ÖPPEN – LEAN THINKING, PREFABRICATION, ASSEMBLY AND OPEN BUILDING THINKING – ALL APPLIED TO COMMERCIAL BUILDINGS

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ABSTRACT

Describes the origin of the Öppen system buildings, how the system has developed and future possibilities. The system combines: lean thinking, all the way from briefing, through design, to construction; prefabrication and assembly of large components; and open building thinking for future adaptability.

The first built example was a university research laboratory where the use of the system reduced the construction cost by 40% below the budget. The constructed building, now in use for five years, has proved fully adaptable. The second example to be built has recently been tendered. Against an identical building with traditional construction, the Öppen system building was cheaper and 50% quicker to construct.

Most commercial buildings are from the 'design one, build one' mould, whereas many aspects of Öppen system buildings will be common from one building to the next, thereby enabling continuous improvement.

Derivatives of the Öppen system are being developed for other types of building, such as schools and laboratories. The Öppen system does not aim to be suitable for all building typologies. It is aimed squarely at the mid-market: buildings that will be used for many years, for clients who need good value, robustness and adaptability.

KEYWORDS

collaboration/collaborative; lean construction; standardisation; customisation; open building; adaptable; Öppen.

INTRODUCTION

HYPOTHESIS

Unlike most commissions, this one starts with a hypothesis not a brief. A brief is constricting, the architect has to address the problem posed by the client. The hypothesis was that it should be possible to reduce construction time and cost, while simultaneously increasing long-term adaptability; all three being achieved while maintaining a bespoke appearance, long-term value and robust durability. This hypothesis builds on 'lean' thinking, 'open building' theory, and the benefits of prefabrication.

This combination of ideas may have previously failed in one of two ways. Firstly, that in adopting open principles, which facilitate future adaptability, the construction cost has increased due to added design redundancy(such as structural redundancy to provide for an unknown future). Secondly, that volumetric prefabrication has brought

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increased cost, probably as a consequence of volumetric manufacturers' business overheads (primarily staff costs).

CAUSE FOR OPTIMISM

The first indication that it might be possible to reduce construction time and cost, while simultaneously increasing long-term adaptability came in 2004 on a 6,000sqm university research building designed by Stubbs Rich Architects where early 'Öppen system' thinking was applied. This reduced construction cost by 40% and significantly shortened time on site. When the project was complete the client was delighted: the building was more useful and flexible than the earlier, and much more expensive, design (Livingstone).

Öppen is a building system that combines lean thinking, open building theory and prefabrication. From the success of this first project, it was understood that the goals could be achieved through the elimination of waste.

WHAT HAVE BEEN THE CHALLENGES TO ACHIEVING THIS GOAL?

In any building project there are many actors: clients, funders, architects, engineers, project managers, contractors, specialist contractors, suppliers and many others. To some extent probably all of these influence the design, however, in the vast majority of projects, it is still the architect who leads the design process, often much influenced by the client who sets the scope of the challenge; and the architect, in response, produces the vision. All the other players follow on in supporting roles.

FROM AN ARCHITECT'S PERSPECTIVE, WHAT ARE THE ISSUES AND HOW COULD THEY BE OVERCOME?

Issue 1: every building is thought to be different.

'Every client is different, so every building is different', is commonly opined. However, it can only be the first occupier who gains the benefit of a building that is truly bespoke to their needs. So, what proportions of users are occupying space which was not designed specifically to <u>their</u> needs? Everyone renting secondhand space; everyone being moved from one part of a building to another; everyone whose activity has changed since the building was designed.

Surely, the vast majority of occupiers fit into one of these categories. It can only be the minority who occupy space that was designed for them to undertake their current activity. Despite this lack of apparent linkage between client design needs and design function, businesses, schools, universities, hospitals continue to function well enough. Maybe not optimally but good enough. It is simply uneconomic to make structural changes to a building to suit every new person, every new activity.

In John Harbraken's book, *Palladio's Children*, he speaks of a hierarchy of levels (Harbraken 2005). These levels are sometimes listed as: national planning; city infrastructure; building structure; skin; services; spaces; and stuff (furniture, fittings and equipment). It is clear that a new person or process might warrant a change at the lowest level, perhaps the moving of a desk or cupboard, but rarely at a higher level such as moving the location of building.

