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Flexible housing: the means to the end.

Jeremy Till^{1*}
Tatjana Schneider¹

¹ School of Architecture, University of Sheffield

* Jeremy Till now works within the School of Architecture and the Built Environment, University of Westminster

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How might flexible housing be achieved? ‘Determinate’ and ‘indeterminate’ approaches are examined using twentieth-century examples

Flexible housing: the means to the end

Jeremy Till and Tatjana Schneider

Introduction¹

The first paper (arq 9/2, pp. 157–166) has already made the arguments as to why flexible housing is a relevant, even essential, part of future housing provision on grounds of social, economic and environmental sustainability. This paper examines ways in which flexible housing may be achieved, using examples from twentieth-century housing.

It is first necessary to define what we mean by flexible housing. Our definition determines flexible housing as housing that can adapt to the changing needs of users. This definition is deliberately broad. It includes the possibility of choosing different housing layouts prior to occupation as well as the ability to adjust one’s housing over time. It also includes the potential to incorporate new technologies over time, to adjust to changing demographics, or even to completely change the use of the building from housing to something else. So flexible housing in our definition is a wider category than that of adaptable housing, which is the term generally used to denote housing that can adapt to users’ changing physical needs, in particular as they grow older or lose full mobility.²

With such a broad definition, it is maybe not surprising that there are multiple methods of achieving flexibility. The approach in this paper is not prescriptive and does not attempt to organise these different approaches into an overall methodology. Instead it explores flexibility through the issue of determinate and indeterminate design, or as we identify ‘hard’ and ‘soft’ systems. This differs from the previous approaches of categorising flexibility, most notably that derived out of the open building movement. Kendall and Teicher’s *Residential Open Building* is probably the most comprehensive and rigorous analysis of flexible housing of recent years.³ However, while the social intents and economic rationale are admirable, the method tends towards suggesting an all-or-nothing approach that is eventually technically determined. This is potentially off-putting to the housing designer or provider. Our approach starts with some basic principles and then suggests alternative methods of achieving flexibility that

allow anything from wholesale change down to quite discreet, but potentially extremely useful alterations.

Built-in obsolescence

The basic principles of flexibility start with its opposite – namely that inflexibility should be designed out. As noted in the first paper, the UK building industry tends to build in obsolescence, but this can be avoided in three manifestly simple, and 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.

The terraced house

In the course of our research by far the most commonly mentioned example of flexibility was the London terraced house, in particular the late eighteenth-/early nineteenth-century examples which are typically flat-fronted and three or four stories, plus basement. Over the course of the years, these have been added both horizontally (at the back) and vertically (the ubiquitous loft extension), knocked through, divided, joined up again and used for countless other purposes.⁴ It is worth, therefore, analysing the aspects of these houses that give them their inherent flexibility. The first is the relatively generous space provision in relation to

contemporary standards. This has allowed subdivision both horizontally and vertically; typically the front room might be divided to provide a kitchen next to the living room, or a bathroom might be inserted between the first floor front and back rooms; vertically the generous height allows false ceilings for services where necessary. Second, their construction repeats a small number of simple techniques, allowing the use of relatively unskilled labour (the infamous and probably mythical firm of Bodgit and Creepaway comes to mind). Finally, the basic layout, and in particular the placing of the staircase allows additions to be made at the rear of the building in a flexible and infinitely variable manner (the ubiquitous back extension).

While not all these aspects of the terraced house can be transferred directly to the contemporary context, they do begin to suggest some generic principles for flexible housing. These are:

- 1 **Space:** There is a correlation between amount of space and amount of flexibility. Some recent schemes have exploited this correlation by providing more space but at lower specification, arguing that flexibility in the occupation of space is of more importance than the niceties of having a fitted kitchen or fully decorated rooms. One such is the Nemausus scheme in Nîmes, France (1985) designed by Jean Nouvel. Here undivided space with double-height areas was handed over in a semi-finished state for the tenants to fit out, though their ultimate choice was restricted by a number of impositional rules that dictated things like the colour of their curtains.⁵ This is also essentially the approach of the loft developer, where an excess of undefined space is handed over to the tenant to use as they will. The corollary of the space-flexibility correlation is that limited space may be seen to limit flexibility, but at the same time there are often demands to use that space in multiple ways; in these cases you have to work harder to achieve flexibility through other design methods.
- 2 **Construction:** There is a relationship between construction techniques and flexibility. The specialist and multi-headed approach to housing construction, particularly in the UK, limits future flexibility in so much as one needs specialised and multiple skills to make any adaptations. Against this, following the example of the terraced house, many of the most successful contemporary flexible housing schemes rely on simple and robust construction techniques, which allow future intervention, or at least place the specialist elements such as services in easily accessible and separate zones so that only one set of specialists is needed to make changes. This latter strategy is in contrast to standard construction when just to update, say, wiring one needs to get, in addition to the electrician, a carpenter to lift floors, a plasterer to patch the ceiling and a decorator to make good in addition to the electrician.
- 3 **Design for adaptation:** Simple, but considered design moves such as the placing of staircases,

service cores or entrances allow future flexibility at no extra cost. However, for this approach to be successful the designer has to project future scenarios and adaptations onto the plan to see what can be accommodated. Exemplary of this approach is the work of the architect Peter Phippen in the UK, with the development of his wide frontage house with a central service and staircase core. This plan form allows free disposition of rooms around the edges, as well the possibility to make additions to the rear of the property.

