can find to intensify visual response from wall surfaces. Color appears to satisfy a fundamental human need, as shown by

> children's art (before they are conditioned to a gray industrial world) and folk art […] A geometrical fundamentalism lies at the core of post-industrial planning and design. We are convinced that this has destroyed our cities and has made even ordinary buildings less human. We suggested that geometrical fundamentalism plays a role in creating the resentment the rest of the world feels against the industrialized western nations. (Salingaros & Mehaffy, 2006, p. 194)

To these activities must be added the possibility of individual customization. The diagrams below suggest the building types where space management will be prominent and where there is potential for individual customization. The list of building types, by no means exhaustive, is based upon Pevsner (Pevsner, 1976). All building types require maintenance, and competent custodians will, in addition to being aware of the physical state of their building, take all necessary steps to be mindful of how to deal with the risks arising from functional obsolescence. Just as professionals, doctors, and architects alike are obliged to keep up to date with best practices, a custodian needs to be aware of new techniques, new equipment, and new services that may enhance the function of the spaces for which they are responsible. Figure 5.20 considers the scope for active participation by the staff of an organization.

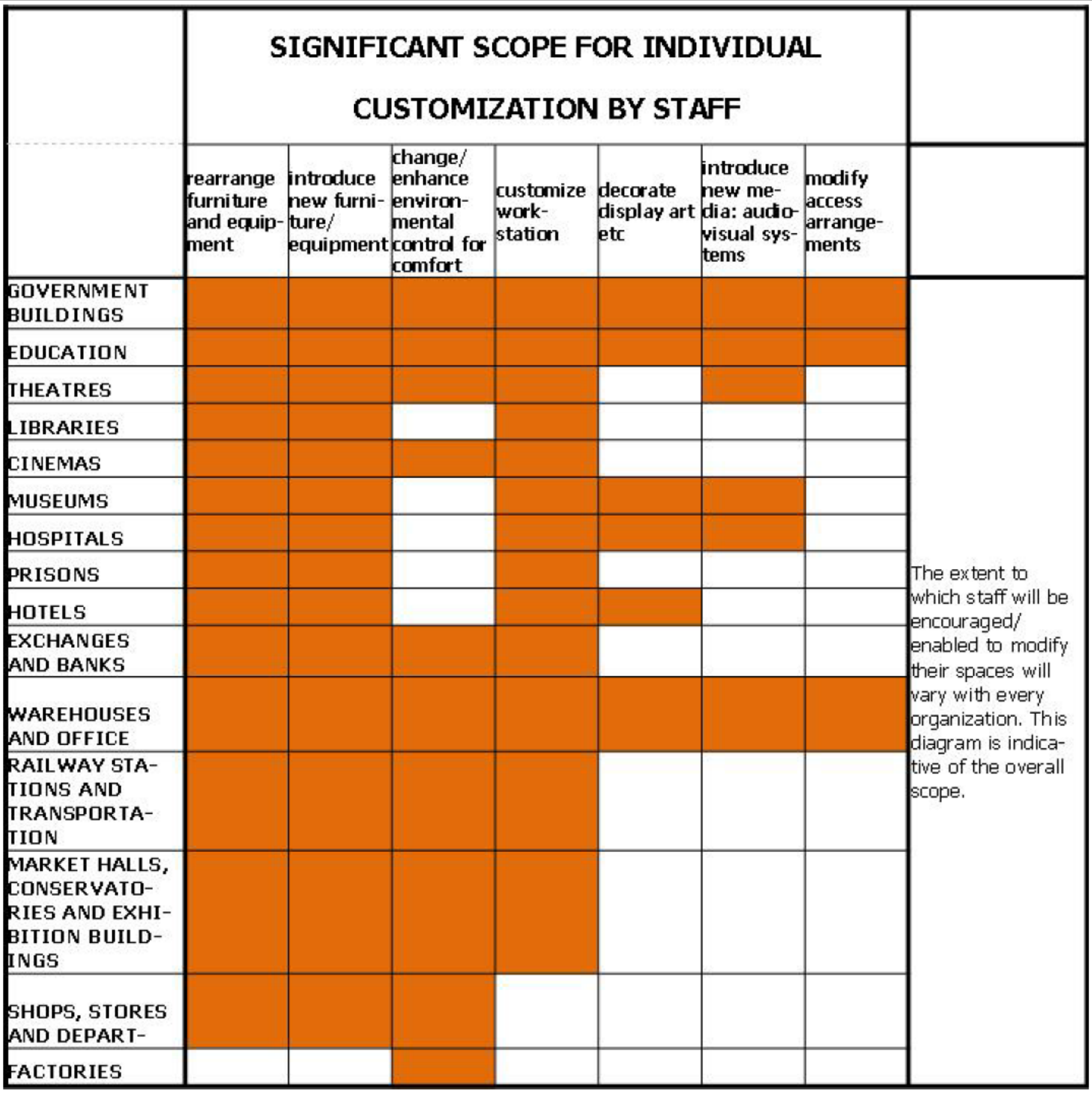


Figure 5.20 Indicative scope for individual staff to customize their environment

The scope for those other than staff to participate in controlling and managing their environment is not as significant as the length of time people are interacting with their environment.

Just as architecture does not stop being significant when it is handed over, the responsibilities of the custodian and users start afresh when the building is used. Planning of a different kind is needed. Considering the inevitable uncertainties to be encountered in the effective management of space, custodians must choose an appropriate way forward. Developed for organizational change by Ackoff, interactive planning proposes the idea that to arrive at a desirable future, one has to create a desirable present and create ways and means to resemble it. Interactive planning is unlike other types of planning such as reactive planning, inactive planning, and preactive planning. This is because interactive planning is focused on systems thinking and is “based on the belief that an organization’s future depends at least as much on what it does between now and then, as on what is done to it” (Ackoff et al., 2001, p.3) (Ackoff, 1981).

Interactive planning promotes democratic control by allowing and facilitating the active participation of various stakeholders in the conceptualization and formulation of programs, projects, strategies and techniques. This empowering shift affords the stakeholders to become committed, engaged and grounded decision-makers. Interactive planning, therefore, according to Zeynep Ocak:

> Expands participants’ conception of what is possible and reveals that the biggest obstructions to achieving the future most desired are often self-imposed constraints. Interactive planning acknowledges creativity and appreciates out-of-the-box thinking. Participants are encouraged to be as creative as possible in coming up with the idealized design and the problem of innovation in multi-project environment can be solved by this way. (Ocak, 2015, p.1637)

5.2.4 Open Building

Books like Brand’s and Hollis’ give a rich account of what we do to buildings when used (Hollis, 2009) (Brand, 1997). The richness and diversity of the experience of buildings in use reinforce the argument that we need to anticipate what may happen and try to allow for every eventuality in the design of buildings. Suppose it can be shown that particular sizes and shapes of space lend themselves more readily than others for many activities. In that case, those sizes and shapes should be preferred as they will more readily accommodate change without disruption. Of course, it is not only activities that change but also the organizations to which they contribute. Hence, the accommodation of change over the life of a building must encompass both spaces and the connections between them. Furthermore, the accommodation of intervention and active participation by generations of users determined and encouraged to personalize and control their individual spaces will also impose requirements on the environment provided by architects. An optimum environment thus combines the highest common factors in terms of spatial provision with the capacity to accommodate change in general and the maximum personalization associated with the use of space. The question then arises: will the provision of spaces that are capable of many activities also be able to accommodate personalization? Flexibility has been explored by the Open Building movement in the USA and internationally. Habraken's separation of the supports of a building from the infill was an essential contribution to the idea of flexibility (Habraken, 2011). It offers the basis for "a well-structured building process with well-defined interfaces. It allows us to at least partially transfer the construction process from building to manufacturing. It is the key to reducing waste by coordinating dimensions and positions instead of improvising on-site by cutting to size: applying information instead of energy" (Open Building Implementation, 2007, p. 8). As Kendall argues, "Buildings are increasingly complex. Social change is accelerating. Given these circumstances, it is important to design and construct multi-unit buildings to avoid conflict, reduce dependencies among and between parties [...] and thus achieve maximum autonomy or freedom of decisions for each individual unit" (Kendall, 2004, p. 1). Kendall's "open building" approach seeks to achieve socially sustainable goals for urban housing:

> This approach can also be seen as a tool for achieving – over time in a given building – the goal of income mixing and community stability. Instead of designing housing according to household income (often assuming fixed incomes over time), an open building approach enables a more dynamic balance between physical assets and changing household income and status over time. It helps avoid the trap of real estate development and building practices based on (income) class. It also is a tool in adjusting our practices from a "scrap and build" approach to urban development to a "sustainable stock" approach. (Kendall, 2004, p. 2)

This is one of the few references to the nature of space itself contributing to social and environmental sustainability. However, in the context of this thesis, participation can be seen to serve the practical and, arguably, the politically neutral objective of extending the life of buildings. Kendall also asks how far the architect's responsibilities should go and his suggestion that much housing can be left for the users to finish and furnish, to the extent they choose, has much to commend it.[46] The flexibility provided from the start will benefit later custodians and users as well as being of obvious and direct benefit to the initiators. Habraken's suggestion to separate the supports of a building from the infill was a vital contribution to the idea of flexibility. Jan Cuperus offers a clear introduction to the Open building movement. The origins of the concept of Open Building is best captured by one of John Habraken's finest quotes:

> We should not try to forecast what will happen, but try to make provisions for the unforeseen […] It offers the basis for a well-structured building process with well-defined interfaces. It allows us, to at least partially transfer the construction process from building to manufacturing. It is the key to reducing waste by coordinating dimensions and positions instead of improvising on site by cutting to size: applying information instead of energy. This is an important condition to re-use building parts, thus extending the lifetime of building parts, without the waste of dumping and recycling, coinciding with degradation and the use of energy. (Cuperus & Dobbesteen, 2005, p. 2807)

As Kendall argues: "Buildings are increasingly complex. Social change is accelerating. Given these circumstances, it is important to design and construct multi-unit buildings to avoid conflict, reduce dependencies among and between parties and the parts of

[46] Poulsom Middlehurst has designed a terrace of custom-build homes in south London for developer Unboxed Homes. "We believe that we are the first to offer 'new build shells' to Londoners," said Unboxed Homes founder Gus Zogolovitch. "We are not trying to maximise our returns at Blenheim Grove, we are trying to make something new," he told Dezeen. "Building an airtight, watertight, structurally sound shell which has the flexibility for customers to design a space that works for them" (Ravenscroft, 2021).

the building they control, and thus achieve maximum autonomy or freedom of decisions for each individual unit" (Kendall, 1999, p. 1).

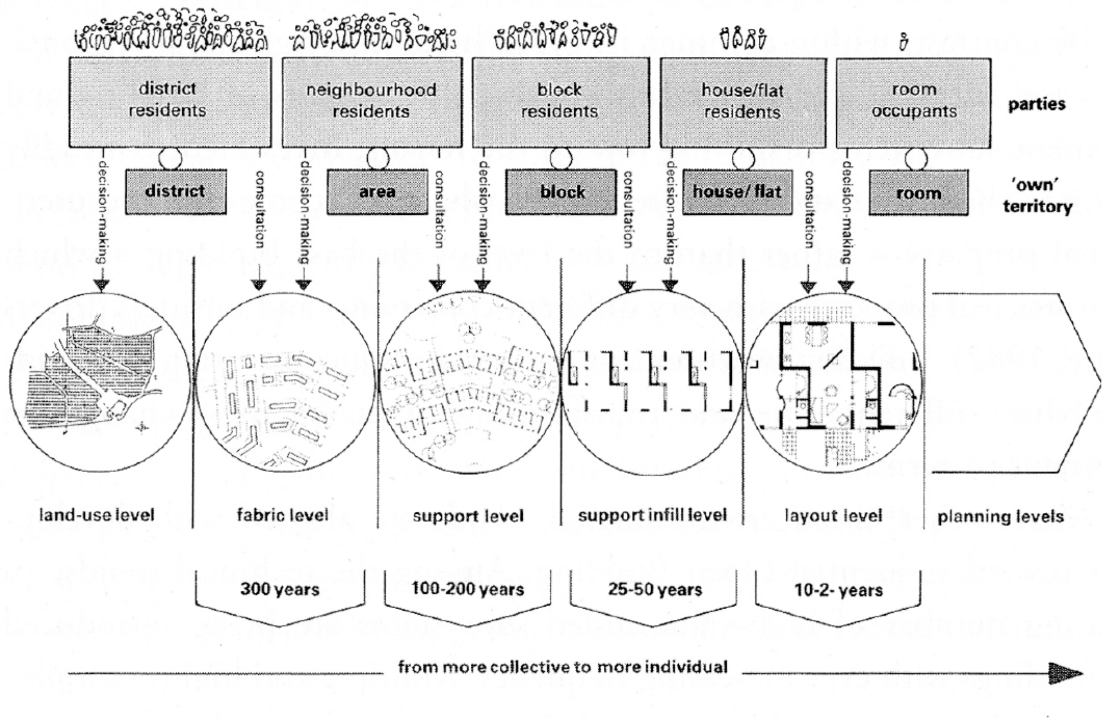


Figure 5.21 Interpretation of layers in support of the Open building approach: (from OBOM, TU Delft, 1990; [9] p. 91) from (Kendall, 2004, p. 3)

Figure 5.21 expands the concept of layers in recognizing the different timescales for human use of and intervention in the built environment. Those who subscribe to an Open Building approach seek to formulate theories about the built environment seen in this dynamic way and develop design and building construction methods that are compatible with it. Recent emphasis has been upon developing the hardware for building components to support the Open Building philosophy (Li et al., 2019). Extending and elaborating the principle of Open Building, Geldermans explores the way in which the application of a circular economy can contribute to the achievement of sustainability goals (Geldermans, 2020).

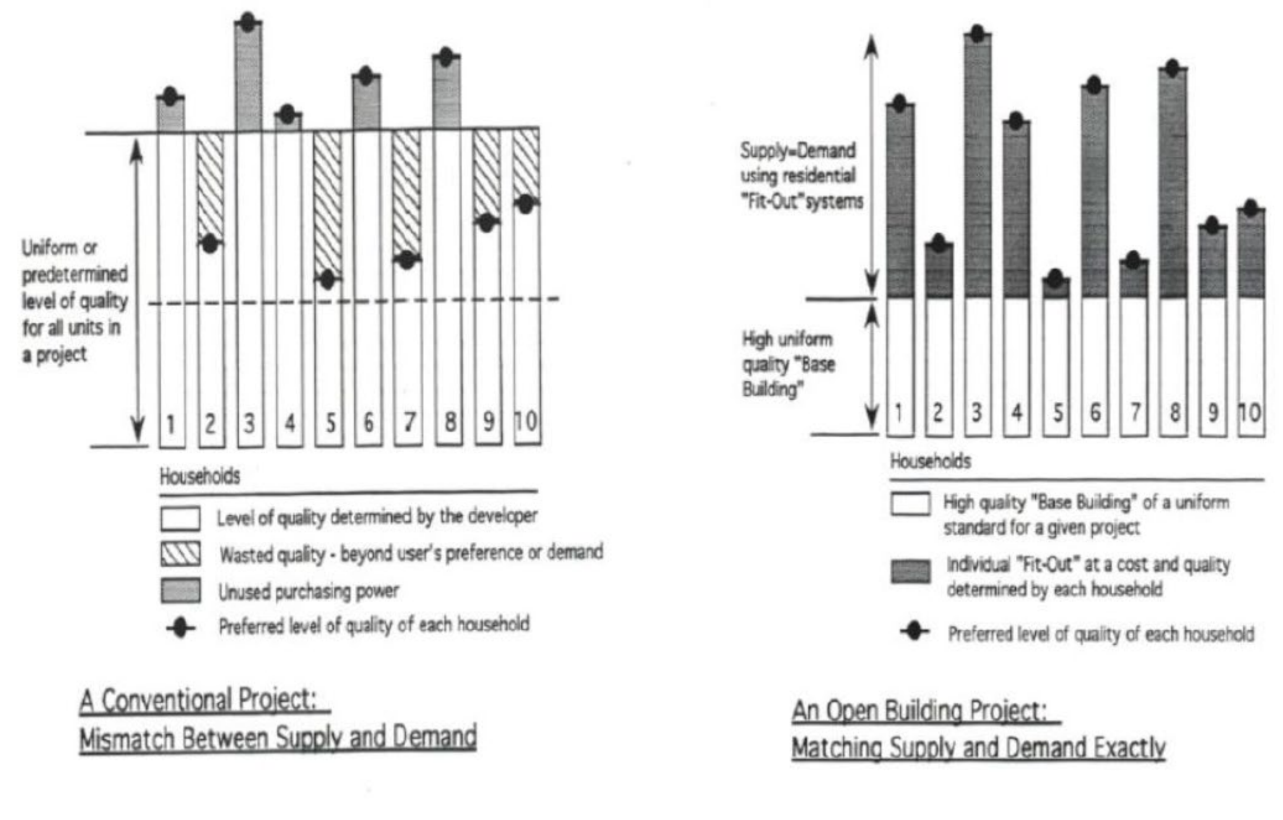


Figure 5.22 The Open Building approach to matching supply and demand compared with the conventional approach: from (Dekker & Kendall, 1994, p. 4)

The conventional architectural response to uncertainty has been found in the pursuit of flexibility. Habraken, in his review of Schneider and Till's book on Flexible Housing, understands the profound potential impact of flexibility fully, arguing that:

> The redistribution of control, implied by the concept of flexibility, is not only of architectural import. It invites adjustment of method for all parties involved in housing, and as such opens new avenues for research. It suggests, for instance, a dedicated residential fit-out industry, delivering and installing the dwelling unit's fit-out as a single product. This industry- to-be has a potential comparable with the automobile industry. Separation between fit-out and collective building also asks consultants on utility systems to reconsider how main lines are best distributed in the flexible building to feed and drain a dwelling's territory at the boundary of which the fit-out contractor will take over and distribute lines to kitchens and bathrooms. […] The purpose of design for flexibility by whatever name is to enable individual control in an otherwise collective environment. (John Habraken, 2008, p. 7)

The overall response to designing for flexibility is promoted by Habraken and summarized in the philosophical concept of "Open Building". This is the term used to indicate several different but related ideas about the making of the environment. For instance: The idea of distinct Levels of intervention in the built environment, such as those represented by ‘support’ and ‘infill’, or by urban design and architecture. The idea that users/inhabitants may make design decisions as well. The idea that, more generally, designing is a process with multiple participants also including different kinds of professionals. The idea that the interface between technical systems allows the replacement of one system with another performing the same function. (As with different fit-out systems applied in a same base building.) The idea that built environment is in constant transformation and change must be recognized and understood. The idea that built environment is the product of an ongoing, never ending, design process in which environment transforms part by part. Habraken develops the relationship between the individual building and the urban fabric of which it is a part. Molenvliet in Holland provides an example of this integrated community approach. The Molenvliet development is one of the critical Dutch projects that fulfil the Stichting Architecten Research (SAR) support and infill methodology. User involvement in decision-making starts with the broader context of the overall neighbourhood plan. The second step is to negotiate built areas in the form of open spaces and building zones. The third step is the planning of the ‘support’ structure. The final stage is to design the individual infills, which determine the floor plans and finishes.

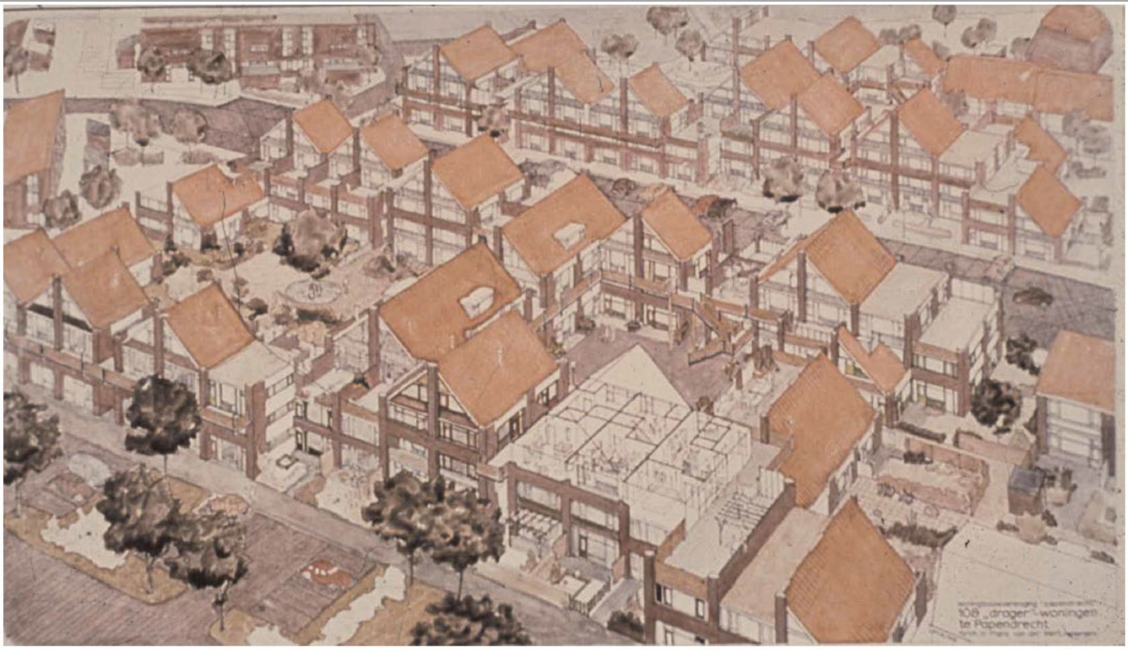


Figure 5.23 Molenvliet housing project in Papendrecht, the Netherlands, by Frans van der Werf, architect (1974). Drawing of the project as it was built which was only a small part of the continuous structure intended to form an urban fabric. Courtesy Frans van der Werf. From (John Habraken, 2008, p. 294)

Here, the support structure, an in situ concrete framework with openings in the slabs, is a combination of seven components: floor decks for vertical mechanical chases and stairs; in situ concrete piers placed parallel to each other on a 4.8-metre square grid; pitched roofs sloped at 45 degrees to provide a habitable attic; wooden frames which act as an armature for specific facade elements; roof terraces located on the flat roof space of the ground floor dwellings; open galleries for upper-level access; and large vertical service ducts containing all wiring and piping for gas and water as well as television and telephone connections. The principle of support and infill allowed the free subdivision of the structure into a complex of apartments ranging in size from one- to six-room units. Using a version of the Dutch 'tunnel' system, the wall piers allow apartments to straddle across two or three bays, a principle further developed in the same architects' Keyenburg project of 1984. Initial decisions about the placement of partition walls were made in conjunction with the future users, who met twice with the architect and a representative of the Housing Association. Contrary to some other developments where tenants were shown possibilities of subdivision, at Molenvliet, they were presented with an empty support plan, which was gradually defined through discussions with the occupants. The work of Till and Schneider in the field of housing helps establish a good range of types of flexibility, and this confirms the view that it is necessary to establish whose flexibility is being served:

> The basic principles of flexibility start with its opposite – namely that inflexibility should be designed out. […] the UK building industry tends to build in obsolescence, but this can be avoided in three manifestly simple, and by non-costly, ways. First, through the consideration of the construction; most directly through the reduction of loadbearing or solid internal partitions but also through the avoidance of forms of roof construction (i.e. trussed rafters) that close down the possibility of future expansion. Second, through technological considerations and in particular the reduction of non-accessible or non-adaptable services. Third, through consideration of the use of space, i.e. through the elimination of tight-fit functionalism and rooms that can be used or accessed in only one way. While these three relatively simple principles would go some way to avoid inflexibility, one other aspect also needs to be addressed. To move from avoiding inflexibility to building-in flexibility it is useful to look to see if we can find generic principles in two building types that are often described as inherently flexible, the English terraced house and the speculative office. (Till & Schneider, 2005, p.287)

Leupen examines the activities within a house and sets out the difficulty of operating a time-based architecture:

> We are faced with a contradiction in terms: the more precisely we are able to decide what requirements a dwelling should meet at the start of its life, the greater the likelihood of a discrepancy arising between the dwelling and its future use. The more precisely architects were able to define the measurable aspects of living and convert them into a design, the more the design neglected the unquantifiable and non-measurable aspects and the less able it was to provide an answer to unpredictable changes in use. One of the concepts that can deal with changeability and unpredictability is polyvalence. Polyvalence means that the building can be used in different ways without structural interventions. (Leupen, 2006, p. 24)

In the context of housing, polyvalence covers the interchangeability of activities between different rooms. Figure 5.24 illustrates a Japanese perspective on the concept.

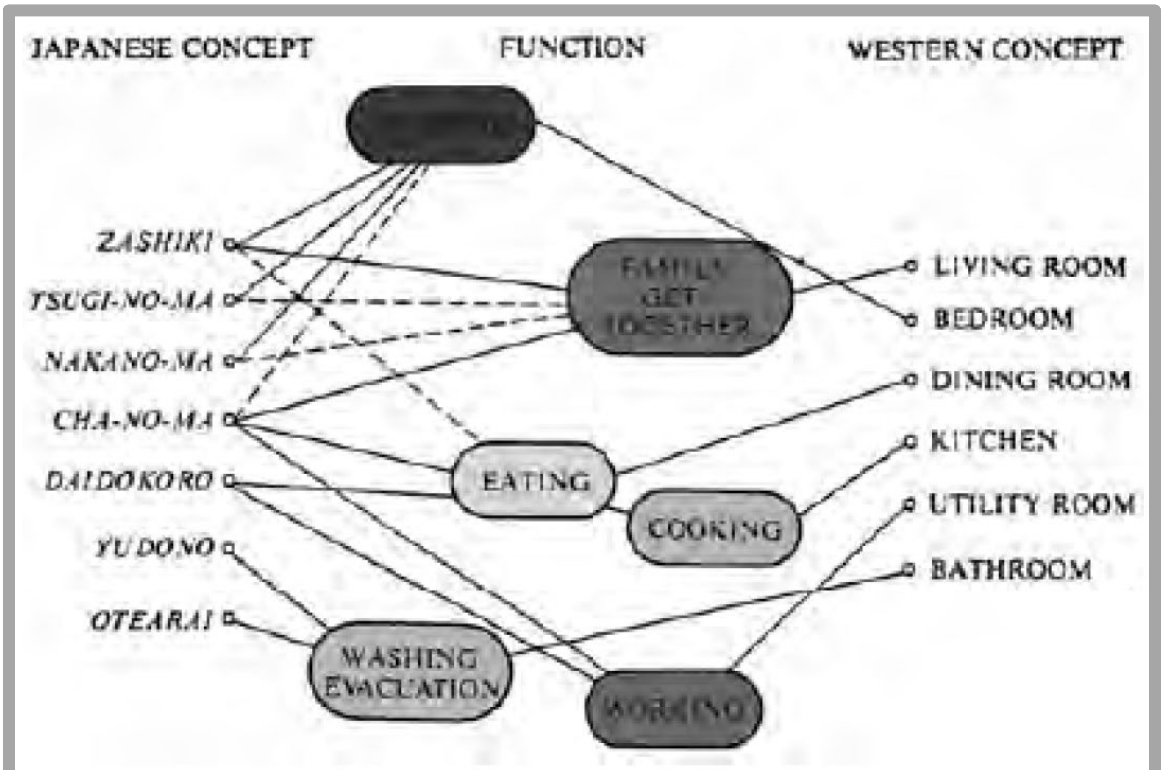
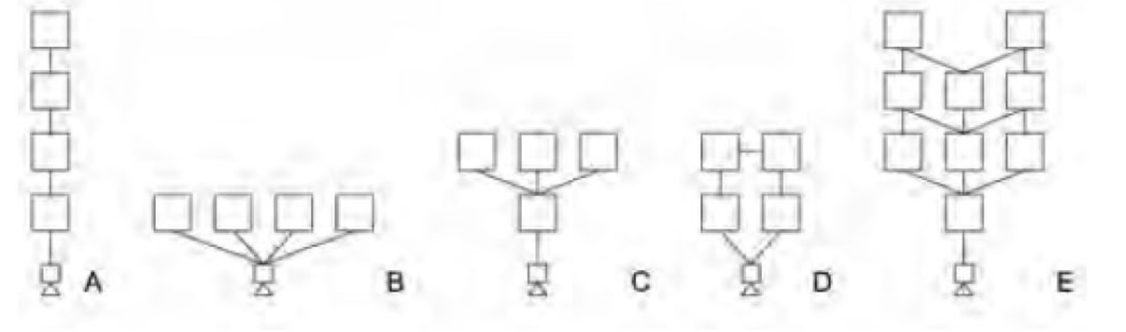


Figure 5.24 Nishihara provides an interesting comparison between western and Japanese home activities. He compares traditional Japanese domestic culture with Western domestic culture in terms of six activities (Nishihara, 1968).

In present-day domestic culture, rooms are set aside for specific activities. In contrast, the traditional Japanese house has several multi-purpose rooms that derive meaning from the objects used there. For example, if the paraphernalia for the tea ceremony is brought out, the room becomes the tea ceremony room; if the sleeping mats are rolled out, and the tea ceremony paraphernalia is put away, the same room becomes a bedroom. Leupen identifies five basic models for the spatial organization of houses, illustrated in Figure 5.25.



5.25 Graph of dwellings. A Chain Model, B Star Model, C Star Model with central room, D Circle Model, E Grid Model (entrance = square + arrow) from (Leupen, 2006, p. 30)

He concludes:

> Clearly, there are degrees of polyvalence.... The number of large rooms is also important. The more rooms that are larger than 16 m2, the more freedom there is to distribute the basic functions among them. Polyvalence is restricted when there is only one large room. Systematic research into how a large number of dwellings regarded as more or less polyvalent actually function in practice could increase our understanding of this fascinating phenomenon. Putting knowledge of polyvalent dwellings into practice could result in a new generation of homes with interesting spatial organisations and substantial expectations (sustainability) as regards changing and unpredictable uses. (Leupen, 2006, p. 31).

Fujino and Noguchi provide a comprehensive review of the potential application of open building principles to Japanese housing taking into account the specific age profile of housing stock (Fujino & Noguchi, 2009, p. 25).

The relationship between an organization and its space needs is central to designing more long-lasting buildings. As Cowan & Sears say: "It is perfectly obvious that, if change becomes normal in society, the artefacts and structures which we build to house our various institutions and activities must themselves be adaptable. Since it is not possible to tear down and renew buildings each time they become obsolete because of changes in activities which they house, the only way that we can adjust our buildings to changing needs is by adapting them" (Cowan & Sears, 1966, p. 3). This research traced the patterns of growth and change in six very different organizations. It concluded that the factors that made a building suitable for modernization were: "First, they must be structurally sound. Second, the average cost per converted dwelling must be less than the cost of rebuilding. Third, there must be at least 40 years of potential life after conversion. Fourth, the dimensions and standards of new rooms created by modernization must as nearly as possible correspond to standards laid down for new buildings" (Cowan & Sears, 1966, p. 3). It can be concluded from this study that buildings should contain spare space from the start, should be capable of internal adaptation and that organizations should re-estimate future space needs regularly. There are stages through which an organization may pass before deciding to build new facilities. In some buildings, it is possible to intensify the use by, for example, timetabling the use of space.[47]

5.3 DOUBLE-DESIGN DEVELOPMENT

5.3.1 Performance of Re-used Space

New analysis by the Local Government Association reveals "nearly one in 10 new homes over the last two years was converted from an office and included no affordable housing or supporting investment in infrastructure such as roads, schools and health services" (Local Government Association, 2018). This example shows how the compatibility of space alone is not a sufficient guarantor of successful reuse.[48] The ingenuity to convert an inherited space to a use for which it was not originally intended is greatly to be applauded in extending the useful life of at least part of the building.

[47] The author pointed out to a custodian in Kuwait that if the teaching day were to be increased they would be able to reduce the size of building by almost half! He replied that this was the only time he would be able to build for his department so wanted to achieve the largest building possible. He was, in a roundabout way, getting his 'spare space'! Another organization in Kuwait was able to achieve a clear strategy for growth by adopting satellite buildings located in each of the districts of the country with a headquarters building serving central functions.

[48] The author noted that in Kuwait there were many residential districts being developed recently without the usual advanced infrastructure traditionally provided prior to individual house construction.

But is it ever as good an environment for its new purposes as a new "purpose-built" environment would be? There are examples in which the re-use creates a better environmental fit for its new use than the original did for the originally intended use: loft apartments created from old factories and workshops come to mind. Nevertheless, Douglas and Ransom maintain the need for innovations in the building industry to help avoid obsolescence and create greater adaptability (Douglas and Ransom, 2013, p. 276).

5.3.2 Compatibility Matrix

A compatibility matrix can establish the ways in which initial designs need to be amended to accommodate future unknown uses. The practical approach to implementation of Double-Design in the UK would use planning and building control legislation taking the form of design rules triggered by land use categories. In order for a proposal to obtain planning permission, it would have to comply with the guidelines generated by Double-Design. The application of Double-Design would help specify an expanded functional intent at the start of any project so that the initial design satisfied the requirements of the initial custodian/user and accommodated the possible requirements of later custodians/users.[49] Double-Design is not intended to necessitate the transition from initial use to subsequent use but to make it easier to achieve. There may be factors included in the requirements of future custodians that are not readily accommodated by the initial provision. The scale of second uses, the need for external

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[49] **However, for now double design must be viewed as rolling a rock up a hill – but it's a rock that needs to be rolled. There has to be consensus that the huge resource investment in a building deserves to be capitalized and utilised for as long as conceivably possible. If the premise was that they should, then more care would be taken over design (Ed Murphy).**

space, car parking, location, and relevant safety provisions will all have a bearing on the potentiality for easy reuse. In its simplest form, a custodian wanting to build for an initial use "x" would be required to make it capable of becoming "a, b and c". There would be a presumption that securing planning permission for the initial use would automatically enable subsequent specified uses without further permissions being required. However, there may be changed circumstances in the local neighbourhood that might render Double-Design ineffective and this would have to be allowed for in legislation for implementation. By reviewing compatibility between the spaces needed for initial and possible future uses, it is intended to establish that the concept has merit and should be pursued. The following advantageous features have been indicated: The positive spatial redundancy incorporated into Double-Design will bring benefits to initial custodians/users and future custodians/users. Spatial redundancy needs to be seen as a societal asset in the same way redundancy in engineering is used to avoid risk. Thus, spatial redundancy will bring benefits both to new projects and to re-use projects. Resource use over the life of the building will be reduced. Waste will be reduced. Transitions from one use to another will be more easily administered: the transition will be faster and cheaper whether the initial custodian is making changes or handing over to another custodian. Custodians and users will benefit from the increased scope for intervention and control enabled by Double-Design. The increased flexibility and adaptability inherent in the application of Double-Design will, over time, improve the spatial match between what future society may need and the built environment that will already be available. The increased flexibility and adaptability will help accommodate the increasing levels of uncertainty that seem likely to be faced by future societies.

5.3.2.1 Double-Design and Public Interest

Architecture and building are already influenced by public interest concerns like health and safety, energy efficiency and the like. The adoption of Double-Design is a logical extension of the ongoing redefinition of long-term public interest and would become an essential component of design guidance for the future. A great deal of ingenuity, time, and cost has been expended in converting inherited space to a new use. This suggests that the applicability of Double-Design must recognize a spectrum of difficulty if applied to existing buildings. Double-Design is intended to be an enabling mechanism that uses the momentum arising from new space-providing projects to achieve longer-term societal goals. Double-Design cannot seek to determine the scale of development. Design teams are rarely, if ever, in a position to affect or even influence the scale of enterprise for which they are required to cater. The responsibility lies with the custodian. While the scale of the initial project and any subsequent reuses are not central to the development of Double-Design, it is legitimate, as observed earlier, for the design team to raise the issues of potential growth and change when determining the brief for any project. Research in this field has covered the optimum size of enterprises (Giancotti et al., 2017) (Kristensen, 2008) (Peters, 1994), the propensity of organizations to grow and the observed patterns of growth (Kemp & Verhoeven, 2002) and even the relationship between altruism, non-economic factors, within the firm and growth potential (Wickert et al., 2016). A custodian starting a project is free and encouraged to add some spatial provision for contingency. A custodian occupying a building and needing to expand has several options, including intensification of use (hot-desking, increasing density of occupancy, altered timetabling and the like); adding space externally (land permitting) or internally (by the acquisition of adjacent property); adding non-contiguous space (retaining headquarters space and developing satellite spaces)[50] or moving altogether to another location.

Several alternative policies for implementation are shown in Figures, 5.26, 5.27 and 5.28.

[50] In developing the headquarters for the Kuwait Public Institute for Social Security, the custodian recognized a limit to the development of the HQ site and accordingly developed satellite buildings in each of the regions of the country served.

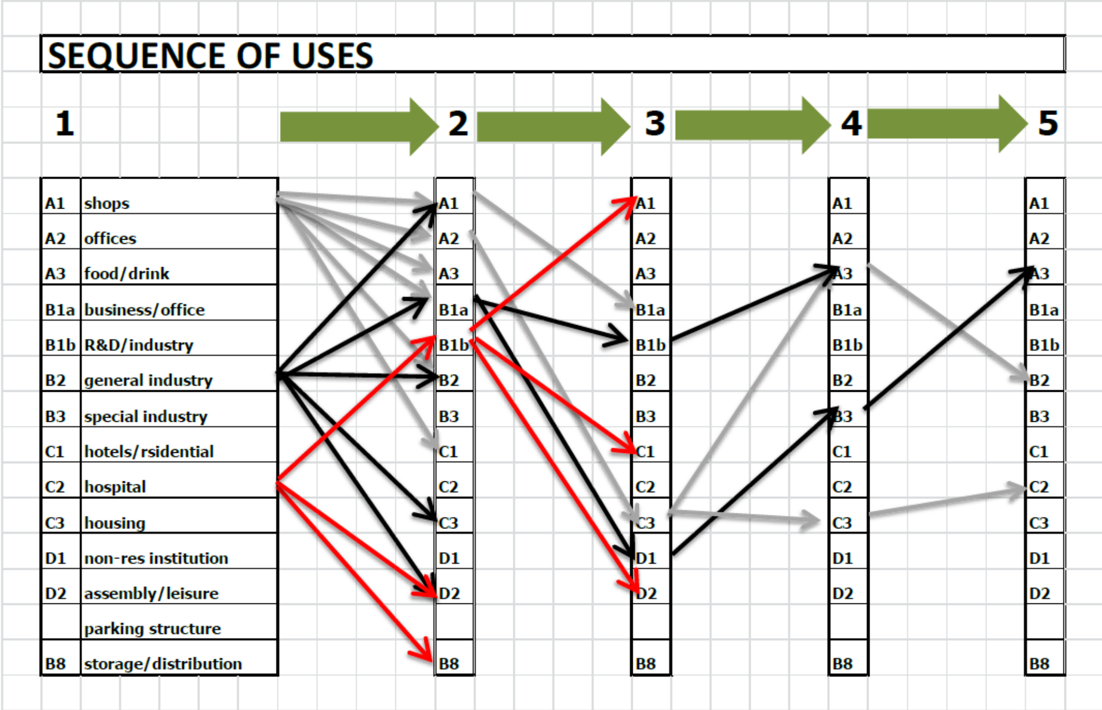

Figure 5.26 Implementation Option 1: central legal control: applies to all uses It is recognized that the implementation of Double-Design would require a comprehensive overhaul of the planning and building control regulatory framework. However, Double-Design would have to apply universally and even internationally to provide a level playing field for all custodians. Within this framework, the implementation strategy could require first uses to become all second and subsequent uses. Alternatively, specific first uses would be required to be transformable into a particular range of second and subsequent uses. The detailed assessments of compatibility would influence this approach.

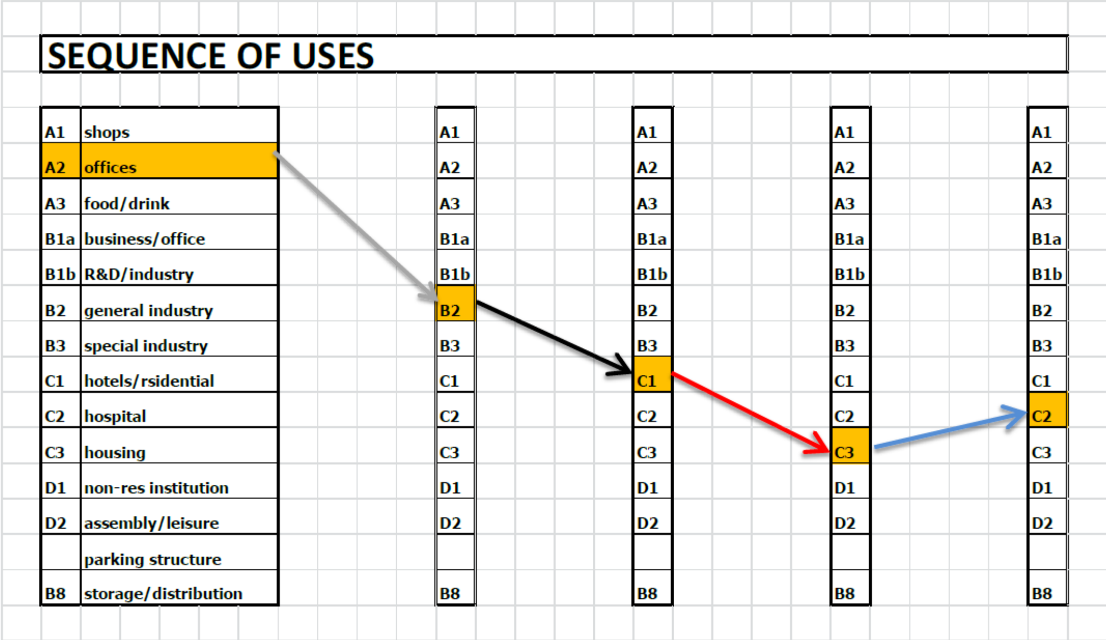

Figure 5.27 Implementation Option 2: a competitive initiative by the individual custodian. A radical alternative approach to implementation, and one that fits more comfortably within a capitalist market framework, allows the initiative for Double-Design to lie with the individual custodian. Thus, a custodian would approach the planning authority with a design that demonstrated that, in addition to its initial use, it was capable of sustaining other uses that are specified. As a reward for this 'far-sightedness', the custodian would be automatically allowed to switch from one use to any of the other 'specified' uses. Custodians would thus be encouraged to think long-term about the value of their investment, taking into account the reduced uncertainty that the robustness of the design would allow. (Imagine how many retail high street investors facing bankruptcy today, 2021, would have benefited from Double-Design?) A further 'intermediate' approach to implementation could be based on an analysis of groups of uses clustered together based on identified compatibilities: this approach would lead to planning applications being made for specific groups of uses rather than an individual use.