Therefore, if a building within its 50 year life span is going to be used by many people not envisaged at the outset, and possibly for processes not even invented at the time of the original briefing, then maybe the only valid building brief is one that calls for adaptable space that is able to accommodate the initial activity and is also easily changed to accommodate subsequent activities. This would be an open building.

Issue 2: some buildings really are different.

What do houses, offices, high-bay warehouses, retail malls, swimming pools and power stations have in common? Probably there are a few common components but so few as not to be worth listing.

Construction covers an enormous breadth and one answer can never fit all typologies. Therefore, the challenge is to first segment the market into typologies and then look for common characteristics. Some typologies have more common characteristics within themselves than others, for example: within the typology of housing, or schools, or offices, or warehouses, whereas most swimming pools or most power stations will be one-off designs. By focussing on typologies with many common characteristics, maximum benefit can be achieved.

Issue 3: if prefabrication is fast and construction on site is slow, why not fully prefabricate?

In Kieran and Timberlake's (2004) book *Refabricating Architecture*, 'quilting' rather than 'weaving' is advocated: construction that is simultaneous rather than sequential. Weaving being the bringing to site of the simple materials and using craft skill to build with them, whereas quilting is the assembly on site of components made off-site.

While off-site prefabrication of components combined with their on-site assembly has clear benefits in terms of time and quality, it has been found to have some shortcomings: the size of components is limited to what can be transported by road; and the cost of prefabricated components has been found to be higher because of the need for a factory with employees and all its attendant overheads.

Therefore, the challenge is to determine where the balance is between: off-site prefabrication of a vast number of small components such as bricks and then building the wall on-site; and, off-site prefabrication of complete rooms and simply connecting the services on-site. Clearly, both extremes are possible and indeed common – the challenge is to find the optimal balance.

Issue 4: a system building with elements of prefabrication or industrialisation does not have the same perceived quality as a traditional building.

Here the challenge is cultural or aesthetic rather than technical or financial. As a result of the brutal appearance of many mass-produced system buildings that were erected in the UK in the 1960s and 1970s, in the 1980s there was a strong move towards vernacular and post-modern styles. Although stylistic tastes have again moved on, there is still, perhaps not unsurprisingly, a dislike of buildings that *appear* to be system buildings. This probably stems from their repetitive appearance and their apparent lack of individuality: a cold and inhuman character.

However, for organisations requiring space quickly, off-site manufactured modular accommodation has its attractions, these organisations have to accept a lack of perceived quality as a penalty (Portakabin). Therefore, the challenge is to determine which aspects of the construction can be systematised whilst still creating a building with individuality, and still achieving the benefits of speed. This approach is similar to the Japanese approach to system buildings where only the frame is systematised (Fukao 2008).

The Öppen system can be viewed as an example of mass-customisation[2]. It has a customised external appearance and customised internal layout, coupled to a mass-produced but unseen structural skeleton.

Issue 5: where is the waste?

Where does the waste in the construction process come from? The answer to this question is wide-ranging.

- the client's brief: if this calls for too much space or too complex a functionality, the design will follow suit, and the building could be wasteful. We have already established that needs change, so perhaps the brief only needs to call for appropriately adaptable space.
- the design: architects and engineers cannot understand *every* aspect of the performance of the materials with which they design. This detailed understanding is probably only held by the specialist trade contractors, and then only for their element. The architects and engineers should limit themselves to designing the junction between assemblies and specifying the performance of those assemblies. Beyond that their drawings add little value, as they will be redrawn by the specialists.
- the design: architects and engineers spending time designing what they have designed before are wasting time. They are not adding value to the project.
- the transfer of risk: any risk can be transferred to someone else, but at a price. The greater the risk, the higher the price. Reducing a specialist trade contractor's risk will reduce their price. Placing risk intelligently will reduce cost. Therefore, the challenge is both to design buildings where lack of experience does not increase risk or cost, and also, with this inexperienced workforce, to understand where risks exist so they can be diminished and appropriately placed.
- the construction time: building anything for the first time, especially a design that has never been built before, will be a slow process.

