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Citation: DAVISON, N. ... et al, 2006. The multispace adaptable building concept and its extension into mass customisation. IN: Scheublin .. et al (eds). Proceedings of the Joint CIB, IASS International Conference on Adaptability in Design and Construction, Eindhoven University of Technology, 3rd-5th July 2006, pp 12.7-12.13

Additional Information:

- This conference paper was presented at Adaptables2006, TU/e, International Conference On Adaptable Building Structures Eindhoven [The Netherlands] 3rd-5th July 2006. It is also freely available at the ICONDA®CIBlibrary: <http://www.irb.fraunhofer.de/CIBlibrary/index.jsp>

Metadata Record: <https://dspace.lboro.ac.uk/2134/5036>

Version: Accepted for publication

Publisher: © CIB

Please cite the published version.

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
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The Multispace adaptable building concept and its extension into mass customisation

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KEYWORDS

Design Adaptable Customisation Building

ABSTRACT

UK government Policy Planning Guidance promotes optimum use of the existing building stock through mixed use in urban centres and encourages conversion of redundant office and retail space into leisure, service or residential uses. Whilst social pressures are evident in the push to more effectively utilise existing building stock, new building stock also has to meet the commercial requirements of the client, which often translates into maximum occupancy of the building. This is encouraging greater innovation in the design of new buildings to allow change of use throughout the structure's lifetime. This paper describes the concepts surrounding an adaptable design for new buildings, along with a review of factors influencing the mode of use. The major physical parameters of storey height, building proximity, plan depth, structural design, services, fire safety, cladding and noise abatement are evaluated in the context of adaptable building use.

In addition to improved building utilisation, the UK government has identified a weakness in the productivity of the construction industry. The report 'Rethinking Construction' (Egan, 1998) suggested that up to 80% of inputs into buildings are repeated and that parallels should be drawn with the designing and planning of new cars in the automotive sector. This suggests that improvements in quality, cost and delivery time of new structures could be achieved through mass-customisation incorporating a significant element of pre-design.

1 BACKGROUND

The requirement for building adaptability is becoming increasingly relevant from both commercial and sustainability perspectives. The UK government has identified, in Policy Planning Guidance notes, the need to optimise the use of existing building stock therefore encouraging the conversion of redundant office and retail space into leisure, service or residential uses. There are several reported international examples of building adaption [Geraedts 2002][Omi 2005].

It is also apparent that the construction industry is exceedingly wasteful in the way that it supplies building space to the UK commercial market. It is common to have a temporary excess of empty office space whilst striving to meet market demands for housing, and vice versa. This is inevitably encouraging clients to look at alternative methods of designing buildings in order to minimise the consumption of construction resources and losing potential rental value. Mixed use developments offer a client both diversified risk and the ability to adjust to changes in market demand for building usage. Recent data from the UK commercial property market demonstrates the rapid change in demand, with activity in the private office sector rising from 3.3% in August 2005 to 12.6% in December 2005 – over the same period activity in the private retail and leisure sector was static at 5.4% in August to 5.7% in December [Savills 2005].

The additional capital cost of incorporating adaptability into a building design remains a barrier to adoption. However, there is data to show that the cost of the built structure is small in comparison with the cumulative cost of services and space plan changes over the life of the structure [Arge 2005]. Environmental benefits of adaptable office buildings have been examined by Larsson [Larsson 1999]. Using data from previous studies relating to embodied energy and energy expended in office buildings, Larsson estimates a 15% reduction in (a) air emissions and (b) demolition solid waste [Environmental research group 1994][M. Gordon Engineering 1997].

This paper details an adaptable building design concept called Multispace, developed by Reid Architecture [Gregory 2005]. The intention of this study is not to develop the ultimate flexible building, but is to explore the differences between flexibility and adaptability, and to make recommendations for adaptable building design that can be fitted out, with minimal changes, to achieve a variety of uses. Our thinking is strongly aligned with that of Brand, who's seminal work on building adaptation put forward key exemplars and principles [Brand 1994].

2 HISTORICAL CONTEXT

2.1 Reid Architecture Offices

Many of us still live, work or meet in buildings that were built over the last 200 years or even earlier. It is unlikely that anyone living in 21st century Britain can avoid using historic buildings in some part of their daily lives. Although there is an element of sentimentality, the reality is that we would have demolished the majority of Georgian and Victorian town houses by now if they did not allow us to use them successfully.

Reid Architecture originally occupied a Georgian terraced town house on Portland Place, London. The building served the London practice well during its growth period but Reid has recently moved to a remodelled 1960's office building. The role of both buildings is very relevant to this study. The Georgian town house was built about 200 years ago for the purpose of accommodating a wealthy family with servants. Over its lifetime it has been adapted to serve small and medium sized consultant businesses and been subdivided to provide small single or two bed flats at the same time. Opposite these premises similar buildings have become embassies, headquarters for professional organisations or hotels.