A few contemporary architects have specifically followed these principles, most notably Caruso St. John's project for terraced housing in Berlin (2001) which draws on the plan form of the traditional UK terraced house, but provides still further flexibility by making all the internal walls non-loadbearing.⁶ The scheme is at the same time simple and sophisticated.

The speculative office

The second type of accommodation that is often mentioned as inherently flexible is speculative commercial offices. These are designed with no specific tenant in mind and allow continual adaptations to be made to the basic shell to suit the occupants at any given time.⁷ Importantly, they also allow upgrading and easy relocation of services. Again, we can identify generic principles that can be transferred to flexible housing;

- 4 **Layers:** The clear identification of layers of construction from structure, skin, services, internal partitions to finishes. This allows increasing control (and so flexibility) as one goes through the layers.⁸
- 5 **Typical plan:** The speculative office is the classic shell and core structure. The external shell is relatively inflexible; the core provides access and services. In between the space is indeterminate, with large spans and open plans allowing non-loadbearing partitions to be put in and removed at will. The speculative office, almost by definition, provides generic space, in contrast to the highly specific and determined space that one finds in most housing. It is what Rem Koolhaas denotes the 'typical plan ... zero degree architecture, architecture stripped of all traces of uniqueness or specificity'.⁹
- 6 **Services:** The disposition of services in the speculative office is carefully considered to allow future change and upgrading. Vertical services are marshalled into easily accessible ducts. Horizontally, raised floors and/or dropped ceilings allow endless permutations in the eventual disposition of service outlets.

Some of these principles from the speculative office have already been exploited in schemes such as Immeubles Lods in France (1972) which explicitly used office building technology and planning principles to give maximum flexibility in the

housing (1970). The obverse is also becoming quite common, with 1960s and '70s office buildings, which no longer have the floorplates or storey height to deal with contemporary office needs and servicing, lending themselves to be converted into housing.

Using these six principles of inherent flexibility from the terraced house and the speculative office you can begin to enter the territory of designing specifically for flexibility in housing. The next stage of our research, and this paper, attempts to develop a more comprehensive classification of methods by which flexibility may be achieved in housing. Our classification draws on some previous approaches,¹⁰ and while it attempts to cover most conditions of flexibility, it does not intend to be prescriptive in setting out a set of rigid rules for potential designers. Our classification works in two directions. First, through investigating flexibility at different scales of housing (from the block, through the building and unit, to the individual room), and second, by indicating methods by which flexibility has been or may be achieved. The rest of the paper concentrates on the latter; we propose two broad categories, use and technology. Use refers generally to the way that the design affects the way that housing is occupied over time, and generally refers to flexibility in plan. Technology deals with issues of construction and servicing, and the way that these affect the potential for flexibility. We then subdivide each of these two categories into 'soft' and 'hard' techniques.