HOW THE ÖPPEN SYSTEM ADDRESSES THESE CHALLENGES

Issue 1: every building is thought to be different.

The Öppen system is based on open building theory in that conceptually it separates a building into three parts: 'skin', 'support' and 'infill'[3]. By making this distinction at the outset, it enables the three parts to be adapted at different frequencies for each element. For instance, the support or structural elements, will only rarely be changed, the skin or external cladding, might only be adapted every 20 years or so, whereas the

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2 A phrase first conceived by Stan Davis in *Future Perfect*. Dell Computers are often cited as a prime example. Customers interact with a company and specify their unique requirements which are then manufactured by automated systems.

3 'Skin' refers to the external elevations. 'Support' refers to the structural frame, floors and roof. 'Infill' refers to the fit-out and services.

infill or fit-out including the services, may be altered every year. Continuing with this notion of separation, the furniture might be changed frequently.

Öppen has focussed on a single typology – that of clear-span workplace buildings, which have many consistent demands – and combined this with an understanding of the hierarchy of levels. This enables designers to think in terms of optimising certain repetitive aspects of the design within a level, while leaving other aspects to be bespoke to the project.

Issue 2: some buildings really are different.

For its first typology, clear-span workplace buildings, Öppen has taken the following segment of the market: teaching space in schools and universities, non-prime offices, ancillary health buildings. These buildings have many common characteristics, such as the following:

Function:

- places where people work
- a range of activities, requiring different internal layouts
- in a range of settings, requiring different external appearances
- internal activity is more important than external appearance

Time:

- quick build time in response to demand
- minimum time on site, as often constructed on an occupied estate

Cost:

- good value, not extravagant
- low whole life cost, low cost of future adaption

Quality:

- need for durability / longevity, say 50 years for the skin and skeleton
- need for adaptability of infill/fit-out, as a result of longevity
- good environmental performance, with an upgrade path

Environmental:

- natural light, well insulated, passive cooling, low solar gain
- natural or mechanical ventilation, heated and maybe cooled

In the UK, the value of this segment in 2010 was: £15billion[4].

Issue 3: if prefabrication is fast and construction on site is slow, why not fully prefabricate?

Öppen acknowledges the benefit of prefabrication. It also recognises the value of the building site. The design of the Öppen skeleton uses prefabricated components (the frame[5], floors[6], roof and perimeter structural walls[7]) that are pre-engineered to be quick and accurate to erect and all these components are designed to be as large as possible. They are delivered to site pre-drilled for quick, simple and accurate assembly. They are lifted into position by crane. Above the ground, the construction

[4] Data from the UK Government Office for National Statistics.
[5] Usually hot rolled steel.
[6] Usually precast concrete, possibly with a structural topping.
[7] Usually a form of insulated preformed structural panel.

is dry. The selection of materials and their assembly is subject to a UK patent (pending).

The system delivers column-free open-plan space up to 15m wide and of any number of 7.2m wide bays. The floor can accommodate the needs of any of the selected activities within this typology. The soffit is completely flat and there is a raised access floor throughout, therefore the distribution of services is easy.

This combination of systematising the highest level (using open building terminology) and designing it to accommodate a number of lower level skins and infills, makes the approach of the Öppen system unusual.

Issue 4: a system building does not have the same perceived quality as a traditional building.

Even the descriptor: 'system building', can devalue the concept. Öppen has sought to overcome this impediment by describing it in a similar way to Intel with their strap line, 'Intel inside'. To date the projects proposed using Öppen have had a wide range of external cladding materials: brick, timber, glass, stone, render. Each looks quite different. These buildings can all be described as having 'Öppen inside'.

Thirteen storey glass-clad offices.

Single storey timber-clad university library.

Two storey brick-clad health sector offices.

Two storey rainscreen-clad small units.

This customised external appearance is achieved through the perimeter structural walls being able to receive any rainscreen or other cladding, and any glazing system. Rainscreen is a type of cladding that is designed to resist most of the rain and wind, and to protect the waterproofing membrane and insulation.

The Öppen system provides easier internal adaptability throughout the life of the building by having no central row of columns. This makes this system building potentially more valuable than a traditional building.