With the expansion of Reid came the requirement to move into larger premises (called West End

House). This building was built as offices in the 1960's and was seen as unattractive and unsuitable for modern office specifications: low storey heights on the upper floors, relatively narrow floor plates, no air-conditioning, poor quality single glazed windows, no reception space and only one lift. A number of significant improvements were made without major alteration to the building shell, which allowed conversion into a high quality, fit for purpose, office building

The crucial idea to learn from these examples is the concept of 'loose fit'. The storey heights and relatively generous room sizes of the Georgian town house at Portland Place allowed it to be used as: (a) High quality residence, (b) Flats, (c) Office space, and also (d) Hotel premises.

West End House did not have high ceilings or big floor plates by modern office design standards, yet it was capable of becoming a high quality office space for an expanding consultant business because the floor layout was relatively simple and open plan and the narrow floors actually benefited the desire to use natural ventilation.

This example demonstrates the potential efficiency of an adaptable building design that would cater for medium to large sized developments, and would accommodate new comfort demands. With buildings that are purpose built and difficult to adapt the cost of refurbishment can be as high as new build. It is more sensible to design buildings that can serve a variety of needs with minimal work to the shell and freedom for the fit out.

2.2 Loughborough University Centre for Collaborative Construction Research building

Few of the existing 'modern' buildings have been intentionally designed for adaptability which makes it difficult for us to assess the effectiveness of that adaptability over time. However, one such building is the Civil Engineering building on Loughborough University campus which, when built in 1970, was designed with structural redundancy to allow for the addition of an extra floor at some time in the future. Its tartan grid with a 14.3m clear span resulted in only four internal columns in its 1000m² floor plate and all rooms were created with a partition system. This building has recently been refurbished (and extended) with the former including removal of all the original partitions to create a landscaped office to encourage research communication and collaboration.

The 'loose fit' approach is again demonstrated as being advantageous in allowing a level of adaptability. It is interesting to note, however, that the ceiling void allowance for services in the original building was 1.5m in depth; the substantial changes in services provision equipment has made much of this void space redundant and demonstrates the difficulties associated with predicting the future design requirements for buildings. The type of changes in the 21st century are likely to be very different to that seen in the past – telecomms and computing technologies will undoubtedly change significantly and requirement for building space will change accordingly [Russell & Moffatt 2001].

3 MULTISPACE

Mixed use urban developments are becoming increasingly common. Adaptable space allows landlords to be able to alter the mix of use to respond to market conditions without altering the shell construction, thus maximising the return at all times and minimising construction time and costs. A recent research document for the British Council of Offices states: "*Office dominated mixed use buildings benefit from higher returns and are associated with lower risk when compared to a single office use alternative.*" [Jones Lang LaSalle 2004]. The logical next step is to design buildings that can accommodate a variety of uses without predetermining their location or extent. Multispace offers the potential for developers to maximise commercial returns and reduce risk associated with mixed use schemes without having to predetermine which parts of the scheme perform a particular use.

An adaptable building meeting the requirements of office, residential and retail uses needs to conform to a range of local/national and client requirements. In order to define the limits for the design of Multispace, the performance requirements of each use was broken down into discrete areas and

comparison of the technical requirements for each parameter made. The extent of parameter overlap, enables definition of the limits for generic design standards. Appropriate design proposals can then be put forward. The key design parameters are:

- 3.1 Storey height (the heart of the problem)
- 3.2 Building proximity, form and plot density
- 3.3 Plan depth
- 3.4 Structural design
- 3.5 Vertical circulation, servicing and core design
- 3.6 Fire safety design
- 3.7 Cladding design

3.1 Storey height

One of the focal issues for any generic design proposal is to achieve a storey height that is high enough to accommodate all proposed uses, yet low enough to avoid waste. The normal storey height for offices is in the order of 3.75 - 4m, whereas high quality residential and hotel (bedroom) storey heights are of the order of 3m. The storey height is determined by:

- Ceiling height required for the use,
- Structural zone
- Services zones
- Planning height restrictions
- Short term economic pressure

The most important technical design aim is to provide a truly adaptable building shell within the lowest possible storey height - for a building of 'normal' width (i.e. between about 13.5 to 18m) a notional target in the range of 3.3 to 3.5m is suggested. (Table 1)

<i>Use</i>	<i>Min. Internal ceiling height</i>	<i>Max. Economic ceiling height</i>
Office ¹	2.65 to 2.7m	3.0m
Residential ²	2.4m	2.7m
Hotel (bedrooms) ³	2.4m	2.7m
Retail ⁴	3.5m single storey	4m single storey to 7.0m if mezzanine insertion envisaged or large supermarket store etc
Generic limits	3.5m on GF	7.0m on GF

Table 1 – Summary of building ceiling heights [Gregory 2005]

The preferred slab technology would utilise two way post-tensioning incorporating bonded tendons, which offers the following advantages:

- Fast site erection
- Very slim slab depth with no projecting beams
- Integral fire protection
- Safe construction and demolition
- Reasonable flexibility for additional riser penetrations between tendons

For these reasons a post-tensioned concrete slab would be most appropriate for a generic structural solution. Typical slab depths for an office building (which has the highest design loads) would be:

- 250mm thick slab for 9x9m structural grid
- 330mm thick slab for 9x12m structural grid

The potential useable space per floor is also defined by service zone requirements, such as HVAC, power, IT services and pipework. The greatest technical design challenge resulting from this is to accommodate varying floor zones with the widest possible variety of ventilation solutions. The greater the storey height, the greater is the range of service solutions possible. A great deal of choice can be

achieved within a storey height of about 3.5 to 3.6m, which can be reduced to 3.3m provided that under-floor servicing systems are acceptable (assuming use of thin slab technology).