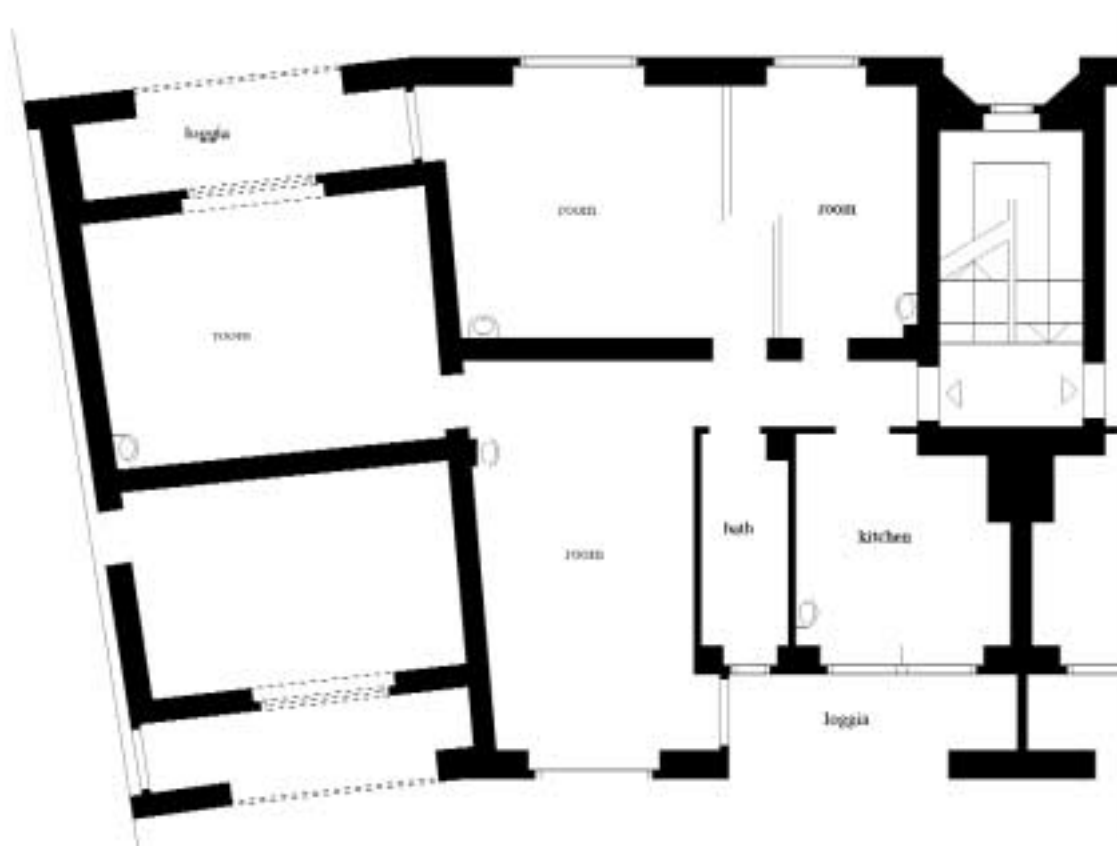
Hard and soft

'Soft' refers to tactics which allow a certain indeterminacy, whereas 'hard' refers to elements that more specifically determine the way that the design may be used. In terms of use it may appear a contradiction that flexibility can be achieved through being either very indeterminate in plan form or else very determinate, but historically both approaches have developed in parallel throughout the twentieth century. Soft use allows the user to adapt the plan according to their needs, the designer effectively working in the background.¹¹ With hard use, the designer works in the foreground, determining how spaces can be used over time. As we shall see, soft use generally demands more space, even some redundancy, and is based on a relaxed approach to both planning and technology, whereas hard use is generally employed where space is at a premium and a room has to be multifunctional.

Soft use

The notion of soft use is embedded in the vernacular house. As Paul Oliver, the key historian of vernacular architecture notes, 'with the growth of families, whether nuclear or extended, the care of young children and the infirm, and the death of the aged, the demands on the dwelling to meet a changing family size and structure are considerable'.¹² In vernacular housing, the range of responses to these issues is then oriented by culture and climate,

¹ Britz Housing, Berlin (1925) by Taut and Wagner. Typical plan from the 'horseshoe' block



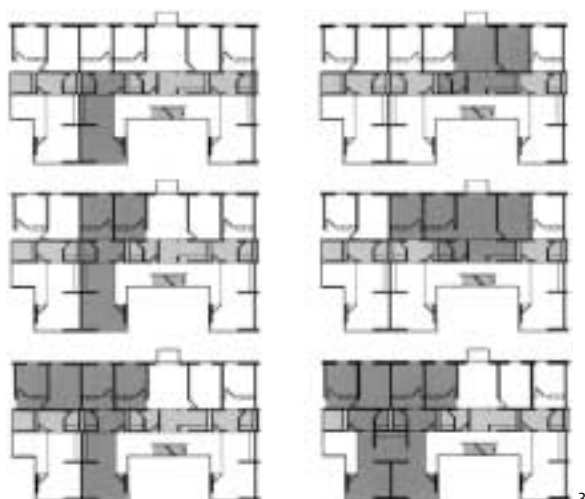
1



Top floor



Typical floor



2 Letná apartment block, Prague (1935) by Eugene Rosenberg. Typical plans

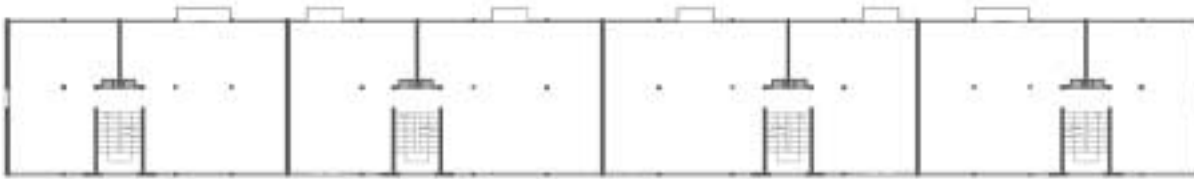
3 Hellmutstrasse, Zurich (1991), by ADP Architektur und Planung: possible arrangements

ranging from the single space used for the whole gamut of family rituals to the simple division of the traditional cottage. Clearly, the intervention of the expert designer removes such approaches from the realm of the vernacular, but nonetheless the principles of soft use remain. Some of the pioneering examples of Modernist housing explicitly use the notion of indeterminacy as a response to the housing shortage crisis in the 1920s and '30s, arguing that a flexible approach could cater for a wider range of occupants. Typical of these is the Britz Project in Berlin (1925–31) designed by Taut and Wagner. The design provides three similarly sized rooms (denoted on the plan simply as 'Zimmer' – 'room') off a central hallway, with the services (bathroom and kitchen) in a separate zone. The occupation of the rooms is thereby left open to the interpretation by various possible user groups [1].