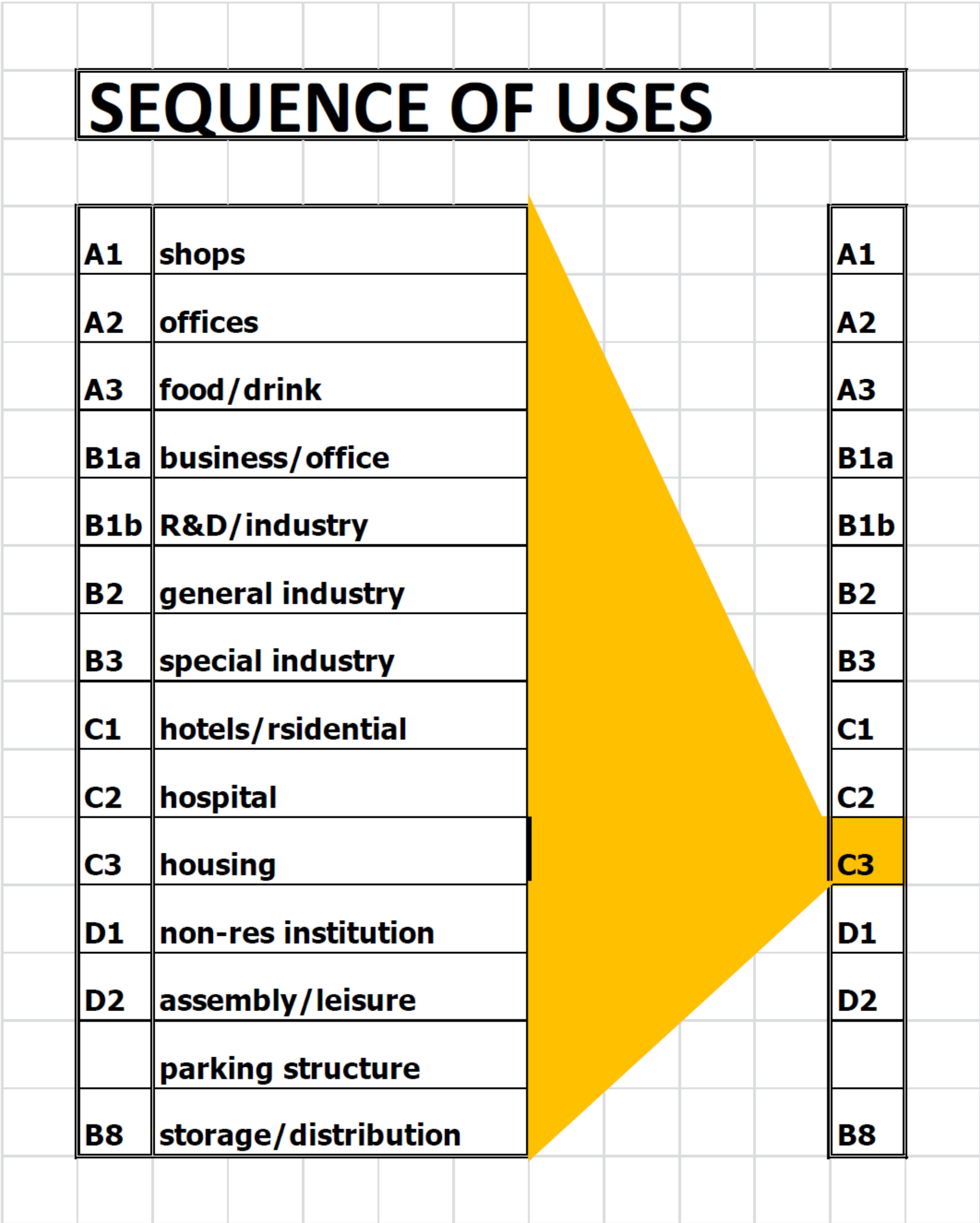

Figure 5.28 Implementation Option 3: all uses must be capable of becoming housing. The application of Double-Design to housing will lead to a different balance between the user and the custodian. If the custodian doesn't know how the user will occupy and use and want to change the space and equipment, then the custodian must incorporate the needed flexibility. The open-building movement anticipates just this change. As a practical matter and observing that, at least in the UK, there is always a shortage of housing, the very least that could be sought is to ensure that all new buildings should be capable of change to housing.

Given the specialist nature of some activities and the observed demand for them, it is possible that some buildings could be exempted from Double-Design regulations. On these grounds, for example, hospitals could be excluded. However, there would be significant benefits from Double-Design *within the hospital,* justifying the universal application of Double-Design. Institutions like universities and hospitals, that contain a variety of spaces, in many ways a microcosm of a city, would benefit from Double-Design.

5.3.2.2 Compatibility Factors

Floor loading and floor-to-floor heights are the two principal factors in the initial analysis. The third principle factor is plan depth, but this is explicitly generated by the scale of development, which Double-Design does not determine. Some building projects may not lend themselves to the easy application of Double-Design. However, as noted in section 3.5 above, the wide range and imaginative scope of observed second uses suggest that the development and analysis of compatibility should maintain that same openness. There are sensible limits to the applicability of Double-Design. Some buildings are too small or too specialized for the application to be realistic. However, Double-Design can be seen as a broadly defined design policy incorporating a nuanced spectrum of design requirements:

Level 1 FLEXIBILITY (capable of different physical arrangements)

Level 2 ADAPTABILITY (capable of different social uses)

Level 3 SPECIFIC MATERIAL AND FUNCTIONAL LIFE WITH MATERIAL RECYCLING

Level 4 LONG LIFE WITH DOUBLE-DESIGN

With a concern for the transition from first uses to housing, a threshold based upon scale could be set at the size of, say, five houses or 465 m^2 (5 x 93 m^2) (Crosby, 2015).

Applying this threshold to the uses shows how the double-design spectrum of policies could be applied to the small (less than 465) and large (more than 465). This spectrum of design approaches has been developed for application to new construction and is illustrated in Figure 5.29.

PRELIMINARY APPLICATION OF DOUBLE-DESIGN POLICY						
	FIRST USE		Level 1 FLEXIBILITY (capable of different physical arrangements)	Level 2 ADAPTABILITY (capable of different social uses)	Level 3 SPECIFIC MATERIAL AND FUNCTIONAL LIFE WITH MATERIAL RECYCLING	Level 4 LONG LIFE WITH DOUBLE-DESIGN
A1	shops	≤ 465				
		≥ 465				
A2	offices	≤ 465				
		≥ 465				
A3	food/drink	≤ 465				
		≥ 465				
B1a	business/office	≤ 465				
		≥ 465				
B1b	R&D/industry	≤ 465				
		≥ 465				
B2	general industry	≤ 465				
		≥ 465				
B3	special industry	≤ 465				
		≥ 465				
C1	hotels/residential	≤ 465				
		≥ 465				
C2	hospital	≤ 465				
		≥ 465				
C3	housing	≤ 465				
		≥ 465				
D1	non-res institution	≤ 465				
		≥ 465				
D2	assembly/leisure	≤ 465				
		≥ 465				
	parking structure	≤ 465	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
		≥ 465				
B8	storage/distribution	≤ 465				
		≥ 465				

Figure 5.29 Applicability of Double-Design and associated design policies to range of building uses

It is suggested here that all 'small' projects should incorporate flexibility and adaptability. They should be made of re-usable components, thus contributing to the conservation of resources despite having a specified short material and functional life. This application is arbitrary and is included here because the small projects will not contribute significantly to the overall sustainability goals. The desirability of the 'small' projects having a long life with Double-Design characteristics will be explored later. Housing is not anticipated to change use, although this cannot be ruled out. Housing, therefore, incorporates flexibility and adaptability with a long life but without any formal presumption to reuse. All other uses, subject to the compatibility analysis, will be subject to Double-Design rules. While there are undoubtedly situations, projects and enterprises for which the future is wholly uncertain, there are also situations in which the uncertainty may be regarded as bounded. For example, in seeking to establish an optimum arrangement of teaching rooms for educational institutions, optimization approaches focus on the size and number of rooms. The efficiency with which the spaces are used becomes an additional input to the timetabling strategies (Fawcett, 2010; Abramson & Abela, 1992) (Pearce, 1996) (Kenny & Foster, 1986). Custodians may be confident that an initial function will last indefinitely and plan to optimize space within a limited and defined range of activities. Even in these circumstances, the application of Double-Design will facilitate change if it is, after all, needed. Kincaid studied the issues related to the reuse of existing buildings (Kincaid, 2002). Kincaid reduced characteristics of the building stock relevant to potential reuse to 25 variables in three groups: location and site, space, fabric and structure. In assessing the viability of the reuse of a specific existing building, Kincaid's methodology requires a review of the extent to which modification of each variable is possible and, subsequently, an assessment of servicing modification. Kincaid identifies 77 distinct uses derived from the Standard Industrial Classification list to assess the potential uses of an existing building. There follows a three-stage process through which the demand characteristics are compared to the available supply-side features (Kincaid, 2002, pp. 22–65). In developing a strategy for new-build, a "matrix of compatibility" is needed to enable custodians to be sure that their buildings will last because both the building fabric and the long-term usefulness of the spaces need to be guaranteed. The compatibility matrices will array a classification of activities against a category of spaces. The matrices will build upon the pioneering work of Kincaid, whose "Use Comparator" was intended to facilitate the search for possible new uses for an existing building (Kincaid, 2002). In Kincaid's study, the physical characteristics of an existing building were measured and readily compared with the physical requirements of the 77 uses.

With Double-Design, there is a need to aggregate the requirements for many uses. Starting with a design for a specific activity, what has to be changed to allow for an additional specific activity? Through an iterative process, the inclusivity of the design can be defined to allow for more activities. Design must consider the physical parameters (space, height, services, floor loading) needed to support both initial activities and changes in use that may or may not be known. For example, demands are made upon space in buildings by *human activities, furniture and equipment, structure, protective fabric, provision for services, provision for maintenance and replacement.* The range and quantity of examples of building reuse suggest that there are already some principles of compatibility at work that facilitate a change from initial to later uses. However, to ensure a smoother and faster transition from initial to later use, it is necessary to examine the physical criteria that enable particular uses. Kincaid's study was intended to help decision-makers decide whether to move into an *existing building*. Kincaid was able to use survey questionnaires to prioritize the factors, and the physical criteria included by Kincaid are:

- FLOOR LOADINGS, establish lower limits of acceptability
- STRENGTH
- SLAB TO SLAB HEIGHT, set lower limits of acceptability
- DEPTH OF FLOOR PLATE, four depth ranges are identified (Kincaid, 2002).

5.3.2.3 Floor Loading

Floor loading is considered first, with a simplified list of building uses. Two steps have been followed to generate the initial matrix. First, the use class orders from UK planning legislation have been reviewed, and classes of use that appear intrinsically unlikely to be susceptible to re-use due to the nature of processes and their non-compatibility with other activities are omitted. These include B4–B7 which cover a range of special industrial processes (*The Town and Country Planning (Use Classes) Order 1987, UK Statutory Instruments 1987 No. 764*, 1987) Second, the recommended floor loadings have been derived from BS 6399, which gives dead and minimum recommended imposed loads for designing buildings. This guidance applies to: new buildings and new structures; alterations and additions to existing buildings and existing structures; and existing construction on change of use (BS 6399 part 1 Loading for buildings Part 1. Code of practice for dead and imposed loads, 1996, table 1). The relationship between the use classes and the list of activities for which specified floor loadings are approximate. The closest equivalent between the two lists has been used. The loads take no account of lateral, wind, dynamic or emergency loadings, or of the "consequence classes" in which higher standards are applied concerning the risks to people. The essence of the approach is anticipated by the advice from the 'designing buildings' website:

> Allowing for higher live loads increases the flexibility of a building, but also increases the cost. For example, UK office buildings have historically been designed and marketed with live loadings of 3.5–4.0 kN/m2; however, this may be an over-provision. 2.5 kN/m2 for floors above the ground floor and 3.0 kN/m2 at, or below, ground floor over may be more appropriate, with 7.5 kN/m2 over 5% of the floor area to allow for future flexibility. (*Designing Buildings: Floor Loading*, 2022)

There are two further factors to be considered. The first is whether the standardized loading following codes is consistent with real-life use (Miller & Hume, 2015). It would be possible to design for the first use and qualify any future loads by in situ load testing. The other factor is the extent to which, with some structural redundancy, loads are redistributed away from components under stress. Miller & Hume conclude their study:

> On the whole, historic buildings function quite well, which may be one of the reasons they have lasted. Should they change use, this does not necessarily have to mean significant changes of loading. Discussion with client and architect and careful consideration of the real actions is essential in order to minimise the strengthening required to that strictly necessary. Loads should not be applied without thought or to a worn mantra. This article does not suggest compromising on risks of overloading, but rather a thorough examination of use. Unrealistic

design loads should not be used when it is impossible to generate that load or when, with a little forethought and simple guidelines on activity, high loading can be avoided. (Miller & Hume, 2015, p. 43)

FLOOR LOADING MATRIX OF COMPATIBILITY

FIRST USE		UD load kN/m2	concentrated kN	SECOND USE: shops	shops	offices	offices	food/drink	food/drink	business/office	business/office	R&D/industry	R&D/industry	general industry	general industry	special industry	special industry
				4	3.6	2.5	2.7	3	4.5	2.5	2.7	5	4.5	5	4.5	5	4.5
A1	shops	4	3.6			1.5	0.9	1	-1	1.5	0.9	-1	-1	-1	-1	-1	-1
A2	offices	2.5	2.7	-2	-2			-1	-2	0	0	-3	-2	-3	-2	-3	-2
A3	food/drink	3	4.5	-1	0.9	0.5	1.8			0.5	1.8	-2	0	-2	0	-2	0
B1a	business/office	2.5	2.7	-2	-1	0	0	-1	-2			-3	-2	-3	-2	-3	-3
B1b	R&D/industry	5	4.5	1	0.9	2.5	1.8	2	0	2.5	1.8			0	0	0	0
B2	general industry	5	4.5	1	0.9	2.5	1.8	2	0	2.5	1.8	0	0			0	0
B3	special industry	5	4.5	1	0.9	2.5	1.8	2	0	2.5	2.7	0	0	0	0		
C1	hotels/rsidential	2	1.8	-2	-2	-1	-1	-1	-3	-1	-1	-3	-3	0	-3	-3	-3
C2	hospital	2	4.5	-2	0.9	-1	1.8	-1	0	-1	1.8	-3	0	-3	0	-3	0
C3	housing	1.5	1.4	-3	-2	-1	-1	-2	-3	-1	-1	-4	-3	-4	-3	-4	-3
D1	non-res institution	4	4.5	0	0.9	1.5	1.8	1	0	1.5	1.8	-1	0	-1	0	-1	0
D2	assembly/leisure	4	3.6	0	0	1.5	0.9	1	-1	1.5	0.9	-1	-1	-1	-1	-1	-1
	parking structure	2	9	-2	5.4	-1	6.3	-1	4.5	-1	6.3	-3	4.5	-3	4.5	-3	4.5
B8	storage/distribution	6.5	9	2.5	5.4	4	6.3	3.5	4.5	4	6.3	1.5	4.5	1.5	4.5	1.5	4.5

FIRST USE		UD load kN/m2	concentrated kN	hotels/rsidential	hotels/rsidential	hospital	hospital	housing	housing	non-res institution	non-res institution	assembly/leisure	assembly/leisure	parking structure	parking structure	storage/distribution	storage/distribution
				2	1.8	2	4.5	1.5	1.4	4	4.5	4	3.6	2	9	6.5	9
A1	shops	4	3.6	2	1.8	2	-1	2.5	2.2	0	-1	0	0	2	-5.4	-2.5	-6.4
A2	offices	2.5	2.7	0.5	0.9	0.5	-2	1	0.3	-2	-2	-2	-1	0.5	-6.3	-4	-6.3
A3	food/drink	3	4.5	1	2.7	1	0	1.5	3.1	-1	0	-1	0.9	1	-4.5	-3.5	-4.5
B1a	business/office	2.5	2.7	0.5	0.9	0.5	-2	1	1.3	-2	-2	-2	-1	0.5	-6.3	-4	-6.3
B1b	R&D/industry	5	4.5	3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
B2	general industry	5	4.5	3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
B3	special industry	5	4.5	3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
C1	hotels/rsidential	2	1.8			0	-3	0.5	0.4	-2	-2	-2	-2	0	-7.2	-4.5	-7.2
C2	hospital	2	4.5	0	2.7			0.5	3.1	-2	0	-2	0.9	0	-4.5	-4.5	-4.5
C3	housing	1.5	1.4	-1	-0	-1	-3			-3	-3	-3	-2	-0.5	-7.6	-5	-7.6
D1	non-res institution	4	4.5	2	2.7	2	0	2.5	3.1			0	0.9	2	-4.5	-2.5	-4.5
D2	assembly/leisure	4	3.6	2	1.8	2	-1	2.5	2.2	0	-1			2	-5.4	-2.5	-6.4
	parking structure	2	9	0	7.2	0	4.5	0.5	7.6	-2	4.5	-2	5.4			-4.5	0
B8	storage/distribution	6.5	9	4.5	7.2	4.5	4.5	5	7.6	2.5	4,5	2.5	5.4	4.5	4.5		

(red)	needed	SHOWS THE ACTUAL AMOUNT NEEDED TO MATCH THE REQUIREMENTS OF THE SECOND USE
(green)	spare	SHOWS THE ACTUAL AMOUNT OF SPARE CAPACITY WHEN ACCOMMODATING THE SECOND USE

Figure 5.30 Compatibility Matrix: floor loading: By comparing the floor loading needed for the initial use with that required for a possible second use, the floor loading 'needed'(shown in red) or 'spare' (shown in green) is identified.

Figure 5.30 sets out the floor loadings recommended. On examination, it is clear that the *parking structure* and *B8 storage/distribution* appear anomalous in needing exceptionally high live loads. A second matrix shown in Figure 5.31 applies the highest common factor to all the initial uses other than *parking structure* and *B8 storage/distribution.* Again, the floor loading 'needed' (shown in red) or 'spare' (shown in green) is identified.

	FLOOR LOADING MATRIX OF COMPATIBILITY showing application of HCF			SECOND USE	shops		offices		food/drink		business/office		R&D/industry		general industry		special industry		hotels/rsidential		hospital		housing		non-res institution		assembly/leisure		parking structure		storage/distribution	
		UD load kN/m2	concentrated kN		4	3.6	2.5	2.7	3	4.5	2.5	2.7	5	4.5	5	4.5	5	4.5	2	1.8	2	4.5	1.5	1.4	4	4.5	4	3.6	2	9	6.5	9
	FIRST USE																															
A1	shops	5	4.5				2.5	1.8	2	0	2.5	1.8	0	0	0	0	0	0	3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
A2	offices	5	4.5		1	0.9			2	0	2.5	1.8	0	0	0	0	0	0	3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
A3	food/drink	5	4.5		1	0.9	2.5	1.8			2.5	1.8	0	0	0	0	0	0	3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
B1a	business/office	5	4.5		1	0.9	2.5	1.8	2	0			0	0	0	0	0	0	3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
B1b	R&D/industry	5	4.5		1	0.9	2.5	1.8	2	0	2.5	1.8			0	0	0	0	3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
B2	general industry	5	4.5		1	0.9	2.5	1.8	2	0	2.5	1.8	0	0			0	0	3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
B3	special industry	5	4.5		1	0.9	2.5	1.8	2	0	2.5	1.8	0	0	0	0			3	2.7	3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
C1	hotels/residential	5	4.5		1	0.9	2.5	1.8	2	0	2.5	1.8	0	0	0	0	0	0			3	0	3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
C2	hospital	5	4.5		1	0.9	2.5	1.8	2	0	2.5	1.8	0	0	0	0	0	0	3	2.7			3.5	3.1	1	0	1	0.9	3	-4.5	-1.5	-4.5
C3	housing	5	4.5		1	0.9	2.5	1.8	2	0	2.5	1.8	0	0	0	0	0	0	3	2.7	3	0			1	0	1	0.9	3	-4.5	-1.5	-4.5
D1	non-res institution	5	4.5		1	0.9	2.5	1.8	2	0	2.5	1.8	0	0	0	0	0	0	3	2.7	3	0	3.5	3.1			1	0.9	3	-4.5	-1.5	-4.5
D2	assembly/leisure	5	4.5		1	0.9	2.5	1.8	2	0	2.5	1.8	0	0	0	0	0	0	3	2.7	3	0	3.5	3.1	1	0			3	-4.5	-1.5	-4.5
	parking structure	2	9		-2	5.4	-1	6.3	-1	4.5	-1	6.3	-3	4.5	-3	4.5	-3	4.5	0	7.2	0	4.5	0.5	7.6	-2	4.5	-2	5.4			-4.5	0
B8	storage/distributior	6.5	9		2.5	5.4	4	6.3	3.5	4.5	4	6.3	1.5	4.5	1.5	4.5	1.5	4.5	4.5	7.2	4.5	4.5	5	7.6	2.5	4.5	2.5	5.4	4.5	4.5		

needed	SHOWS THE ACTUAL AMOUNT NEEDED TO MATCH THE REQUIREMENTS OF THE SECOND USE
spare	SHOWS THE ACTUAL AMOUNT OF SPARE CAPACITY WHEN ACCOMMODATING THE SECOND USE

Figure 5.31 Compatibility Matrix: floor loading: shows by how much the floor loading for the initial use needs to increase to accommodate all the identified second uses.

5.3.2.4 Floor-to-floor heights

Floor-to-floor height is the second indicative factor in the search for degrees of compatibility.

USE CLASS ORDERS	KINCAID USE CATEGORIES	FLOOR TO FLOOR HEIGHT
Class A1. Shops	4 TO 10	**5.5**
Class A2. Financial and professional services	32 TO 33	**4.5**
Class A3. Food and drink	11	**4.2**
Class B1. Business	35 TO 50	
(a)as an office other than a use within class A2 (financial and professional services),		**4.5**
(b)for research and development of products or processes, or		**4.5**
(c)for any industrial process,		**5.5**
Class B2. General industrial	12 TO 31	**5.5**
Class B3. Special Industrial Group A		**5.5**
Class B8. Storage or distribution		**10.97**
Use for storage or as a distribution centre.		
Class C1. Hotels and hostels	51 TO 53	**3.6**
Class C2. Residential institutions	54	**4.5**
Class C3. Dwellinghouses	1 TO 3	**3.6**
Class D1. Non-residential institutions	55 TO 58	**4.5**
(f)as a public library or public reading room,	61	**5.5**
(g)as a public hall or exhibition hall,		
Class D2. Assembly and leisure		
(a)a cinema, (b)a concert hall,	63 63	**6.1**
(c)a bingo hall or casino,	63	
(d)a dance hall,	63	
parking structures		**3.5**

Figure 5.32 Compatibility Matrix: floor-to-floor heights

Figure 5.32 summarizes the published guidance on the floor-to-floor heights. The entire table is included as Appendix Six. Note that only uses that are, *a priori*, suitable for the application of Double-Design to initial uses are included in the table. As expected, there is a wide range of floor-to-floor heights.

	INDICATIVE FLOOR TO FLOOR MATRIX OF COMPATIBILITY	F TO F (m)	SECOND USE	shops	offices	food/drink	business/office	R&D/industry	general industry	special industry	hotels/rsidential	hospital	housing	non-res institution	assembly/leisure	parking structure	storage/distribution
				5.5	4.5	4.2	4.5	4.5	5.5	5.5	3.6	4.5	3.6	4.5	6.1	3.5	11
	FIRST USE																
A1	shops	5.5			1	1.3	1	1	0	0	1.9	1	1,9	1	-0.6	2	-5.5
A2	offices	4.5		-1		0.3	0	0	-1	-1	0.9	0	0.9	0	-1.6	1	-6.5
A3	food/drink	4.2		-1.3	-0.3		-0.3	-0.3	-1.3	-1.3	0.6	-0.3	0.6	-0.3	-1.9	0.7	-6.8
B1a	business/office	4.5		-1	0	0.3		0	-1	-1	0.9	0	0.9	0	-1.6	1	-6.5
B1b	R&D/industry	4.5		-1	0	0.3	0		-1	-1	0.9	0	0.9	0	-1.6	1	-6.5
B2	general industry	5.5		0	1	1.3	1	1		0	1.9	1	1.9	1	-0.6	2	-5.5
B3	special industry	5.5		0	1	1.3	1	1	0		1.9	1	1.9	1	-0.6	2	-5.5
C1	hotels/residential	3.6		-1.9	-0.9	-0.6	-0.9	-0.9	-1.9	-1.9		-0.9	0	-0.9	-2.5	0.1	-7.4
C2	hospital	4.5		-1	0	0.3	0	0	-1	-1	0.9		0.9	0	-1.6	1	-6.5
C3	housing	3.6		-1.9	-0.9	-0.6	-0.9	-0.9	-1.9	-1.9	0	-0.9		-0.9	-2.5	0.1	-7.4
D1	non-res institution	4.5		-1	0	0.3	0	0	-1	-1	0.9	0	0.9		-1.6	1	-6.5
D2	assembly/leisure	6.1		0.6	1.6	1.8	1.6	1.6	0.6	0.6	2.5	1.6	2.5	1.6		2.6	-4.9
	parking structure	3.5		-2	-1	-0.7	-1	-1	-2	-2	-0.1	-1	-0.1	-1	-2.6		-7.5
B8	storage/distribution	11		5.5	6.5	6.8	6.5	6.5	5.5	5.5	7.4	6.5	7.4	6.5	4.9	7.5	

[green] SHOWS AMOUNT OF FIRST USE INDICATIVE F-F HEIGHT THAT IS SPARE WHEN CONVERTED TO SECOND USE
[red] SHOWS AMOUNT OF FIRST USE NEEDING TO BE ADDED TO MATCH SECOND USE REQUIREMENT

Figure 5.33 Compatibility Matrix: floor to floor heights

Within the matrix above, the figures in green show the amount (m) of floor-to-floor heights in each first use that is spare when a second use is installed. Again, within the matrix, the figures in red show the amount of floor-to-floor heights needing to be added to accommodate the second use.

	INDICATIVE FLOOR TO FLOOR MATRIX OF COMPATIBILITY	F TO F (m)	SECOND USE	shops	offices	food/drink	business/office	R&D/industry	general industry	special industry	hotels/residential	hospital	housing	non-res institution	assembly/leisure	parking structure	storage/distribution
				5.5	4.5	4.2	4.5	4.5	5.5	5.5	3.6	4.5	3.6	4.5	6.1	3.5	11
	FIRST USE																
A1	shops	5.5			18.2	23.6	18.2	18.2	0	0	34.5	18.2	34.5	18.2	-11	36.4	-100
A2	offices	4.5		-22		6.67	0	0	-22	-22	20	0	20	0	-36	22.2	-144
A3	food/drink	4.2		-31	-7.1		-7.1	-7.1	-31	-31	14.3	-7.1	14.3	-7.1	-45	16.7	-162
B 1a	business/office	4.5		-22	0	6.67		0	-22	-22	20	0	20	0	-36	22.2	-144
B 1b	R&D/industry	4.5		-22	0	6.67	0		-22	-22	20	0	20	0	-36	22.2	-144
B2	general industry	5.5		0	18.2	23.6	18.2	18.2		0	34.5	18.2	34.5	18.2	-11	36.4	-100
B3	special industry	5.5		0	18.2	23.6	18.2	18.2	0		34.5	18.2	34.5	18.2	-11	36.4	-100
C1	hotels/residential	3.6		-53	-25	-17	-25	-25	-53	-53		-25	0	-25	-69	2.78	-206
C2	hospital	4.5		-22	0	6.67	0	0	-22	-22	20		20	0	-36	22.2	-144
C3	housing	3.6		-53	-25	-17	-25	-25	-53	-53	0	-25		-25	-69	2.78	-206
D1	non-res institution	4.5		-22	0	6.67	0	0	-22	-53	20	0	20		-36	22.2	-144
D2	assembly/leisure	6.1		9.84	26.2	31.1	26.2	26.2	9.84	9.84	41	26.2	41	26.2		42.6	-80.3
	parking structure	3.5		-57	-29	-20	-29	-29	-57	-57	-0.6	-29	-0.6	-29	-74		-214
B8	storage/distribution	11		50	59.1	61.8	59.1	59.1	50	50	67.3	59.1	67.3	59.1	44.5	68.2	

9.84	SHOWS PERCENTAGE OF FIRST USE INDICATIVE F-F HEIGHT THAT IS SPARE WHEN CONVERTED TO SECOND US
-57	SHOWS PERCENTAGE OF FIRST USE NEEDING TO BE ADDED TO MATCH SECOND USE REQUIREMENT

Figure 5.34 Compatibility Matrix: floor to floor heights: spare and needed amounts expressed as percentages

Figure 5.34 displays the same data, but ‘needs’ and ‘spare’ are expressed as percentages. To explore the possible advantages of an intermediate floor-to-floor height, a further matrix was prepared. This is shown in Figure 5.35. The initial uses causing the most difficulty (the assembly/leisure and storage/distribution categories) are omitted. Within the matrix, the figures in green show the percentage of floor-to-floor heights in each first use that is spare when a second use is installed. The resulting matrix reveals that many uses would be accommodated but that there are significant redundancies. These are suggested by the percentages of floor-to-floor heights indicated as spare in the matrix below.

	INDICATIVE FLOOR TO FLOOR MATRIX OF COMPATIBILITY hcf applied	F TO F (m)	SECOND USE	shops	offices	food/drink	business/office	R&D/industry	general industry	special industry	hotels/rsidential	hospital	housing	non-res institution	assembly/leisure	parking structure	storage/distribution
				5.50	4.50	4.20	4.50	4.50	5.50	5.50	3.60	4.50	3.60	4.50	6.10	3.50	11.00
	FIRST USE																
A1	shops	5.50			18.18	23.64	18.20	18.20	0.00	0.00	34.50	18.20	34.50	18.20		36.36	
A2	offices	5.50		0.00		23.64	18.18	18.20	0.00	0.00	34.50	18.20	34.50	18.20		36.40	
A3	food/drink	5.50		0.00	18.18		18.20	18.20	0.00	0.00	34.50	18.20	34.50	18.20		36.40	
B1a	business/office	5.50		0.00	18.18	23.64		18.20	0.00	0.00	34.50	18.20	34.50	18.20		36.40	
B1b	R&D/industry	5.50		0.00	18.18	23.64	18.20		0.00	0.00	34.50	18.20	34.50	18.20		36.40	
B2	general industry	5.50		0.00	18.18	23.64	18.20	18.20		0.00	34.50	18.20	34.50	18.20		36.40	
B3	special industry	5.50		0.00	18.20	23.60	18.20	18.20	0.00		34.50	18.20	34.50	18.20		36.40	
C1	hotels/residential	5.50		0.00	18.18	23.64	18.20	18.20	0.00	0.00		18.20	34.50	18.20		36.40	
C2	hospital	5.50		0.00	18.20	23.60	18.20	18.20	0.00	0.00	34.50		34.50	18.20		36.40	
C3	housing	5.50		0.00	18.20	23.60	18.20	18.20	0.00	0.00	34.50	18.20		18.20		36.40	
D1	non-res institution	5.50		0.00	18.20	23.60	18.20	18.20	0.00	0.00	34.50	18.20	34.50			36.40	
	parking structure	5.50		0.00	18.20	23.60	18.20	18.20	0.00	0.00	34.50	18.20	34.50	18.20		36.40	

18.20	SHOWS PERCENTAGE OF FIRST USE INDICATIVE F-F HEIGHT THAT IS SPARE WHEN CONVERTED TO SECOND USE

Figure 5.35 Compatibility Matrix: floor to floor heights based upon 5.50m

5.3.2.5 Depth of Space

The third component of compatibility assessment is the most taxing. It is concerned with the depth of spaces needed to accommodate activities. The shape of spaces is inextricably linked with their depth and scale, so assessing space/depth for different uses is more complex than with single-factor determinants like floor loading and floor-to-floor heights. Steadman et al. draw attention to the "loose relationship of form to function" (Steadman et al., 2000, p. 73). Although their purpose was to simplify the representation of built forms for developing research databases, their analysis recognized the distinction between naturally lit spaces and spaces that required artificial light. This becomes the first of their criteria for classification. As they say: "the constraints of daylighting must put an effective limit on the maximum allowable depth of side-lit space away from the windows" (Steadman et al., 2000, p. 77). For day-lit offices, the depth needed is 14 m. For offices that incorporate air-conditioning and artificial lighting, the depth is some 22 m. The second criterion covers the average size of rooms. The depth of houses, some 7 m, was influenced by the size of rooms and not so much by the need for daylighting. Rooms that are regularly assembled into larger spaces, houses, hotels, hospital wards, and the like are ***cellular spaces.*** Moving to larger rooms, there are spaces whose size is determined by function and occupancy, including lecture theatres, assembly ***halls,*** cinemas, and other auditoria. There are also large single-activity or ***open-plan*** rooms. Figure 5.36 shows a simplified analysis of the impact of lighting on building functions.

GENERIC FUNCTIONS MATRIX		
	DAYLIT	**ARTIFICIALLY LIT**
CELLULAR SPACE	domestic spaces, hotels,office accommodation	basements,
HALLS	churches, courtrooms	cinemas, theatres, tv studios
OPEN-PLAN SPACE	sports,	warehouse, distribution centre, offices, shops

Figure 5.36 Generic functions matrix based upon lighting requirements

This analysis is further developed by Steadman et al. to produce a list of Principal Form Types: These types are shown in Figure 5.37.

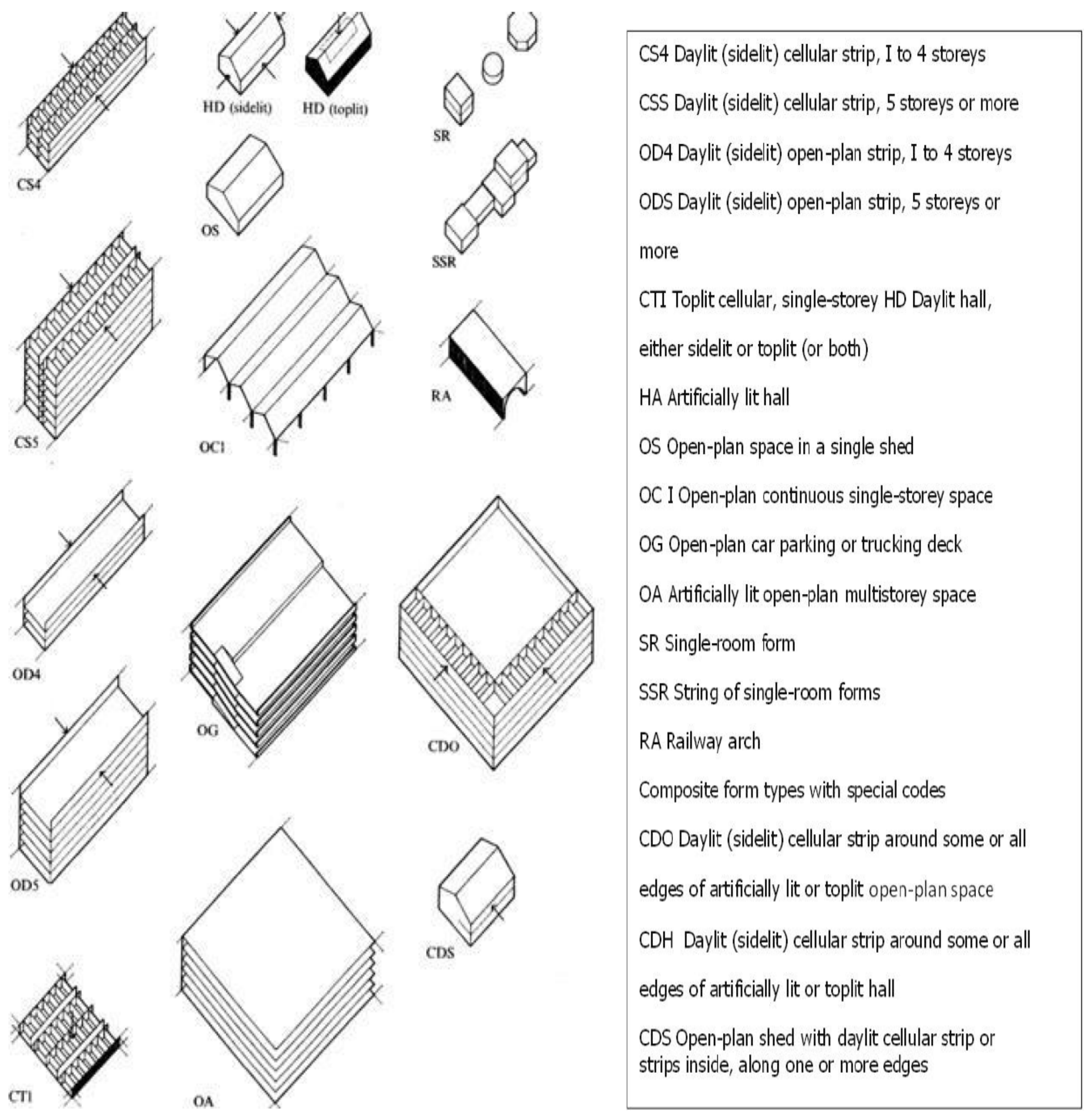

Figure 5.37 Principle form types: (taken from (Steadman et al., 2000, p. 78)

Finding spatial compatibilities amongst these disparate shapes is impossible if compatibilities were sought between 'finished', that is, fully designed, buildings. This is not the case as compatibilities are to be sought through the deconstruction of these shapes and by focusing upon the activities that have given rise to them. This assessment may well help to identify pairings where no apparent compatibility can be sought. Figure 5.38 sets out the list of uses, broken down where necessary to overcome problems of oversimplification, together with the classification of spatial types (from Steadman et al. 2000).

	FIRST USE			CELLULAR SPACE	HALLS	OPEN-PLAN
A1	shops	retail	DAYLIT			
			ARTIFICIALLY LIT			
		supermarkets	DAYLIT			
			ARTIFICIALLY LIT			
		open markets	DAYLIT			
			ARTIFICIALLY LIT			
A2	offices	cluster of workstations plus shared meeting rooms	DAYLIT			
			ARTIFICIALLY LIT			
A3	food/drink	restaurants bars cafeterias	DAYLIT			
			ARTIFICIALLY LIT			
B1a	business office	larger clusters of workstations	DAYLIT			
			ARTIFICIALLY LIT			
B1b/c	R&D/industry	research and development industrial processes compatible with residential areas	DAYLIT			
			ARTIFICIALLY LIT			
B2	general industry	manufacturing	DAYLIT			
			ARTIFICIALLY LIT			
B3	special industry		DAYLIT			
			ARTIFICIALLY LIT			
C1	hotels/hostels	hotels hostels	DAYLIT			
			ARTIFICIALLY LIT			
C2	residential institutions	residential institutions	DAYLIT			
			ARTIFICIALLY LIT			
		hospitals nursing homes	DAYLIT			
			ARTIFICIALLY LIT			
		residential schools colleges and training centres	DAYLIT			
			ARTIFICIALLY LIT			
C3	housing	dwelling house small care home	DAYLIT			
			ARTIFICIALLY LIT			
D1	non-res institution	medical centres	DAYLIT			
			ARTIFICIALLY LIT			
		primary school creche day centre	DAYLIT			
			ARTIFICIALLY LIT			
		secondary school	DAYLIT			
			ARTIFICIALLY LIT			
		higher education	DAYLIT			
			ARTIFICIALLY LIT			
		museum library exhibiion hall worship	DAYLIT			
			ARTIFICIALLY LIT			
D2	assemby and leisure	cinema concert hall dance hall	DAYLIT			
			ARTIFICIALLY LIT			
	parking structure		DAYLIT			
			ARTIFICIALLY LIT			

Figure 5.38 Building uses, lighting and spatial types; setting the scene for compatibility matrices

Each use is then reviewed with possible second uses. Given the wide range of individual circumstances attending each example of space, this assessment is informed at this stage by common sense rather than by absolute rigour. Consequently, the results are indicative only.