3.2 Building Proximity

Proximity of building blocks is generally determined by:

- Natural daylight penetration
- Views and privacy (particularly for residential/hotel uses)
- Spatial proportions
- Space required for access roads, car parking, communal spaces and gardens.
- Space separation to prevent fire spread and access for fire fighting
- Economy: ratio of built area to plot size.

Previous research [Martin] has proven that courtyard or atrium forms are most efficient when the depth of building is restricted to a dimension smaller than the overall plot size. In a study of relative development efficiency for a standard office design and an adaptable design, Multispace can achieve the same development area or more, within a given height limit, because of the lower storey height, despite the Multispace floor-plate having a lower area than the office floor-plate designed to the maximum allowable BCO recommendations [BCO 2005] for floor depth.

3.3 Plan depth

Plan depth is generally determined by:

- Natural daylight penetration
- Proximity to views
- Spatial proportions
- Space required to accommodate the smallest internal room component/component group
- Economy: ratio of envelope area to floor area enclosed

If retail, with its greater plan depth requirement, is restricted to the ground floor, then the generic limits would be 13.5-21.0m on the upper floors. The deeper the floor plate the more efficient the development will be (area of envelope to internal floor area ratio). However in large developments a variety of floor plate depths will bring benefits of diversity when attracting potential tenants. The benefits and methods of ensuring good daylight penetration into office floor plates has been detailed elsewhere [Gregory 2004]

3.4 Structural design

The structural grid must ideally co-ordinate with all uses so that they are fully interchangeable, without the need for significant transfer structures or uneconomically long spans. The generic limits for span in an adaptable structure would be 6-12m, although this will be very much dependent on structural system and cost sensitivity.

3.5 Vertical circulation, servicing and core design

The most onerous requirement for lift design is likely to be mixed use requiring separate lift services for office, residential and/or hotel uses. The issue to consider is whether the cost difference between providing for offices and other uses is so great that we would need to alter the number and type of lifts to suit each use. If lifts need to be inserted after the shell has been erected then the core must be designed to accept additional shafts without loss of floor plate efficiency.

Security and separate lift shafts for each use must be considered when more than one use co-exist in one building. In the same way plant size and location must be considered. Again offices are often more heavily serviced than residential or hotel buildings.

3.6 Fire Safety design

Travel distance between stairs has a major impact on optimum floor plate efficiency for any building. Generic design limits for an adaptable building define limits on occupancy (1/6sqm) , no of people (150-180), maximum travel distance (30m two way), no of stairs (2) and stair width (1.4m).

3.7 Cladding design

In addition to cost and appearance (including planning constraints), choice of cladding is also determined by thermal, acoustic, ventilation and natural light requirements.

A summary of adaptable building requirements are shown in Table 2.

	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

Table 2 – Summary of adaptable building requirements [Gregory 2005]

4 CUSTOMISED BUILDING SOLUTIONS

As a pre-designed adaptable building solution, Multispace also offers the opportunity to exploit the production benefits associated with a mass customised solution, with improved pre-design resulting from a better understanding of the production process. Reviews of the construction industry identify the need to eliminate inefficiencies in the construction process. Egan states *“Not only are many buildings, such as houses, essentially repeat products which can be continually improved but, more importantly, the process of construction is itself repeated in its essentials from project to project”*, [Egan 1998]; this would suggest a considerable gain in value could be achieved through minimising design, engineering and manufacturing costs by following a customised building approach.

Indeed some of the features of Multispace have already been incorporated into a ‘Customised Office Solution’ [Laing O’Rourke 2005]. This design has now been used on eight office developments, with appreciable benefits in terms of cost certainty, minimised construction time and potential adaptability being gained by the clients.

5 CONCLUSIONS

This paper has presented an historical insight into building adaptability and detailed an adaptable building concept. It can be concluded that;

1. Existing buildings can offer adaptability of use.
2. Rapidly changing technology presents some difficulties when predicting future building design.
3. An adaptable building design can be developed which facilitates rapid change of use of new structures – design criteria are summarised in Table 2.

6 ACKNOWLEDGEMENTS

We would like to acknowledge Chris Gregory for his technical input into the programme. We also wish to express our thanks to our funders, EPSRC and to Reid Architecture, Buro Happold and Laing O'Rourke.

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