A more refined version of this strategy can be found in one of the classic projects of Czech Modernism, the Letná project in Prague (1935) by Eugene Rosenberg in which each floor typically comprises two apartments of different size.¹³ Within the individual apartments, rooms are of an equal size and can be accessed separately from a central lobby, while the services are contained in a separate zone [2].

This indeterminacy approach is also beautifully exploited in the Hellmutstrasse scheme in Zurich (1991) by ADP Architektur und Planung, which is one of the most sophisticated flexible housing schemes of recent years. The project arose out of a community led approach with all members of a housing cooperative contributing to the design process. The design is split into three distinct horizontal zones. At the top is a line of similarly sized rooms divided by loadbearing partitions, and with the possibility of inserting non-loadbearing partitions to define circulation. Below this there is a row of serviced spaces that can be either bathrooms or kitchens. Finally, at the lowest level, there is a zone containing what is usually a kitchen and living space, but which can also be used as a self-contained studio apartment. All apartments are accessed from an external staircase and shared balconies. The overall arrangement allows multiple arrangements to be achieved, from large groups of single people living together right down to self-contained one-person studio apartments. The zoning also allows future changes to be made with ease, though in practice this would require neighbouring apartments to simultaneously agree to changes in terms of expansion and contraction [3].

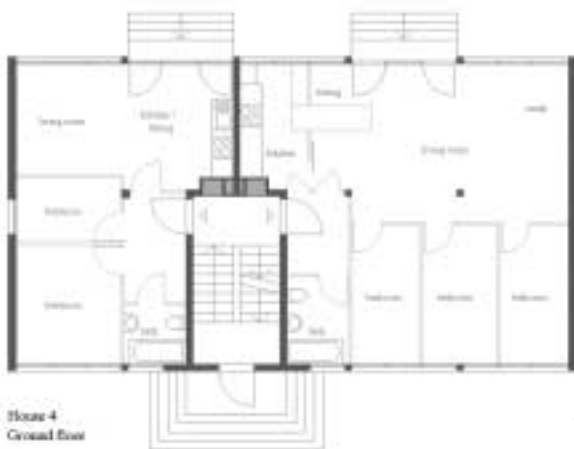
If one approach to soft use depends on the designer providing a physically fixed, but socially flexible, layout, a more common solution is to provide raw space that can then be divided according to the needs of the occupants. This is not as straightforward as it may sound. Provision of open space alone does not suffice, or at least it may be inefficient in terms of space usage. The designer has to carefully consider the best points for access (generally in the centre of the plan), the position of servicing (either in specific zones or else widely



House 4
Second floor



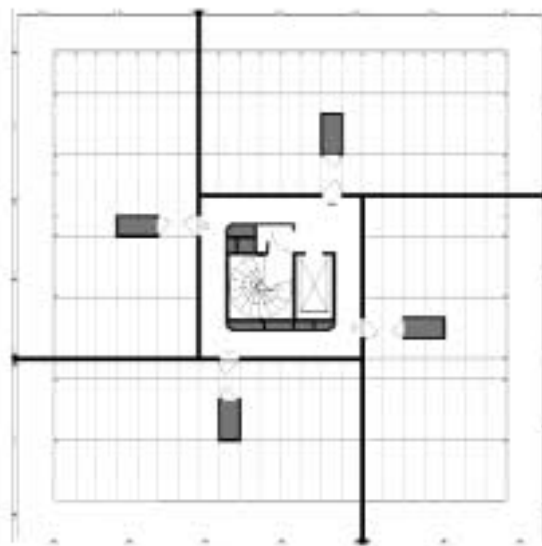
House 4
First floor



House 4
Ground floor

This approach to indeterminate open space was facilitated by the new constructional systems available to the early Modernist architects, which allowed larger span structures and light infill partitions. Some of the earliest examples can therefore be found in classic Modernist housing schemes such as the model housing at the Weissenhofsiedlung in Stuttgart (1927). In the block designed by Mies van der Rohe, a simple framed structure allows the residents to divide their apartments up as they wish, though the final layout is limited by the positioning of columns; the provision of the servicing is also minimal by today's standards [4].