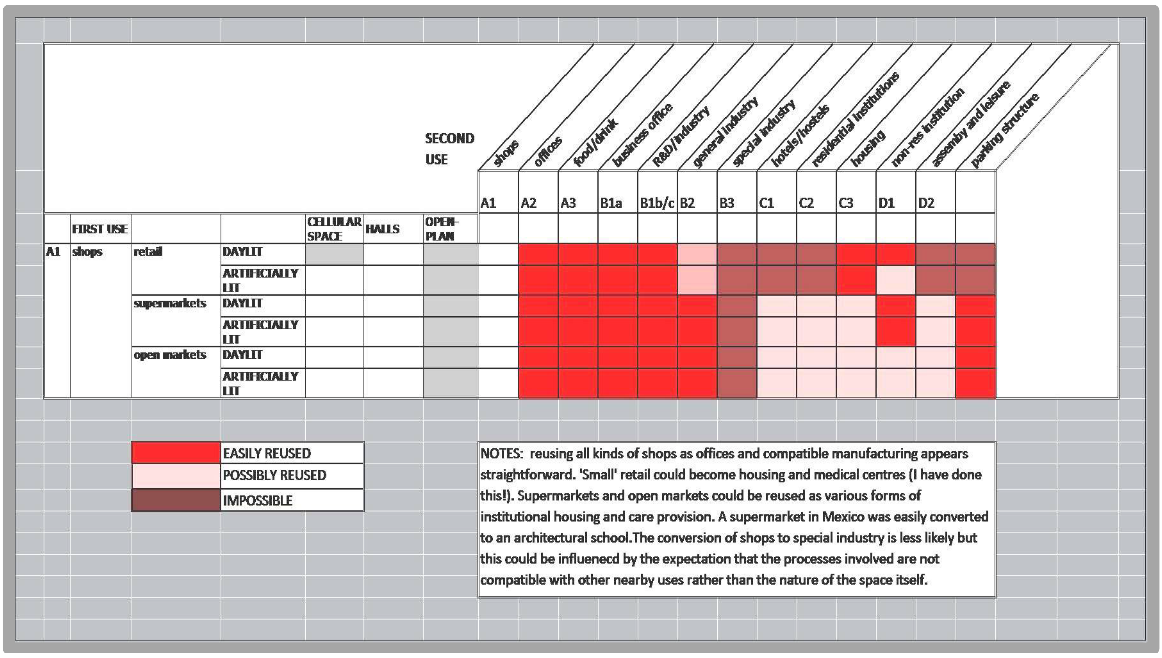

Figure 5.39 Compatibility matrix: A1 SHOPS

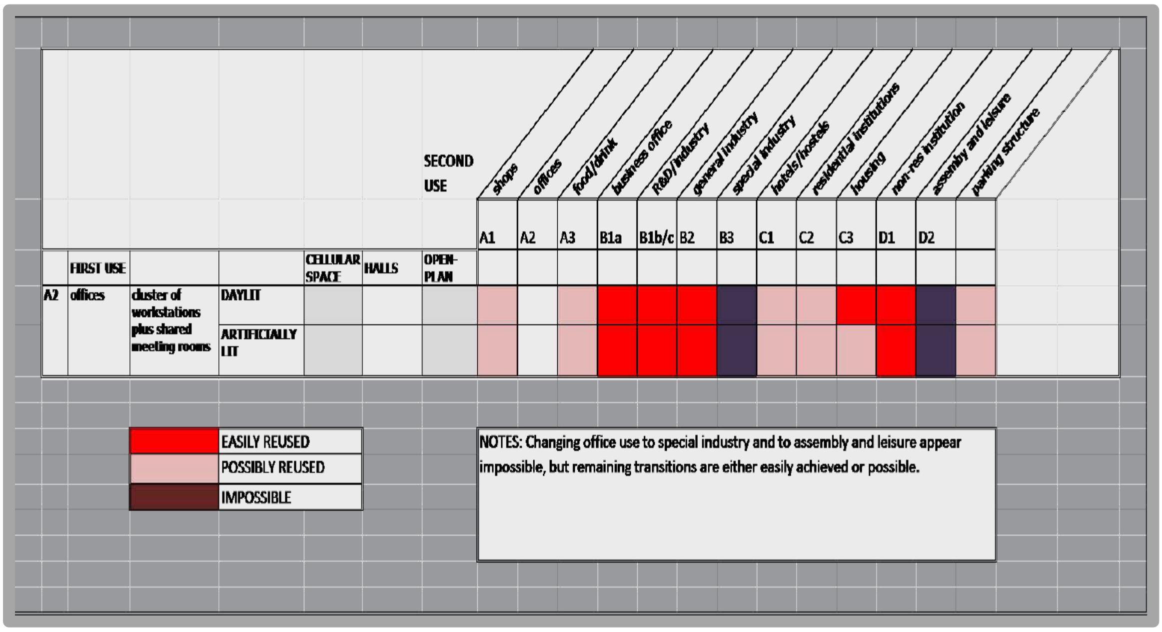

Figure 5.40 Compatibility matrix: A2 OFFICES

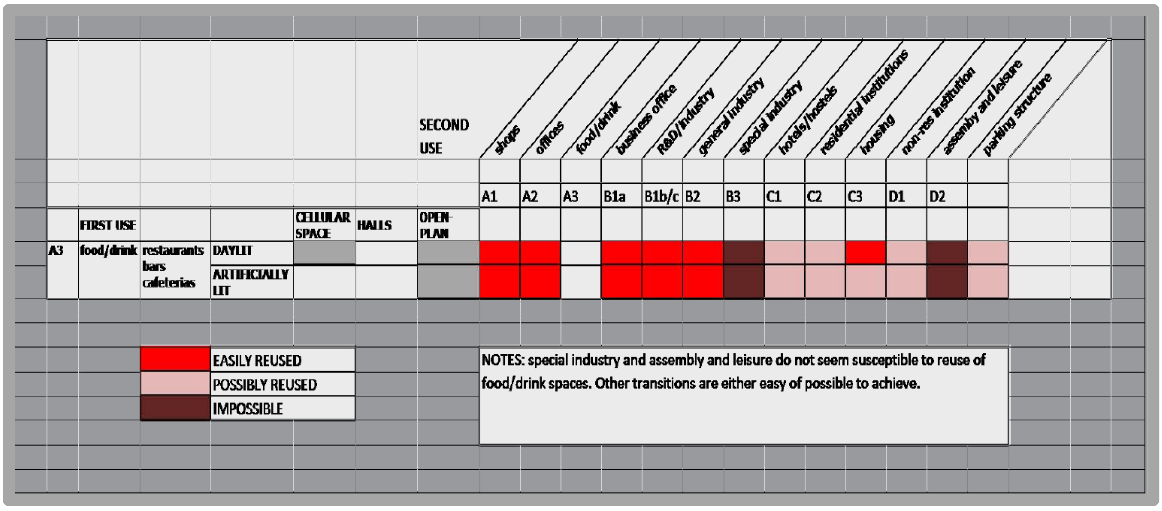

Figure 5.41 Compatibility matrix: A3 FOOD/DRINK

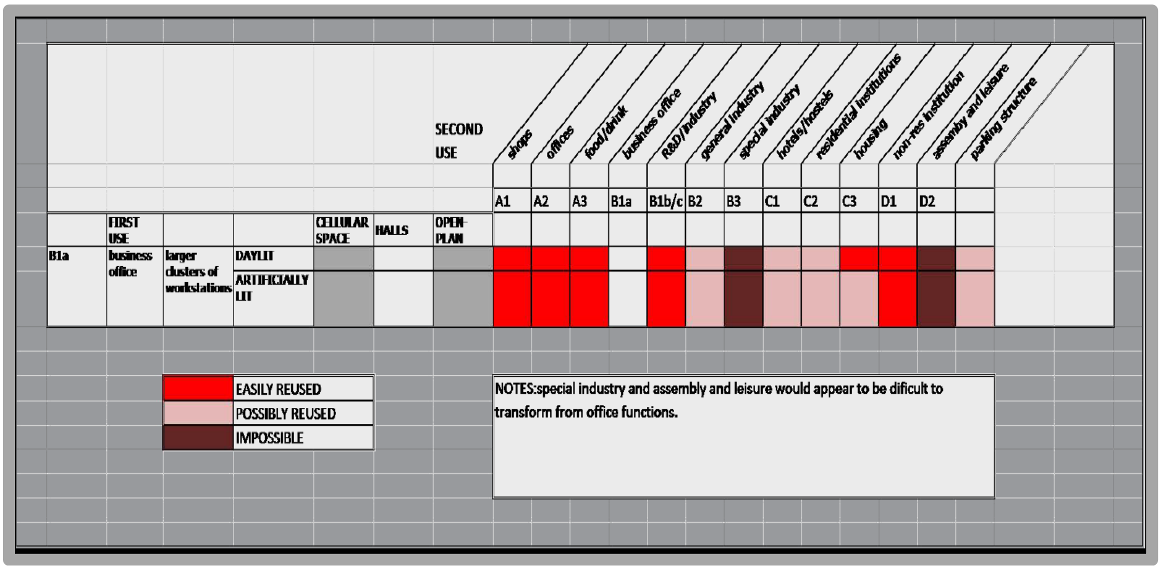

Figure 5.42 Compatibility matrix: B1a BUSINESS/OFFICE

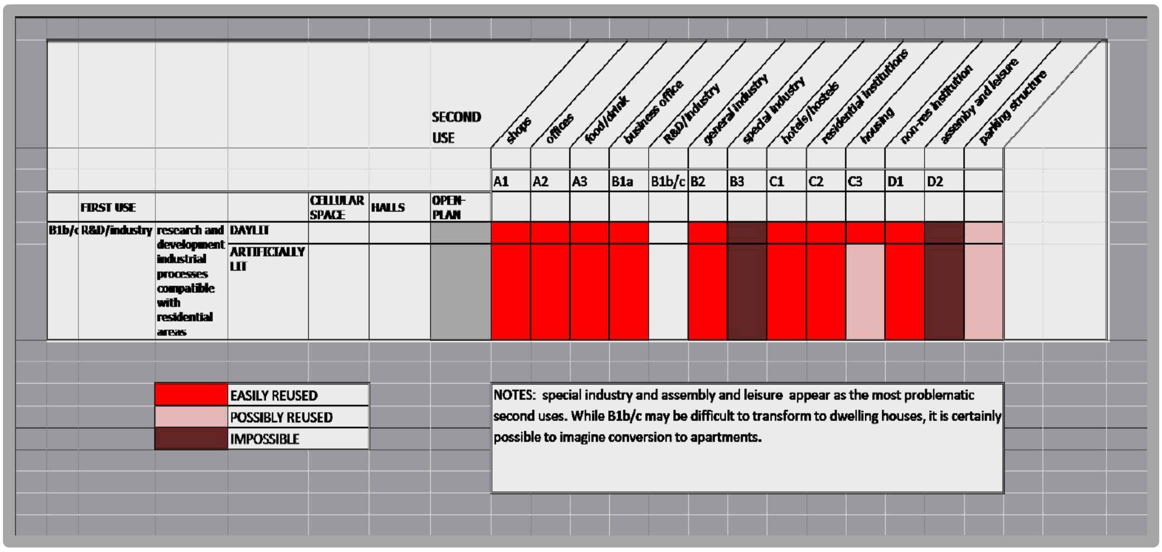

Figure 5.43 compatibility matrix: B1b/c R&D/INDUSTRY

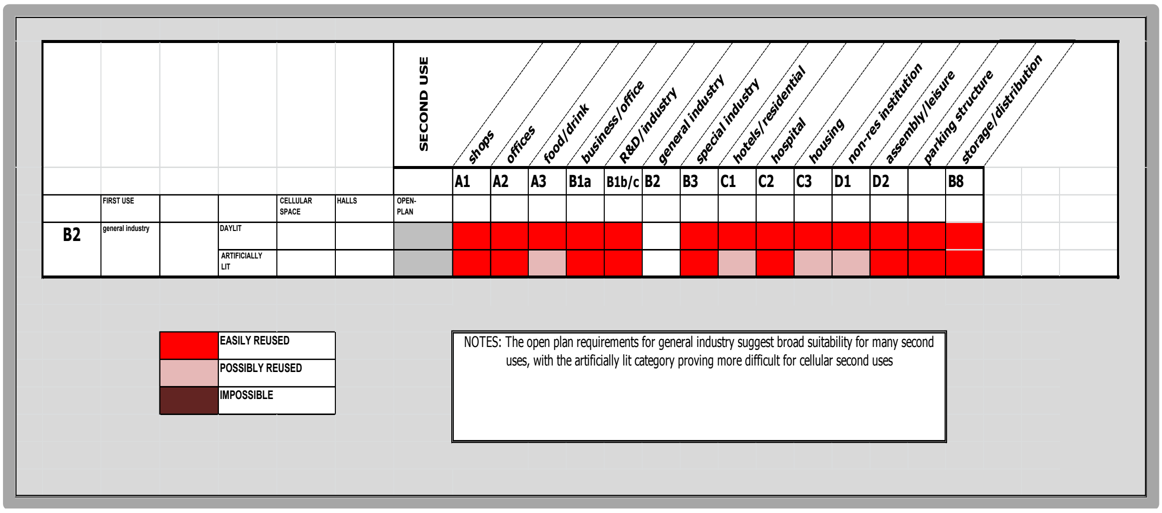

Figure 5.44 Compatibility matrix: B2 GENERAL INDUSTRY

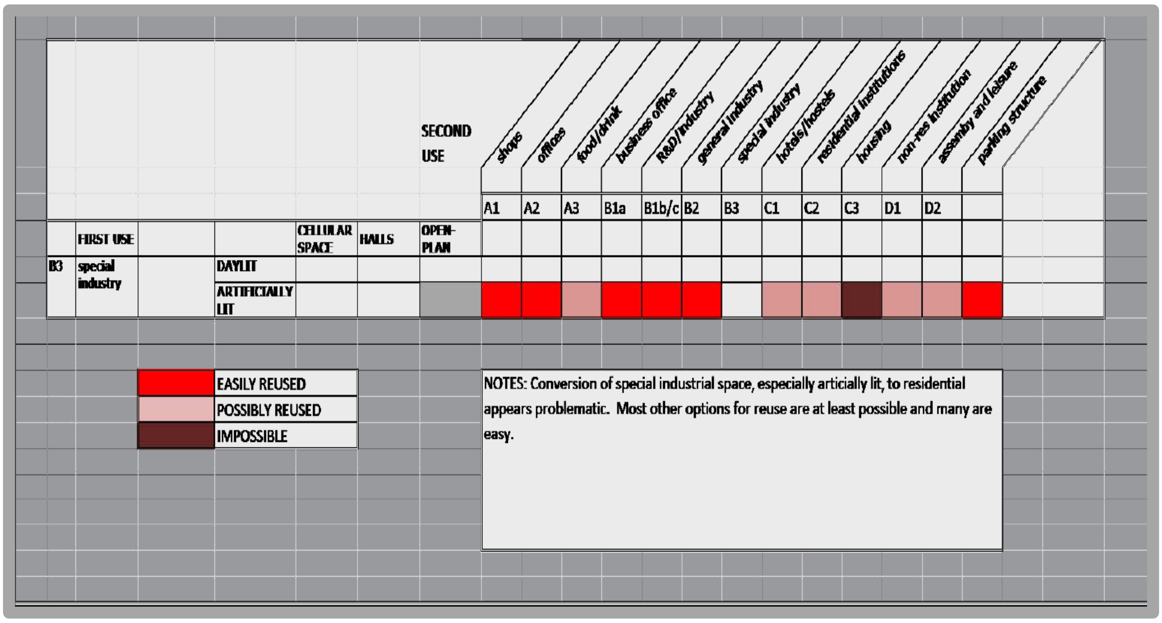

Figure 5.45 Compatibility matrix: B3 SPECIAL INDUSTRY

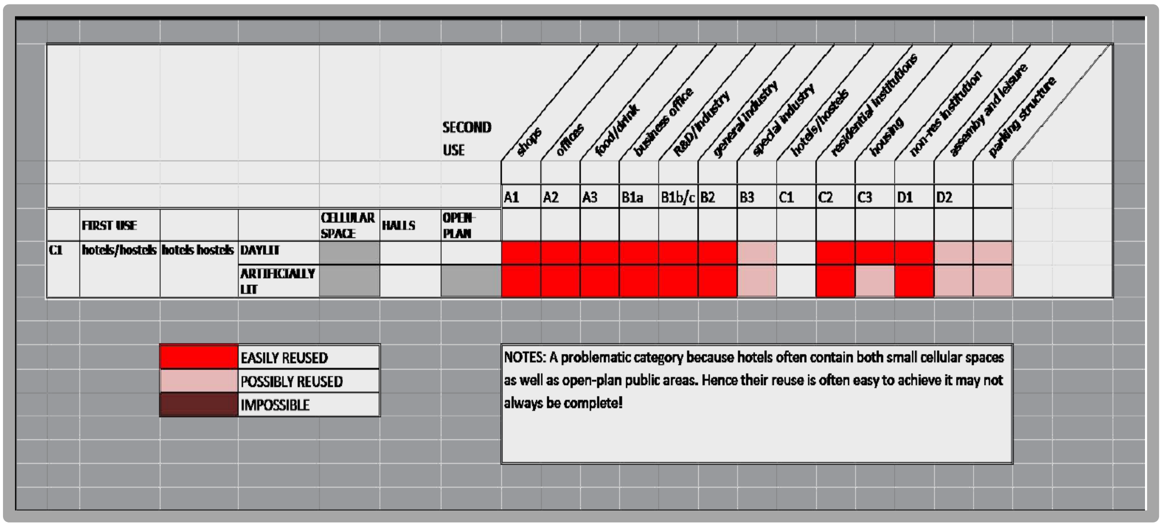

Figure 5.46 Compatibility matrix: C1 HOTELS/HOSTELS

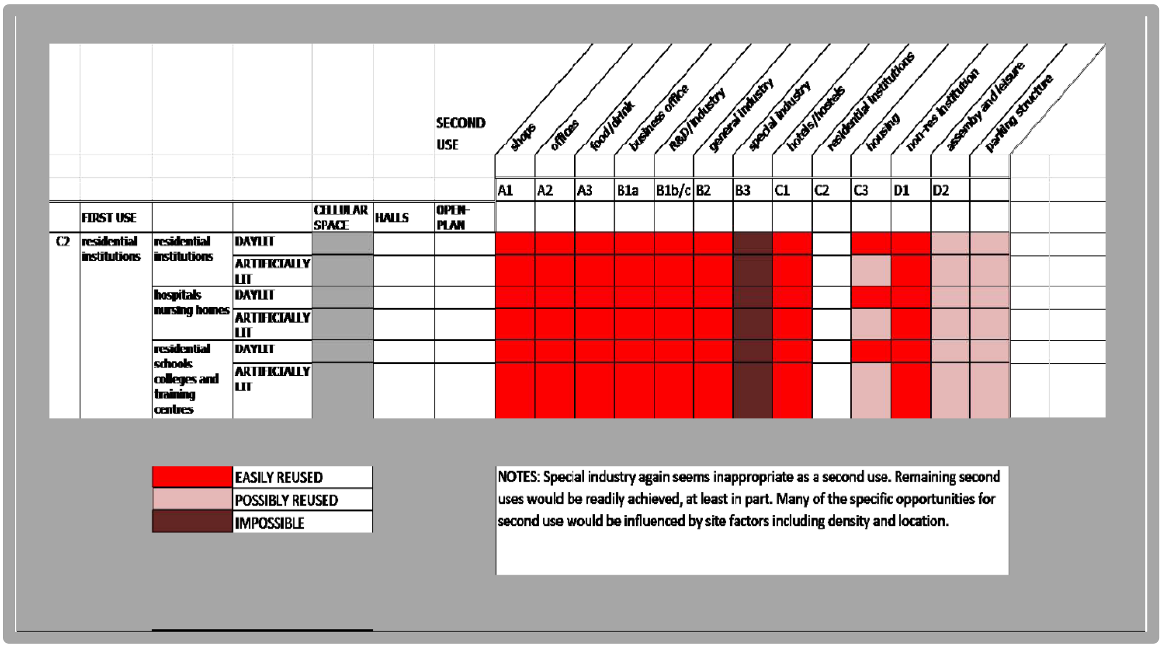

Figure 5.47 Compatibility matrix: C2 RESIDENTIAL/INSTITUTIONAL

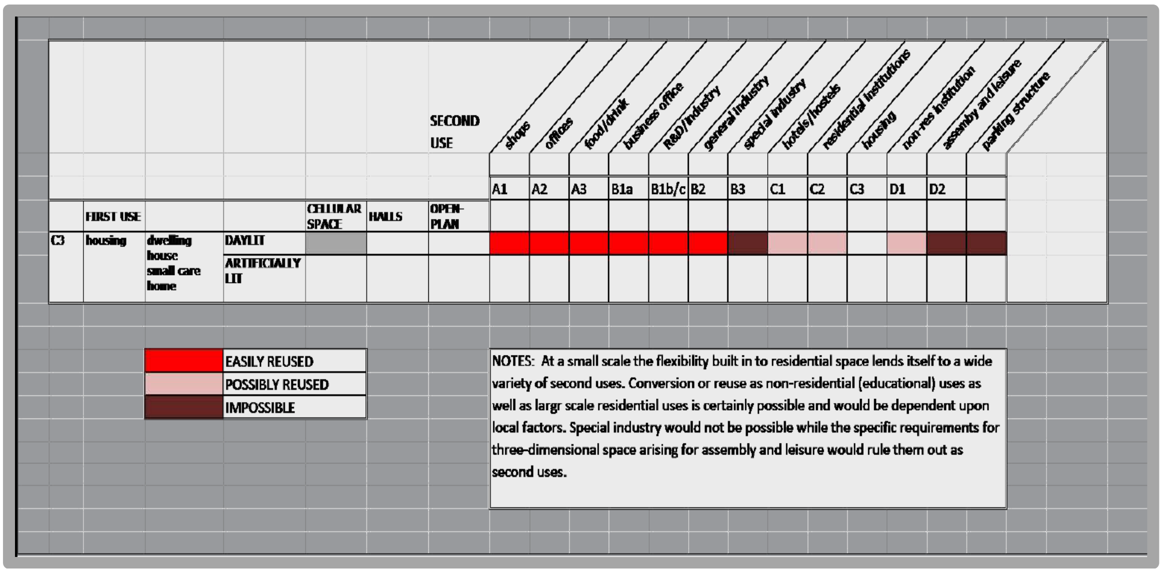

Figure 5.48 Compatibility matrix: C3 HOUSING

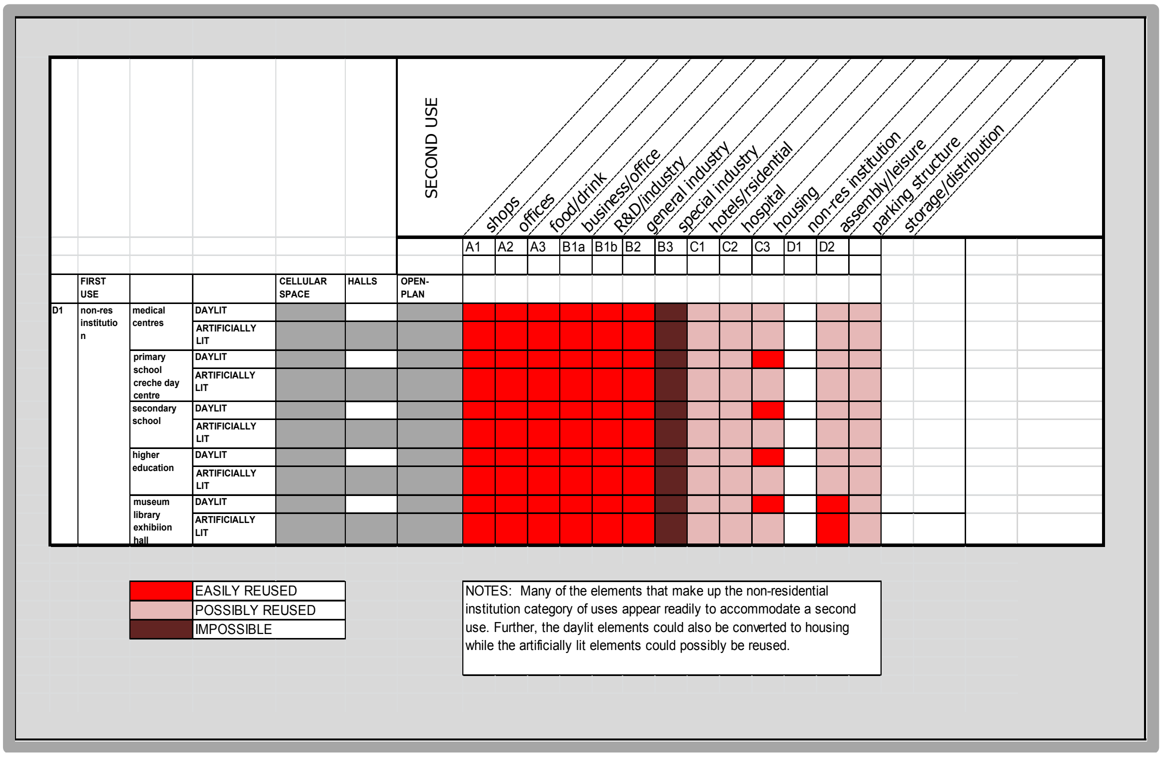

Figure 5.49 Compatibility matrix: D1 NON-RESIDENTIAL INSTITUTION

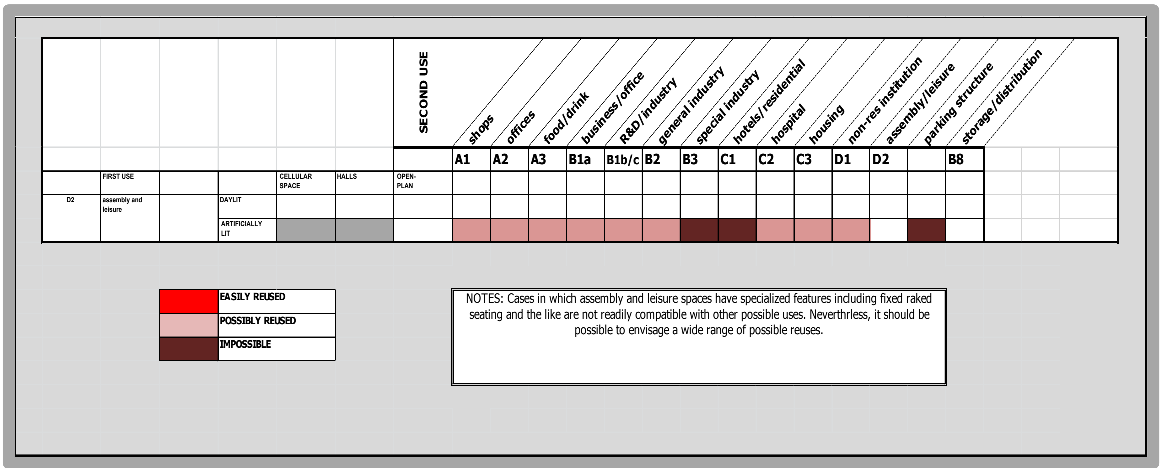

Figure 5.50 Compatibility matrix: D2 ASSEMBLY/LEISURE

5.3.2.6 Depth of Space Summary of Compatibilities

The outcome of the pair-wise assessments of compatibility is summarized in Figure 5.51.

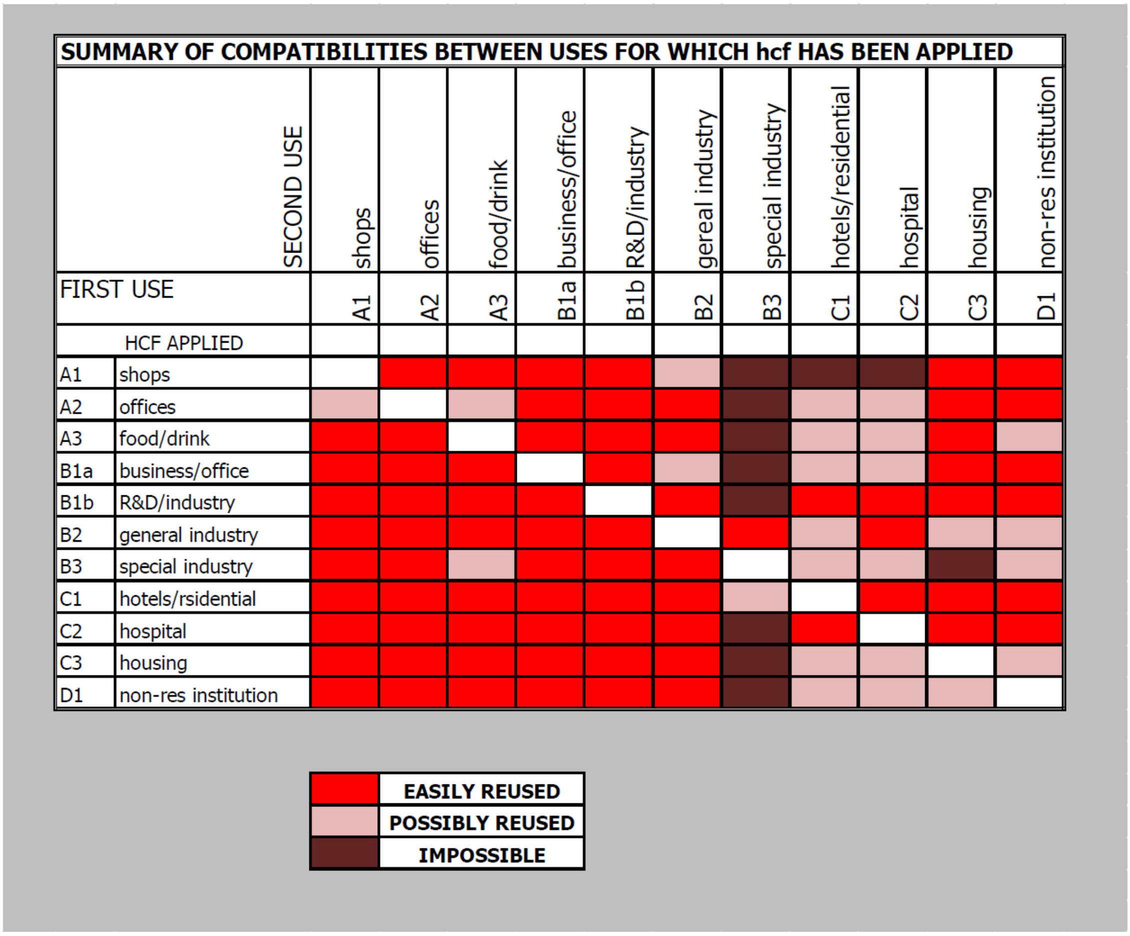

Figure 5.51 Compatibility matrix: summary of compatibilities between uses for which Highest Common Factor has been applied

5.3.2.7 The Application of Double-Design

Figure 5.52 suggests how the steps in the Double-Design process would work:

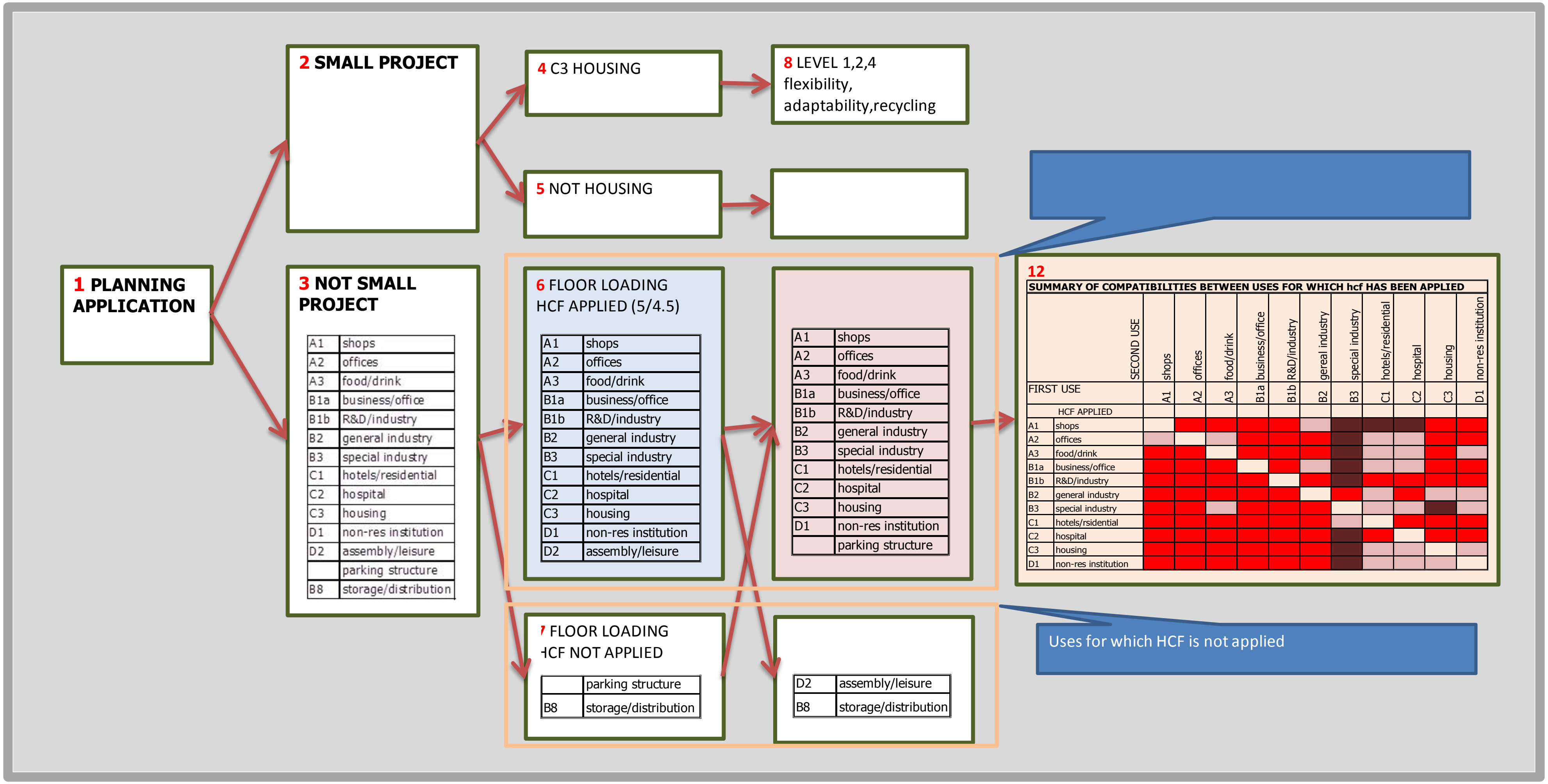
1 PLANNING APPLICATION
2 SMALL PROJECT
3 NOT SMALL PROJECT
A1 shops
A2 offices
A3 food/drink
B1a business/office
B1b R&D/industry
B2 general industry
B3 special industry
C1 hotels/residential
C2 hospital
C3 housing
D1 non-res institution
D2 assembly/leisure
parking structure
B8 storage/distribution
4 C3 HOUSING
5 NOT HOUSING
8 LEVEL 1,2,4 flexibility, adaptability,recycling
6 FLOOR LOADING HCF APPLIED (5/4.5)
FLOOR LOADING HCF NOT APPLIED
12
SUMMARY OF COMPATIBILITIES BETWEEN USES FOR WHICH hcf HAS BEEN APPLIED
SECOND USE
FIRST USE
HCF APPLIED
gereal industry
hotels/rsidential
Uses for which HCF is not applied

Figure 5.52 Implementation of Double-Design: decision-making process starting with planning application.

Step 1 Planning Application: Custodians would apply for planning permission to the planning authority who would separate small projects (step 2) from not small projects (step 3).

Step 2 Small Projects: The planning authority would separate the small housing projects (step 4) from those not housing projects (step 5).

Step 3 Not Small Projects: The planning authority would divide these between those for which HCF applied to floor loading (step 6) as well as floor-to-floor (step 10), leaving uses for which HCF was not applied (step 7 and step 11).

Step 4 Housing Small: housing has Double-Design levels 1, 2, and 4 applied; flexibility and adaptability are incorporated into the design and recycling potential applied to materials (step 8).

Step 5 Not Housing Small: not housing has Double-Design levels 1, 2, and 3 applied; flexibility and adaptability are incorporated into the design (step 9).

Steps 6 and 10 Floor loading and floor-to-floor: with HCF applied Combining steps 6 and 10 produces a design requirement for each of the uses to follow the HCF for floor loading and floor-to-floor. The outcome of steps 6 and 10, with the HCFs incorporated, facilitates the second uses summarized in Step 12.

Step 7 and 11, where floor loading and floor-to-floor HCF cannot be applied. While these uses (parking structures, storage/distribution and assembly/leisure) are not included in the 'mainstream' uses in steps 6 and 10, based upon their extreme requirements, they may nevertheless be capable of specific reuses related to those extreme characteristics.

The scale of spatial requirements for later uses will influence the practicality of a transition from first to later use. Unless there is the capacity to expand, the scale of the initial build will constrain the capacity to allow for future uses. While some uses may have specific sizes and shapes, such as a theatre or stadium, others comprise multiples of a unit of space, such as a workstation. This factor of spatial divisibility represents an important constraint upon the full implementation of Double-Design.

5.3.2.8 Building Services

One of the factors that need to be built into the guidance given by Double-Design is the provision for changes to service provision. Design professionals have come a long way from when architects designed and handed their drawings to engineers 'to make them work'. Integration within the design team is now standard, and there is a recognition that provisions made early in the design process will be proved worthwhile in building use. However, the future of building services is challenging to forecast and accommodate. Varming, an Irish consulting engineer, describes the significance of building services: "Sustainable development and building engineering entails wide-ranging policies that serve the future and provide a smart way of living, working, and consuming energy. As one of the wealthiest, this sector offers one of the most economically beneficial paths for reducing energy demand and supporting adaptation" (Varming, 2015). Towler also identifies important themes affecting the future for building services:

> Whilst green design will be easiest to implement for new construction, it is the retrofit and refurbishment of 4.6 million existing buildings that represents the biggest challenge, the most pressing need and the biggest market potential. Buildings that adapt to people (rather than the other way around) will be a major evolution and will lead to more productive environments, a higher level of satisfaction and comfort for occupants and the ability, for example, to avoid conditioning unoccupied spaces. The trend is moving towards an increase in demand for individual control. This implies for example, that in an open plan office, each desk would have its own fan coil unit and could be controlled individually. Building users also expect the speed of response to change. This will manifest itself in two distinct ways: The reality (the building conditions actually

change) and the perception (what the building users perceive). (Towler, 2015, pp. 6–7)

Making design provisions for the themes suggested above is likely to benefit the initial custodians significantly. It ought, as a matter of course, to be an essential part of the briefing. Services take up space horizontally and vertically and may be substantial occupiers of space. The provision of 'spare' space for future services is familiar in many projects, the need for which is reinforced by the recognition that services generally have a shorter life than other building materials and therefore need regular replacement.[51] Perhaps an additional percentage allowance should be considered with respect to spatial needs and floor-to-floor heights; this could be incorporated into the Double-Design guidance.

5.3.2.9 Fire Precautions and Means of Escape

The compatibility of requirements for means of escape in case of fire between different building uses raises complex issues, and the full implementation of any conclusions will need further research. To explore the problem at this stage and at a level itself compatible with the consideration afforded above to floor loading and floor-to-floor heights, the focus is upon the spatial aspects of means of escape rather than upon the many material specification criteria that are already in place in the UK Building

[51] Unnecessary 'spare' provision is hard to avoid in every case. For a new university in Kuwait the custodian insisted on hard wiring every seat and every desk to the central server so that teachers could access prepared presentations. Space was provided for electrical services with false floors and substantial vertical ducts as it was anticipated at the time that wireless connectivity was many years away and might not be so reliable!

Regulations (HM Government, 2019a; HM Government, 2019b).[52] The diagrams below show how the spatial implications of means of escape for housing depend upon the configuration of the design with additional requirements related to the height of floors above ground. Custodians conforming to Double-Design would have to show how their starting configuration would change to allow the transition to safe housing and other uses as allowed for. For example, the kind of physical transformation envisaged by Vandkunsten Architects and illustrated in Figure 5.53 might be needed to achieve safe housing. A move towards simpler building forms that could accommodate more easily escape provision for future uses would be beneficial (Brand, 1997).

[52] Different countries have developed and applied different standards and the reasons behind these would repay further study. A colleague of the author employed by the Architect's Journal in the 1970s to prepare design guidance in this field found that the French regulations were, at the time, extremely lax because all their testing for evacuation had been undertaken by uniformed gendarmes running in unison to the exits.