A more developed approach can be found in schemes such as that at Montereau-Surville in France (1971) designed by Les Frères Arsène-Henry, or the Järnbrott Experimental Housing in Sweden (1953). In a 10-storey building at Montereau, only the central service core is fixed with the remainder left open as in a speculative office. The scheme is designed to a 900mm module, allowing WCs and bathrooms (900,

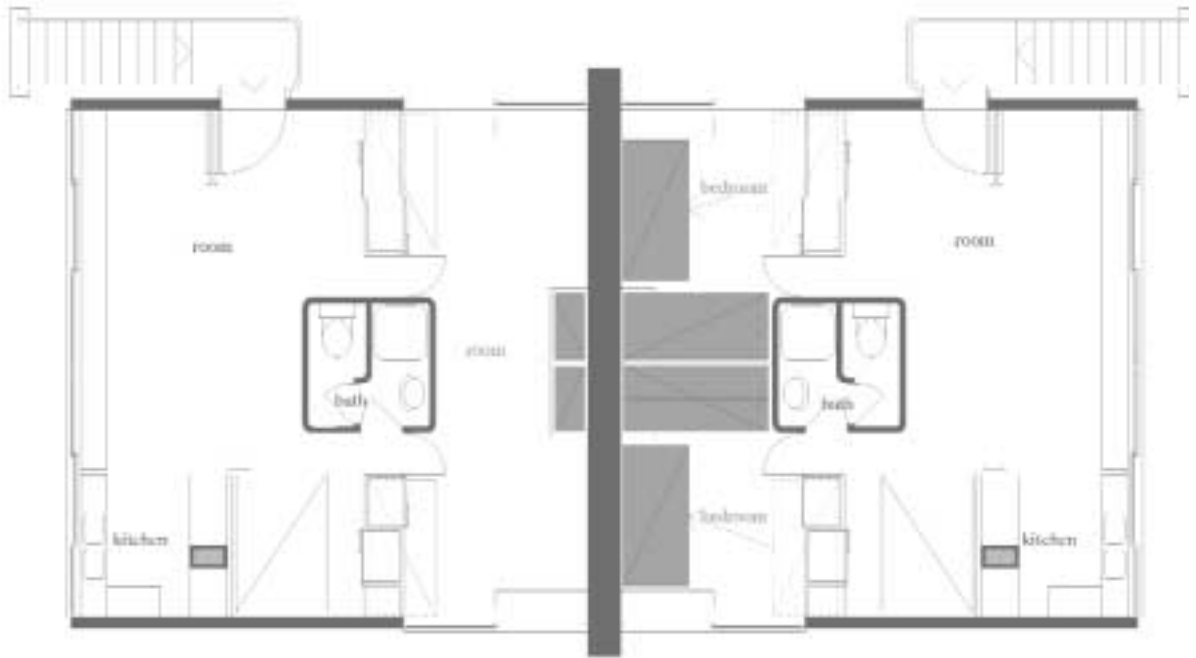


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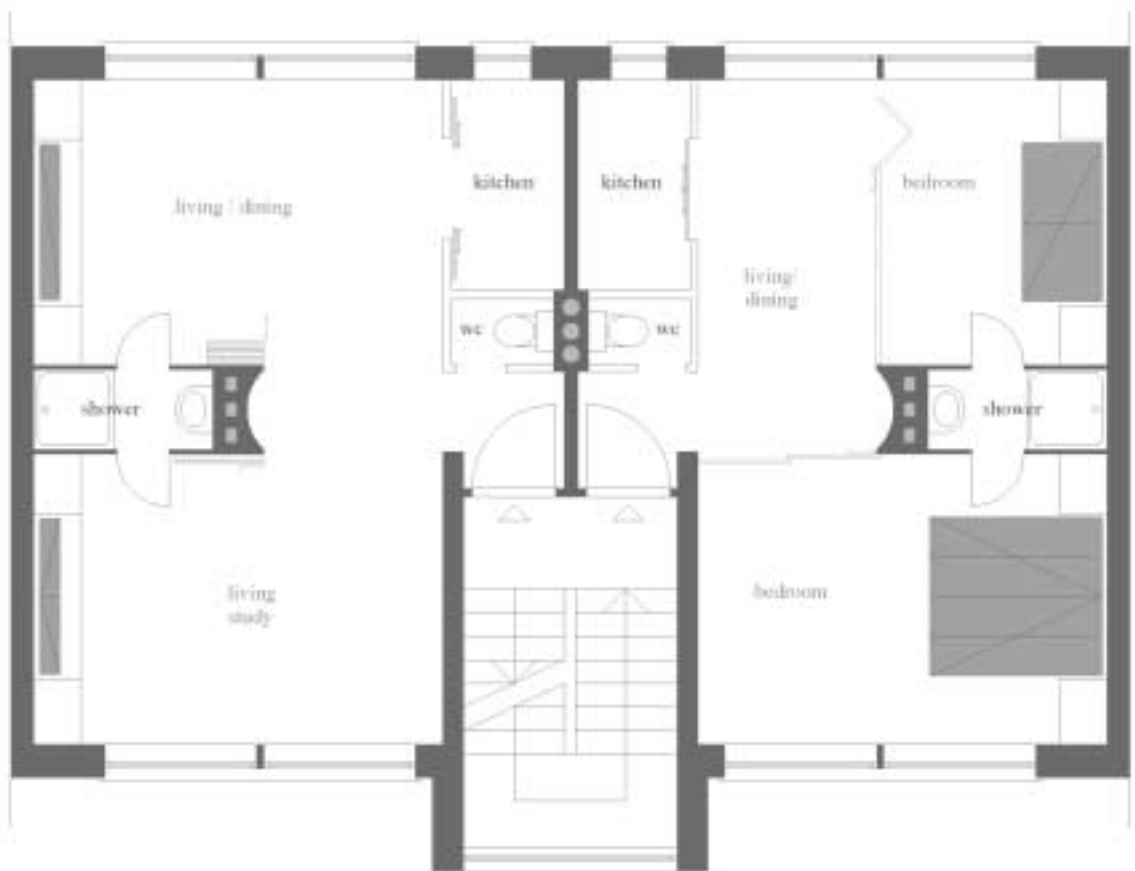
distributed) and the most efficient module size (a standard module allows repetition in structural division and components but should not limit options for subdivision). To ensure an efficient and flexible use of space, designers will often use hypothetical layouts to test their access, servicing and module strategies.

4 Weissenhofsiedlung, Stuttgart (1927) by Mies van der Rohe. Generic layout (bottom), typical plans (top)

5 Montereau-Surville (1971): Les Frères Arsène-Henry: 'empty' plans prior to internal division



6



7

6 Maison Loucheur (1928–9) by Le Corbusier: day plan (left) and night plan (right)

7 Kleinwohnung project (1931) by Carl Fieger: day plan (left) and night plan (right)

1800), bedrooms (1800, 2700 and 3600) and living rooms (2700, 3600 and 4500) to be accommodated. The architects designed 10 hypothetical layouts, but in the end none of these was taken up; the prospective tenants quickly learned to plan on a squared grid, especially if this exercise was done in the actual spaces. The modular system extended to the treatment of the external facades, so that the exterior appearance was dependent on the tenant's chosen internal layout and positioning of panels, a rare example of architects passing over aesthetic control to others [5].¹⁴

The Järnbrott Experimental Housing is one of the few flexible housing schemes to have been properly evaluated after occupation.¹⁵ Again it works on the principle of an open plan space with fixed bathrooms and kitchens, and tenants being shown alternative layouts. A survey carried out 10 years after completion found that the majority of changes had been made within the smaller units. This finding supports a common theme from our research interviews, namely that the provision of more space in itself provides a certain degree of flexibility, while smaller units are exactly the ones that require the most flexibility to be built in.

Hard use

The notion of soft space lends itself in particular to a participative approach to design, allowing a degree of tenant control at both design stages and over the life of the building. In contrast, hard use is use that is largely determined by the architect. To this extent hard use is consistent with the typical desire of the architect to keep control, and it is therefore maybe not surprising that hard use is associated with some of the twentieth century's iconic architects. Thus in the *Maison Loucheur* (1928–9) designed by Le Corbusier, a combination of folding furniture and sliding walls allows different configurations for day and night. Le Corbusier, in typically polemical style, argues that the purchaser is paying for 46m² of space but through the cleverness of the design is actually getting 71m² of effective space [6].

This scheme identifies some of the common features of hard use. First, the way it operates best where space is at a premium. Second, the use of moving or folding components. Third, the highly specific nature of the configurations produced. Classic examples of hard use such as *Lawn Road* apartments (1934) by Wells Coates, the seminal *Schröder Huis* (1924) by Rietveld, and *Kleinwohnung* project (1931) by Carl Fieger, all use these strategies [7].

There are comparatively few hard use flexible housing schemes in relation to the continuing interest in soft use approaches; they are generally confined to demonstration or one-off projects, and usually accompanied by a rhetorical stance which may be at odds with the real needs of the users, for whom the discipline of moving walls and folding beds on a daily basis is likely to be over-onerous. The fate of *Lawn Road* is instructive here. Originally the scheme was occupied by a group of young intellectuals, including Marcel Breuer, László

Moholy-Nagy, and Agatha Christie, who were sympathetic with the ideology of the project. As they moved on, the apartments became increasingly difficult to rent out, and eventually the empty scheme fell into disrepair. Following its recent renovation, *Lawn Road* now houses a mixture of government 'keyworkers' in shared ownership tenure (nurses, teachers and so on who would otherwise not be able to afford London house prices) and young professionals, apparently attracted by the lifestyle choice that the apartments offered, though not put off by the very high cost per square metre of the leasehold apartments.¹⁶ The minimal space standards and discipline associated with hard use may thus have a future relevance for two groups of people, one of which has no other choice but accept small, the other which sees small as a beautiful lifestyle accessory.