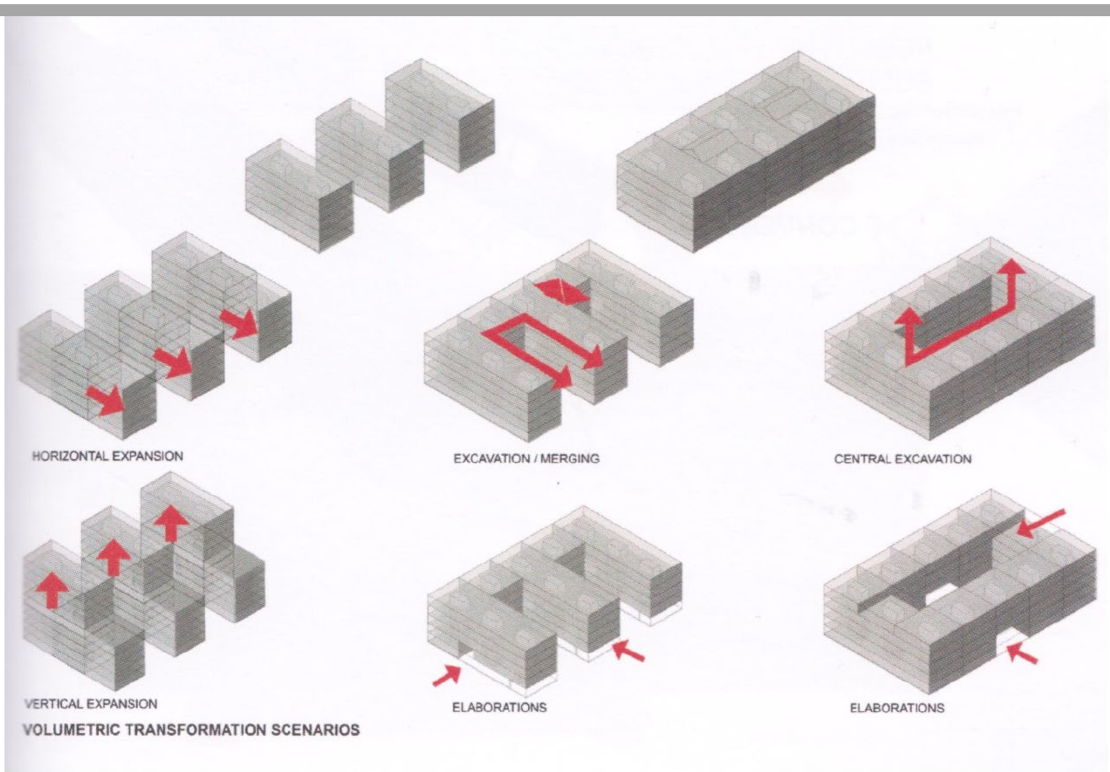

Figure 5.53 Implementation of Double-Design: example of designed anticipation for future change: Vandkunsten Architects from (Schmidt & Austin, 2016, p. 221)

Moving forward to consider the regulations applicable to non-housing uses, Volume 2 of Part B lists the groups of activities (with nearest equivalent use classes added) as shown in Figure 5.54.

PURPOSE GROUPS FROM BUILDING REGS PART B		**NEAREST EQUIVALENT USE CLASSES**	
1	residential	housing	C3
2A	residential institutional	hospital, non-residential institutional	C2,D1,
2B	residential other (hotels)	hotels/residential	C1,
3	office	offices, business/office,	A2, B1a,
4	shops and commercial	shops, food and drink,	A1,A3,
5	assembly and recreation	assembly/leisure	D2
6	industrial	R&D/industry, general industry, special industry	B1b,B2,B3,
7A	storage (and others not included above)	storage/distribution	B8
7B	car parks	parking structures	

Figure 5.54 Purpose groups from Building Regulations shown with nearest equivalent Use Classes

Considering the provisions for horizontal escape, the regulations introduce factors, including occupancy and travel distance, to the necessary steps in the design process to achieve compliance. Figure 5.55 clearly illustrates the difficulties encountered in basing a design upon the highest common factors in each of these fields.

Table 2.1 Limitations on travel distance

Purpose group	Use of the premises or part of the premises		Maximum travel distance[1] where travel is possible in: One direction only (m)	More than one direction (m)
2(a)	Residential (institutional)		9	18
2(b)	Residential (other):			
	a. in bedrooms[2]		9	18
	b. in bedroom corridors		9	35
	c. elsewhere		18	35
3	Office		18	45
4	Shop and commercial		18	45
5	Assembly and recreation:			
	a. buildings primarily for disabled people		9	18
	b. areas with seating in rows		15	32
	c. elsewhere		18	45
6	Industrial[3]	Normal hazard	25	45
		Higher hazard	12	25
7	Storage and other non-residential[3]	Normal hazard	25	45
		Higher hazard	12	25
2–7	Place of special fire hazard[4]		9[5]	18[5]
2–7	Plant room or roof-top plant:			
	a. distance within the room		9	35
	b. escape route not in open air (overall travel distance)		18	45
	c. escape route in open air (overall travel distance)		60	100

NOTES:

1. If the internal layout of partitions, fittings, etc. is not known, direct distances, rather than travel distances, should be assessed. The direct distance should be assumed to be two-thirds of the actual travel distance.
2. Maximum part of travel distance within the room. This limit applies within the bedroom and any associated dressing room, bathroom or sitting room, etc. The distance is measured to the door to the protected corridor that serves the room or suite. Sub-item (b) applies from that point along the bedroom corridor to a storey exit.
3. In industrial and storage buildings, the appropriate travel distance depends on the level of fire hazard associated with the processes and materials being used.

   Higher hazard includes manufacturing, processing or storage of significant amounts of hazardous goods or materials, including any of the following.

   - Any compressed, liquefied or dissolved gas.
   - Any substance that becomes dangerous by interaction with either air or water.
   - Any liquid substance with a flash point below 65°C, including whisky or other alcoholic liquor.
   - Any corrosive substance.
   - Any oxidising agent.
   - Any substance liable to spontaneous combustion.
   - Any substance that changes or decomposes readily, giving out heat when doing so.
   - Any solid substance with a flash point less than 120°C.
   - Any substance that is likely to spread fire by flowing from one part of a building to another.
4. Places of special fire hazard are listed in the definitions in Appendix A.
5. Maximum part of travel distance within the room/area. Travel distance outside the room/area should comply with the limits for the purpose group of the building or part.

Figure 5.55 Building Regulations: means of escape and limitations on travel distances from(*The Building Regulations 2010 APPROVED DOCUMENT B Volume 1: Dwellings*, 2019, p. table 2.3)

The regulations also specify numbers of exits, the number and width of escape routes for dwellings and non-dwellings. If the philosophy behind Double-Design is understood by practitioners and embraced in legislation it would be possible to design for the highest safety standards applicable to the anticipated second and subsequent uses. In cases where later uses may not be capable of specification at the planning stage, custodians and their teams must be clear regarding the provisions being made for the future.

5.3.3 Morphology

A robust geometrical narrative has been established, especially by academics in the UK. While more concerned with form and shape than the use over time to which forms and shapes are put, their analyses provide an invaluable background for applying Double-Design. Modern guidance on architectural morphology starts with March and Steadman (March & Steadman, 1971). Combining mathematics with architectural understanding, their pioneering work can be seen to have influenced the scope of academic analysis and design thinking. Of particular relevance here is their reference to "band planning" by which Joedicke classified office buildings (Joedicke, 1962). This established the significant determinants of building depth concerning functional relationships and environmental requirements. The optimal balance to be sought between such conflicting factors features prominently in their discussion of spatial allocation procedures. The additive and permutational approaches are described. The additive approach starts with a blank sheet into which spaces are added one by one. The permutational process requires the initial production of a complete plan; this is followed by sequential swapping about of rooms to reduce the 'cost' (March & Steadman, 1971, p. 303). While many attempts to optimize space arrangements have been and continue to be published, there is a point at which the purely mathematical approaches have to accommodate the real constraints of architectural design. These include the need for natural light, the structural bay sizes, the size of floors above and below, and so on. As March and Steadman recognize: "we require that the circulation routes of the building, the corridors and staircases, form some coherent and economical system, and do not ramble about chaotically. […] there has to be some tidying and reorganizing of the layout done by hand afterwards, before the result is acceptable as a building design" (March & Steadman, 1971, p. 316). Whitehead and Eldars' work sought to find optimal solutions to room arrangements based, especially those in hospitals, upon the criterion of distance (Whitehead & Eldars, 1964).[53] One of the few scholars not afraid to tackle activities and space is Fawcett, focusing upon "the ways that buildings serve human activities" (Fawcett, 2016, p. 10). For example, in studying the transformational potential in offices, health care and higher education, he draws attention to the fact that they operate in near-complete isolation from one another, despite increasingly convergent dependence upon the same digital revolution (Fawcett, 2016, p. 26). As he says: "the way buildings are used is a function of three factors: the space, the activities, activity-space management. If any of the factors change, the capacity changes as well" (Fawcett, 2016, p. 27).

The principal ways of increasing capacity are shown in Figure 5.56: either increase the space or improve the management of the space (Fawcett, 2016, p. 27).

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[53] The author was working in the hospital field at the time of this important publication and remembers feeling uneasy at the gross over-simplification of the problem; the criteria of distance and of travel time between spaces were incomplete indicators of performance. The application of such simplifications begged more questions than were solved: for example, optimizing travel time might be in the interests of staff, depending upon how they were paid, but not, at the same time, of patients and visitors!

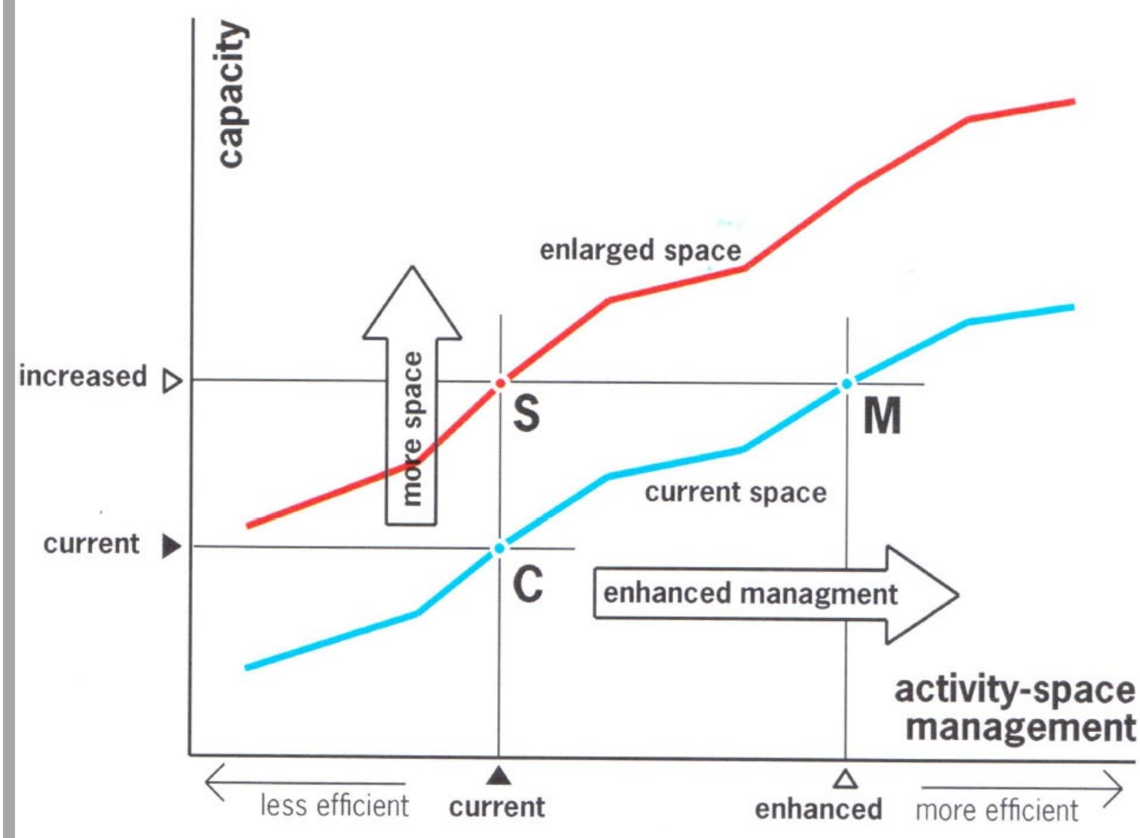

Figure 5.56 Activity-space interaction: the dynamism of space management from (Fawcett, 2016, p. 27).

The aspect that unifies these approaches to both two and three-dimensional design is that measures are introduced to assess the performance of different designs, however the designs were produced. Work in the field advanced rapidly, and as long ago as 1974, Gero was able to provide a review which concluded: "However, the problem of developing non-economic formulations remains a thorny one, and not only for architects (viz. the environmental impact studies being carried out for different projects throughout the world) and one approach has been to use time as the base or to define 'economics' in a much broader sense" (Gero, 1974, p. 196). Commercial and academic software aiming to optimize spatial allocation have advanced to the point at which some eight competitive companies are available, as assessed by Capterra (*Capterra.Co.Uk*, 2020). As these and other spatial allocation programmes are used through the life of buildings, the more critical it becomes to avoid designing tightly around any one optimization outcome. Thus, given the intended framework of Double-

Design to provide flexibility and adaptability in good measure, it will be possible for many different optimizations to occur as the custodians and users respond to changing needs. There is, with this arrangement, a layer of what might be regarded as meta-architecture protecting the long-term interests of the building and its custodians and users. While the meta-architecture guarantees the overall building envelope, individual instances of optimization can be installed and readily changed, reflecting the fit-out layers described by Duffy and Brand (Brand, 1997) (Duffy, 1992) as well as being hinted at by Habraken (Habraken, 1987) If a building is to last for, say, 150 years or more, what does it comprise? How can it be defined? After all, a building has many attributes, physical features by which it can be recognized. Do they all need to last for the same length of time, or should there be some hierarchy in play such that specific determining or critical features are the ones that need to survive while others may come and go? The life span for buildings is typically determined using the classic capitalist model, which seeks profit maximization within regulatory constraints and standards. Changing the framework within which life spans are selected requires the introduction of different concerns. In this thesis, these additional concerns have included sustainability and reuse, with the latter associated with an enhanced capacity for custodian and user intervention. Starting with the layers approach described by Duffy (Duffy, 1990, p. 17) and later popularized by Brand (Brand, 1997, p. 13), it is clear that some layers, reflecting fundamental structure and materials, are more readily designed to last than others.

LAYERS					IMPACT	
DUFFY	**BRAND**		**SUGGESTED RENEWAL TIME**	**NOTES**	**SUSTAINABILITY**	**INTERVENTION**
SITE	SITE	geographical setting, location, legally defined lot	ETERNAL	it is hard to argue with the Brand and Duffy assessment that the site is eternal!	NA	NA
SHELL	STRUCTURE	foundations, load-bearing elements,	30-300	Brand claims that the structure "is the building". Structure with Skin are together the major candidates for defining what must last	**YES**	NO
	SKIN	exterior surfaces	20			
SERVICES	SERVICES	communications, electrical systems, plumbing, HVAC, elevators, escalators	7 to 15	While engineering design for services may establish longer life for services systems in the future, services will need to be replacable, if only to facilitate the introduction of innovations that enhance performance in terms of comfort and/or environment	YES	YES
SCENERY	SPACE PLAN	interior layout	3 to 30	This category can best be defined as including all the space defining but non-permanent elements like partitions, false ceilings, doors and the like	YES	**YES**
SET	STUFF	furniture	DAILY to MONTHLY	Defined by being able to be chosen and moved around by users without affecting any other layer	YES	**YES**

Figure 5.57 Layers of building: assessment of impact on sustainability of intervention in different layers

Figure 5.57 summarizes the analysis of Duffy and Brand. It suggests that the main impact upon sustainability will arise from the longevity of the shell (structure plus skin), and the main impact upon intervention will occur from the design and specification of scenery (space plan) and set (stuff). The design and specification of services will impact sustainability in material use and waste avoidance and upon intervention by ensuring that custodians and users enjoy accessible control over levels of comfort and service. The rates of change have been considered in natural systems, and buildings follow a similar path. As O'Neill et al. say: "The dynamics of the system will be dominated by the slow components, with the rapid components simply following along" (O'Neill et al., 1986, p. 98). Steadman has provided valuable insight on the limitations of computer-generated design options based upon single-factor constraints and has suggested a morphological approach to understanding the geometries of different building forms (Steadman, 2018). In seeking reasons why so many buildings are rectangular, Steadman suggests three possibilities: Architectural instruments favour the use of simple rectilinear forms. Architects are following a western conception of three-dimensional space from Euclid to Descartes. Awareness of gravity and the awareness of the body for locomotion guides us towards orthogonal buildings. The intrinsic flexibility built into Double-Design may also facilitate the correction, improvement or modification of an unsatisfactory design. At the very least, custodians and their design teams should be fully informed about the concepts underlying Double-Design. Changing uses where the geometric and environmental requirements of the first and future uses are similar or demonstrably compatible is not problematic. However, the cases of interest are those where the compatibility with a second use may only be achieved by changes to the design for the first use. Abramson has described how many architects (the Archigram Group) and critics (including Reyner Banham) were culturally seduced in the 1960s and later by obsolescence despite the research agendas initiated at the time aimed at understanding and mitigating its processes (Abramson, 2017, pp. 73–77) (Dutton & Mann, 1996) It has needed the new demands of a response to climate change to move the issue forward. There is a need to disrupt the intimate relationship that has traditionally appeared to tie the fabric of a building to its use. The deconstruction, the separation of long-lasting supporting shell/infrastructure from the 'as long as needed' interior fit-out packages, will challenge the accepted wisdom of short-termism while contributing to the achievement of critical societal goals. In searching for morphological compatibilities amongst building forms suitable for different functions, the kind of analysis initiated by March and Steadman, covering stacking, nesting and fitting, will need to be refreshed (March & Steadman, 1971, pp. 145–177). In a similar spirit, the pioneering consideration of modular construction in determining appropriately sized modules for a range of uses should be explored urgently (Bemis & Burchard, 1933). Critically, a way needs to be found to embrace the dynamism of use in spatial analysis.

5.4 TESTING DOUBLE-DESIGN

A distinction must be drawn between tests of Double-Design as an idea and tests that may be applied within a design process influenced by the implementation of Double-Design. Although these overlap, they are covered here in support of the idea itself. While generative design and its commercial software promoters may prove invaluable in providing evaluative insight into the development of designs for a multi-function future, existing approaches are briefly reviewed below.

5.4.1 Space Syntax

Techniques developed from space syntax can be incorporated into a framework for design evaluation and testing. In the study of urban spatial patterns, the conceptual understanding of how physical space envelops activities has been developed. In introducing spatial syntax, Hillier says;

> Architectural and urban design, both in their formal and spatial aspects, are seen as fundamentally configurational in that the way the parts are put together to form the whole is more important than any of the parts taken in isolation. The configurational techniques developed for research can, in fact, just as easily be turned round and used to support experimentation and simulation in design. In linking theoretical research to design in this way, we are following a historical tradition in architectural theory which has both attempted to subject the pattern aspect of things in architecture to rational analysis, and to test these analyses by embodying them in real designs. The difference now is only that the advent of computers allows us to bring a much great degree of rigour and testing to theoretical ideas. (Hillier, 2007, p.1)

Space syntax has shown how existing or planned buildings may be mapped mathematically. If there were a way to map future organizational structures, it would be possible to use the future patterns, or some highest common factor amongst them, to establish the most robust design; that is, the one best able to accommodate the widest range of future organizational needs within a given range of constraints. To the extent that space syntax methodology can be added to generative design software, it could have an important part to play in the successful implementation of Double-Design.

5.4.2 Scenario Writing

Scenario building can be incorporated into a framework for design evaluation and testing. Scenario building is one of the methods suggested by Blyth and Worthington to anticipate the future. As they suggest, the strategy for a future building should be sufficiently robust to cope with a variety of directions the organization might go. To test the resilience of a building strategy, alternative scenarios can be proposed. Typical scenario variables may include:

- Speed of growth and change
- Mix of staff and alternative patterns of work
- Alternative mix and balance of functions
- Changes in use and take up of technology
- Change of ownership, political agenda, or cultural expectations (Blyth & Worthington, 2010, p. 47).

5.4.3 Life-cycle Options

In this approach, a lifecycle option is a feature of a design or plan that makes it possible for new decisions to be made in the future. A simple example: if the future size of a hospital, university or factory is uncertain, build for current requirements and retain open space into which the buildings could be expanded. The hypothesis here is that the application of life-cycle options will help to test the robustness of designs. As Fawcett states:

> Growth and change cannot be predicted, which is why flexibility is sought. In the absence of credible predictions, people have relied on judgment, (and educated guesswork), when designing and investing in flexible environments for growth and change. There are two ways in which this could lead to poor outcomes: Under-provision for flexibility, leading to future problems that could have been avoided if there had been better provision for growth and change. Over-provision for flexibility, when provision is made for anticipated future growth and change, but not used. Lifecycle options transfer decision-making from people in the present to people in the future who will know more about the changing state of the world. (Fawcett, 2011, pp. 13–29)

5.4.4 Life-cycle Costing

Published studies suggest that the additional costs of high-performance buildings are not exceptionally high, but to persuade the government and interested parties to accept Double-Design, it will be necessary to calculate the costs and benefits more accurately. In their review of evaluative software for life-cycle costing (LCC), Kovacic and Zoller suggest:

> In terms of sustainability, optimization of following costs is in close relationship to the issue of affordability and often stands in direct relationship with minimization of energy-consumption. The early planning phases play crucial role for the determination of future performance of a building throughout the life cycle – here the optimization potential is still very large, at very low cost. In the latter planning phases the change possibility rapidly decreases with simultaneously increasing costs. (Kovacic & Zoller, 2015, p. 1)

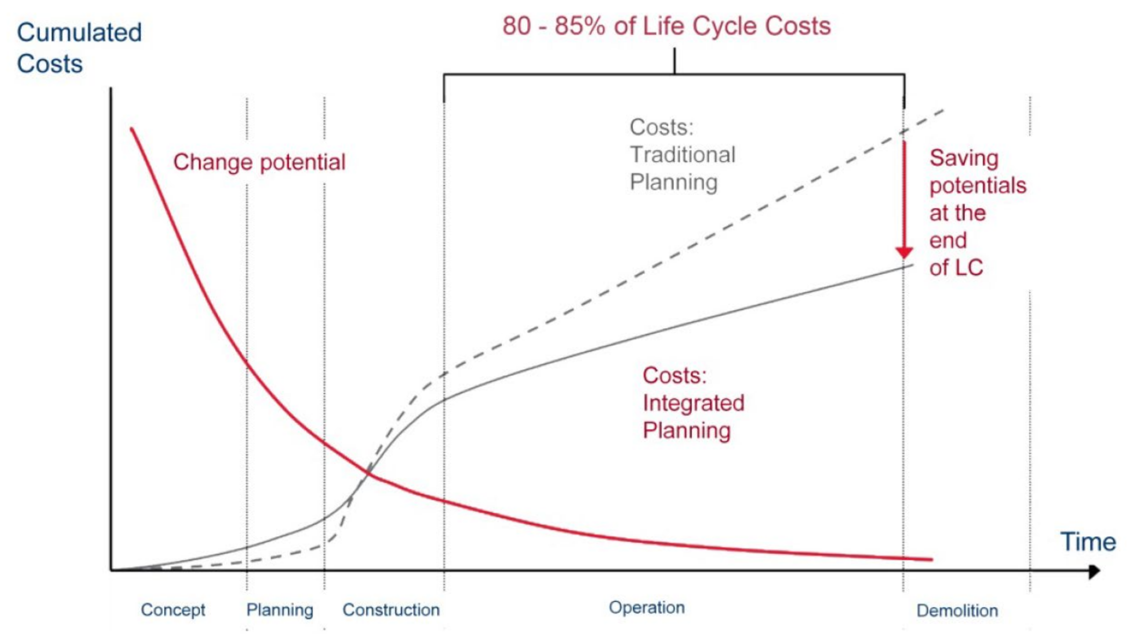

Figure 5.58 Cost development vs change potential over building life cycle from (Kovacic & Zoller, 2015)

Kovacic and Zoller show convincingly that the outcomes of LCC analysis are extremely sensitive to input factors like interest rate. Thus, even when all building parameters are constant, the application outcomes of different software are very varied. (Kovacic & Zoller, 2015, p. 1).

The literature review carried out for the EU by Davis Langdon Management consultants reported as follows:

> There is an enormous amount of literature which relates to LCC and LCA [life-cycle assessment]. Some of it (particularly academic papers) develops numerous models of high level of technical complexity but displaying a rather low level of practicality. After investigating existing practices and case studies within Davis Langdon as well as talking to other cost consultancies (all using their unique house-developed cost models), it was discovered that the scope and range of information which clients find useful and need from the LCC calculations is not that extensive. […] The still open topic is the quality of data which goes into the LCC models. The facility data (environmental, performance and cost) is provided by variety of organisations. It is often incomplete and in variety of incomparable formats. […] Risk evaluation has been researched and analysed in great details, clear division of methods into qualitative (risk registers, matrices, etc.) and quantitative (mathematical modelling of uncertainty) gives forecasters powerful tools. Clients, however use mainly sensitivity analysis results – calculations using likelihood/probability of projected values within pre-determined ranges and Monte Carlo simulation. Motive scenarios and analysis of a range of service lives is usually considered as the most informative and useful. Data for LCA and sustainability assessment is widely available and quite extensive. Clients however still are mainly concerned with CO2 emissions and energy use as the two main environmental indicators. (Davis Langdon, 2005)

Inaba and Clouette suggest the challenge of life-cycle options:

> Thinking about life cycle doesn't mean specifying long-lasting materials or component systems. Rather, it concerns the social and economic viability of the building, which means not only a long life, but also adaptability to changing preferences, uses, and associated management operations. It requires formal design decisions that will have great impacts on the operating costs and energy use of the building. It necessitates an approach to the building construction as a forward-compatible assembly, comprised of a series of interdependent material and technological layers with different schedules of replacement. Finally, it means designing a form and its spaces so they accommodate changes in program, yet have some logic about its massing, figuration, and dimensions that reduces capital costs associated with each conversion. (Inaba & Clouette, 2014, p. 3)

The idea behind this thesis is that there will be benefits from ensuring that all buildings should last longer. The interdependence of adaptability and longevity is suggested by Inaba & Clouette: "A building's adaptability can be understood through an analysis of its life cycle. If the design of program, form, and forward-compatibility is a means of achieving adaptability, life cycle analysis is the measure of the success of extended lifespan building design. A building's value at any moment is dependent on how the lifecycles of various components align" (Inaba & Clouette, 2014, p. 8). Figure 5.59 refers.

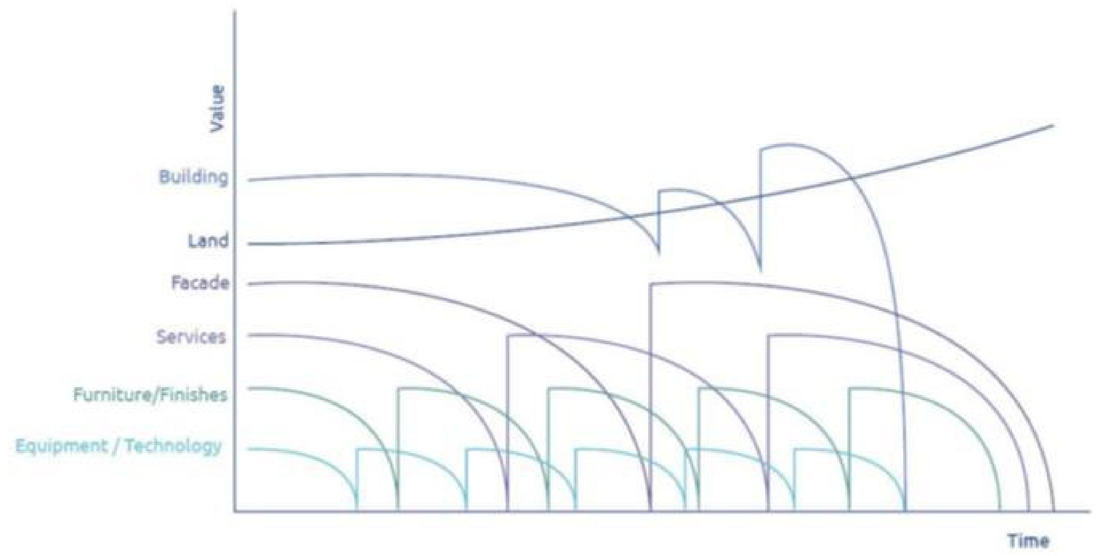

Figure 5.59 Building value: shows how value at any moment is dependent on how the lifecycles of various components align. Diagram by C-Lab, from (Inaba & Clouette, 2014, p. 8).

Commercial software is available that might help establish the comparison, but detailed and accurate input data is required to be based on fully designed and specified projects. It is beyond the scope of this thesis to provide such input but, if the proof of concept is achieved, the application of such comparative tests can play an essential part in future research. Based upon the account of building services as a percentage of total capital expenditure: "the mechanical portion of a construction project is often a significant percentage of the total project cost. Typically, mechanical construction consumes 15 per cent, and electrical construction consumes an additional 10 per cent of the total project cost" (Orth & Mains, 2007, p. 1). As Wu and Clements-Croome point out: "building service systems are complex encompassing many different kinds of components […] there is a trade-off between components' reliability and their life-cycle costs" (Wu & Clements-Croome, 2007, p. 30). Available data has been reviewed to establish a reasonable basis for assessing maintenance and operation costs. The BCIS (Building Cost Information Service) discuss maintaining and operating buildings and how the costs can vary depending upon the functionality of the building's occupancy. The latest annual update to the BCIS life cycle cost data provides estimates for the maintenance and operation of buildings of over 100 types and shows that total costs can range from £4,850/100 m^2 per annum for factories to £11,000/100 m^2 per annum for hospitals. The running costs comprise:

- Maintenance costs, including maintenance and renewal of building fabric and services decorations.
- Operation costs, including cleaning utilities (water and energy). Examples of the estimates are given in the following table.

The additional two columns, shown in Figure 5.60, show the relevant capital costs of some building types and the percentage of capital costs that should be applicable to maintenance and occupancy based upon relevant building cost estimates derived from the same source. (*The Varying Costs of Maintaining and Operating Buildings of Different Functions*, 2018)

Building	Estimated £/m^2 gross floor area per annum						
	Maintenance	Decoration	Cleaning	Utilities	Total	capital cost/m^2	% of capital cost
Factories	£17.10	£2.10	£12.80	£19.80	£51.80	£1,200.00	0.04
Universities	£33.60	£2.70	£15.00	£18.20	£66.50	£2,000.00	0.033
Shops	£24.60	£3.20	£20.80	£31.00	£79.60	£1,500.00	0.05
Swimming pools	£32.60	£2.70	£17.60	£42.70	£95.60	£2,500.00	0.04
Hotels	£31.50	£3.70	£30.40	£30.40	£96.00	£2,500.00	0.04
Hospitals	£40.10	£3.70	£45.40	£28.30	£117.50	£2,500.00	0.047

Figure 5.60 Estimated maintenance costs for different building types (*The Varying Costs of Maintaining and Operating Buildings of Different Functions*, 2018)

The assessment of the annual costs of maintenance and operation is based upon published data for building costs. In the development of the illustrative generic buildings, a percentage of .05 has been chosen. As the authors advise: maintenance and operating costs will be influenced by many other factors, including hours of operation, intensity of use, current condition and location (*The Varying Costs of Maintaining and Operating Buildings of Different Functions*, 2018).

INDICATIVE COMPARISON SHORT V LONG LIFE BUILDINGS				**TYPE A (50 YEARS)**	**TYPE B (150 YEARS)**
	NOTES	**BUILDING**	**M&E SERVICES**	costs are expressed in units	
CAPITAL COSTS	type B costs at 125% of type A	65	35	100.00	125.00
MAINTENANCE per annum	building and services capital costs x .05 per annum for type A building and services capital costs x .025 per annum for type B (reflecting higher specification)			5.00	3.13
MAINTENANCE OVER BUILDING LIFE	50 years for type A and 150 years for type B			250.00	468.75
PERIODIC REPLACEMENT OF SERVICES every 15 years	full services costs every 15 years			116.67	656.25
PERIODIC CAPITAL INTERVENTION every 15 years	capital building costs x 10% every 15 years			21.67	121.88
END OF LIFE COSTS	capital building and services costs x 10%			10.00	10.00
TYPE A				503.33	
TOTAL COSTS	type A x 3			**1,510.00**	**1,385.00**
COSTS PER ANNUM				**10.07**	**9.23**
TOTAL CAPITAL DEPLOYED				**365.00**	**246.88**

Figure 5.61 Indicative cost comparisons between short-life and long-life buildings

Figure 5.61 describes the basis for other assumptions made to establish an indicative comparison between different building strategies to provide space for one hundred and fifty years. Factors excluded are land, fees, financing and inflation. Future work will seek to provide more comprehensive input data through more fully worked case studies using software incorporating environmental performance characteristics and financial performance measures.

Based on the assumptions made, which are subject to detailed assessment as part of future testing, the long-life option uses fewer financial resources. Software by

Costmodelling Limited has been used further to test the differences between short- and long-life buildings. (Costmodelling Limited, 2020).

INDICATIVE COMPARISON SHORT V LONG LIFE BUILDINGS		**TYPE C FACTORY 25 YEARS LIFE**	**TYPE D FACTORY 75 YEARS LIFE**
	NOTES		
CONSTRUCTION COSTS	base cost estimate	8007720	12613539
RENEWAL COSTS		3207871	12643962
MAINTENANCE COSTS		4370153	10580203
TOTAL LIFE CYCLE COSTS AT NPV		12678593	21706434
LIFE CYCLE COSTS	per m2 per annum	839.09	1322.85
	allowance for type c x 3	38035779	
advantage of long life over 3X short life			**16329345**
INDICATIVE COMPARISON SHORT V LONG LIFE BUILDINGS		**TYPE E HOUSE 25 YEARS LIFE**	**TYPE F HOUSE 75 YEARS LIFE**
	NOTES		
CONSTRUCTION COSTS	base cost estimate	393143	460599
RENEWAL COSTS		193201	678408
MAINTENANCE COSTS		126425	313613
TOTAL LIFE CYCLE COSTS AT NPV		578581	807502
LIFE CYCLE COSTS	per m2 per annum	2025.55	2353.52
	allowance for type c x 3	1735743	
advantage of long life over 3X short life			**928241**

Figure 5.62 life-cycle costs: indicative comparison for factory and housing, twenty five and seventy five year life, based on software by (Costmodelling Limited, 2020)

Figure 5.62 covers two different generic building types, factory and house, each with a 25-year or 75-year life. The tables summarize the data from the application of the software. The financial aspect of comparing short-life with long-life buildings can only be regarded as suggestive of a comprehensive environmental impact comparison. The factors needing to be incorporated in such a comparison are emerging from recent and ongoing research. For example, UCL Engineering has published several Factsheets covering Embodied Carbon, Lifespans & Decisions, and Health & Well-being (UCL Engineering, 2016): Their study compared the costs of rebuilding a small housing estate with retrofitting it and concluded that rebuilding new, low-energy houses was significantly more expensive than retrofitting. Further, retrofitting indicated significant lifetime emissions savings (UCL Engineering, 2016, p. 4). Conclusions from a related study suggest:

> Refurbishment of social housing can deliver significant improvements in energy, environmental and health performance, which can lead to costs savings and improved living standards for residents. Refurbishments can have lower overall lifetime costs than demolition and construction and can cause less disruption to communities and residents. Engaging residents in regeneration decisions is crucial and has resulted in successful refurbishment of a number of social housing properties. (Bell, 2014, p. 1)

The integration of environmental with other factors in the assessment of building longevity is commanding considerable research attention. Bell considers the improvement of energy and greenhouse gas emissions:

> There is a growing body of research suggesting that extending the lifecycle of buildings by refurbishment is preferable to demolition in terms of improved environmental, social and economic impacts […] Residential buildings generate greenhouse gas (GHG) emissions through two processes: occupants' use of a building (*operational energy*); and the extraction, manufacture and transportation of materials for a building's construction and demolition (*embodied energy*). The greatest impacts on global warming are likely to be through the energy consumption and emissions of a building during its lifetime rather than its construction and demolition. However the embodied energy of a building will become more significant as the UK achieves more stringent building standards and takes steps to decarbonise electricity generation. The operational energy of residential buildings contributes 23% of the UK's greenhouse gas emissions. Retrofitting to reduce energy consumption can also deliver other benefits, including reduced fuel bills and increased thermal comfort, and can be done by: **Improving energy performance** through improvements to the building fabric, installing more efficient appliances and controls, and improving occupant understanding of how energy is used in the home; **Switching fuel sources**, such as using renewable resources on-site to generate heat or power, or

> connecting to neighbourhood energy supplies such as low carbon heat networks. (Bell, 2014, pp. 1–2)

Schwartz et al. communicate the urgency of the pursuit for an integrated performance assessment approach:

> The reduction of carbon emissions has become a priority for the building industry, in particular due to recent sustainability-driven building regulations and policies. Recent studies have examined how new computational technologies that utilise Building Information Modelling (BIM) can address a range of sustainability-related issues. Amongst those, the assessment of building environmental impact has been highlighted as being of particular importance as it can offer valuable guidance to design teams and policy makers. Results from a test study indicate that the practical application of the proposed embedded framework constitutes a useful and intuitive workflow that could potentially improve the environmental performance of different building systems by augmenting existing materials databases and by supporting the collaboration between the design and construction supply chains. (Schwartz et al., 2016, p. 1)

Jrade & Jalaei have reported that integrating BIM with sustainable design techniques such as LCA could potentially improve traditional design strategies and assist in the development of high performing buildings by introducing new information tools that minimize the gaps in the existing assessment frameworks (Jrade & Jalaei, 2013). They present:

> A methodology for modelling the procedures of implementing sustainable design for building projects at their conceptual stage by integrating BIM, LCA and relational databases with a workable model. The model includes a 3D (BIM) module, an LCA module and a LEED and Cost module. The databases of the model are based on collected data from the literature, suppliers, publishers, CaGBC, (Canada Green Building Council) and USGBC (U.S. Green Building Council) websites. (Jrade & Jalaei, 2013, pp. 15–16)

Building on the work of Jrade & Jalaei and others, Schwartz et al. focus upon the derivation and reliability of input data. They conclude that:

> Semantic representation of BIM models can be utilised for material EPD (environmental product declarations) specifications. It further concludes that the representation of domains of knowledge, using ontologies, allows for the additional incorporation of various inventories of knowledge and domains and the possible enrichment of building models (Schwartz et al., 2016, p. 12)

The development of robust and comprehensive evaluative tools that may be applied at every stage of the design process would represent a significant breakthrough in the ability of custodians and their design teams to be confident in the physical performance of buildings. The development would also help to confirm the value of Double-Design in terms of financial and environmental impact. The additional costs that may be attributable to the requirement for buildings to achieve higher standards are of great concern to custodians and investors alike and will be central to the debate regarding the implementation of Double-Design. Chegut et al. concluded their review of this issue:

> Currently, there is no systematic evidence addressing differences in input costs between green and conventional construction, but the general perception of developers and investors seems to be that converting to more efficient, green construction is substantially more costly, especially when it involves refurbishment of existing buildings. […] The main findings show higher marginal costs for more efficient, green construction and refurbishment projects. On average, costs are higher by 6.5 percent, but we document significant variation in the marginal cost of green construction based on the extent of environmental performance. Analysing the composition of construction costs, we find an economically and statistically significant premium in design costs and preliminaries, as well as in finishes and fitting costs for green buildings, which is robust to different model specifications. (Chegut et al., 2019, pp. 15–16)

In drawing attention to the conventional way private developments are financed, Chegut et al. suggest that the higher design fees necessary to design higher value buildings are likely to reduce the willingness of property developers to engage in green building practices. "Moreover, these fees are typically fully paid by the developer, since external equity or debt is not available at this stage of the development process" (Chegut et al., 2019, p. 15).

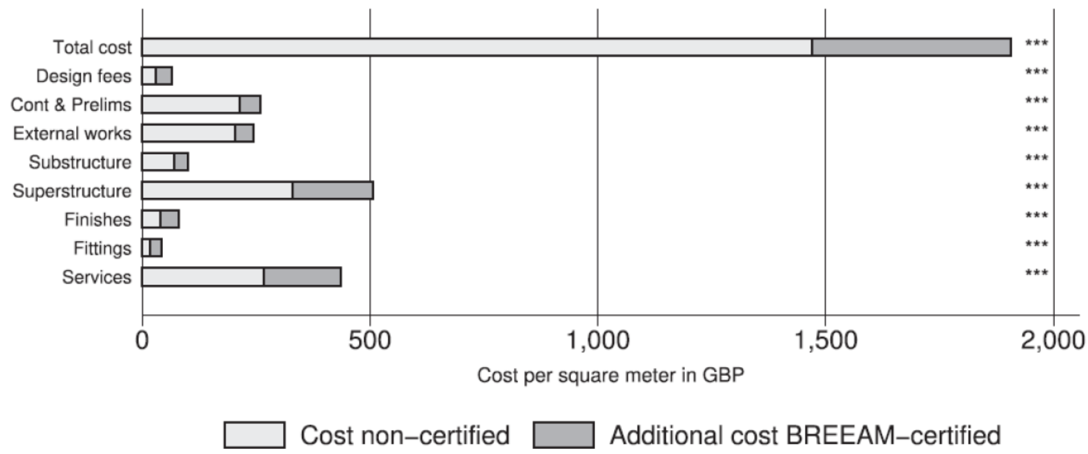

Figure 5.63 Mean construction costs by element from (Chegut et al. Fig1)

In starting to address some of the problems associated with 'green' financing, innovative approaches to the specification and funding of projects are underway in Canada:

> UniverCity collaborated with the City of Burnaby in developing environmental standards and rewards developers for exceptional features and practices. The bylaw is the most stringent in North America in its demand for high green standards. Every building has been built to a performance standard that, for the past decade, exceeded the Model National building code requirements by 30% for energy efficiency and 40% for water efficiency. SFU Community Trust also offers a 10 per cent density bonus for projects that achieve advanced energy goals (reaching an efficiency level that is 45 per cent higher than code) or that include upgraded stormwater management. (SFU Community Trust, 2009)

Even within a commercial framework, the business case for sustainable design keeps getting stronger:

> High-performing buildings can be sold at a premium, with the average green building worth 7 percent more than its traditional counterpart. Green buildings, on average, are 14 percent less costly to operate than traditional buildings, with most new builds today achieving significantly more energy savings than that. Market demand for green building is doubling every three years. That second bullet – the operational savings over the lifespan of a building – gets most of the attention when it comes to sustainable design. Yet what impact does sustainable design have on owners with a finite construction budget or developers who won't own the building after construction? Historically, this group has been told that a high-performing building will only cost them *more* money to construct – dollars that may not be available in project financing. But it is no longer true that sustainable buildings have to be more expensive. We have delivered many deep green projects that came in below cost or at similar price points to what those same buildings would have cost without sustainable design elements. We did this by focusing on three tactics for improving sustainability: leveraging integrated

design, employing energy modelling and programming for efficiencies. (Landreneau, 2017) (*World Green Building Trends 2016 Developing Markets Accelerate Global Green Growth*, 2016).

When it comes to the general acceptability of Double-Design, there are problems of perception to be overcome,[54] but there is also a prospect that the longer time horizon will assist financing options.[55]

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[54] Developers usually build a property for a reason and that it is fit for the purpose they require. This ensures they get exactly what they want at a palatable price. Having to build in, ifs, buts and maybes, could prove unfavourable, particularly if they intend to keep the building long term for their own specific use. People don't like spending money unnecessarily (Ralph Stratton).

[55] In addition to your already range of implications, the implication for financing might play a role: that mortgage financing might be able to work with reduced costs because its duration might be lengthened through double design. And I think the social aspects, for community use and diversity and social mix will be worth exploring (Peter Marcuse).

CHAPTER SIX: IMPLEMENTATION

6.1 RESPONSES TO DOUBLE-DESIGN CONCEPT

The full implementation of Double-Design will require the understanding and support of institutions and people likely to be directly affected. Therefore, before beginning to assess the potential impact of Double-Design, comments were invited from professionals and academics from several countries, including the UK, USA, Kuwait, Greece, Venezuela, Denmark, Mexico and Ireland. They included architects, planners, structural and services engineers, financial experts and clients, and academics working in these fields. The invitation to comment was based upon a brief explanation of the concept together with a questionnaire. Full details of the invitation and all the responses are provided in Appendix Seven.

While disappointed in the response to invitations sent to UK political parties[56], the enthusiasm and creativity of those who have responded has confirmed the significance and relevance of the concept.

Based upon the responses, the concept of Double-Design has been well-received and is considered timely and its implementation would command wide support. It is seen as a significant contributor to sustainability: "An interesting topic and important in terms of long term carbon costs. We are still a long way away from taking this seriously in planning and architecture in the UK. In places like China where most of their (concrete and steel framed) building infrastructure built in the boom of 1990–2010 is obsolete, the implications are huge" (see Appendix Seven for full questionnaire responses).

[56] A timely reminder, perhaps, of difficulties to implementation that will need to be overcome in the future.

There is broad agreement that current designs and programs are too rigid and that whimsical (iconic) architecture should be avoided in favour of the more traditional 'form-follows-function'. Several responders suggest that the value of flexibility and user participation goes beyond its practical utility: "what is the higher-order functional, structural and poetic purpose and response for archetypal buildings that could accommodate multiple 'currently known' and 'future unknown' functions (changing living, work and leisure patterns) going forward? To some extent – it points to a 'social, economic and environmental wrapper or filter' for existing and future building typographies – to promote environmental resilience." This suggests an additional emphasis on beauty and community involvement. Examples are referred to where aspects of flexibility are already built into design guidance used by developers.

The democratization of space as a potential outcome has been especially welcomed: "I really like your proposal. I love the title – especially the 'democratization of space'. Is the idea that for every structure, residential and other, there should be the ability to adapt to an alternate use? Really innovative and creative."

Several responders have recommended more research into the characteristics of old buildings that have worked for new uses. This is what would have been expected from Kincaid's group at UCL had their funding not been very precipitously switched.

A respondent with direct experience confirms the difficulty experienced at Warwick and Loughborough in maintaining a "rigid" diagram intended to accommodate change and growth: "Unfortunately the hospital (Northwick Park) is now a vast hotchpotch of conflicting buildings and styles and the original intent has been lost."

Concerns are expressed about the cost implications of Double-Design, especially the difficulty of persuading developers to make provision for the future: "I would be interested to see a cost model which estimated percentage uplift between current building/design methods and your proposal, this would be key to willingness to adopt; however, if you could demonstrate cost effectiveness it would go some way to providing assurances to anyone concerned." However, several responders view the impact on long-term financing as potentially important: "I think your idea of double design has a lot of potential. In addition to your range of implications, the implication for financing might play a role: that mortgage financing might be able to work with reduced costs because its duration might be lengthened through double design. And I think the social aspects, for community use and diversity and social mix, will be worth exploring."

"My interpretation of 'double design' is that it may, by its nature, involve a degree of 'over design' to compensate for the potential future adaptability of the structure and its performance under a variety of loading conditions." An approach to implementation could include on-site load testing before a change in use. It is also noted that many structures are overdesigned.

Responders are concerned with the length of time it may take to change the law to introduce Double-Design and highlight practical issues concerning warranties and guarantees for long-life materials. In addition, anxiety is expressed that legislation that loosened up planning control would exacerbate problems already caused (e.g. low-quality housing in disused offices). Nevertheless, there is strong support for the conversion of buildings to housing and regret that the concept has not been implemented already: "If they had followed your 'Double Design Approach' many more 50's and 60's [sic] buildings would not have been demolished."

As part of the programme of persuasion leading to the implementation of Double-Design, responders have suggested the need to prove how additional flexibility will work in practice: "However, for now double design must be viewed as rolling a rock up a hill – but it's a rock that needs to be rolled. There has to be consensus that the huge resource investment in a building deserves to be capitalized and utilized for as long as conceivably possible. If the premise was that they should, then more care would be taken over design."

If there are wholly unknown future uses, a responder asks philosophically, how can their requirements be specified? This is a stimulating question requiring a distinction between universally flexible space, on the one hand, and space that has specific identifiable characteristics for particular uses.

While many did, not all responders support an increased professional role for architects during a building's life use phase. But the scepticism about this expanded role for architects is based upon the idea that it will not be necessary provided that buildings are beautiful and capable of personalization.

6.2 IMPACT ON DESIGN AND CONSTRUCTION PROCESS

The reuse of existing buildings should not ignore the potential benefits of applying the principles of Double-Design. Figure 6.1 suggests the way in which the responsibility of custodians and their teams may include consideration of reusing existing buildings prior to embarking upon a new-build project.

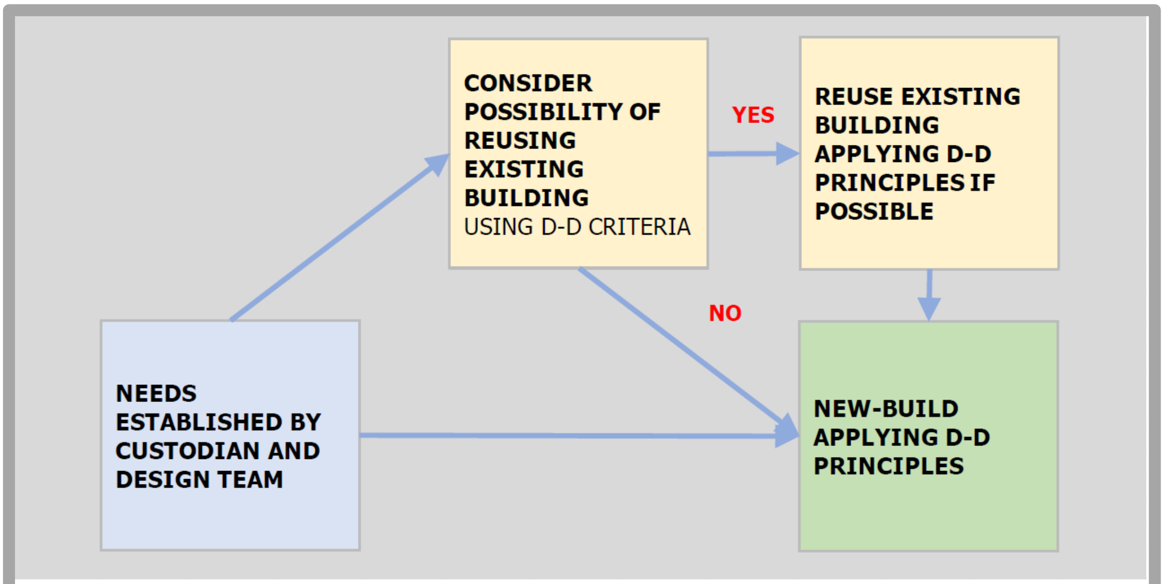

Figure 6.1 Design process: recognizing the potential for the underlying principles of Double-Design to be applicable to existing buildings as well as to new-build

The processes assessing the needs for space for activities in existing buildings are very similar to those for new construction, and several studies, referred to in previous chapters, have highlighted the environmental and waste-reducing value of reuse. The same software helping to find an optimum design solution is likely to apply to options in existing and new buildings.[57]

6.3 IMPACT ON CONSTRUCTION INDUSTRY

The impact of these changes will be far-reaching. Every new building over a specific size will, in effect, contribute to the infrastructure serving society. Each successive use

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[57] **The worst recent period of housing and office building for adaptability has been since World War 2 [sic] when the negative influence of quantity surveyors became prominent thus reducing storey heights, generally trying to save money all to the detriment to the life of the building. If they had followed your 'Double Design Approach' many more 50's and 60's [sic] buildings would not have been demolished (Sir Nigel Thompson).**

will be able to effect an easy transition to its own freshly-defined needs. With the full implementation of Double-Design, all new buildings must be seen as contributing to a use-neutral infrastructure in which the shell (structure and skin) is regarded as more or less permanent. The changing needs of individual groups of custodians and users are met within the shell utilizing 'fit-out' with sufficient flexibility and adaptability to accommodate their spatial needs and sufficient aesthetic individuality to meet their psychological aspirations. The implementation of Double-Design could lead to a restructuring of the construction industry. The long-term elements of the built environment were seen as an open infrastructure into parts of which were placed functional units explicitly designed to achieve the wellbeing and efficiency of their custodians and users.[58] The elements comprising such an infrastructure would include structure together with provision for mains services and their distribution with provision for enhancement over the life of the building. In this way, the needs of society for overall resource efficiency are satisfied by a long-life infrastructure. In contrast, the needs of individual enterprises are met through the provision of local "units" that address specifically defined clusters of functional and aesthetic requirements. *"Infrastructure+fit-out hubs"* could be one outcome of Double-Design. If these are seen as contributing to long-term societal goals, a way would need to be found to encourage individual custodians to cooperate to achieve more significant infrastructure+fit-out elements than would be achieved by the laissez-faire situation

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[58] I suppose the question is about timeframes – what happens after 150 years? It will certainly delay or postpone demolition and the waste associated with it – and spread out the annual carbon credit/debit associated with it. I wonder if on its own, double design doesn't necessarily dictate a construction process and therefore can't guarantee construction waste reduction – but guidance on construction might become an explicit dimension of the double design philosophy/methodology (Rod Bond).

found today. It is not easy to see how this would work within the current political and economic framework. However, the threat of catastrophic environmental damage affecting the planet might create the need for new kinds of cooperation (Till, 2020a). This, in turn, could help towards a more helpful scale of new infrastructure within which the necessary clusters of activities, changing over time, would find a place that worked for however long they were needed. This speculation suggests that there may be an optimum way to use materials in construction related to their sustainability 'credentials'. A new question arises after distinguishing, albeit speculatively, between long-life infrastructure and short-life infill pods. Do the materials used for construction have particular characteristics suggesting appropriate deployment to one or other of those categories of the built environment? Following a traditional design method, a problem would be identified, alternative solutions defined, and, following evaluation, a solution meeting the chosen criteria would be selected for implementation. However, in the light of environmental concerns affecting resources generally and construction materials, in particular, the rules of 'problemistic search' might apply (Posen et al., 2018b). The solution (in this example, construction materials) would solve a problem based on their characteristics. Hence, structural materials with an intrinsically long life expectancy would, for environmental reasons, be required to be used in long-life elements. This is, after all, only following the advice of many scholars, including Straka: "it is essential to prolong the life span of buildings as this will reduce the environmental impact of construction" (Straka, 2006, p. 10).

Figure 6.2 indicates that reconfiguring the original layers and shearing diagrams of Duffy and Brand could lead closer to an optimum arrangement.

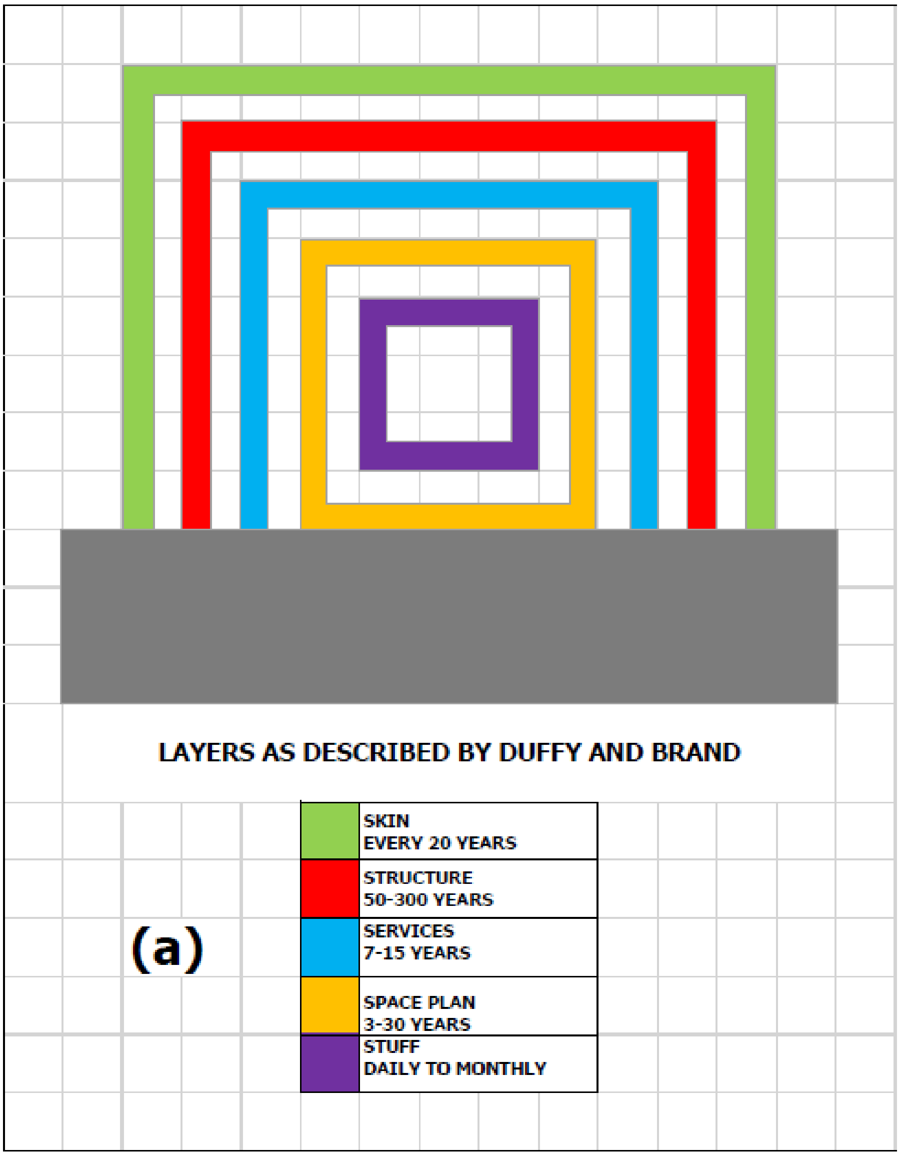

Figure 6.2 (Part 1) Reconfiguring the layers: diagram (a) shows the original time anticipated as appropriate for the longevity of each layer.

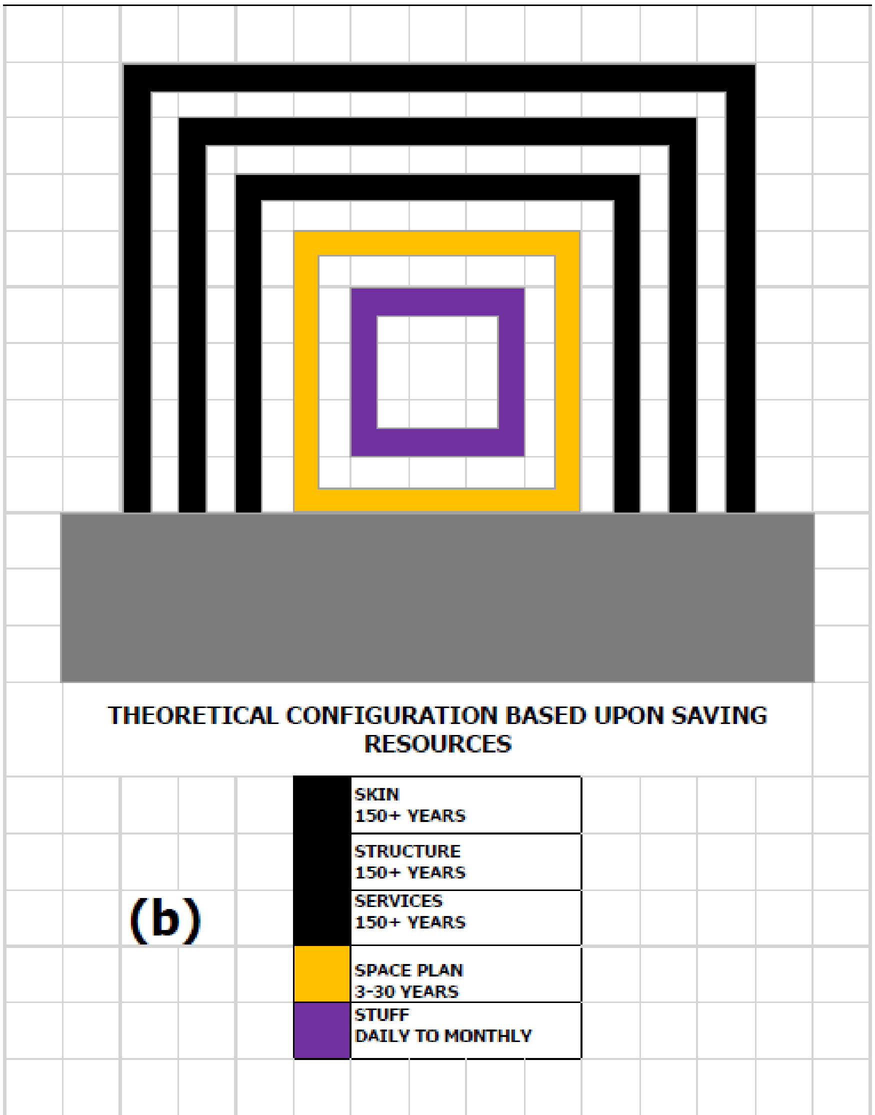

Figure 6.2 (Part 2) Reconfiguring the layers: diagram (b) shows the three 'supporting' layers with the longest life. However, the difficulty of including the services layer is apparent.

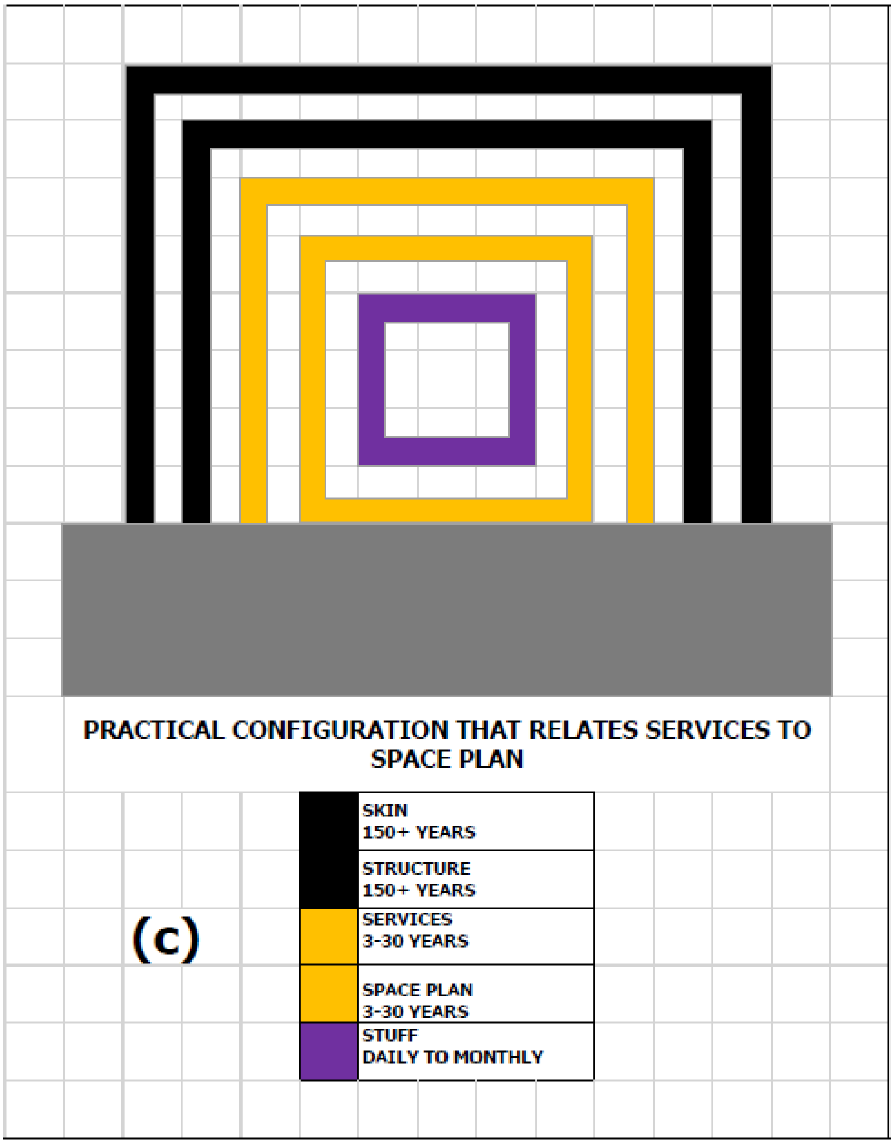

Figure 6.2 (Part 3) Reconfiguring the layers: diagram (c) From a functional and responsiveness point of view, it would be more logical to associate the service layer with the space planning layer as shown here.

This rearrangement of the industry would encourage those wishing to build local "units" to decide for themselves the degree of completion required in the light of the ability and interest of users to take over where the professionals leave off. In addition, this would address one of the principles of the Open Building movement that has received minimal official comment or support: namely, that it should not be assumed in a housing development that all residential projects must be finished internally to the same level or standard.

The idea of reconfiguring the layers has been advocated by Fernandez in the 'Theory of Diversified Longevity'. Echoing several aspects of Open Building, he argues that those with an interest in preserving the future should be:

> Treating the design of buildings as a service in time. Design is focused on achieving an appropriate durability as well as engineering into the building itself the ability to adapt for any number of future scenarios. Scenario buffered design also places value on construction modes that allow for an inconclusive finish to the building. In some instances the best strategy may be a range of conclusions at the completion of the building. In other words, as opposed to completing the building all to the same level of finish, the designers may purposefully leave certain areas "unfinished", or simply finished to a significantly lesser degree, This would allow the users to determine the appropriate materials to be used, as well as allowing the organization to monitor the evolution of use of the space and then plan accordingly. (Fernandez, 2002, p. 5)

He concludes by suggesting that:

> Strategies of diversified lifetimes and localized production are important for the simple reason that they provide many more options for a building to creatively respond to the environment, including the users' interests. And as users' interests change, the building may respond accordingly, In addition, the building may also be able to evolve into an agile material resource. […] the diversified lifetimes approach to the design of buildings has great potential for more efficiently managing the real estate assets of large building owners by spreading the risk of meeting the facilities demands on the business. (Fernandez, 2002, p. 9)

6.4 IMPACT ON PROFESSION

Several assumptions about architecture have been challenged in this thesis. The consequences of modifying the traditional relationships between architects, custodians, users and society at large can be summarized as follows:

- Architects are obliged to think beyond the initial custodian and use and could thereby develop a continuing role in the life and changes for the building's use.[59]

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[59] **I do think there could be specialist disciplines to engage at differing stages across the buildings life-course – (supported by advanced building diagnostic tools – structural/energy/ fabric, etc.) – original designers should have roles/responsibilities to track, plan and organise**

- Custodians have a responsibility to build long-lasting and long-useful buildings

- The separation of shell from fit-out for design purposes facilitates the provision of flexible and adaptable space

- Providing flexible and adaptable space encourages users to be actively engaged in making the most of their environment

- The testing of alternative designs based upon the principles of Double-Design will take account of multiple future occupancies and will be undertaken during the life of the building whenever needed

A case has been made for the role of the architect to be extended to cover the period in which a building is in use. This is discussed speculatively in Appendix Five. There is, however, an additional theme emerging from the analysis of building longevity. Asked to prepare detailed proposals for a new department at a private university in Kuwait, the author (of this thesis) wrote: "So far as the built environment is concerned, architecture and engineering serve the same goals – to create an environment that is safe and satisfying. The way in which the professions of architect and engineer have developed separately, for whatever reasons historically, has not served the public well. Architects have become aesthetically arrogant and have sometimes lost touch with their underlying technical knowledge base. Engineers, on the other hand, have become trapped by their reliance on scientific knowledge that finds it hard to accommodate the irritating diversity of human needs" (Cassidy, 2005, p. 6). The wholly interdependent responsibilities of architect and engineer need to be recognized in any future realignments of professional responsibility.

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for a building's life-course. This will have an influence on practice – (how many practices will live for 150-200 years! (Rod Bond).

6.5 IMPACT ON REGULATORY FRAMEWORK

The impact of the findings of this thesis could be far-reaching, changing the mindset of custodians, users and their architects within a new framework of planning and design legislation.[60] From a practical point of view, the most appropriate way to implement Double-Design will be the planning system. The balance between private property and the state's interest lies at the heart of Proudhon's philosophical position (Proudhon, 1876). Proudhon nevertheless held to his dictum that 'property was theft' but allowable at a small scale, regarding the ownership of property as a necessary inhibitor of state control. In the posthumously published *Theory of Property*, he argued that: "property is the only power that can act as a counterweight to the State".(Proudhon, 1876) Hence, "Proudhon could retain the idea of property as theft, and at the same time offer a new definition of it as liberty. There is the constant possibility of abuse, exploitation, which spells theft. At the same time property is a spontaneous creation of society and a bulwark against the ever-encroaching power of the State" (Copleston, 1994, p. 67).

The philosophical sanction for the implementation of Double-Design relies upon the readiness of the state to override the short-term interests of property owners to serve the long-term interests of society at large. Such long-term interests have been constantly changing. The origins and development of the planning laws in UK trace a

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[60] Obviously the ability to change the permissible land use would be essential, as would be the ability to change building height. Having the original architects and engineers involved for life is prudent. Your project would be as much a regulative exercise as a design task. I am very curious to see what prototype you propose (Evelyn Simos Ali).

process in which the understanding of the 'public interest' has regularly been altered and updated (Cullingworth & Nadin, 2002) (Eversley, 1973). Starting with the public health response to the problems associated with the surge of urban growth in the 19th century, town planning has developed into a complex and sophisticated set of rules seeking to balance the rights of individuals with the broader interests of the community as a whole by protecting and promoting the health and welfare of individuals and groups. The balance is not static, and several commentators have drawn attention to its evolutionary nature. Concluding her review, Nagy says:

> The public, the society has new interests and it is essential to find out which are those in order to create such conditions for the land use planning to allow their achievement. […] However, it is important to aspire to such planning decisions that contribute to and consider the public interest. Meantime, this also serves the interests of planning as a profession in an ethical and rational manner distinguishing the planning profession from other occupations. (Nagy, 2015, p. 7).

Drawing upon experience in the US, Cordes concludes:

> The protection of private interests in property is essential to societal welfare and has long been protected in our legal system. Yet private land ownership has at the same time always been subject to the broader public interest, especially as it concerns the future or potential uses of property. What that public interest is has necessarily evolved over time, with the earlier emphasis on development giving way in more recent years to an equal emphasis on sensible planning and protection of environmentally sensitive lands. Yet the core principle has always remained the same: land, and especially undeveloped land, is a public resource whose use must be guided by public concerns. (Cordes, 1999, p. 28).

While recognizing that there has been some significant deregulation of planning and building law over recent years, the longer view of the process by which the state's interests have been applied, sometimes against the short-term interests of individuals, must include the possibility of further change. If societal goals for sustainability are to be met, for example, the contribution of mandatory design guidance incorporating Double-Design should not be overlooked.[61] The advice and techniques to be developed would have application in several places. Planning legislation could require new-build owners to consider robust approaches to design. Codes of Practice covering particular building types, for example, universities and hospitals, could incorporate advice about the deployment of spaces that optimize both initial and changing uses. All new buildings could be required to be capable of conversion to housing. Evaluation techniques for the review of alternative designs could include methods to test for robustness. There could be more firmly based recommendations for incorporating the themes of change and growth and re-use in the briefing for new buildings and post-occupancy evaluation. There could be a requirement that planning applications be accompanied by a Future Use Assessment, along the lines of an Environmental Impact Assessment. Double-Design could be implemented by legislation demonstrably in the public interest to complement existing health and safety legislation. There is a need to distinguish the characteristics of a space, with its associated equipment and environment, from the characteristics of the custodians and users for whom it is provided. This may seem obvious, but consider, in developing design strategies for the future, it is recommended that the design provide specific characteristics deemed desirable. For example, the space should be "adaptable" or "flexible". The space should enable a range of interventions so that adaptability and flexibility become

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[61] If enforcement of provision of 'Double Design' by law is envisaged, and related possible changes of Building Regulations, hope this is achievable as any changes take such a long time to approve and implement/enforce by law with local authorities (Maysoon Jamali).

characteristics of the space. But without encouragement, guidance, and education regarding when and how to intervene, the putative benefits will be lost, and the intention of facilitating a longer useful life will be thwarted. Since one of the intentions is to ensure longer functional usefulness, it thus seems essential that custodians and users be aware of their space's capacity to help them manage their environment proactively. A precedent for this kind of information flow exists in the form of maintenance manuals that are bequeathed to custodians after construction and before full occupancy. The production by the design and construction team of a similar document setting out the opportunities for the application of the *ilities* (see Appendix Four) during building use would be a mandatory part of the implementation of Double-Design. The design team's continuing involvement throughout the building's life would also contribute to a competent custodian and user activity. Certain kinds of project may be able to demonstrate exceptionally valuable characteristics within the Double-Design spectrum, for example, very long-life, low-carbon footprint, ease of reuse, etc. Are there tax breaks or subsidies that could help promote best practice, even working within a market framework that seems otherwise destined to sabotage good practice?

6.6 IMPACT ON USERS

In a longer-lasting built environment, psychological satisfaction will need to be achieved by handing over more control to users and enabling greater user participation in modifying furniture and scenery in the short term. This is not to say that the external appearances of all buildings will be boring sheds. It is to say that the building as a whole must respect its own longevity.[62] There is a need to reconcile two opposed requirements. It has been suggested above that buildings need to be longer-lasting and capable of different uses in the future from those originally intended. On the other hand, and perhaps necessarily to serve people's interests for variation, entertainment and diversion, buildings need to be differentiated one from another and sometimes to be unique and iconic. As Penn points out, the differentiation may be ethical, aesthetic or process in origin (Penn, 2015). Traditionally, internal arrangements, furniture and interior design respond to the specific functional needs within a longer-lasting shell.[63] These internal flexibilities will remain critical to the achievement and maintenance of full functionality for the structural and material life of the building. Hence, when they are desired or needed, iconic characteristics will have to be achieved independently of the function. Most recognizable buildings are single-function and integrate the internal and external shape of the building, thus rendering them less susceptible to significant changes of use. To achieve society's interests for resource conservation and the individual's interest for differentiation, separating the robust long-life serviced functional shell from the iconic components is necessary. Historical styles of architecture integrate interior and exterior elements and inevitably set a challenge for

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[62] The key is that the transition needs to be easy and natural – what Alexander calls 'smooth transformation' – and the resultant spatial forms and centres need to be really enriched – its not enough for the transition to be functional and effective – it needs to be enhancing and desirable – poetic, inclusive – democratic! (Rod Bond).

[63] I often think that the Australian Aboriginal concept of non-ownership could teach us a lot. Some of my happiest times at university involved claiming a space to work and personalising it for the time I was there, and leaving it for the next person to enjoy when I moved on. I have had quite a lot to do with the Arts University Bournemouth over recent years and the most successful buildings are the most robust, that allow space personalisation without ownership. A kind of Double Design where the initial architectural design allows for further design adaption by the end users (Tom Reynolds).

ingenuity in changing activities. Designing for future uses as well as the initial use should overcome this weakness. So it becomes possible to imagine an architecture that makes the differentiation between buildings variable and temporary. At the same time, the long-lasting functional elements, the shed behind the façade, accommodate a succession of uses.[64]

6.7 IMPACT ON ENVIRONMENT

The environmental benefits of Double-Design have been set out in principle, and the impact on resource utilization and waste reduction will need to be confirmed in future research. However, the extra resources that may be required initially to ensure the desired longevity and high performance of each specific building will, on the basis of evidence available so far, be offset by the overall need for fewer resources over time.[65]

6.8 DEMOCRATIZATION OF SPACE

With its intrinsic adaptability and flexibility, a longer-lasting built environment will better meet future spatial requirements, thus contributing to the potential democratization of space. Over time and as more and more 'new space' is added, the available space will respond to changing spatial needs more efficiently. By designing

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[64] I see it more as an urban planning and design idea – about providing some form of spatial organisational framework, supporting much more mixed and varied used possibilities – sensitive to sequential enrichment – yet operable in a world of uncertainty. While I think it can enable the environment to be more responsive to changing social context – I'm not sure how it plays out in terms of changing fashions/styles, etc. (Rod Bond).

[65] Double Design and the Democratization of Space should be adopted and will make sufficient differences to the environment to make the future desirable again. The life of buildings must be lengthened to hundreds of years and should naturally accommodate changing patterns of use. Developing the built environment must become society's investment rather than something from which a few can profit (Richard D'Arcy).

consciously for future uses, the extent to which the current distribution of space determines or influences the ability to match future needs is reduced or modified. At the same time, the inhibiting constraints represented by the present allocation and distribution of space would be gradually overcome. As a result, there would be less dependence upon ingenuity to create the spaces needed for future activities. This is because, if Double-Design is incorporated, it should be easier to overcome incompatibilities between the characteristics that are necessary for the future and those available from inherited spaces. Space provided as a consequence of Double-Design would not be limited to reflecting only the priorities of the initial custodian. Still, it would be 'open' to the possibility of reflecting later and different priorities as second and subsequent custodians brought their requirements into focus through implementing their projects. The effect of this process would lead, over time, to a stock of space that was readily available to be used for a variety of activities. To the extent that the resulting space could respond to the needs of the time without having to overcome the constraints arising from the social values and priorities embedded in the inherited estate, Double-Design can be seen to be democratizing space. Underlying the concept of Double-Design is the possibility that the present generation is able and prepared to set aside its short-term self-interest to benefit people in the future. This possibility goes to the heart of social and political ideology and is given added urgency by the science-led debate concerning the planet's survival. As Arendt pointed out: "If the world is to contain a public space, it cannot be erected for one generation and planned for the living alone; it must transcend the life-span of mortal men" (Arendt, 1958, p. 55). Even before the onset of environmental concerns, the idea of societal altruism was commanding scholarly attention. Arguing that sociological theory had provided uncritical support for economic concepts like the rationality of self-interest, Monroe introduced her search for an alternative approach to what she called rational actor theory:

> Rational actor theory originated in the classical microeconomics of Adam Smith. In its purest form, it refers to behaviour by an individual actor – a person, a firm, or a political entity – designed to further the actor's perceived self-interest, subject to information and opportunity costs. The genius of Smith's invention – the market mechanism, regulated by an invisible hand – solved a problem that had troubled philosophers since Hobbes made his famous argument that there was one basic human nature and that this nature was self-centred: how can a society of selfish citizens produce collective welfare without authoritarian government? Smith's answer provided a venue through which the pursuit of individual welfare could result in collective wellbeing. (Monroe, 2001, p. 152)

Her goal is:

> To effect a paradigm shift within political science, away from rational choice theory – arguably the leading approach since the 1970s – and toward a theory in which we understand political actions as a function of how we see ourselves in relation to others. I call this a theory of perspective, and have argued that rational choice is effectively a limiting case of the broader theory. […] Only by understanding how people see themselves in relation to others can we begin to build a science of politics that allows for the complex interrelationship between the human needs to protect and nurture our self-interest and the needs for human sociability. Political science is a discipline looking for a new paradigm, a discipline ready for a new paradigm. Psychology and identity provide that paradigm through a theory of perspective on self in relation to others. (Monroe, 2001, p. 166)

More recently, Weinstein sets out the global context for a creative altruism:

> The perception that a common humanity exists and the type of thinking related to this perception can lead to altruistic behaviour. This is an especially important task because intolerance, homelessness, and many other of today's social problems are caused or intensified by egocentric, self-interested behaviour and the perception of some people that others are less than human. Many problems can be solved if we follow Kant's categorical imperative. We know that people in situations of conflict often do forget that we are all human. They tend to deal with others in terms of stereotypes or as enemies. The failure to recognize our common humanity does stand in the way of effective resolution of a large proportion of the problems faced in today's society. […] By insisting that we are all human beings, all part of one world, we may be able to be more effective actors. We would then be prepared to meet the challenges of this late sensate era and, at last, to realize the promise […] of what Sorokin (Sorokin, 1941) called "the ennoblement of human personality". (Weinstein, 2004, p. 55)

These socio-political theories may seem remote from the day-to-day political debate needed before Double-Design is accepted as being in the long-term interest of society. Nevertheless, it is important that a clear academic understanding is emerging that accommodates the urgent redefinition of 'public interest'. The environmental argument for change is set out in an activist blog:

> Sharing things and helping other people may damage the economy, but it's a great way to decrease our environmental footprint. Since the earth's resources are finite, competing to out consume one another is a self-destructive course of action. This, however, is the natural outcome of capitalism, with its focus on money at the expense of all else. As technology has increased the impact of human activity on our environment, concerns about environmental matters such as pollution, climate change, resource depletion are being treated increasingly seriously. As a species, we have a decision to make about how (some would say whether) we want to develop genetic engineering. It well illustrates the dangers of taking a proprietary approach. On the one hand, a successful development would yield great dividends in the form of sales, royalties from intellectual property rights etc. On the other a failure could cause catastrophic damage to the environment. The cost to planet earth of disastrous environmental damage would go not only exceed the resources of any company or state to put right, it could go beyond any financial reckoning. Standard economics doesn't have a lot to say about calculations of this nature. Environmental safety seems unlikely to be assured under capitalism, which insulates people from their effect on their environment. Altruistic economics, by contrast, encourages people to consider the impact of their actions on others. ('Environmentalism & Altruism,' 2020)

The difficulties to be overcome have been anticipated by Popp, who uses survey data to develop a test for altruism in the valuation of environmental amenities. In particular, the paper:

> Develops a test for the hypothesis that current generations are willing to altruistically preserve the environment for future generations. Two tests are developed: one for strong altruism, in which only the societal benefits matter in an individual's willingness to pay, and one for weak altruism, in which individuals show concern for both their own self-interest and the welfare of future generations. The results suggest that individual valuations place almost equal weight on self-interest and altruism. Concern for future generations has led some economists to argue that the social discount rate used in such situations should be lower than the private discount rate observed in market transactions. The conclusion that there exists concern for future generations implies that this would be in accordance with individual preferences if there was reason to believe that similar altruistic concerns were not expressed in the marketplace. (Popp, 2001, p. 349)

CHAPTER SEVEN: CONCLUSIONS AND FUTURE RESEARCH

7.1 CONCLUSIONS

This thesis has sought to balance a philosophical concern for the future of design with exploring a concept capable of practical application. Based upon experience gained as a practitioner, the concept of Double-Design would, when implemented, address many of the concerns and unanswered questions arising from that experience. The implementation of Double-Design will not be easy. However, the process by which technological and policy innovations are spread is well understood. From the cultural anthropology of Rogers (Rogers, 2003) through the geographical and spatial aspects of innovation diffusion (Hägerstrand, 1967), the importance of innovation for the construction industry has also been emphasized (Slaughter, 2000) (Van de Ven et al., 1999). Concerning the *realpolitik* of persuasion, Mintron argues that:

> Policy entrepreneurs play an important role in articulating innovative ideas onto government agendas. They work hard at developing close ties with people through whom they can realize their policy goals and they seek to develop convincing arguments for selling their policy ideas. Naturally, policy entrepreneurs, like other actors in the policy-making process, must be aware of the constraints imposed by election cycles and interest group opposition to their proposals. But many possibilities remain for policy entrepreneurs to form relationships and develop arguments that will help them gain approval of policy innovations. (Mintrom, 1997, p. 30)

With an emerging consensus that architectural priorities must shift from object to process, from completion to use, an appropriate response must be found. There is no sign of this response within the normal range of architectural experience, and nor is it covered in professional qualification, training or public expectation.[66] There is no mechanism for the architect's engagement in, let alone partial responsibility for, the building in use. This thesis explores the possibility that buildings should be designed to last. The achievement of this aim would make a significant contribution to environmental sustainability. While widespread support for several aspects of the Double-Design concept has been identified, the principle that buildings can and should be designed for a succession of uses over a very long life has yet to be recognized as a valid goal for the built environment. Moreover, there has been no exploration of the full extent to which multiple uses could be accommodated *because* of the intention of the original design. However, the extensive reuse of buildings has demonstrated the viability of spaces intended for one use being deployed, sometimes with difficulty, for later use.[67] Furthermore, establishing spatial and constructional compatibilities between the requirements for first and subsequent uses has indicated the potential for Double-Design to be based upon a logical technical footing. Functional obsolescence will need to be slowed down by incorporating flexibility and adaptability and through the application of Double-Design so that the initial design anticipates as wide a range of known and unknown future uses as possible. Applying moral values to issues like

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[66] I don't believe legislative control is necessary, but rather the need to train students to analyze, evaluate, and manage the adaptability of structures to alternative uses. Architects are educated to design and build new buildings. It is the money and ego. I believe there is too much emphasis on design; as a result, students are constantly developing strategies and technology to make tomatoes out of potatoes. They paint the potato red, glue on some stems and leaves and call it innovation. No matter how much they try, it is still a potato. And now you are proposing a PHD thesis for something every five year old knows. Give them a cardboard box and they will show you DOUBLE DESIGN (Rafael Franco).