Technology

If one method of achieving flexibility in housing is through a consideration of use through design in plan, another is through the deployment of technology.¹⁷ Clearly these two approaches are not mutually exclusive. We have seen how the development of long span structures allowed the elimination of loadbearing partitions, which in turn allows soft use. However, in other schemes it is the chosen technology rather than the specifics of the plan that is seen as the primary means of achieving flexibility. Technology here encompasses construction techniques, structural solutions, and servicing strategies, or a combination of these approaches. Again we have divided these approaches into 'hard' and 'soft'.

Hard technology

By hard technologies we mean those technologies that are developed specifically to achieve flexibility, and which are the determining feature of the scheme. Of all these, the approach that has been most systematically developed is that of the open building movement. This grew out of John Habraken's research and his book *Supports: an alternative to mass housing*. The book is based around a critique of mass housing, arguing that mass housing 'reduces the dwelling to a consumer article and the dweller to consumer'.¹⁸ Habraken argues for an alternative in which the user is given control over the processes of dwelling. The bold move in the book is then to harness this social programme to a technical solution. The basic principles are straightforward, namely that housing should be considered as a structure of supports and infills. The supports provide the basic infrastructure and are designed as a long-life permanent base. The infills are shorter life, user determined and adaptable. The support and infill approach also implies different levels of involvement on the part of the user and professional, with professionals relinquishing complete control, particularly at the level of the infills. So far so good. Reading the sections on supports forty years after they were first written, one is struck by their polemical and open-ended nature; they should be seen as a challenge to



8



9

8 Genter Strasse, Munich (1972) by Otto Steidle with Doris and Ralph Thut; frame and infill

9 Diagon Houses, Delft (1971) by Herman Hertzberger.

normative ways of thinking, but have instead been taken on as a more determinist orthodoxy under the flag of open building.

In the few examples of open building that have actually been constructed, the emphasis has shifted to the technical and constructional aspects and away from the more socially grounded implications of flexible housing. So it is not surprising that the initial interest in open building in the early 1970s waned because of the dearth of available technical solutions such as suitable infill systems.¹⁹ One of the few UK projects constructed at the time (the so-called PSSHAK scheme at Adelaide Road, 1979) has hardly been changed over the intervening years despite the explicit flexible intent of the constructional technique; the main reason is apparently that the instructions as to how the infill kit could be adapted were not passed on to subsequent tenants.²⁰

The main outlet for open building has been in Japan where the Ministry of Construction has funded a number of experimental projects, most of which have been driven by a technically determined agenda.²¹ This is not to deny that the essential principles of open building do address the needs of flexible housing. However, there is a danger in these and other open building projects of getting obsessed by the techniques, and in this the technology becomes an end in itself rather than a background means to an end. This determinist aspect of hard technology²² is not, of course, limited to the field of

flexible housing, but can be traced in the course of twentieth-century attitudes to technology.²³

Soft technology

Architects are notoriously susceptible to siren calls of technology as a means (but quickly becoming the ends) of denoting presumed progress. The foregrounding of hard technology allows these delusions to be perpetuated. This suggests that in flexible housing, as in other architecture, one should move from the determinism of hard technology to the enabling background of soft technology. Soft technology is the stuff that enables flexible housing to unfold in a manner not completely controlled by the foreground of construction techniques. In flexible housing this approach can be seen in a number of schemes, many of which exploit the layering principles of open building, but in a more relaxed and less determinist manner. So in the Genter Strasse scheme in Munich (1972) designed by Otto Steidle with Doris and Ralph Thut, a prefabricated frame can be filled according to users' needs and wants.²⁴ Over the last 30 years, volume, interiors, and uses have changed considerably [8].

This scheme, and others like it, exploits soft technology in the form of a structural system that allows changes to be made at a future date. This system may be in the form of an expressed frame, as in the Genter Strasse scheme, or else simply a grid structure that does away with the need for loadbearing internal partitions, as in the Brandhöfchen scheme, Frankfurt (1995) designed by Rüdiger Kramm in which the structure's only loadbearing elements are beams and columns; none of the internal walls is loadbearing, meaning that even party walls can be removed to combine two smaller units into one large unit. Small service cores are located on each grid line (at the north facade), allowing for a range of connection possibilities.