[67] It is instructive to note that the pioneering research work of Kincaid and his colleagues at UCL about the reuse of existing buildings was brought to a halt due the funding priority being switched to energy-related aspects of design (private conversation).

resource use and waste overcomes any anxieties that may remain concerning the opportunistic appropriation of the green agenda and politically motivated ideas for sustainability. Consideration of the underlying nature of materials reveals a design approach that follows Duffy's "layers" concept to its logical conclusion. Long-lasting materials could be used to provide building infrastructure, the outer shell, capable of containing a succession of the more frequently changed and responsive interiors that could be constructed of short-life sustainable or recyclable materials.[68] Buildings designed to achieve physical longevity should have an associated capacity to continue functioning with smooth transitions between uses. The longitudinal case study of the University of Warwick science buildings over fifty years of use confirms the need to accommodate an extensive range of uncertainties in architectural design. The study reinforces the requirement that flexibility and adaptability must be incorporated in design if lasting usefulness is to be achieved. The provision of flexibility, adaptability and redundancy contribute to spatial robustness in a way that enables custodians and users to accommodate uncertainty.

Several approaches to the implementation of Double-Design have been described, ranging from a fully comprehensive and compulsory framework within modified town planning legislation to a process favouring entrepreneurial competition. To the extent that Double-Design is accepted as being in the public interest, its implementation will rely upon incorporation within the regulatory framework. There would need to be an

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[68] **Also is there a half-way house? Could we design the superstructure to continue, or even be flexible enough to be adapted, and then do a remodel of the walls and interiors to suit another purpose? I suspect this would be more amenable as an investment model. (Ed Murphy).**

enhanced definition of the public interest to include the principles behind Double-Design, including resource conservation criteria covering materials and energy. Several essential themes come together. The possibilities for longevity, arising from material longevity, with moral concerns for resource conservation and a capacity for unlimited design testing through generative design must inevitably ease the way for the implementation of Double-Design. Favourable responses to the concept of Double-Design from the UK and international experts are recorded and are included as Appendix Seven. The responsibility for commissioning new space reflects a particular distribution of economic and social power, but the physical environment will need to respond as this changes. Such a response will be more readily achieved if all new buildings incorporate Double-Design, thus improving the fit between future space needs and future available space, and leading, albeit slowly, to a democratization of space. The identification and exploration of Double-Design as a concept needing to be pursued vigorously with a view to its urgent adoption must therefore be seen as a significant contribution to the debate about the future of architecture and space provision. The confluence of powerful and disconnected themes could lead to radical and comprehensive changes in the way buildings are designed and used. Material technology is enabling the achievement of longer building life. Applying moral principles to resource conservation and waste helps overcome doubts about the politicization and commodification of environmental issues. Developments in generative design software could make it possible to test design alternatives that reflected the requirements of many different building uses. The incorporation of adaptability and flexibility could encourage the active engagement of users and custodians in making the best use of their buildings. A built environment incorporating these themes will make a significant contribution to dealing with uncertainty. The practicality of applying Double-Design based upon the compatibility of design requirements, including floor loadings and floor-to-floor heights, has been demonstrated, albeit subject to additional costs. However, the difficulties of extending the criteria to include the more complex and demanding factors like means of escape need to be addressed. Perhaps the long-term advantages of Double-Design will be so recognized by custodians that they will be prepared, in their submitted designs, to show exactly how present provision or future changes will achieve the necessary degrees of safety.

Architecture must reconcile the logic of using the right materials with the logic of enabling the right activities. The container has to be made of something and human activity has to be contained. The criteria to be used in determining what is "right" in each case must be established with reference to the values and ambitions of the host culture.

Choosing the right materials will be influenced by a desire to contribute to long-term environmental goals by using long-life materials or, for the same reason, by a desire to use recyclable or readily renewable material.

Choosing the right activities will be influenced by understanding the responsibility of present custodians, acting in the public interest, to provide space for the future as well as for their own immediate needs.

Finding creative design solutions that are consistent with these principles, while at the same time satisfying the human need for comfort and well-being, represents the enduring challenge for architecture.

Considering the strength of the antecedent ideas, covering adaptability, growth and change, the desirability of high-performance buildings, adaptive reuse, sustainability and so on, as well as the solid arguments for Double-Design itself as a logical development of them, it is tempting to ask why it has not already been adopted as self-evident common sense?

7.2 FUTURE RESEARCH

This exploration of the Double-Design concept has given rise to several topics for future research, including:

The appropriate amount of space – this thesis has been concerned with the nature of space and with the different ways in which the quality of space may contribute to architectural and societal goals. However, the amount of space needed to accommodate different activities should also be addressed if a comprehensive assessment of spatial robustness is to be achieved. What is the appropriate amount of space required for each activity? Is it possible to objectify space standards? How can issues of fairness in the distribution of spatial standards be managed?[69] As noted, the size of spaces is critical in determining resource use. Therefore, just as incentives may need to be found to encourage the appropriate implementation of Double-Design, they may also need to reward custodians who do not build "too much" space.

[69] A Shaman was asked "what is poison?": "Anything beyond what we need is poison. It can be power, laziness, food, ego, ambition, vanity, fear, anger or whatever". Tolstoy also has strong ideas concerning what is appropriate when it comes to land ownership, greed and ambition, especially in his short story 'How Much Land Does a Man Need?' (Tolstoy, 1993).

Propensity to accommodate change – the propensity to accommodate changes in existing property was identified as significant by Kincaid (Kincaid, 2002), and the idea was refreshed by Schmidt & Austin (Schmidt & Austin, 2016). Further research that matched the need for change in different building use categories (called 'dichotomy of uses' by Schmidt & Austin, p. 145) would add to the understanding of physical characteristics that lead to a greater capacity to accommodate change.[70] [71]

Costs of compatibility – the matrices of compatibility have shown how much physical provision (floor loading and floor-to-floor heights) would need to be increased to achieve the highest common factor amongst differing uses. However, the cost implications of the increases also need to be considered in preparation for presenting Double-Design to decision-makers. Overcoming the barriers to implementation will need to include more research into the potential costs of achieving compatibilities and addressing the remaining issues of scale and location.

Project scale and appropriateness of material use – the distinction made between small and large projects in the application of Double-Design should be reviewed as part of further research, together with the distinction between the environmental impact of long-term Double-Design and the short-term use of recycled and sustainable materials.

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[70] One idea for your research might be to identify older buildings (50 years +) that are still deemed to be "fit", and look at the reasons why they remain fit beyond reasons of good stewardship by their owners. What physical features do such buildings have, etc.? (Michel de Jocas).

[71] I believe the crucial contribution would be a study of redesigns and what makes them possible. Particular cases. Then your suggestions would have the power of empirics. Also, what makes the built environment resistant to redesign--programs and designs that are too rigid (Martin Krieger).

What exactly makes it difficult to achieve multiple uses over time? How 'special' does an activity need to be to not fit in?

Building evaluation – the balance between judging buildings as objects and judging them for what they achieve over their life has, led by art critics and the practices they promote, swung dangerously towards the former at the expense of the latter. What kind of building evaluation could begin to alter this balance? Post-occupancy evaluations do not have the public or professional appeal that may be needed. Perhaps a statutory requirement for the custodian, with their design team and with the active engagement of users, to carry out and publish periodic reviews would help.

Wittgenstein started (in *The Tractatus)* trying to show the strict logical structure of language and its relationship to the world, but his later work (*Philosophical Investigations*) emphasized the fluid nature of language. Is it unreasonable to suggest analogously that while most of my architectural work has been based upon the logic of adherence to the strict brief, I now search for the fluidity of multiple use?

APPENDIX ONE: POETICS OF REUSE

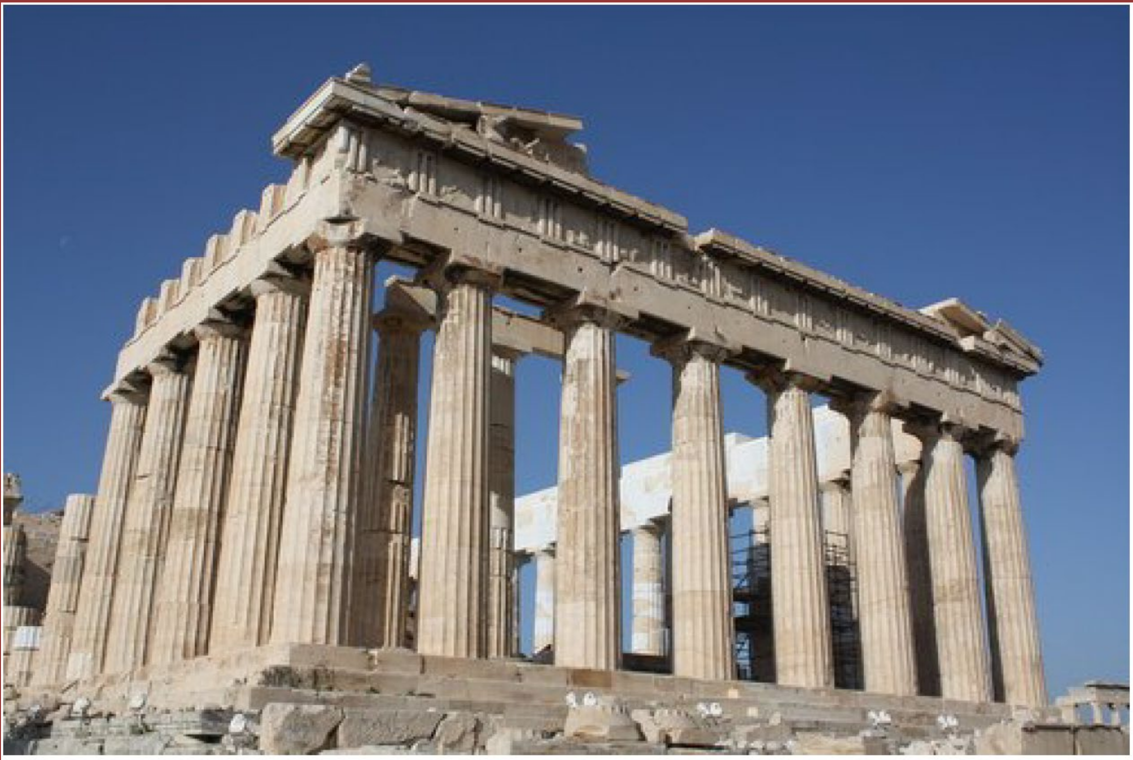

Figure A1.1 The Parthenon, Athens

The history of the Parthenon, shown in Figure A1.1, together with the histories of many monuments, illustrate the compelling narrative power of the twin processes that inevitably attend the use and material decay of all structures built for human occupancy. The case of the Parthenon, for example, covers dramatic functional change as well as a range of material interventions, including repair and maintenance and the recycling of stone from other projects as revealed in Figure A1.2.

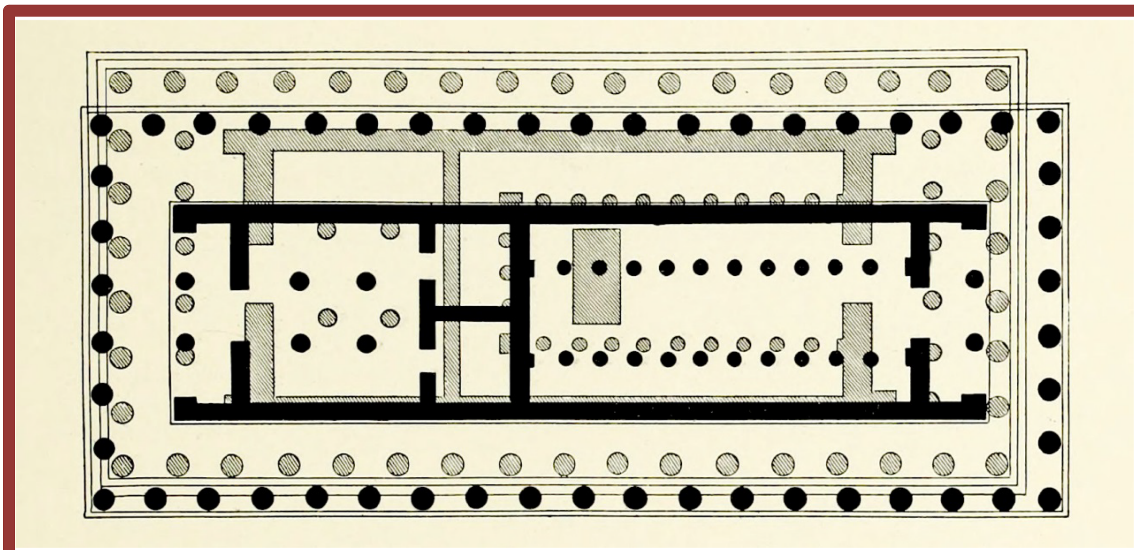

Figure A1.2 The Parthenon, Athens: The Older Parthenon (in black) was destroyed by the Achaemenids during the Destruction of Athens in 480–479 BC and then rebuilt by Pericles (in grey). An earlier structure, known as the Older Parthenon, or Pre-Parthenon, once existed on the site of the current Parthenon. The Parthenon was built between 447 and 432 B.C and was dedicated to the Greek goddess Athena. In the sixth century A.D., the Christian Byzantines conquered Greece and converted the Parthenon to a Christian church. The Parthenon remained a Christian church until 1458 A.D. The Ottoman Turks converted the Parthenon into a mosque yet kept many Christian paintings and artefacts intact. In 1687, facing attack from the Christian Holy League, the Ottomans converted the Parthenon into an ammunitions depot which was bombarded, causing hundreds of deaths and massive structural damage. After centuries of being ruled by the Turks, the Greeks fought for independence in the 1820s. The Acropolis became a combat zone, and the Turkish Army removed hundreds of marble blocks from Parthenon ruins. They also used the lead-coated iron clamps, which held the blocks together, to make bullets. From the rubble, the Turks cleared a space and built a smaller mosque. In the 18th century CE, foreign tourists frequently helped themselves to a souvenir from the celebrated ruin. (Cartwright, 2012) (History.com Editors, 2018) (Wikipedia, 2019)

Over time, the reuse of the building, changing from Greek temple to Christian church to mosque to ammunition dump, illustrates an extraordinary determination and ingenuity to adapt an inherited environment to new purposes. But while the functional changes are well known, recent research throws dramatic light upon the repair and maintenance aspects of the building's history and even upon the source of materials used. Like other dedications and more portable accumulated valuables in a sanctuary, temples and their blocks were considered the property of the deity. Architectural blocks, whether of limestone or marble, were intrinsically valuable because of the cost of quarrying, transporting and shaping them, and their storage and use were part of the economy of a sanctuary, accountable as the deity's property. Occasionally, architectural blocks could be sold off or recycled as raw material, but the regular custom was to make use of the property within the sanctuary, just as discarded or broken dedications were normally buried within the sacred precinct. For the most part, old blocks were consigned to foundations and thereby also buried, but in some cases such material was reused in more visible contexts (Miles, 2011).

> Alterations to the Parthenon and differing aims for its use over the years successively transformed the building's interior with little change to its exterior. "The details and methodology of the Roman alterations are revealed more fully than before. […] including the reuse of architectural members (*spolia*) from a 'stoic' Hellenistic building complex in Athens […] The use of *spolia* is a constructional method characteristic of the late Roman Empire, which called for the disassembly of a [sic] unused or less important building to reassemble another more significant one. In the case of the Parthenon, the architectural members transferred to the Acropolis possibly from the Diogeneion–Ptolemaion complex were reused for the renovation of the building's interior colonnade – a feature of aesthetic value as well as of practical necessity for the construction of a new roof. […] Secondary material from these pagan stoic buildings was apparently employed due to the Athenian society's incapacity for quarrying new marble – an expensive, labour-intensive enterprise. Nevertheless, this pagan Athenian community still had the authority and sufficient means to dismantle an entire building complex and transfer it to the Acropolis for the purpose of repairing the temple of the goddess Athena. The use of *spolia* in the Parthenon and the extensive use of plaster to reconstruct missing parts of the columns and capitals show an intention to redress the temple's losses without replacing entire members. This *ad hoc* tactic was far removed from the original Greek ideal stemming from the creation of a temple as a sacred offering to the god – which called for a spirit of purity, honesty and virtually no regard for expense – during the Classical, Hellenistic or even Augustan eras. The renovation of a destroyed building during these earlier periods was usually achieved through the construction of a completely new one or at least the replacement in full of damaged members." Lambrinou, 2018)

The redeployment of materials from one building to another (Spolia [Latin, 'spoils']), with repurposed building stone for new construction or decorative sculpture reused in new monuments, is the result of an ancient and widespread practice whereby stone that has been quarried, cut and used in a built structure, is carried away to be used elsewhere (Kinney, 2006). This provides a historical precedent for Design for Deconstruction: "the systematic disassembly of a building generally in the reverse order of construction, in an economical and safe fashion for the purposes of preserving materials for their reuse" (Keeler & Burke, 2009). Visitors to Fountains Abbey in

Yorkshire walk past Fountains Hall built from stone plundered (recycled) from the Abbey. "The Hall has seen many uses over the years – stately home, courthouse, an estate employees' lodging and a farmer's house" (National Trust, 2020). Looking at the history of buildings in use from a cultural viewpoint rather than a technical one provides a helpful understanding of the processes of obsolescence and degeneration at work. As Woodward asserts: "When we contemplate ruins, we contemplate our future. […] to a painter or architect, the fragments of a stupendous antiquity call into question the purpose of their art" (Woodward, 2002, p. 2). Woodward echoes the stories of stone plundering for the Parthenon in his account of rebuilding Rome, where the Colosseum was leased as a quarry by the Popes (Woodward, 2002). The perversity of the shared fascination with ruins is widely recognized (Cairns & Jacobs, 2014). Woodward describes the emotive power of ruins, arousing nostalgia and occasional encouragement to write *en plein air* in the minds of travellers. Shelley wrote, in the preface to Prometheus Unbound: "This poem was chiefly written upon the mountainous ruins of the Baths of Caracalla, among the flowery glades" (Holmes, 1974, pp. 489–509). The titanic battle between buildings as the symbols of tyranny and the regenerative forces of nature was the inspiration behind some of Shelley's finest works. As Woodward says: "Nature had never seemed more beautiful than in its destruction of tyranny." The literal deconstruction of monuments at the hands of the natural processes of decay is a central theme of Shelley's *Ozymandias*. The apocalyptic demolition of cities and their overrunning by nature is also a theme in nineteenth-century novels like *After London or Wild England* (Jefferies, 1885). Visiting, studying and even stealing and relocating ruins seem to have satisfied some deep psychological need and this theme has been celebrated in an exhibition at the TATE in London (Macdonald, 2014) and in blogs and websites dedicated to the exploration of ruins (Greco, 2012). One of Double-Design's unexpected, but possibly no less desirable, outcomes is that there would be fewer ruins. Those interests only satisfied by ruins would need to find satisfaction elsewhere, perhaps through the agency of "built-in bomb damage"[72] or simply building shapes that replicate damage and decay (e.g. Gehry and Libeskind, according to Woodward). While historians and archaeologists track the reuse of space and materials, and cultural commentators record how buildings in decline have inspired poets and artists, Cairns and Jacobs embrace with relish the processes of decay themselves. "Buildings, although inanimate, are often assumed to have 'life'. And it is the architect, through the art of design, who is the authorized conceiver and creator of that life" (Cairns & Jacobs, 2014, p. 1). They argue that "developing receptiveness towards the negative realms of wasting and death is profoundly important for contemporary architecture" (Cairns & Jacobs, 2014, p. 1). Their book looks awry at:

> Standard architectural concerns such as what comprises good form, what generates effective function and utility, and how architecture might best add positive value to the world. It does so not to kill architecture off. We broach these negative states of buildings in order that architecture might live better with the malforming and deforming facts of its existence. […] not as a death sentence for architecture, but as a path to a new way for it to be in the world." (Cairns & Jacobs, 2014, p. 2)

They have a well-developed interest in the processes of decay but less interest in its avoidance or delay. However, their interest certainly overlaps with this research in drawing attention to the importance of construction waste. Their thesis is based upon a reverence for an anthropomorphic view of architecture in which buildings are imbued with "life" and must therefore suffer from death and other "natural" occurrences. The authors themselves, even in the subtitle of their book, acknowledge the perversity of

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[72] A description of the irregular roofscapes of office buildings from the 1960s especially in London.

their view. Although the ramifications of the metaphor are explored with vigour, there is no escape from the conclusion that the fundamental assumption is false. The forces at work on the fabric and use of buildings are man-made and far from analogous to those in nature. It is indeed perverse to regard the introduction of time into the discussion of architecture when common sense would have it there all the time, properly reflecting human changes. What they assume as the self-evident truth of capitalism plays into their story of buildings and architecture as a cyclically replaced phenomena: "Architecture in capitalist contexts is foundationally bound to destruction" (Cairns & Jacobs, 2014, p. 54). Their argument that architectural creativity is predicated upon the constant need for replacement and innovation in the face of building decay is only supported within the framework of a throw-away society. They approvingly quote Berman: "everything that bourgeois society builds is built to be torn down […] all these are made to be broken tomorrow, smashed or shredded or pulverized or dissolved, so they can be recycled or replaced next week, and the whole process can go on again and again, hopefully forever, in ever more profitable forms" (Berman, 1982, p. 99). They conclude correctly that architecture must not be seen as creating a static and fixed entity but as a backdrop for what they call "the real eventful flux of being". (Cairns & Jacobs, 2014, p. 66). Changes to individual buildings, brought about for many reasons, impact the city and the way its occupants understand the city. Post-modernist commentators see the drama of such slow-moving changes as confirming the importance of time as a critical factor in architectural development. De Arce suggests three principles that condition the transformation process:

> The first of these is that 'towns need permanence as much as they need transformation'. What the permanence gives is a sense of the town's cultural memory and a sense of itself which has been built up over time. The second is the need for a network of meaningful places within a town to give cohesiveness to the transformation process. Without this sense of a town's structure given by the relationship of places rather than systems of transport or activity zone, the transformation process is too fragmented to be effective. A third principle is the need to understand the relationship between temporary and permanent elements in the city. […] the plan of the town as an example of a permanent element,

> explaining that although this can be modified, it can only be done in such a way as the essential relationships of the plan are maintained. (de Arce, 2015, p. xvi)

The way in which form and function may be transformed over time is described by Rossi:

> The amphitheatre at Nimes had a precise and unequivocal form as well as function. It was not thought of as an indifferent container, but rather was highly precise in its structure, its architecture, and its form. But a succession of external events at a dramatic moment in history reversed its function, and a theatre became a city. In this way, form, the architecture of urban artefacts, emerges in the dynamic of the city. It is in this sense that I speak of the Roman cities and the forms left by them: for example, the aqueduct at Segovia that crosses the city like a geographic artefact, the Merida bridge in Estremadura, the Pantheon, the Forum, the theatres. Over time these elements of the Roman city became transformed and their functions altered, and when looked at from the point of view of urban artefacts, they suggest many typological considerations. Another outstanding example is Sixtus V's project for the transformation of the Coliseum into a wool mill; here too the extraordinary form of the amphitheatre is involved. On the ground floor laboratories were planned, and on the upper levels there was to have been housing for the workers; the Coliseum would have become a huge workers' quarter and a rationally organized building. (Rossi, 1982, p. 87)

Domenico Fontana was instructed to re-plan the Colosseum as a silk-spinning factory housing its workers. The role of nostalgia, or, rather, the capacity of a culture to exploit the symbolism of its predecessors to confirm the position and dignity of current rulers, is described with respect to Fontana: "His works are paradoxical in their interest of reconceiving of the ancient and adhering strictly to ancient guidelines, but in envisaging these works in such a way that they are completely modern conceptions of the ancient rules. This is important to the field because we need a more comprehensive understanding of the origins of the architectural monograph which began in the early modern period" (Walker, 2016, p. 16).

APPENDIX TWO: BUILDING STOCK BACKGROUND DATA

The scale and nature of the existing building stock provide the context within which to explore the potential for change. In the UK, more than 20% of the housing stock was built before 1919, and, of the total stock, nearly 6.9 million homes have had at least one extension, some 30% of the housing stock (Department for Communities and Local government, 2016, p. 5). The average new home in England will have to last 2,000 years if the sluggish rate of house building and replacement continues, the Local Government Association warns (LGA, 2017). About three-quarters of the commercial office buildings standing in 2010 will still be standing in 2050, and these will account for 60% of the building stock in 2050 (Clark & Johnston, 2013).

> For the year 2017 and for Great Britain, the value of new construction (excluding infrastructure) was £109.69 billion and for repair and maintenance the value was £56.5 billion (*Output in the Construction Industry*, 2018). The value of construction new work in Great Britain continued to rise in 2019, reaching its highest level on record at £118.977 billion (Office for National Statistics, 2021)
>
> Within the UK, the construction industry is the largest consumer of resources, requiring more than 400 million tonnes of material a year (WRAP, 2018). 33% of the total generated waste in Europe is from construction and demolition (Mastrucci et al., 2017).

Countries spend a great deal of money, ingenuity and time on the reuse, repair and maintenance of their building stock. With historically low interest rates continuing to facilitate private sector investment in the industry, the marginal fall in public sector work has been far outweighed by the continuing expansion of the private sector, with growth coming from the housing sector in particular.

Another indicator of the dynamics of change in response to social change can be derived from statistics published by the NHS. For example, the estimated market value of land and property surplus to requirements in 2016 is given at UKP 252m, while in

July 2017 alone, surplus NHS property was sold for UKP 5.5m. (*NHS Properties for Sale*, 2017)

In an article in Public Finance, Barej reports that:

> The amount of public sector land up for sale in England has more than doubled. […] Figures from the Commons library indicated the amount of NHS land under consideration for sale last financial year was more than 1,332 hectares, up 144% from the 545.7 hectares identified in 2015/16. The figures, released by the Labour party […] also show the surplus NHS land put up for sale went up by 125 plots from 418 plots in 2015/16 to 543 plots in the space of a year. (Barej, 2017)

Fifty-four million square feet of commercial property is built every year. The commercial property industry has been adding an average of about 54 million square feet of new space every year in the last decade across the three main property sub-sectors, representing approximately 0.7% of the total stock of commercial property. This reflects a value (including the land) of around £12 billion – contributing 1% to the UK's GDP each year. However, activity over the last five years has been running at half the previous rate, particularly in the retail and office sectors. Despite a growing population and economy, new construction is barely covering the loss of stock through demolition and change in use to residential. The net amount of commercial property floor space has increased by just 1.3% in aggregate over the last ten years, according to the IPF's The Size and Structure of the UK Property Market End-2015 Update. (*PIA-Property-Report-2016-Final-for-Web.Pdf*, 2016)

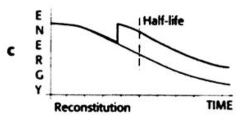
Output from the global construction industry is expected to rise to $12.7 trillion in 2022, up from $10.6 trillion in 2017. However, despite this promising outlook, the industry has gained only 1% of productivity due to a lack of digitisation in the last 20 years. This creates an opportunity to add $1.6 trillion by innovating in this area (Raconteur, 2019).

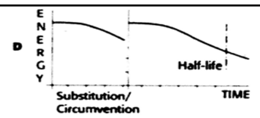
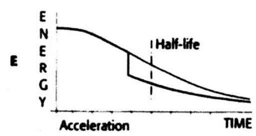
Meanwhile, the highly durable products that construction provides add significantly to the wealth of the nation. More than three-quarters of the nation's stock of its vital capital assets are the products of construction. These total £3,620 billion, about half of which are houses that provide shelter, security, and a sense of community for households and a critical source of wealth. (Raconteur, 2019, p. 4). Measured by the economic value it adds (gross value added) for the National Accounts, construction's contribution to the UK economy in 2018 amounted to about £116.3 billion, equating to 6.1% of total gross domestic product (Raconteur, 2019, p. 8).

APPENDIX THREE: INTERVENTIONS

The chart below offers a comprehensive list of interventions classified initially between those aimed at maintaining the status quo and those aimed at achieving change.

INTERVENTIONS TO MAINTAIN STATUS QUO			
CATEGORY	**INTERVENTION**	**SOURCE**	**DEFINITIONS**
1 ACTIVELY KEEPING A BUILDING THE SAME	**1.1 PRESERVATION**	(Baines, 1923)	method involving the retention of the building or monument in a sound static condition, without any material addition thereto or subtraction therefrom, so that it can be handed down to futurity with all the evidences of its character and age unimpaired
		(English Heritage, 2006).	to keep safe from harm
		(BS 7913: 1998)	Arresting or retarding the deterioration of a building or monument by using sensitive and sympathetic repair techniques. Preservation means 'the state of survival of a building or artefact, whether by historical accident or through a combination of protection and active conservation'
		(Weeks and Grimmer, 1995)	It also can be defined as 'the act or process of applying measures necessary to sustain the existing form, integrity and materials of an historic property . Preservation focuses on the maintenance and repair of existing historic materials and retention of a property's form as it has evolved over time. It includes protection and stabilization measures. Preservation is defined as the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property. Work, including preliminary measures to protect and stabilize the property, generally focuses upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction. The limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project. However, new exterior additions are not within the scope of this treatment. The Standards for Preservation require retention of the greatest amount of historic fabric along with the building's historic form.
	1.2 MAINTENANCE	(BS 3811:1993)	combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function
		(BS 7913:1998)	routine work necessary to keep the fabric of a building, the moving parts of machinery, grounds, gardens or any other artefact, in good order
		(Ashworth, 1997)	In other words, it consists of regular ongoing work to ensure that the fabric and engineering services are retained to minimum standards
		(Douglas, 2006)	**Built-in maintenance** is maintenance that is required in every building to meets the functional needs of the owner/occupier.
			Built-on maintenance is a form maintenance performed on materials that have been included in the building, but are not necessary for its function. As an example, consider the need for carpeting on the office corridor floor of a warehouse area. A value-engineering analysis would probably eliminate the need to provide such a carpet.
			Condition-based maintenance is a form a preventive maintenance. It is initiated as a result of knowledge of an item's condition from routine or continuous monitoring.
			Contingency maintenance is similar to reactive maintenance, except that it contains an element of planning. It is sometimes referred to as 'casual maintenance'. Unplanned requisitioned or emergency maintenance can fall under this heading.
			Corrective maintenance is carried out to restore (including adjustment and repair) an item that has ceased to meet an acceptable standard.
			Cyclical maintenance comprises those items of maintenance, which recur at regular intervals such as redecoration, changing filters or the resurfacing of roads or paths, etc. It is termed cyclical because the maintenance process will have to be repeated regularly during the life of the building.
			Day-to-day maintenance deals with instances of essential repair, which cannot be left until the next routine maintenance cycle without serious consequences. Thus day-to-day maintenance is difficult to predict and organize.
			Emergency maintenance is maintenance that is necessary to be attended to immediately. It aims to avoid serious consequences, usually in terms of safety and security. Unforeseen breakdown or damage may necessitate emergency maintenance.
			Fixed time maintenance: activities repeated at pre-determined intervals, within a planned maintenance system.
			Just-in-time maintenance is maintenance derived from manufacturing and delivery industries in which the basic approach is to continually reduce (product) costs. This is achieved by stressing the elimination of waste, no rejects, no delays, no stockpiles, no queues, no idleness and no useless motion.
			Opportunity maintenance is work done as and when possible within the limits of operational demand.
			Planned maintenance is organized and carried out with forethought, control and the use of records to a predetermined plan.
			Planned preventive maintenance is carried out at pre-determined intervals, or to other prescribed criteria, and intended to reduce the likelihood of an item not meeting an acceptable standard.
			Reactive or unplanned maintenance is maintenance that is left until there is a major breakdown or a serious complaint from the user before action is taken.
			Reliability centred maintenance (RCM) is a method of maintenance designed to anticipate the mode and consequences of failure. It helps to select the appropriate tasks to prevent failure before it occurs based on risk and experience.
			Running maintenance is maintenance carried out while the item is in service.
			Schedule maintenance is designed to cover the items that deteriorate at a more or less uniform rate and which have a high degree of urgency.
			Shut-down maintenance is maintenance that needs to be carried out on an item when it is taken out of use.
			Statutory maintenance is required by law to prevent serious injury or damage should failure occur. Examples of this type of maintenance are servicing of lifts and associated plant, electrical equipment, water treatment, steam boilers, pressure vessels and air conditioning.
		(Iselin and Lemer, 1993)	**Periodic renewals:** regular changes of items, such as replacing carpets, painting or overhauling compressors .
			Planned short service life: a decision that the service life of a facility should be shorter than might typically be expected; implies selection of components that have low first cost and low durability; similar to the term 'planned obsolescence' used in the automobile and consumer products industries

2 ACTIVELY RESTORING A BUILDING TO A PREVIOUS (INITIAL) STATE	**2.1 RESTORATION**	(Watt,2007)	restoring the physical and/or decorative condition of a building to that of a particular date or event
		(BS 3811)	To bring back an item to its original appearance or state
		(Weeks and Grimmer, 1995)	It is often undertaken to depict a property at a particular period of time in history, while removing evidence from other eras. This usually involves reinstating the physical and/or decorative condition an old building to that of a particular date or event. It includes any reinstatement works to a building of architectural or historic importance following a disaster such as extensive fire damage. Restoration may also be defined as 'the act or process of accurately depicting the form, features and character of a property as it appeared at a particular period in time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period'
		(Grimmer, 2017)	is defined as the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period. The limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a restoration project. The Restoration Standards allow for the depiction of a building at a particular time in its history by preserving materials, features, finishes, and spaces from its period of significance and removing those from other periods.
	2.2 REBUILDING	(BS 7913: 1999)	Remaking, on the basis of a recorded or reconstructed design, a building or part of a building or artefact that has been irretrievably damaged or destroyed
	2.3 RENOVATION	(Douglas, 2006)	Upgrading and repairing an old building to an acceptable condition, which may include works of conversion. renovation – restoring a building to an acceptable condition, which may include works of conversion
	2.4 RECONSTRUCTION	(British Standards Institution, n.d.)	reassembling a building using 'extant materials and components supplemented by new materials of a similar type, using techniques approximating to those believed to have been used originally, based on existing foundations and residual structure, historical or archaeological evidence'
		(BS 7913: 1999)	The re-establishment of what occurred or what existed in the past, on the basis of documentary or physical evidence .
		(Weeks and Grimmer, 1995).	Reconstruction, in other words, re-creates vanished or non-surviving portions of a property for interpretative purposes
		(Grimmer, 2017)	**Reconstruction** is defined as the act or process of depicting, by means of new construction, the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location. The Reconstruction Standards establish a limited framework for recreating a vanished or non-surviving building with new materials, primarily for interpretive purposes. The Guidelines are introduced with a brief overview of the primary materials used in historic buildings; the exterior and interior
	2.5 STABILIZATION	(Douglas, 2006)	Substantial maintenance and adaptation works to ensure a building's long-term beneficial and safe use. It often includes major repairs and strengthening works such as stitching and underpinning
	2.6 REPAIR	(BS 8210: 1993)	is the 'restoration of an item to an acceptable condition by the renewal, replacement or mending of worn, damaged or decayed parts' .
		(BS 7913:1998).	'work beyond the scope of regular maintenance to remedy defects, significant decay or damage caused deliberately or by accident, neglect, normal weathering or wear and tear, the object of which is to return the building or artefact to good order'
		(Ashworth, 1997)	**Repair** is associated with the rectification of building components that have failed or become damaged through use and misuse
	2.7 MITIGATION	(Harris, 2001)	Defined as acts that alter the environment that supports the deterioration mechanism. Hence it is external to the fabric and does not affect the fabric directly
3 ACTIVELY RESTORE AFTER DAMAGE			
	3.1 REINSTATEMENT	(Douglas, 2006)	Major repair and restoration works to put back a building to its condition prior to substantial damage such as fire, flood or earthquake.
INTERVENTIONS TO ACHIEVE CHANGE			
4 CONSERVE FOR SAME USE	**4.1 REFURBISHMENT**	(Watt, 2007)	Modernizing or overhauling a building and bringing it up to current acceptable functional conditions . It is usually restricted to major improvements primarily of a non-structural nature to commercial or public buildings. However, some refurbishment schemes may involve an extension. *(Revamp) An informal term used to describe overhauling a building to upgrade its appearance and facilities. It is sometimes used by laypeople as an alternative expression to refurbishment.*
	4.2 CONSOLIDATION	(Douglas,2006)	Basic adaptation and maintenance works to ensure a building's ongoing beneficial use.
	4.3 CONSERVATION	(International Council on Monuments and Sites, 1964)	making a building fit for 'some socially useful purpose'
		(Feilden, 2003, p. 3)	action taken to prevent decay and manage change ... embraces all acts that prolong the life of our cultural and natural heritage'
		(BS 7913:1998)	action to secure the survival or preservation of buildings, cultural artefacts, natural resources, energy, or any other thing of acknowledged value for the future' Preserving a building purposefully by accommodating a degree of beneficial change.
		(English Heritage, 2006)	process of managing change in ways that will best sustain the values of a place in its contexts, and which recognises opportunities to reveal and reinforce those values'
	4.4 RECONSTITUTION	(Harris, 2001)	 Is the exact opposite of mitigation in directly re-establishing a level of performance

5 CONSERVE FOR DIFFERENT USE	**5.1 ADAPTATION**	(Watt, 2007)	accommodating a change in the use of a building, which can include alterations and extensions
		(Chudley, 1983)	Any work to a building over and above maintenance to change its capacity, function or performance. In general terms adaptation means the process of adjustment and alteration of a structure or building and/or its environment to fit or suit new conditions
			However, more specifically it is also considered as work accommodating a change in the use or size or performance of a building, which may include alterations, extensions, improvements and other works modifying it in some way. ***(Remodelling)*** *This is a North American term analogous to adaptation. It essentially means to make new or restore to former or other state or use.*
	5.2 ADAPTIVE REUSE	(Iselin and Lemer, 1993)	Conversion of a facility or part of a facility to a use significantly different from that for which it was originally designed
	5.3 ALTERATION	(Watt, 2007)	Modifying the appearance, layout or structure of a building to meet new requirements . It often forms part of many adaptation schemes rather than being done on its own.
	5.4 CONVERSION	(Watt, 2007)	making a building of one particular type fit for the purposes of another type of usage. Making a building more suitable for a similar use or for another type of occupancy, either mixed or single use.
	5.5 REHABILITATION	(Watt, 2007)	Work beyond the scope of planned maintenance, to extend the life of a building, which is socially desirable and economically viable
		(Weeks and Grimmer, 1995)	It is a term that strictly speaking is normally confined to housing. Rehabilitation can also be defined as 'the act or process of making possible a compatible use for a property through repair, alteration and additions while preserving those portions or features which convey its historical, cultural or architectural values'
	5.6 RECYCLING	(Douglas,2006)	Transforming or re-utilizing a redundant or other underused/unused building or its materials for more modern purposes.
6 CHANGES TO IMPROVE OR ENHANCE PERFORMANCE	**6.1 RETROFITTING**	(Iselin and Lemer, 1993)	The redesign and reconstruction of an existing facility or subsystem to incorporate new technology, to meet new requirements or to otherwise provide performance not foreseen in the original design .
		(Ashworth, 1997)	In other words, retrofitting is the replacement of building components with new components that were not available at the time of the original construction
	6.2 IMPROVEMENT	(Douglas, 2006)	Bringing a building and/or its facilities up to an acceptable or higher standard as required by the building regulations or occupier, possibly including alterations, extensions or some degree of adaptation. Beneficial improvement entails replacing something with a new item on a like for-like basis. ***(Renewal)*** *Substantial repairs and improvements in a facility or subsystem that returns its performance to levels approaching or exceeding those of a recently constructed facility.*
			Substantive improvement on the other hand, involves the replacement of an element or component with a new item having a higher performance rating.
	6.3 UPGRADING		Enhancing the performance characteristics of a building's major elements, components and/or services.
	6.4 MODERNIZATION	(Watt, 2007)	Bringing a building up to current standards as prescribed by occupiers, society and/or statutory requirements.
	6.5 REVITALIZATION	(Watt, 2007)	Extending the life of a building by providing new or improving existing facilities, which may include major remedial and upgrading works
		(Watt, 2007)	extending the life of a building by providing or improving facilities, which may include works of repair
	6.6 SUBSTITUTION/CIRCUMVENTION	(Harris, 2001)	 Assumes the substitution of new material which will outlive the existing material. With circumvention, not only is the material substituted but also the way the material functioned. It goes outside the original envelope.
7 INTERVENTIONS THAT ENLARGE THE BUILDING	**7.1 EXTENSION**	(Watt, 2007)	Expanding the capacity or volume of a building, whether vertically by increasing the height/depth or laterally by expanding the plan area.
	7.2 REPLICATION	(Wong, 2017)	An appropriate strategy not only to conserve unprotected historic buildings but especially if such replication encourages historic ways of building.
	7.3 RELOCATION		Dismantling and re-erecting a building at a different site. It can also mean moving a complete building to a different location nearby.
8 OVERALL MANAGEMENT	**8.1 TEROTECHNOLOGY**	(BS 3811, 1993)	This is a combination of management, financial, engineering, building and other practices applied to physical assets in pursuit of economic life-cycle costs : Terotechnology is aimed at achieving the best possible value for money for a user from the procurement and subsequent employment of a physical asset. It is concerned with total costs over a building's full life, and is derived from the Greek word 'tereo', I care.
	8.2 ACCELERATION/DEMOLITION	(Harris, 2001)	 This implies doing in an orderly way what would otherwise happen in an uncontrolled and possibly dangerous manner
	8.3 NON-INVASIVE CHANGES	(Watt, 2007)	This important category of interventions covers the rearrangement and replacement of furniture and fittings. 1 Rearrangement- moving furniture and fittings to suit activities 2 Replacement- acquiring new furniture and fittings

APPENDIX FOUR: PRODUCT DESIGN

A growing body of academic researchers, companies, independent think tanks, government bodies and other policy stakeholders have addressed the topic of product design longevity. The 2015 conference aimed to embrace this emerging area of research, sharing knowledge and expertise to explore the influence that product longevity has on environmental, economic and social sustainability. A multi-disciplinary approach to this topic is vital, and contributions were thus invited from scholars from various backgrounds, including design, geography, anthropology, business management, economics, marketing, consumer behaviour, sociology and politics.

Designing for the future has become of great significance in the field of product design and manufacturing. For example, de Weck et al., echoing the concern expressed earlier about designing only for first use, argue:

> In the epoch of *great inventions and artefacts*, the implicit mandate of the engineer and inventor was to "design for first use." The aim was to design and build an artefact that would "work" and fulfil its primary function when first turned on or started up. If it did not, it was back to the drawing board. Immediate functionality was the main focus. Little or no attention was paid to side effects or other more subtle behaviours, especially those that might be far in the future. (De Weck et al., 2016, p. 65)

De Weck et al. introduce the "ilities" as indicative of characteristics of systems desired beyond the first use: "The ilities are central to any discussion of engineering systems, and require a very precise definition: The ilities are desired properties of systems, such as flexibility or maintainability (usually but not always ending in "ility"), that often manifest themselves after a system has been put to its initial use. Quality was the other ility to emerge in this early epoch" (De Weck et al., 2016, p. 66). Figure A4.1 confirms the increasing significance of the "ilities".

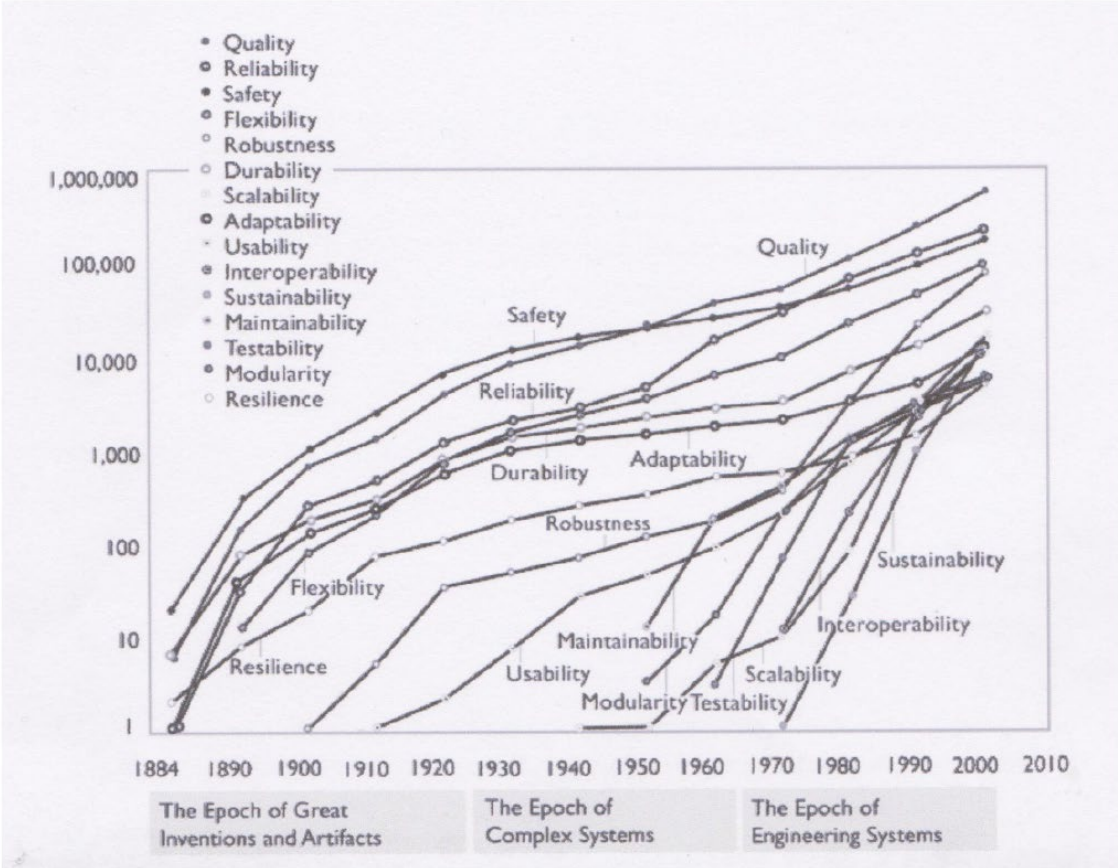


Figure A4.1 Cumulative number of journal articles in which an ility appears in the title or abstract of the paper (1884–2010) from (De Weck et al., 2016)

The life of a product is accepted as a critical part of the product value whereas, as noted elsewhere in this thesis, architecture is still dominated by a culture in which it is seen as an object, as a container, rather than valued through its capacity to contain.

Fricke and Schulz name four aspects of changeability: Adaptability, Flexibility, Robustness and Agility, where the latter describes how rapidly a system can change (Fricke & Schulz, 2005). Haberfellner and de Weck used the term agility synonymously with adaptability (De Weck et al., 2016). The Merriam Webster dictionary defines the words adapt, adaptable and flexible as follows: to adapt stands for "to make fit (as for a new use) often by modification" and adaptable stands for "capable of becoming adapted". In contrast, the word flexible is explained as "capable of being flexed", "yielding to influence", or "characterized by a ready capability to adapt to new, different, or changing requirements". According to these definitions, adaptable can be considered as "capable of extrinsic modification" whereas flexible can be regarded as "capable of intrinsic modification" (*Merriam Webster*, 2011). A third term to be derived from the term adaptive is robust. Robust systems can withstand external noise factors without changing themselves (Taguchi, 1987).

Kissel et al. focus on Design for Adaptability (DfA):

> The *ability of adapting something* expresses to perform this task in a reasonable time with a rational amount of effort. Therefore, we determine the adaptability of a system as the triangulation of time, effort, and costs to perform an adaption. The faster, easier, and cheaper the adaption is, the higher the system's adaptability. Hence, we define adaptability as the ability of a system to perform external adaption cost-efficiently and effectively. (Kissel et al., 2012, p. 3)

Modest design guidance supporting housing adaptability by making provision for the future incorporation of elevators for multi-level buildings is widely available but not mandatory (Habinteg, 2010).

There are some similarities between buildings and products, enough to consider that what may apply to one may apply to the other. It is helpful to look at systems longevity being actively developed by systems engineers. Browning and Honour introduce the search for a measure of life-cycle value (LCV), stating that:

> A goal of systems engineering and associated endeavours is to produce enduringly valuable systems. […] We are especially interested in what we call enduring systems – i.e., products with relatively long lifetimes. Most large, complex, and expensive systems are anticipated to have a fairly long life cycle, and even simpler systems' life cycles are extending from the perspective of the product platforms that give rise to multiple product generations. LCV is becoming more important as the complexity and costs of systems increase, as the environments of system operation become more dynamic, and as designers and customers become more aware of its implications. […] Therefore, designers must consider not only how to meet specifications that will satisfy stakeholders today but also the trajectories of markets and technologies that will determine what it takes to satisfy stakeholders in the future. (Browning & Honour, 2008, p. 3)

Despite the dominance of profitability as providing a significant driver for change, Kissel et al. do offer some insight into how the approach to value can be disaggregated: "When a system gets adapted, its artefacts (tech. components or software) can be *attached, detached, transformed, scaled, merged,* or *separated"* (Kissel et al., 2012, p. 5).

Figure A4.2 shows the points in the product design process where adaptation can be introduced.

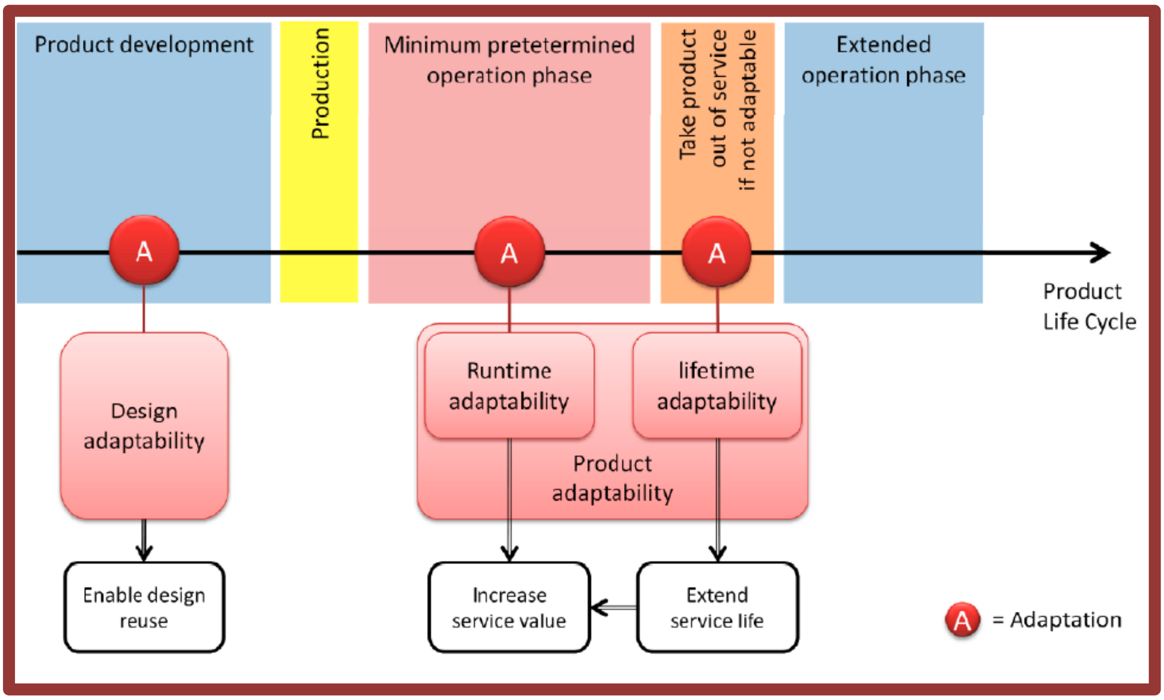


Figure A4.2 Life cycle phases identifying the points along ther design process at which "adaptation" must be applied: from (Browning & Honour, 2008, figure 5.1)

The concept of lifetime value, illustrated in Figures A4.3 and A4.4, complements the ideas associated with the interventions related to structural deterioration and functional obsolescence.

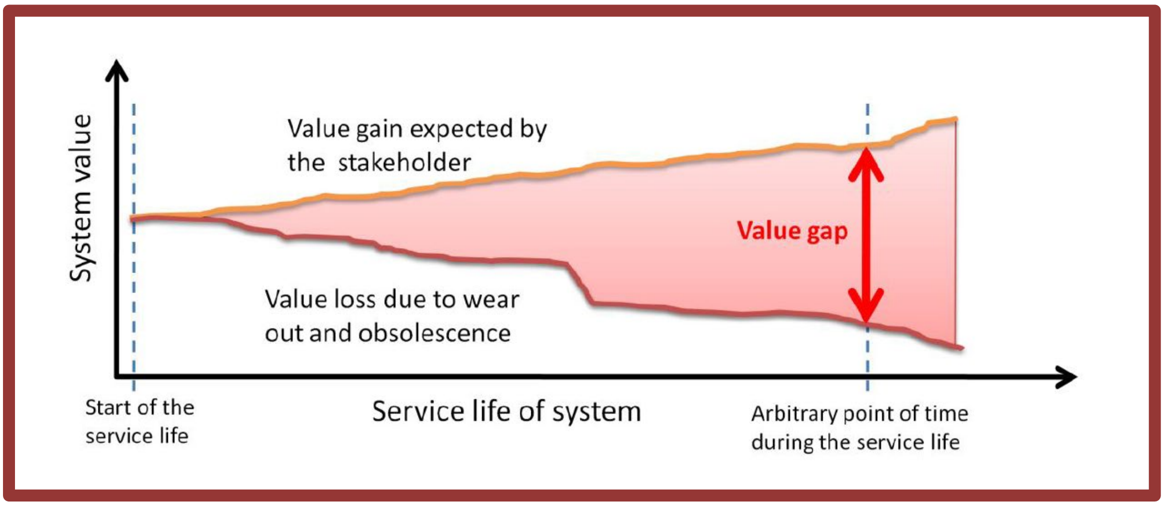


Figure A4.3 The growing value gap of a system: from (Browning & Honour, 2008, figure 1.1)

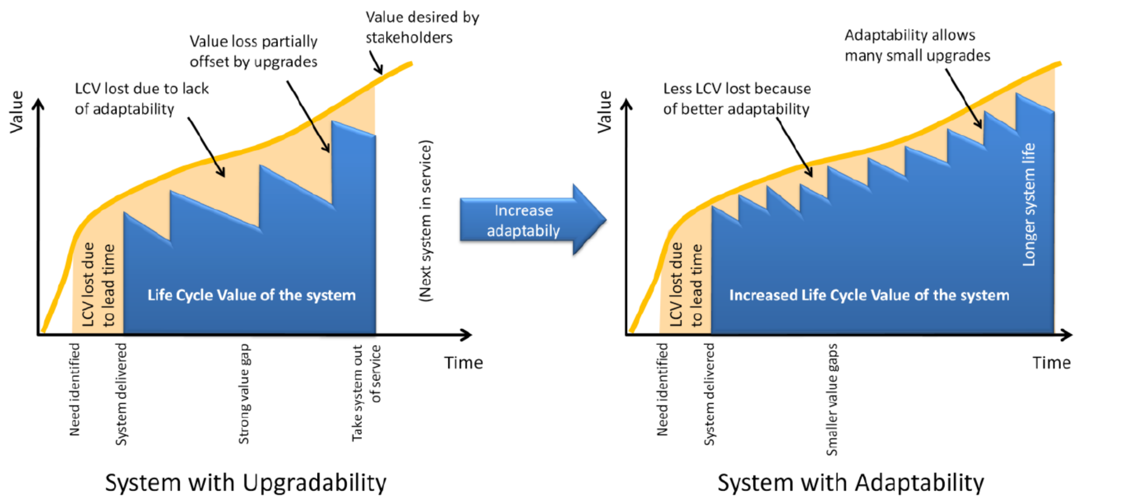


Figure A4.4 Life Cycle Value: suggests that adaptability enables smoother transition to achieve a longer system life: from (Browning & Honour, 2008, figure 1.2)

The developing methodology requires the systematic evaluation and costing of alternative adaptations, taking into account scenarios that may be assessed using Monte Carlo or other statistical forecasting methods.

The Amisa team provide an example of a product for which changeability was a major requirement:

> The customer's need for adaptability of a laptop is apparent when a hard drive needs to be replaced, RAM be upgraded, or a new USB device be plugged in. Furthermore, the architecture design of a personal computer is characterized by decoupled, modular decomposition of its main components […] Therefore, the PC can easily be used as an intuitive example for Design for Adaptability and helps to understand the principles and methods in this evolving research field. (AMISA Consortium & Contract 262907, 2014, p. 12)

The engineering approach to adaptability helps to distinguish between adaptability for "known" or specifically anticipated change, on the one hand, and unforeseeable change, on the other. While the preliminary analysis by the AMISA team is suggestive of the overall similarities between products and buildings, it must remain for another time to assess the full possibility of applying their methodology to buildings.

De Neufville summarizes the new approach to engineering problems:

> A fundamental evolution is occurring in the field of management of technology and innovation, in the field of systems planning and design. It is due to the introduction of the concepts and use of "real options" that represent the flexibility of the system to adjust to new circumstances, avoiding the downsides and exploiting the upsides. The value of this flexibility has not been recognized by the traditional methods of project evaluation, the procedures associated with discounted cash flows. This new methodology entails a deep, almost revolutionary change in the way technical professionals think about technology management and design. It brings them to:
>
> - Recognize that the value of the projects is integrally associated with the fluctuations of the market, and thus that they need to be closely in touch with these matters in order to design appropriate products;
> - Understand that uncertainly is not always a risk to be avoided, but also presents valuable opportunities that can be exploited;
> - Adopt a proactive stance toward risk, looking not just to respond to it passively, but to manage it proactively through the use of real options; and
> - Introduce far more flexibility, justified in terms of its option value, into the design of systems than has been the norm. (Neufville, 2003, p. 18)

From a cost viewpoint, the methodology for product design could seem to apply to buildings as well. After all, Double-Design is intended to achieve many of the "ilities" espoused by product designers. Yet, the engineering systems for which the new methods are being developed are firmly embedded in the market economy. Indeed the merging of marketing and product development divisions in major corporations has been recommended (Neufville, 2003). It remains doubtful whether the global criteria for sustainability are capable of incorporation.

Nevertheless, the engineering approaches loosen up the understanding of the processes involved in product/building life. The incorporation into products/buildings of the ilities does not imply that they will all be activated. The separate articulation of each of the desired characteristics, together with an assessment of the likelihood that each would be deployed and in what circumstances and at what additional cost, provides a fresh way of looking at design. The recognition of the importance of the "ilities", for example, suggests that the life of a product is accepted as a critical part of the product value whereas, as noted elsewhere in this thesis, architecture is still dominated by a culture in which the product of architectural activity is seen as an object, as a container, rather than its capacity to contain.

A significant innovation in the approach to improving the design process in engineering was made by Steward. He recognized that the interdependence of the elements and factors involved in design were not accounted for in traditional project planning approaches like CPM and PERT. He noted that:

> Engineering design involves the specification of many mid variables which together define a product, how it is made, and how it behaves. Before some variables can be determined, other variables must first be known or assumed. This implies a precedence order of the variables, and consequently of the tasks of determining these variables. In engineering design this ordering will contain circuits, i.e., A cannot be determined unless B is first known or assumed, but B cannot be determined unless A is first known or assumed. (Steward, 1981, p. 71)

By analysing the dependencies between the identified variables, he shows how a precedence matrix is constructed and then, by iteration, partitioned or rationalized to produce a matrix that indicates where information must be guessed or estimated to complete the design.

This framework appears to offer some exciting opportunities for design process analysis, including some examples that cross the tribal boundaries between architecture and engineering research, most notably the work at Loughborough University on adaptability (Austin et al., 1999). Within engineering, the effects of Steward's modest paper have proved dramatic. A literature review paper by Browning in 2016 listed 553 footnotes (Browning, 2016).

An earlier paper by Browning introduces DSM (Design Structure Matrix) as follows: "Products, processes, and organizations are each a kind of complex system. the classic approach to increasing understanding about a complex system is to model it, typically by 1) decomposing it into subsystems about which we know relatively more; 2) noting the relationships between (the integration of) the subsystems that give rise to the system's behaviour; 3) noting the external inputs and outputs and their impact on the system" (Browning, 2001, p. 292).

Summarizing the difficulties to be encountered in applying DSM-based techniques, Browning continues: "In practice, DSM-based approaches may have to overcome barriers resulting from organizational inertia, scepticism, 'not invented here' syndrome, ignorance, etc. Typically, such attitudes stem from more fundamental problems, such as a lack of system thinking and closed-mindedness. […] While a somewhat decentralized approach can ameliorate the 'amount of data' problem, the submodel assimilation and verification challenges remain" (Browning, 2001, p. 302).

The DSM approaches may encompass information flow, dependencies and both static and time-based systems. Browning concludes his assessment:

> DSMs facilitate intelligent system decomposition and integration analysis – whether the system is a product, a process, or an organization. The system is analysed and structured by rearranging the DSM, either by clustering or by sequencing. In many cases, merely building a DSM model provides a useful approach to organizing and visualizing system information. […] Enterprises that recognize, understand, and exploit the relationships between product architecture, organization structure, and process configuration should benefit from significant improvements. (Browning, 2001, pp. 303–304)

Yet, the technique appears to have served the interests of a *more efficient* design process in terms of time and resources rather than a better product.

APPENDIX FIVE: CURRICULUM FOR BUILDING USE

Architecture as a discipline has no role or professionally required part to play in the use of buildings. However, as more is understood about use, more should be taken back of the territory sacrificed to or stolen by the facility managers and others.[73] There is an emerging consensus that time is a critical component in understanding architectural space. There is a notation, Thiel, (1961) that tracks movement and perception over time. There is an analytic method, space syntax, that enables an understanding of movement and spatial transition and allows comparisons between different design options regarding movement and organizational structure. There is mathematical analysis of enclosed space in the morphology of March and Steadman. *What we do not see is the activities over time that are driving and shaping the space.* What is needed is *a morphology of activity* to complement the *morphology of space.*

Education for architects and others for an enhanced role during the use of buildings should include an understanding of organizational theory, and the work of Ackoff is especially relevant in advocating interactive planning incorporating stakeholder

[73] Which brings us to the importance of design in building for longevity, and architects understanding of what constitutes good design, how buildings get used, and what we as society and users expect from them. I am not sure that the profession is fully up to speed in how it educates architects to understand what design for longevity entails. This brings us full circle to where I started and the industry-design paradigm. It's not there yet, but in ten years it may well be a necessity. (Ed Murphy).

participation and constant testing and communication (Ackoff, 1981) (Ocak, 2015) (Ackoff et al., 2001)

Responsibility for ensuring the long life and long usefulness of buildings in use requires specific education and training. It is not sufficient for a completed building to have the capacity to apply the 'ilities'. There needs to be an embedded understanding of their relevance, which can only be achieved through education that demonstrates their value.

In seeking spatial compatibilities between initial building uses and subsequent uses (to achieve Double-Design), is it possible to generate an activity-based notation rather than relying upon the indicative notation implied by the spaces required by those activities? A single activity can be seen to generate a particular space in the over-simplified world of anthropometric guidance. That single activity has to be seen as the generator or the propagator of an unknown number of other related activities. It is, after all, the space needed by a cluster of contiguous activities that drives towards a particular shape of the enclosure. For example, a work-station in an office or a laboratory or a classroom does not of itself generate the need for space. It is only the starting point (or volume) of a spatial continuum that must logically include the space needed to attend meetings, the cafeteria, the bathrooms, the access ways and the escape routes. These together make up a contiguous whole for each individual and, taking into account the overlap of space utilization, it is the aggregation of such volumes that ultimately requires enclosure and determines the spatial limits. The briefing process for buildings requires the custodians and users with their design teams to anticipate all the extended contiguities of space that the stated starting positions may generate. Perhaps by focusing upon *all the activities that might be related to a given activity, over time,* it will become possible to address Hägerstrand's concern for the quality as well as the quantity of interaction. A contributory weakness of the architect's position in society is that he has a fleeting relationship to his 'product', a relationship usually ended when a building is handed over. To overcome this, the profession could build up its expertise on the use of the building, on the interventions that are possible and, related to and supported by the principles of Double-Design, to develop a long-term relationship with the spaces for which they have some responsibility. The topics that could be included in educating for such a new responsibility include:

- Briefing for continuing use
- Nature of activities
- Space provision: quantity and quality
- Organizations: growth and change
- User consultation and engagement
- Material maintenance
- Building materials characteristics
- Testing alternative layouts; computer skills
- Architecture and engineering: understanding history and professionalism

The case study described in Chapter Four suggested that in the cases of Warwick University and Loughborough, the integrity of their planning diagrams came to an end at least in part due to the absence of the original architects. There was no one in place to champion the principles upon which those original plans had been based. A mandatory extension to the architects' contract to cover the use of the building together with periodic post Occupancy Evaluations could help to overcome this problem.

APPENDIX SIX: USE CLASS ORDERS/FLOOR-TO-FLOOR HEIGHTS

The diagram below sets out the recommended floor-to-floor heights for Use Classes.

Activities unsuitable for the application of Double-Design are included for purposes of completion but are shown shaded.

USE CLASS ORDERS	A PRIORI SUITABILITY FOR DOUBLE-DESIGN AS INITIAL USE	KINCAID USE CATEGORIES		FLOOR-TO-FLOOR HEIGHT	NOTES	
PART A						
Class A1. Shops					Department stores 5-5.5 FF (Coleman, 2010)	
Use for all or any of the following purposes:						
(a) for the retail sale of goods other than hot food,	Y	6				
(b) as a post office,	Y					
		4	small shops			
		5	large shops			
		7	specialized shops			
(c) for the sale of tickets or as a travel agency,	Y	8		5.5		
(d) for the sale of sandwiches or other cold food for consumption off the premises,	Y					
(e) for hairdressing,	Y	9				
(f) for the direction of funerals,	Y	10				
(g) for the display of goods for sale,	Y					
(h) for the hiring out of domestic or personal goods or articles,	Y					

(i) for the reception of goods to be washed, cleaned or repaired,	Y					
where the sale, display or service is to visiting members of the public.						
Class A2. Financial and professional services				4.5	The target floor-to-floor height is based on a floor to ceiling height of 2.5 m to 2.7 m for speculative offices, or 3 m for more prestige applications, plus the floor depth including services. The following target floor-to-floor depths as shown in the table below should be considered at the concept design stage: Prestige office 4 – 4.2 m Speculative office 3.6 – 4.0 m Renovation project 3.5 – 3.9 m (Engineering Students' Guide to Multi-Storey Buildings, 2020.)	
Use for the provision of:						
(a) financial services, or	Y					
(b) professional services (other than health or medical services), or	Y	33	other services			
(c) any other services (including use as a betting office) which it is appropriate to provide in a shopping area, where the services are provided principally to visiting members of the public.	Y	32	betting			
Class A3. Food and drink				4.2	So my advice is to start with a 14'-0" floor-to-floor assumption and adjust by 8" increments if it becomes necessary. Share this with the design team and ask them to verify at the first opportunity that it works for them (Architekwiki, 2020)	
Use for the sale of food or drink for consumption on the premises or of hot food for consumption off the premises.	Y	11				
PART B						
Class B1. Business						
Use for all or any of the following purposes:						
(a) as an office other than a use within class A2 (financial and professional services),	Y			4.5	See A2 above	
(b) for research and development of products or processes, or	Y			4.5	See A2 above	
(c) for any industrial	Y			5.5	see B2 below	

process,						
being a use which can be carried out in any residential area without detriment to the amenity of that area by reason of noise, vibration, smell, fumes, smoke, soot, ash, dust or grit.						
		34	office machinery computers			
		35	medical instruments			
		36	retail sale			
		37	post and courier			
		38	finance insurance real estate (support)			
		39	finance insurance real estate			
		40	computer			
		41	R&D			
		42	general business			
		43	public admin			
		44	medical practice			
		45	other health			
		46	social work			
		47	activities of membership			
		48	radio/TV activities			
		49	news agency			
		50	extra-territorial organizations			

Class B2. General industrial						
Use for the carrying on of an industrial process other than one falling within class B1 above or within classes B3 to B7 below.	Y			5.5	The maximum height of a road truck is 4.5 m, so there is usually no point in higher doors (except waste transfer buildings, aggregate stores and the like which need to cater for tipping trucks up to 11 m high – and of course Aircraft Hangars). Fork lift truck masts may be higher, dictating a 6 m eaves height. 5.6 m is the minimum height in which 2 storeys of office can reasonably be built (John REID & Sons Ltd, 2020)	
Manufacturing		12	food			
		13	tobacco			
		14	textile			
		15	leather			
		16	wood			
		17	publishing			
		18	machine tools			
		19	elec tools and equipment			
		20	motor vehicles			
		21	transport equipment			
		22	light manufacturing			
		23	fuels and chem products			
		24	basic metals			
		25	fab metal			
		26	metal recycling			
		27	mineral-based			
		28	rubber and plastic			
		29	construction industry			
		30	wholesale trade			
		31	cargo handling			
Class B3. Special				5.5	As B2 above	

Industrial Group A						
Use for any work registrable under the Alkali, etc. Works Regulation Act 1906 (1) (a) and which is not included in any of classes B4 to B7 below.	Y					
Class B4. Special Industrial Group B						
Use for any of the following processes, except where the process is ancillary to the getting, dressing or treatment of minerals and is carried on in or adjacent to a quarry or mine:	N					
(a) smelting, calcining, sintering or reducing ores, minerals, concentrates or mattes;	N					
(b) converting, refining, re-heating, annealing, hardening, melting, carburising, forging or casting metals or alloys other than pressure die-casting;	N			NA		
(c) recovering metal from scrap or drosses or ashes;	N					
(d) galvanizing;	N					
(e) pickling or treating metal in acid;	N					
(f) chromium plating.	N					
Class B5. Special Industrial Group C						
Use for any of the following processes, except where the process is ancillary to the getting, dressing or treatment of minerals and is carried on in or adjacent to a quarry or mine:						

(a) burning bricks or pipes;	N					
(b) burning lime or dolomite;	N					
(c) producing zinc oxide, cement or alumina;	N					
(d) foaming, crushing, screening or heating minerals or slag;	N					
(e) processing pulverized fuel ash by heat;	N					
(f) producing carbonate of lime or hydrated lime;	N					
(g) producing inorganic pigments by calcining, roasting or grinding.	N					
Class B6. Special Industrial Group D						
Use for any of the following processes:						
(a) distilling, refining or blending oils (other than petroleum or petroleum products);	N					
(b) producing or using cellulose or using other pressure sprayed metal finishes (other than in vehicle repair workshops in connection with minor repairs, or the application of plastic powder by the use of fluidised bed and electrostatic spray techniques);	N					
(c) boiling linseed oil or running gum;	N					
(d) processes involving the use of hot pitch or bitumen (except the use of bitumen in the manufacture of roofing felt at temperatures not exceeding 220°C and also the manufacture of	N					

coated roadstone);						
(e) stoving enamelled ware;	N					
(f) producing aliphatic esters of the lower fatty acids, butyric acid, caramel, hexamine, iodoform, napthols, resin products (excluding plastic moulding or extrusion operations and producing plastic sheets, rods, tubes, filaments, fibres or optical components produced by casting, calendering, moulding, shaping or extrusion), salicylic acid or sulphonated organic compounds;	N					
(g) producing rubber from scrap;	N					
(h) chemical processes in which chlorphenols or chlorcresols are used as intermediates;	N					
(i) manufacturing acetylene from calcium carbide;	N					
(j) manufacturing, recovering or using pyridine or picolines, any methyl or ethyl amine or acrylates.	N					
Class B7. Special Industrial Group E						
Use for carrying on any of the following industries, businesses or trades:						
Boiling blood, chitterlings, nettlings or soap.	N					
Boiling, burning, grinding or	N					

steaming bones.						
Boiling or cleaning tripe.	N					
Breeding maggots from putrescible animal matter.	N					
Cleaning, adapting or treating animal hair.	N					
Curing fish.	N					
Dealing in rags and bones (including receiving, storing, sorting or manipulating rags in, or likely to become in, an offensive condition, or any bones, rabbit skins, fat or putrescible animal products of a similar nature).	N					
Dressing or scraping fish skins.	N					
Drying skins.	N					
Making manure from bones, fish, offal, blood, spent hops, beans or other putrescible animal or vegetable matter.	N					
Making or scraping guts.	N					
Manufacturing animal charcoal, blood albumen, candles, catgut, glue, fish oil, size or feeding stuff for animals or poultry from meat, fish, blood, bone, feathers, fat or animal offal either in an offensive condition or subjected to any process causing noxious or injurious effluvia.	N					
Melting, refining or extracting fat or tallow.	N					
Preparing skins for working.	N					

Class B8. Storage or distribution				10.97	A study in 2016 identified approximately 73% of existing warehouse and distribution facilities, as well as those under construction, between 300,000 to 600,000 square feet were 32′ clear. When you assess how much inventory will fit in a building, it is as much about how high you can rack as it is about floor space. Evaluating the most common racking and pallet heights (56″ pallet height / 64″ rack module, 64″ pallet / 72″ rack module and 72″ pallet height / 80″ rack module), it's pretty easy to see the cost savings. When using the most common pallet configuration of a 64″ pallet height, then a 32′ clear height building only accommodates 5 pallets. However, a 36′ clear height building allows for another pallet position, which improves storage capacity by 20% for the operator/tenant. Similarly, a 56″ pallet configuration allows for an increase to six positions (in some instances seven positions depending on roof slope), which improves storage capacity by 12%. A 72″ pallet height allows for stacking of five pallets high instead of four pallets, which improves storage capacity by 25%. It's clear to see how a 4′ increase in a building's clear height creates additional vertical cube capacity ranging from 12% to 25%. This is a significant cost savings compared to paying rent and operating expenses for 12% to 25% more square feet" (Understanding Warehouse Efficiency | 36′ Clear Heights & What It Means to Warehouse Operators, 2018)	
Use for storage or as a distribution centre.	Y					
PART C						

Class C1. Hotels and hostels				3.6	Ceiling Height: 2.5 m minimum, 2.7 m optimum (Iklim, 2020).	
Use as a hotel, boarding or guest house or as a hostel where, in each case, no significant element of care is provided.	Y	51	hotels and hostels low-cost			
		52	hotels and hostels medium-cost			
		53	higher education residential			
Class C2. Residential institutions						
Use for the provision of residential accommodation and care to people in need of care (other than a use within class C3 (dwelling houses)).	Y	54	residential institutions	4.5	A minimum ceiling height of 3000 mm is required in Operating rooms, Interventional Imaging rooms and Birthing rooms. Ceiling mounted equipment must be able to achieve the required clearance height of 2150 mm when in the stowed position, especially within circulation areas (Space Standards and Dimensions – Guideline Section – International Health Facility Guidelines, 2015)	
Use as a hospital or nursing home.	Y					
Use as a residential school, college or training centre.	Y					
Class C3. Dwellinghouses				3.6	The minimum floor to ceiling height in habitable rooms is 2.5 m between finished floor level and finished ceiling level. A minimum floor to ceiling height of 2.6 m in habitable rooms is considered desirable and taller ceiling heights are encouraged in ground floor dwellings (Design for London, 2010)	
Use as a dwellinghouse (whether or not as a sole or main residence):						
(a) by a single person or by people living together as a family, or	Y	1				
(b) by not more than 6 residents living together as a single household (including a household where care is provided for residents).	Y	1				
		2	multiple occupancy			
		3	private with staff			

PART D						
Class D1. Non-residential institutions						
Any use not including a residential use:						
(a) for the provision of any medical or health services except the use of premises attached to the residence of the consultant or practitioner,	Y			4.5	"Ceiling Heights in Laboratories D RM section 4.4.3.4 includes a required minimum ceiling height of 9'-0" and an optimal ceiling height of 9'-6" in laboratories. Although laboratories by their nature are individually planned and must respond to the requirements of the research to be conducted, good practice and long experience has proven that these ceiling heights are necessary to provide the flexibility required by evolving research programs. Laboratories are regularly updated to reflect changes in staffing, equipment and research protocols. A new lab or major renovation should be designed to accommodate the planned use for which programming and planning is conducted, but also to accommodate future equipment and functions that can reasonably be anticipated for the space. Although ultimate flexibility and universal adaptability is an unrealistic expectation, a laboratory design is not successful if it cannot accommodate a reasonable range of upgrades and changes." (National Institutes of Health, 2018) "Laboratory storey heights would typically be 4.5 m-5 m, compared with a typical office storey height of 3.5 m-4 m. This can result in the whole building being constructed to the greater storey height, which increases costs of frame, cladding and vertical services distribution. Alternatively the laboratory and office components of the building may be separated and constructed to their own standards, depending upon the site and footprint opportunities." (Barton & Breen, 2015)	
		55	primary ed			
		56	secondary ed			
		57	higher ed			
		58	adult and other ed			
(b) as a crèche, day nursery or day centre,	Y					
(c) for the provision of education,	Y					
(d) for the display of works of art (otherwise than for sale or hire),	Y					
(e) as a museum,	Y					
(f) as a public library or public reading room,	Y	61	library	5.5	Adequate ceiling height. Most book shelves are high (typically 7' or 7'6"), and 8' ceilings are almost always too low. Suspended uplights (the only satisfactory way to light small libraries) usually hang down at least two feet from the ceiling, so ceilings need to be a minimum of 10 feet high to keep the lights 8 feet off the floor. Most libraries do better with ceilings 11 or 12 feet high (canvas.highline.edu, n.d.)	
(g) as a public hall or exhibition hall,	Y					
(h) for, or in connection with, public worship or religious instruction.	N	60	religious organizations			
		59	veterinary			

Class D2. Assembly and leisure						
Use as:						
(a) a cinema,	Y	63	motion picture and video	6.1	(City of London, n.d.)	
(b) a concert hall,	Y	63				
(c) a bingo hall or casino,	Y	63				
(d) a dance hall,	Y	63				
(e) a swimming bath, skating rink, gymnasium or area for other indoor or outdoor sports or recreations, not involving motorised vehicles or firearms.	N	65	sporting			
		66	well-being activities			
Parking structures	Y			3.5	Typical parking structures have a floor-to-floor height from the ground to the second level of roughly 10.5 to 11.5 feet. The inclusion of mixed-use space will require this height to be anywhere from 16 to 19 feet, depending on the type of structural framing system and the mechanical ducting needs. Most efficient stand-alone parking structures will use parked-on ramps, with a slope of 5 to 6 percent. When the floor-to-floor height increases by 5.5 to 7.5 feet, these efficient parked-on ramps are most likely not going to work simply because there is not enough length in the building to accommodate them. A typical garage ramp might be 180 feet in length, but with an increase of 6.5 feet in floor-to-floor height, this length would need increase approximately 110 feet, bringing the total ramp length to 290 feet. Most downtown blocks are not long enough to accommodate this. As a result, an express or speed ramp will need to be introduced. This will affect the parking efficiency (square foot per stall) and the framing system (Purinton, 2012).	
Sui generis	N	67	ship repair			
		68	elec and gas manufacture			
		69	water			
		70	motor repair			
		71	petrol sale			

		72	pipeline transport			
		73	air transport			
		74	telecom			
		75	plant rentals			
		76	sewage and refuse disposal			
		77	washing and dry cleaning of textiles			

APPENDIX SEVEN: COMMENTS ON DOUBLE-DESIGN CONCEPT

In order to test the concept of Double-Design, the author has invited comments based upon a brief explanation and questionnaire, which is included below. Please note that in cases where respondents have not arranged their comments according to the questionnaire, their notes have been allocated by the author to the most appropriate field.

INVITATION TO COMMENT – SPATIAL ROBUSTNESS: Double-Design and the Democratization of Space PhD THESIS, University of Plymouth (Work in progress, 2017–)

Michael WA Cassidy BA (Arch) (Lon) MCP (Berk) ARB

23 February 2021

INTRODUCTION I have been exploring the idea of designing buildings for future unknown uses as well as for the initial use. I have called this approach **Double-Design**. The approach is based on the desirability of ensuring that buildings last, physically, for much longer than they do now (perhaps a minimum of 150 years) and, given that this is technically achievable, that they should be fully and productively usable until it is no longer possible to maintain them. The idea is also supported by the recognition that many buildings over the course of time go through multiple changes in their use of space. While the idea is a direct response to socio-economic, resource and climate concerns, there are other advantages that remain to be confirmed in more detail through further research. Through a case study that examined how an institutional building had performed in terms of functional obsolescence and structural deterioration, I realized how important it is for buildings to help the custodians and users to accommodate uncertainty. **Double-Design** will help to allow for unpredictable change and changes in use. The compatibility between requirements for the different uses that may be needed over time has been established using a matrix approach in which the highest common factors for critical aspects of building design (like floor loading, floor-to-floor heights and the like) are assessed. It is possible to imagine that the planning, health and safety legislation could be extended to cover broader environmental goals related to resource use and energy consumption. This enhanced understanding of the public interest would provide the necessary context for **Double-Design**. While scholars around the world have looked at aspects of adaptability and flexibility to achieve limited extension of building life, the implications of **Double-Design** are very far reaching and would represent an exciting challenge for the future of architecture. The intention is that first custodians and users will need to be satisfied as well as future custodians and users.