The provision of services, as in the Brandhöfchen scheme, is another aspect to be considered in the soft technology approach. This can be achieved in three ways. First, through the strategic placing of service cores to allow kitchens and bathrooms to be placed within specific zones but not to be permanently fixed. Second, through the ability to access services so that they can be updated at a later date. Third, through the distribution of services across the floorplate so that they can be accessed in any plan arrangement. The way that most housing is serviced, and in particular the wiring, remains an obstacle to flexible housing. The incorporation of electrical outlets into internal partitions is often necessary to meet standards of provision or disability requirements, but this also limits future change. The distribution of services through raised floors following office design principles gets over the first but not the second of these problems; it is also potentially more expensive. An alternative solution to the servicing problem is the 'living wall' concept developed by PCKO Architects, in which services are concentrated along a linear service wall, which is easily accessed from the outside (to allow service

providers to make changes with minimal disruption) as well as internally (when internal layouts are changed).

Conclusion

It will be seen from the above that our sympathies lie with a 'soft' approach to the design of flexible housing. As noted, soft use and soft technology are by no means mutually exclusive, and in the best examples the social and technical aspects of the project support each other, as in the Diagoon Houses, Delft (1971) by Herman Hertzberger. The principle behind the houses is based on the idea of the 'incomplete building'; meaning that a basic frame leaves space for the personalised interpretation of the user, i.e. number of rooms, positioning, functional uses. The occupants themselves will be able to decide how to divide the space and live in it, where they will sleep and where they will eat. If the composition of the family changes, the house can be adjusted, and to a certain extent enlarged. The structural skeleton is a half-product which everyone can complete according to his own needs. The interiors show a fine balance

between order and chaos, the architecture accepting but not getting overwhelmed by the vicissitudes and changes of everyday life [9].

While most of the examples given have been at the scale of the individual apartment, it is important to note that our approach to flexible housing can and should be applied at all scales. At the scale of the whole building, soft use and/or technology will allow both a variety of sizes in housing provision, as well as the potential for mixed use. At the scale of the room, flexibility can be considered through both use and technology, the former in the consideration of how a single room may be used for a variety of purposes, the latter through the incorporation of flexible components. At whatever scale, it is clear that flexible housing can be achieved through a careful consideration of use and technology and without significant, if any, additional cost; it does not rely on an overt display of formal or technological gymnastics. In this, the soft approach to flexible housing assumes a background role which, while not necessarily according to the tendencies of progressive display that architecture often adopts, weaves itself into the heart of social empowerment.

Notes

- This paper is based on a research project, 'The Past, Present and Future of Flexible Housing', funded by the Arts and Humanities Research Council.
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- The term 'soft' is drawn from Jonathan Raban's seminal book on urban culture, *Soft City*: '... the city goes soft; it awaits the imprint of an identity. For better or worse, it invites you to remake it, to consolidate it into a shape you can live in'.
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- Alice Friedman makes it clear that the divisible open plan design was conceived in close collaboration with the client for the house, Truus Schröder, and so not the whim of the architect as controller.
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- Open building is by no means the only example of 'hard technology' in the flexible housing sphere. Others include the Danish Flexibo system and the 'Optima' housing system designed

- by Cartwright Pickard for the UK market. See respectively: Fællestegnestuen 'Flexibo, Amager: Arkitekter: Fællestegnestuen, with Viggo Møller-Jensen, Tyge Arnfred and Jørn Ole Sørensen', in *Arkitektur DK* 23, pt. 6 (1979), 232-9 and D. Littlefield, 'DIY for Architects', in *Building Design* 1643 (2004) 20-1.
23. It should be noted that a few schemes also consider the section as means of allowing flexible use over time. For example, the unbuilt Projekt Wohnhaus (1984) by Anton Schweighofer is based on an unfinished double-height space which the occupants would 'grow' into through the addition of floors and walls. Anton Schweighofer, 'A central space as a "kitchen studio": changeable flats: projects and buildings; Architects: Anton Schweighofer', in *werk, bauen + wohnen* 71/38, pt. 3

(1984), 28-35.

24. Otto Steidle, 'Anpassbarer Wohnungsbau', *Baumeister* 74, pt. 12 (1977), 1163-6.

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Biographies

Jeremy Till is an architect and Professor and Director of Architecture at the University of Sheffield where he has established an international reputation in educational theory and practice. His widely published written work includes *Architecture and Participation* and the forthcoming *Architecture and Contingency*. He is a Director in Sarah Wigglesworth Architects, Chair of RIBA Awards Group

and will represent Britain at the 2006 Venice Architecture Biennale.

Tatjana Schneider studied architecture in Kaiserslautern, Germany and Glasgow, Scotland. She practised in Munich and Glasgow, and researched a PhD at Strathclyde University. Now a Research Associate at Sheffield University, she is co-writing with Professor Jeremy Till a book on Flexible Housing for publication by Architectural Press.

Authors' address

Professor Jeremy Till
Dr Tatjana Schneider
School of Architecture
University of Sheffield
Western Bank
Sheffield
S10 2TN
UK
j.till@sheffield.ac.uk
t.schneider@sheffield.ac.uk