IMPLEMENTATION AND COMMENTS The implementation of this approach in the UK could take several forms. One approach would be to change the planning laws and building regulations to require that all new buildings over a certain size would be subject to **Double-Design**: this would ensure a 'level-playing field' for developers. Another approach, which would appeal to the more entrepreneurial, would encourage individual custodians and developers to propose long-life, multiple-use buildings in exchange for incentives which might include national and local tax breaks and the avoidance of planning consent for any change of use. Future research will seek to establish the pathways and sequences of uses that will contribute most to environmental goals. Given the continuing shortage of housing, one approach to **Double-Design** would identify all those uses which MUST be capable of becoming housing. The ideas that have given rise to **Double-Design** are based upon my experience as an Architect and Planner for fifty years and in some twenty-five countries. I would like my thesis to refer to the opinions of other experienced professionals with an interest in the future of the built environment, and the responses to this idea would form a section of my thesis chapter on 'implementation'. **Focusing upon the potential impact of Double-Design, outlined below with questions, I would be interested to know your views.** Please let me know if you would prefer your contribution to be acknowledged or anonymous, and whether you will be able to respond in writing or would prefer to discuss by telephone.

POTENTIAL IMPACT OF DOUBLE-DESIGN The effects of extending the useful life of new buildings by means of **Double-Design** could include: Minimizing resource use over the life of the building. Even allowing for the extra cost of building to last, **Double-Design** should realize very substantial resource savings. Several authors have pointed out that the additional costs of incorporating adaptability in new buildings are marginal (Vimpari & Junnila, 2016) and that, given accurate information about environmental targets, custodians should be prepared to pay more for longer lasting projects.

DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY? Reducing the production of construction and demolition waste.

DO YOU AGREE THAT THIS TOO WILL HELP? Minimizing transaction [change of use] costs in money and time. Responding more rapidly to changing needs. It may be very important for some organizations to be able to introduce innovations quickly to avoid an elaborate change of use process. The significance of this advantage is confirmed with business models of decision making in dynamic organizations (Lyneis & Sterman, 2016).

DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS? Improving the fit between future space needs and future available space. The responsibility for commissioning new space or for refurbishing and re-using existing space reflects a particular distribution of economic and social power that happens to obtain at a particular time. As this distribution of power changes, the physical environment will need to respond. Such a response will be more readily achieved if all new buildings incorporate **Double-Design**. Building developers would be encouraged to see each new element of space as a contribution to a spatial infrastructure which, over time, will be a better match for changing needs – leading to the democratization of space in so far as the built environment will be better able to accommodate the changed requirements of the future.

DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY? Design emphasis upon flexibility and adaptability would contribute to extended functionality enabling more effective responses to uncertainty.

DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE? Building design professionals (Architects, Engineers and designers) could have a lasting interest in and responsibility for the use of finished buildings throughout the building life rather than ending their involvement with the completion of the initial building.

DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?

Thank you for your consideration

Response by Norma Isa Figueroa Architect, Kuwait and Puerto Rico							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
It seems that in order for this flexibility and sustainability to be incorporated into the initial building, there are many upfront expenses. Why would initial owners want to front these expenses? What are the incentives? The added expenses, which I am aware are also added value, might even make the building a costly one for the real estate market they are located in.	My final thought is based on my experience in american cities. In a society where profit and money are the bottom line, where buildings are literally abandoned when the size does not work anymore, or when the action moved away, or when it became too small, why would any corporation want to build their building for future users? Do they really care about the environment and the future? Money is Now. In just a small city in Texas I saw big malls abandoned when the companies decided to move a few miles to a better and fancier location. The huge abandoned mall sat in a sea of parking space, deteriorating with time. Land there is relatively cheap. I also saw this happen to smaller strip malls, bowling alleys and entertainment cities. How can your proposal address this issue?	1. I agree that resource savings are a valuable contribution to sustainability.	2. I agree that reducing the production of construction and demolition waste will also help.	3. I agree that enabling easier transitions from users would be very advantageous.	4. I am not so sure that when double-design is implemented, buildings will be able to better respond to the changing needs of society. I think this point is for you to prove as part of your thesis and research.	5. I agree that flexibility and adaptability should be essential design components for the future. But this is something that has been a goal of many designers for decades. What new means to achieve this goal are you proposing?	6. I am not so sure there would be an important expanded role for building professionals following the introduction of double-design. It might make them obsolete, who knows? Again, this is a point that you will need to prove with your thesis.

Response by Gina Cinali: Danish academic and administrator

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
I REALLY like your proposal. I love the title - especially the "democratization of space". is the idea that for every structure, residential and other, there should be the ability to adapt to an alternate use? Really innovative and creative.	it makes sense to make buildings last more than 150 years. I thought that many (especially very old) buildings do last much longer. Although from the repairs to my homes in the US and Denmark, I know that everything goes, and that newer structures - and appliances - seem built NOT to last. I remember being floored to hear that Kuwait considered 17 years a normal lifespan of many buildings - at least that was their depreciation schedule on various accounts....how wasteful.		Is the idea to create a certain "plasticity"... pardon my ignorance.. in the materials, to accomodate reconfiguration, stretching, floating - in case of water rising/floods. But anything that can reduce waste, make buildings more affordable and last longer/differently would be a huge improvement.				

Response by TOM REYNOLDS Architect

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
The need to provide a built environment where the buildings can be designed to accommodate living, working, creating, making, trading, and socialising, or some or all of these at once is a powerful idea…..A kind of Double Design on steroids. This would require a light touch approach to planning, where volume, urban grain and infrastructure can be controlled, with a much more flexible approach to use, perhaps only confined to controlling antisocial uses and personal and environmental wellbeing and safety. It would be interesting to see how communities would come together and organise themselves in a sustainable way. A kind of managed but liberal community that brings back that concept of society certain political figures were so keen to to eradicate in the 1980s.	If we look at the buildings that have survived many hundreds of years they all seem to have two things in common . a They are all extremely well built and robust b They all provoke a positive emotional response in most of those who see and use them. I would call this the fundamental importance of beauty in our built environment. These buildings last because we feel great in them and around them. They are established and they have memory. Beauty and quality are essential to successful Double Design.. I often think that the Australian Aboriginal concept of non ownership could teach us a lot. Some of my happiest times at university involved claiming a space to work and personalising it for the time I was there, and leaving it for the next person to enjoy when I moved on. I have had quite a lot to do with the Arts University Bournemouth over recent years and the most successful buildings are the most robust, that allow space personalisation without ownership. A kind of Double Design where the initial architectural design allows for further design adaption by the end users.	Yes, absolutely; The concept of buildings being made of modular components that can be reconfigured/relocated to accommodate any use may be a way to enable Double Design, although creating a system that is robust enough to last hundreds of years of change is probably dubious.	Yes, absolutely	Yes, absolutely	Yes, absolutely. It seems particularly pertinent in these times of extreme change where the requirement for adaptable buildings is becoming more and more apparent. Here are just a few thoughts on the matter. This is where we as a society need to abandon the quest short term profit and invest capital in creating real quality in our buildings. The payback in the future will be huge in so many ways.	Yes. But only if the building fabric is robust enough to last, and the quality of the design is of a high enough standard to generate a positive emotional response in the vast majority of people who use the building. Otherwise adaptable or not the building will not survive.	Yes, but not completely necessary if the basic building fabric is beautifully designed and robust enough to take adaption and personalisation.

Response by MAYSOON JAMALI Architect and project manager: Iraq and Kuwait

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
[illegible] and challenging research subject, even more so being such long term, and it has great potential. Buildings are massive investments and need to be flexible and adjustable / updated regularly to suit functional changes, and related services needs and technology advances these days. Profit / pay back especially short term and return on investment is the prime reason for investments especially when borrowing is involved to finance projects. More so if it is not for the investors main use - headquarters or other. If enforcement of provision of 'Double Design' by law is envisaged, and related possible changes of Building Regulations, hope this is achievable as any changes take such a long time to approve and implement / enforce by law with local authorities.	The time scale of 150 years and more, is a challenge, as what will the limitations of change and design criteria be-it space provisions, facilities adaptability and flexibility of space, building services systems related to adjustable functions, provisions be based upon? How can these be determined over such a long period of time. Technology changes and new systems at present change so fast continually over short periods. It is a very long period for predicting what technology, new science and energy needs as well as building materials and systems. If total flexibility of change of use is to be considered for a very long building life, this will be more challenging.	Will systems and materials used initially for the building be sustainable and last for so long and provision of guarantees / warranties of materials / systems used initially are very short, a few years at most. How will it be covered over a long period as well as insurance covers etc. Costs for extra finance provisions and budget requirements may prove difficult for developers to agree to, especially if the investment purpose is selling the development after completion rather than keeping and managing the asset.	YES	YES	YES	YES	YES

Response by RAFAEL FRANCO Architect and educationalist: MEXICO AND USA							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
To be candid, I was surprised to see your proposal for DOUBLE DESIGN, when I have been doing this for 50 years. In my undergraduate portfolio I stated my interest in developing adaptable buildings, and the role of the architect as the master builder of Gothic churches still in use today. I don't believe legislative control is necessary, but rather the need to train students to analyze, evaluate, and manage the adaptability of structures to alternative uses. Architects are educated to design and build new buildings. It is the money and ego.	I believe there is too much emphasis on design; as a result, students are constantly developing strategies and technology to make tomatoes out of potatoes. They paint the potato red, glue on some stems and leaves and call it innovation. No matter how much they try, it is still a potato. And now you are proposing a PHD thesis for something every five year old knows. Give them a cardboard box and they will show you DOUBLE DESIGN.						

Response by MARTIN KRIEGER Professor of Planning at the School of Policy, Planning, and Development of the University of Souther							
GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
I believe the crucial contribution would be a study of redesigns and what makes them possible. Particular cases. Then your suggestions would have the power of empirics. Also, what makes the built environment resistant to redesign--programs and designs that are too rigid,							

Response by JEFF TIDMARSH Architect							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
I have just completed six years on a framework program of work at Broadgate with British Land. The location, quality of environment means that the original occupants many of whom were original tenants back in the 80's want to remain but grow their business. This has taken the form; decanting into refurbished buildings, new build, and partial demo and rebuild. This is a reflection of known unknowns and unknown unknowns. The known; an ambition for more improved commercial space, the unknown a drive from the original brief of banking fortress into additional 24/7 operation of retail, restaurants and entertainment.The funding model and the buildings position in that cycle will always influence matters, at 100LS we were unable to demolish entirely to build a quicker cheaper building as the site alone would not secure the mortgage!	• Structure split into ground work and frame • Envelope • Services • Fit out The strip back to frame and building enlargement proved effective as British Land were able to bring modern sustainable environment to an expectant market, rather than wait. The building also highlighted an elemental division in construction consistent in many buildings from the 60's onwards	My personal view is it will need carrot and stick to drive changes you rightly consider, the accelerated sea change in home/office working brought about by the Covid pandemic The stick I fear is some way off as the legislation and development of the building safety bill absorbs the industry and it legislators for the next 3-5 years.					

Response by SUSAN ROAF Emeritus Professor of Architectural Engineering at Heriot Watt University, Edinburgh.							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
Very interesting. It needs a bit of flesh on the bones - if I was advising you I would say - what are the key benchmarks for durability in design - how about using a case study of the RR in Oxford - adaptable for pandemics - compare to historic hospitals (see Alan Short - recovery of Natural Environments) put is again the history of thermal comfort and the rise and rise of AC. through corrupt means and the focus that COVID has put on the importance of natural ventilation	if you want a building to last 150 years make it work without grid energy for periods at least... dont design it with a computer....						

Response by PETER MARCUSE Professor Emeritus of urban planning (son of Herbert Marcuse)							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
I think your idea of double design has a lot of potential. In addition to your already range of implications, the implication for financing might play a role: that mortgage financing might be able to work with reduced costs because its duration might be lengthened through double design. And I think the social aspects, for community use and diversity and social mix will be worth exploring.	I am impressed by your project, and wish you well in carrying it out.						

Response by TOM FEWINGS Structural engineer							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
My interpretation of 'double design' is that it may, by its nature, involve a degree of 'over design' to compensate for the potential future adaptability of the structure and its performance under a variety of loading conditions. Such loading conditions being typically derived from standard building code documentation (such as Eurocode 1 here in the UK). As one of the key motivations for 'double design' appears to be sustainability have you considered if such standardisation of loading is always an accurate reflection of loads applied to structures in practice? For example, is a building designed for domestic loading conditions actually unsuitable for office loads in any or all scenarios?	There seems to me two options to explore here. One could be review of the building codes in respect to loading. The other could be to design for the initial intended use, but if this use changes, qualify capacity by undertaking in situ load testing on a case specific basis. The Institute of Structural Engineers have some published research on this (albeit fairly limited) with some interesting findings. I've attached the document for your reference. This suggests many buildings may already be over designed. This might be especially true of more modern buildings when you also consider that variable (imposed) and permanent (dead) loads are typically factored in design by 1.35 and 1.5 times their 'theoretical' published values.		The other area that may be worth some discussion is the theory of 'structural redundancy'. My understanding of this concept revolves around a building's potential to 'shed' (redistribute) loads to other areas if certain components become over stressed. In application, this could help determine a building's capacity to carry additional load associated with any future change of its use. I hope the above is of interest.				

Response by ROD BOND Architect and IT researcher: Ireland: UK							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
I've found your proposition really interesting as a thought experiment – and it has nudged me to consider how ' double design' might differ from current approaches to adaptability, flexibility, mutli-functional spaces, universal/inclusive design, as well as the more overarching issues around sustainable design – energy efficiency, and long-term, life-cycle and embodied energy approaches. It brings innovative/responsive ' transgressive change' strategies into dynamic tensions with 'positive conservation' – and could lead towards a more 'transcendental approach and question' - what is the higher-order functional, structural and poetic purpose and response for archetypal buildings that could accommodate multiple 'currently known' and 'future unknown' functions (changing living, work and leisure patterns) going forward. To some extent – it points to a 'social, economic and environmental wrapper or filter' for existing and future building typographies – to promote environmental resilience.	A key challenge is the concept of 'fit' – tight fit, good fit and 'loose fit' – and the principles of adaptability, flexibility, extensibility and tolerance. To some extent, Double Design has quite a bit in common with the principles of Universal Design (inclusive design / design for all etc). If design is too tailored – it can accommodate the wider needs of a more diverse and inclusive society. The key is that the transition needs to be easy and natural – what Alexander calls 'smooth transformation' – and the resultant spatial forms and centres need to be really enriched – its not enough for the transition to be functional and effective – it needs to be enhancing and desirable – poetic, inclusive - democratic!. When stripped back – I get a sense that the heart of the matter is spatial organisation – dimension, grid, proportion and harmony – and how we relate our building actions to our landscape.	Yes. With the improvements in energy efficiency – I think the sustainability challenge is increasingly leaning towards the problem of 'embodied energy' within buildings, and the construction process from material extraction to decay/disposal. Buildings that 'last' should positively contribute to optimising embodied energy – why constrain to 150 years! Despite their 'lasting' nature – buildings, and their materials have organic degradation characteristics – so I think the devil will be in the detail in relation to maintenance and incremental renewal/component/system replacement strategies. After 150 years – how much of the original building will be evident – structure (spatial organisation)/ fabric (skin/cladding/insulation) / systems – Cabling/HVAC / sanitary ?	This is linked to the point above. I suppose the question is about timeframes – what happens after 150 years!. It will certainly delay or postpone demolition and the waste associated with it – and spread out the annual carbon credit/debit associated with it. I wonder if on its own, double design doesn't necessarily dictate a construction process and therefore can't guarantee construction waste reduction – but guidance on construction might become an explicit dimension of the double design philosophy/methodology	There is little doubt that enabling easier transition from one use to another would be advantageous. This not only effects 'change of use' (ie offices to housing / bedroom to home office – church to community centre etc) – but also changes of process, pathway or practice within organisations (ie multi-occupancy wards to single en-suite bedrooms in hospitals / dormitories to single rooms in nursing homes – local community hospitals being outpatient clinics/health centres) I suppose there are macro urban problems that Double Design could address – re-purposing our high-streets with the demise of retail because of on-line trade. Or changing the retail experience to shop window physically and transact later digitally.	That would be my hope!. Without fully understanding what Double Design would look like at guidance and implementation levels (ie principles / methodology / tool-kit / design assessment framework / recommendations etc) - at the moment, I see Double Design as one of several strategies that could lead to more responsive and inclusive environments. At a concept absorption level - with Universal Design pointing towards ergonomics , inclusivity and personalisation, and Sustainable Design addressing the energy (operational and embodied) consumption – I have a sense that Double Design – is a wider overarching framework – about 'place-making over time' giving the environment – and its fabric – time to breath over a couple of generations. I see it more as an urban planning and design idea – about providing some form of spatial organisational framework, supporting much more mixed and varied used possibilities – sensitive to sequential enrichment – yet operable in a world of uncertainty. While I think it can enable the environment to be more responsive to changing social context – I'm not sure how it plays out in terms of changing fashions / styles etc.	Yes I do!. However I think the challenge is where flexibility, adaptability and extensibility are considered for knowable, possibly predictive changes in uses/practices (ie toggling between offices and housing) – and where that openness is being providing for unknown future uses – (ie future multi-storey personal drone parking and take-off - greening building facades – multi-generational family structures – from 0 to 150 years old! – robots etc - creative spaces for unemployed on universal income etc). For me there is a question about how much design and provision is undertaken at the building feasibility and initiation stage – and how open it is to adaptation / re-design at later stages in its evolution. Does a building go into palliative care when its 130! – or is it reconsidered as a national monument! And who decides ?	Absolutely!. While I do think there could we specialist disciplines to engage at differing stages across the buildings life-course – (supported by advanced building diagnostic tools – structural / energy / fabric etc) – original designers should have roles/responsibilities to track, plan and organise for a buildings life-course. This will have an influence on practice – (how many practices will live for 150-200 years! - how will they manage succession/governance – and the role of digital representations/ models/BIM etc as dynamic records of the building's evolving state.). I think building commissioners and occupiers have roles and responsibilities here also.

Response by RICHARD A D'ARCY Architect and CAD pioneer

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
I believe vehemently that the design process is deterministic, that the objectives of a project are tempered by the resources available, the constraints imposed by regulations and standards and the environment introducing issues based on minimum use of energy and sustainable methods and materials. The mantra "Long life, loose fit, low energy" with which Alex Gordon became associated seems a natural expression of this. In design terms, therefore, I subscribe to the Mies van de Rohr approach where form follows function rather than the somewhat whimsical approach of the Post-Modernists. The COVID-19 epidemic has made enormous changes to our way of life almost overnight. Patterns of behaviour have had to change radically to accommodate governmental guidance and rules where guidance has been ignored. All of this to reduce the spread of the disease, keep hospital admissions to a level we can just manage, and mitigate the seriousness of the symptoms where isolation has failed.	Somehow, as a society, we seem to have lost our way in developing the built environment. The objective of today's property development is more to do with profit than investment. You have only to consider the sprawling housing developments erupting from our landscape to pose some very serious questions. The housing estates of today provide accommodation of varying quality and quantity but almost always with a garden too small to be of any use and a garage which will only ever be used as a store room. The purchasers are only too pleased to at last be on the housing ladder. The perceived demand for housing has never been higher yet there is a huge stock of commercial and office accommodation empty and likely so to remain.				So, "Double Design and the Democratization of Space", is music to the ear in a world that is stridently discordant. A few thousand years ago humans took shelter in caves to protect themselves from changes in the environment. As the species succeeded, accommodation was expanded by excavating additional spaces; simple and effective with little environmental impact. Numbers have caused us now to operate in the built environment but we would be well advised to retain the same principles where shelter is more or less permanent and can be adapted to fulfil changing roles and requirements. Double Design and the Democratization of Space should be adopted and will make sufficient differences to the environment to make the future desirable again. The life of buildings must be lengthened to hundreds of years and should naturally accommodate changing patterns of use. Developing the built environment must become society's investment rather than something from which a few can profit. The environmental question remaining is whether such structures, to have such a long life, must be able to float what with global warming and rising sea level.		

Response by MARTIN STEARMAN Architect and construction manager ex-Atkins

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I am puzzled, because, by the statement itself, if the future uses are unknown, it's not possible to define the criteria that will satisfy that unknown requirement, therefore the range of specification it is proposed to be built in cannot be defined.	I am reminded of the old, very old, UCL study on the size of Georgian Drawing Rooms , that suggested 150 sq ft , as the perfect size for a flexible space.	YES	YES	YES	YES	It is of course possible to design in by a "robustness " in the specification and dimensions of the physical/structural contained spaces, but there's no mention of that.	YES

Response by ANDREW CARR, Brady Mallalieu Architects,							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
		Yes - absolutely vital and the right thing to do.	Yes - absolutely	In principle this seems like a sensible thing but I wonder of the wider implications of it: - Designing to a limited number of scenario's would allow for this to be managed but this relies upon a present day prediction to guess what will happen in the future. (Stuart Brand - 'All buildings are predictions, All predictions are wrong.)' This is hard to do unless in a very limited way. - More open scenarios attempting to allow for more unpredictable change might but, taken to a polemic it has the potential to deregulate building control and/or planning which could be problematic. The UK is suffering from permitted development tights creating sub standard housing from disused office buildings As you note it might be easier to think of it in terms of a set of criteria for spaces involved in floor to ceiling heights, loadings, spatial adaptability, etc. I imagine you are well versed in this. The work of Stewart Brand, Bernard Leupen, et al on Time-based Architecture and Robert Schmidt III, come to mind though I'm sure your bibliography is more thorough.	Yes but it will depend on the thinking/standards/whatever implicit in 'double-design'. As a term it is very catchy but I sense what you are really pushing as is double/triple/quadruple/perpetual design - this is more than a single alternative use which double would imply.	Yes, in broad principle, but I think it is a more complex nuanced question. Should every building then be capable of hosting every possible use? Might it be appropriate that some buildings are more tailored to a particular use. It quickly becomes complex and hard to describe in a clear, definable way. There is a helpful essay by Lily Chi entitled 'The Problem of the Architect as writer' which contrasts the approach of Aldo Rossi and John Hejduk - I discuss it in the paper below. This is a bit out of context compared to your more focused study but might be helpful somehow! Essentially Hejduk designs very tailored things and Rossi creates more open platforms/stages for life. The latter is perhaps where you are pitching double design. In Rossi's case this ended up being an attitude to the city, particular the Italian city where buildings are built, used, re-used and continue to live on now. They have not been consciously designed as being flexible and adaptable but have become so. They become a grain than we learn to inhabit in new ways rather than being 'double-designed' as such. Hertzberger (Lessons for Students in Architecture) also discusses mosques that have become churches, amphitheatres car parks and so on. Again these are very particular buildings that take on a new life.	Yes - Post Occupancy Evaluation is part of this too and is not bound into an architecture appointment and/or fee. It is generally an add-on done out of interest or as research by others. A potential danger in a uk context is that 'double-design' is simply added on as a planning condition. A box it ticked and a more significant architect-end user(s) is denied. Some standards, like Lifetime Homes standards, already require future locations for lifts/stairlifts, bathroom adaptions and so on. London Housing standards also require alternative furniture layouts for rooms which, in a very, very simple way, starts to ensure a space is capable of being occupied in more than one way. However it is possible to meet all of the above and still have a hard to adapt/occupy home. Julia Park has some research on this in a housing context. All the boxes and ticked but he result is not really int he spirit of what the standards hope to achieve.

Response by EVELYN SIMOS ALI Architect and conservation specialist: Kuwait

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
The concept is great. I cannot imagine how the implementation would work out. What could you do to create double-design other than to have available land, an expandable structural grid and a modular system? Obviously the ability to change the permissible land use would be essential, as would be the ability to change building height. Having the original architects and engineers involved for life is prudent. Your project would be as much a regulative exercise as a design task. I am very curious to see what prototype you propose.							Having the original architects and engineers involved for life is prudent.

Response by MICHEL DE JOCAS Consultant specializing in project briefing

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
What an intriguing and apropos topic for your thesis! Here in North America there is a lot of chatter about converting empty office towers into residential buildings in a post-Pandemic world. I actually instructed my broker to sell whatever stocks I owed (not much, let me assure you) of companies dealing in office real estate. As you know the focus of my professional life has been on institutional building planning. We often work with our clients to arrive at building "fit-to-function" assessments that echo what you described in your thesis outline. I am attaching a document that you might find interesting. Generally, the older the building, the more likely it might be given an "Unfit" rating because it was subjected to too many ill-advised or poorly designed cycles renovation over time.	One idea for your research might be to identify older buildings (50 years +) that are still deemed to be "fit", and look at the reasons why they remain fit beyond reasons of good stewardship by their owners. What physical features do such buildings have, etc.						

Response by LOUIS HELLMAN Architect cartoonist

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
Your proposal is reminiscent of the 60s and Llewelyn Davies Weeks' concept of indeterminacy or the design of buildings to incorporate growth and change and I recall we took this on board when designing our thesis for the new University of Canterbury. I recently had reason to visit Northwick Park Hospital which I remember LlDW planned for growth and change so that departments could be added or retracted according to need. Unfortunately the hospital is now a vast hotchpotch of conflicting buildings and styles and the original intent has been lost. The original "brutalist" blocks now have the patina of a heritage protected style. Again in the 70s Alex Gordon developed his notion of Long Life, Low Energy, Loose FIt, or the construction of basic structures that could be adapted for various functions along the lines of what we used to call the "dufflecoat" principle or one or two basic spaces which could fit most functions. Again has this been tested in practice?	Your idea of Double-Design seems highly appropriate for today's post-pandemic world where redundant office towers are being converted to housing or permitted design planning allows roof extensions and so on, not to mention the use of parametric models in computer design where such built-in flexibility could easily be incorporated into the programmes' software.					The current push for retrofitting existing buildings rather than demolition and rebuilding as an energy saver would also be ideal for Double-Design. In many ways the use of computers, energy conservation and inclusivity for minority users means that science or a rational approach should rule design decisions in future away from seat-of-the-pants subjectivity, though this will in no way inhibit creativity, rather enhance it. The idea also seems appropriate to urban planning where the use of motor cars is being limited, cycle ways and pedestrianisation is proliferating and multi-storey carparks are being abandoned.	

Response by RALPH STRATTON financial advisor							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
One issue is of course cost. Developers usually build a property for a reason and that it is fit for the purpose they require. This ensures they get exactly what they want at a palatable price. Having to build in, if, buts and maybe's, could prove unfavourable, particularly if they intend to keep the building long term for their own specific use. People don't like spending money unnecessarily. Large Factory units are often already designed to enable a 2 storey facility or just one as required, utilising partitions and mezzanine levels etc. So in some way they are easily converted for multi use. I suppose the first consideration would be feasibility on footprint and then on height. If you were able to have a building that could be easily adapted from one floor to two, that would be interesting but you would then have to put in a lift due to the need for disabled access. With all these scenarios, off the top of my head and possibly barking up the wrong tree, but they have expense written all over them.	If thinking from one extreme to another, I thought of my house which has a good footprint and has a ground and first floor. If I were to change it into a car showroom for example, I would have to move the stairs and take down the ground floor walls. Upstairs would be the office and downstairs would hold the cars. Due to supporting walls, extra large steels would be needed to support the first floor. If I were building my home from scratch with this in mind, the steels and layout would have to be a major consideration. I dread to imagine what the steels would cost let alone the need to install partition walls etc. I then thought of Falcon House (work) which is three stories tall and was purpose built as a business centre. If that were to be a car showroom one day, I would only need the ground floor for cars and have two storeys of height, free. I then thought of my home car showroom again and what if I decided to sell boats etc which had a height greater than that of my current ceilings.						

Response by PETER BISHOP professor at UCL							
GENERAL COMMENTS	**STRATEGIC CONCERNS**	**DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?**	**REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?**	**DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?**	**DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?**	**DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?**	**DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?**
An interesting topic and important in terms of long term carbon costs. We are still a long long way away from taking this seriously in planning and architecture in the UK. In places like China where most of their (concrete and steel framed) building infrastructure built in the boom of 1990-2010 is obsolete the implications are huge.		TES	YES	YES	YES	YES	YES

Response by SIR NIGEL THOMSON Engineer ex-deputy chairman ARUP

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
I entirely agree with your approach, In fact since the mid 60's I have always been designing for adaptability and change. I was first introduced to this approach by the architect John Weeks for the design of Northwick Park Hospital. The philosophy we followed was that for hospital design the only constant was to design for change, for adaptability and extendability. Since that time I have always designed for adaptability but I accept it is not common practice but as you suggest I agree that it should be. This approach I accept ought to be applied in the design for most projects whether it be housing, hospitals, universities, schools, factories, shopping centres, office buildings, even prisons and possibly theatres but probably not to power stations. However because of the massive way Battersea Power Station was originally built we have been able to redesign the buildings for housing, shopping and leisure!	It is worth noting that designing for loose fit is also important. For instance the Georgians, the Victorians and the Edwardians built solid facades and had generally high ceilings for most of their housing which has made them suitable for re-use for different building types such as office building as well as housing. The worst recent period of housing and office building for adaptability has been since World War 2 when the negative influence of quantity surveyors became prominent thus reducing storey heights, generally trying to save money all to the detriment to the life of the building. If they had followed your 'Double Design Approach' many more 50's and 60's buildings would not have been demolished.						

LEWIS OATWAY Electrical Engineer

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
I have read your SPATIAL ROBUSTNESS: Double-Design and the Democratization of Space introduction/outline document and in general I feel you are focusing on an area which needs far more consideration throughout the industry, i.e. life cycle performance. You also seem to suggest extending this further to create buildings which will outlast current buildings built to current standards and guidance. In theory this is a great idea, encompassing all aspects which are generally acknowledged as essential to reduce the negative effects of the construction industry on the environment and simultaneously allow us to prosper and grow. The choice of materials, construction methods and even geographical location will undoubtedly play into this, would embodied energy be introduced? Something which is overlooked in regs and guidelines currently.	1.How would the building adapt to changing regulations such as u values which have seen significant improvements over the last 50 years? 2.Services such as electrical wiring, HVAC and domestic services would presumably need to be easily removed and replaced without disrupting the building fabric, i.e. a conduit system for the electrical wiring to enable cabling to be pulled out and replaced? 3.How would the internal space be adaptable to cater for all of the potential uses during its' life cycle? 4.What tests, monitoring and simulations would need to be carried out to prove its' suitability throughout its' life cycle? Or once built is it treated in the same way as most current buildings and effectively left alone and maintained as necessary? 5.How would the building adapt to changing physiological, psychological, sociological needs over its' life cycle? 6.Presumably an element of "smart" would need to be incorporated to assist with the above and to enable	I'm sure you would agree that simple POE studies are rare and energy-in-use rarer still, so it would certainly be a large challenge to have such a method introduced. I agree wholeheartedly that it would need regulatory reforms and/or governments to apply incentives and pressure for stakeholders to adopt, particularly as they all have budgets to meet and tend to revert back to tried and tested methods to achieve the current standards.			I would be interested to see a cost model which estimated percentage uplift between current building/design methods and your proposal, this would be key to willingness to adopt, however if you could demonstrate cost effectiveness it would go some way to providing assurances to anyone concerned. A few other items that spring to mind;		

ED MURPHY Building Services Engineer and Building Performance Consultant

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Currently, the construction industry decision making is led by capex, not opex . This needs to change and there are signs it may be about to in the face of mounting pressures from climate change. However, for now double design must be viewed as rolling a rock up a hill - but it's a rock that needs to be rolled. There has to be consensus that the huge resource investment in a building deserves to be capitalized and utilised for as long as conceivably possible. If the premise was that they should, then more care would be taken over design.	However, this also necessitates an industry that is willing to build with quality and to do it with more certainty of outcome. This pre-supposes a different procurement paradigm to the one we live with now. To achieve this, I have been advocating for some time now the industry turn to Agile Methods and Scrum. Building for longevity, and by default with quality, involves longer term investment decisions in design. Currently investment horizons are 25 years. In theory buildings need only last that long before the land rather than the building needs to be recycled. Land in all of the major cities has been accumulating value faster than buildings, and this more often than not drives the decision to recycle the asset.					The next question is does a second use mean that the building's chances of success in its second life are constrained or compromised? There are lots of examples of successful second generation buildings which suggest not. Also is there a half-way house? Could we design the superstructure to continue, or even be flexible enough to be adapted, and then do a remodel of the walls and interiors to suit another purpose. I suspect this would be more amenable as an investment model.	Which brings us to the importance of design in building for longevity, and architects understanding of what constitutes good design, how buildings get used, and what we as society and users expect from them. I am not sure that the profession is fully up to speed in how it educates architects to understand what design for longevity entails. This brings useful circle to where I started and the industry-design paradigm. It's not there yet, but in ten years it may well be a necessity.

MARIANTHI CONSTANTINU Town Planner, Venezuela

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
I have given thought to your "double design" for longevity of buildings. What came up for me was: we are wasting buildings, providing them for a world that is finished as the building comes to serve it. It is Mad Max time but we're singing to Mitch Miller and his gang.					Why can't we easily convert office buildings or even a few sections of them, to housing? Dorm- like rooms with minimum cooking would be easy. Why can't we use shopping malls for all kinds of civic uses? Some of them do already. Even their parking areas, which become dead night spaces, could be turned to evening shelters, nighttime housing. Why not include high rescue cocoons in public buildings? It was done in wartime. People can shelter there for brief or long periods while their usual world lies in ruins, awaits repair (earthquakes, volcanic ash, tsunamis, mud and snow avalanches, wars). I was at the public discussion for a new civic building in Sechelt. I asked whether they designed it to also shelter people in case of floods (remember, the place has coastline everywhere) they looked at me puzzled.		

Response by Ali Al-Rqobah, Engineer and businessman: Kuwait

GENERAL COMMENTS	STRATEGIC CONCERNS	DO YOU AGREE THAT THE RESOURCE SAVINGS WOULD BE A VALUABLE CONTRIBUTION TO SUSTAINABILITY?	REDUCING WASTE: DO YOU AGREE THAT THIS TOO WILL HELP?	DO YOU AGREE THAT ENABLING EASIER TRANSITION FROM ONE USE TO ANOTHER WOULD BE ADVANTAGEOUS?	DO YOU AGREE THAT AS DOUBLE-DESIGN IS IMPLEMENTED, THE BUILDING STOCK WILL BE BETTER ABLE TO RESPOND TO THE CHANGING NEEDS OF SOCIETY?	DO YOU AGREE THAT FLEXIBILITY AND ADAPTABILITY SHOULD BE ESSENTIAL COMPONENTS OF DESIGN FOR THE FUTURE?	DO YOU AGREE THAT THERE COULD BE AN IMPORTANT EXPANDED ROLE FOR ARCHITECTS, ENGINEERS AND DESIGNERS FOLLOWING THE INTRODUCTION OF DOUBLE-DESIGN?
		Yes, I do believe so.	Yes.	Indeed- optimizations.	Absolutely correct. Double-Design must establish a code of buildings such specification to be followed by and implemented by the designer.	No doubt.	From engineering ethics, they must explain these specifications & codes to custodians explicitly; or it can be mentioned as an option in their form of contract. Nevertheless, it should be the responsibility of the state entity to guard such code at least to be mentioned as an option.

APPENDIX EIGHT: ETHICS CHECKLIST, INFORMATION SHEET AND INFORMED CONSENT FORM

Faculty of Arts and Humanities Ethics and Integrity Committee (FREIC)

Undergraduate and Taught Postgraduate research

Ethics checklist

Section A: Project Details

Project: *SPATIAL ROBUSTNESS: Double-Design and the democratization of space, an exploration of designing for multiple uses*

Project contact details:

Name of researcher/student: Michael W A Cassidy BA MCP ARB
Contact details: michaelwacassidy@live.com: michael.cassidy@plymouth.ac.uk Name of Supervisor: Prof. Pieter de Wilde
Contact details of Supervisor: pieter.dewilde@plymouth.ac.uk
Name of Course/Module: PhD / Built Environment

What is this project about?

The thesis is an exploration of the concept of Double-Design, the implementation of which would lead to buildings being designed to last physically for much longer than at present and being designed to be useful functionally for the whole of their physical life.

Section B:

B1: Participants

Do any of your research methods involve the following:

		Yes	No
Vulnerable Groups:	Participants from vulnerable groups – for example, children and young people, those with a learning disability or cognitive impairment, or individuals in a dependent or unequal relationship?)		X
Sensitive Topics	Sensitive topics – for example, participants' sexual behaviour, their illegal or political behaviour, their experience of violence, their abuse or exploitation, their mental health, or their gender or ethnic status?		X
Gatekeeper Consent	Groups where permission of a gatekeeper is normally required for initial access to members – for example, ethnic or cultural groups, native peoples or indigenous communities?		X

Openness and Honesty	Deception or which is conducted without participants' full and informed consent at the time the study is carried out?		X
Confidentiality	Access to records of personal or confidential information, including genetic or other biological information, concerning identifiable individuals?		X

Risks and Benefits	A risk of causing psychological stress or anxiety or other harm or negative consequences beyond that normally encountered by the participants in their life outside research?		X

If Yes, explain what measures will be taken to ensure adequate protection/support.

B2: POTENTIAL RISKS TO THE STUDENT(S)

	Yes	No
Is the research likely to involve any psychological or physical risks to the student?		X

If Yes, explain what measures will be taken to ensure adequate protection/support.

B3: CONFIDENTIALITY AND HANDLING OF DATA

	Yes	No
Will the research require the collection of personal information from participants that is not anonymised?		X
Will any part of the research involving participants be audio/film/video taped or recorded using any other electronic medium?		X

If YES, have you attached an Informed Consent form and have you read the GDPR guidance?

B4: PARTICIPANT INFORMATION AND INFORMED CONSENT

Have you attached a copy of the following

	Yes	No
Information Sheet	X	
Informed Consent Form	X	

Information Sheet

Project: *SPATIAL ROBUSTNESS: Double-Design and the democratization of space, an exploration of designing for multiple uses*

Project contact details:

Name of researcher/student: Michael W A Cassidy BA MCP ARB
Contact details: michaelwacassidy@live.com: michael.cassidy@plymouth.ac.uk Name of Supervisor: Prof. Pieter de Wilde
Contact details of Supervisor: pieter.dewilde@plymouth.ac.uk
Name of Course/Module: PhD / Built Environment

What is this project about?

The thesis is an exploration of the concept of Double-Design, the implementation of which would lead to buildings being designed to last physically for much longer than at present and being designed to be useful functionally for the whole of their physical life.

What will you have to do if you agree to take part?

Respond to a questionnaire

Informed consent

Your participation is voluntary and it is up to you whether you wish to participate.

Right to withdraw

We hope that you feel able to help us with this study. If you decide that you do not want to continue to take part in the study, you are free to withdraw any time up until January 2022. **What are the advantages or disadvantages of taking part?**

You may find the project interesting and enjoy answering questions about the research.

Debriefing

There will be an opportunity to learn about the outcomes of the research. You may obtain information on my progress and request copies of outputs at any time by contacting the researcher through the above contact details.

Confidentiality

Information related to individuals is limited to the names of those to whom questionnaires have been sent, together with a brief indication of their background that is already in the public domain. Responses from the questionnaires are set out in an Appendix to the thesis which will be available online in accordance with University of Plymouth archive accessibility policy.

Feedback

Please feel free to contact Michael at any time if you have questions about this research study.

Informed Consent Form

Project: *SPATIAL ROBUSTNESS: Double-Design and the democratization of space, an exploration of designing for multiple uses*

Project contact details:

Name of researcher/student: Michael W A Cassidy BA MCP ARB
Contact details: michaelwacassidy@live.com: michael.cassidy@plymouth.ac.uk Name of Supervisor: Prof. Pieter de Wilde
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Name of Course/Module: PhD / Built Environment

What is this project about?

The thesis is an exploration of the concept of Double-Design, the implementation of which would lead to buildings being designed to last physically for much longer than at present and being designed to be useful functionally for the whole of their physical life.

Basis of request to participate:

The questionnaires comprise "ad hoc and informal interviews that are not inherently fundamental to the outcome of the research"[1]. On this basis, further ethical approval has not been sought. Rather, feedback has been gathered on the principle of Double-Design and its implementation following the development of theory.

Invited participants have been offered the choice of anonymity but none has taken this up.

[1] ArtREISC Ethics Guidance (V5 Aug-19) p3

SECTION C: SUPERVISOR

Supervisor: Please tick the appropriate boxes. The study should not begin until all boxes are ticked:

	Yes	No
The student has read and understands, in the context of this study, the guidance on research ethics	X	
The student has the skills to carry out the study	X	
The student has appropriate measures to gather and store data in order to maintain the confidentiality of personal data used or collected in the study.	X	
The Information Sheet and (where required) The Informed Consent form to be provided to participants is appropriate	X	

The Student is NOT required to submit an application for Ethical Approval to the Faculty of Arts and Humanities Ethics Sub Committee	X	

Any significant change in the question, design or conduct over the course of the research should be notified to the faculty or school research ethics officer and may require a new application for ethics approval.

If you have answered 'YES' to all questions the student can proceed with the study.

*If you have answered 'NO' to **any of questions in Section C**, or there are significant ethical issues in the research then the student will need to submit an application for ethics approval to the Faculty of Arts and Humanities Ethics and Integrity Committee.*

Please note that it is your responsibility to follow the FREIC guidelines in the conduct of your study. **This includes providing information about the study, consent forms and debriefing information as appropriate and ensuring confidentiality in the storage and use of personal data*.**

Signature(s) of student(s)

Michael Cassidy

Date: 26 April 2019

Signature of supervisor: Prof. Pieter de Wilde

Date: 26 April 2019

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