Through market testing, it has been found that a straightforward project can be delivered more quickly and at a lower cost using the Öppen system than an equivalent temporary modular building. Further, an Öppen system building will be more durable, more adaptable, and it will look like a *real* building.

Issue 5: where is the waste?

- the client's brief: an Öppen system building is inherently adaptable. This means that finalising the brief for the fit-out can be delayed until part way through the construction of the skin and skeleton.
- the design: with the Öppen system, architects' and engineers' fees are lower as much of the detailed design is already completed.
- the design: through collaboration with the supply chain, the method of integrating all of the key components is already resolved.
- a lack of knowledge: the Öppen system is simple. It is designed to be quick and easy to assemble without requiring a skilled craftsman.
- the transfer of risk: by repeating the same design and detailing, lessons can be learnt and improvements made.
- the construction time: by repeating the same key elements, the contractors can learn from previous experience. This enables continuous improvement.

EVIDENCE THAT THE ÖPPEN SYSTEM BUILDING DELIVERS THE ANTICIPATED RESULTS

FIRST EXAMPLE A 6,000SQM ADAPTABLE RESEARCH BUILDING FOR A UNIVERSITY.

This project was initially designed by another architect and the cost of the project exceeded the university's available budget. Stubbs Rich Architects were appointed in 2004 to redesign the project. The building had to meet the same brief and functionality and be of similar appearance, but be at a much lower cost.

Prior to redesigning the building, Stubbs Rich planned a visit to California to assess the US approach to designing flexible research buildings (i.e., UCSD, UCSC, UCLA, Stanford, UCD). In summary, the findings were that the research buildings were often over complicated and took so long to deliver that the research programme had moved on before the building came into use. From this it was clear that adaptability was a key requirement. 'Open building' thinking was clearly appropriate, whereby the building is designed in such a manner as to facilitate easy adaptability of the internal fit-out. This is easy to accomplish in an office building, much less so in a highly serviced research laboratory. Öppen is a system building designed on open building principals.

The research building was redesigned based on early Öppen system building thinking. As a result, the construction cost was reduced by 40%. The building has now been in use for over five years and has proved to be just as adaptable as hoped; it accommodates many activities that were not anticipated in 2004. Since it came into use, many of the research programmes undertaken by occupants have changed.

SECOND EXAMPLE AN ADMINISTRATION BUILDING FOR THE NATIONAL HEALTH SERVICE (NHS).

Stubbs Rich Architects designed a 1,000sqm two-storey building with a layout and appearance that suited both the Öppen system and a traditional building. Five tenders were sought, two contractors offering the Öppen system, three contractors offering a traditional method of construction. One of the contractors with the Öppen system was successful, his price was lowest and programme shortest: 20 weeks against 41 weeks for a traditional building. The building will complete by the end of 2012.

This near-halving of the construction programme gives the clearest evidence of the much improved efficiency of the Öppen system. The speed is achieved through: the components coming to site in large pieces; the envelope achieving early weather-tightness; and the ability to twin-track the external envelope and internal fit-out.

To both the university research client and the NHS client, adaptability was a key benefit. These are building owners who will keep their buildings for a long time. Over this period the people who use the buildings, the internal arrangements, and the uses to which the buildings are put are certain to change many times. The ability to make internal changes in a straightforward manner is a major, and on-going, benefit.

NEXT STEPS

With a first example complete and an imminent second, thought now turns to how we can achieve further improvements.

1. NEXT STEPS – POST-OCCUPANCY LEARNING

Most buildings fall into the 'design one, build one' methodology. In this type of process, only limited benefit can be gained from any post-occupancy review.

For the contractors, having spent a massive amount of effort determining how to construct a building they have never seen before, all that learning is of little value if that design is never to be built again. Contrast this with constructing a design that is to be repeated many times. Here it is highly beneficial to analyse every activity and to find every improvement, every reduction in risk, in time and in cost. This benefit applies throughout, from the designers to the suppliers of the materials.

2. NEXT STEPS – BUILDINGS AS COMMODITIES

It is anticipated that it will be possible to offer a building at a fixed price to include everything, except the land. The price could include design fees and the construction cost, with a standard specification and a list of options, much like for a new car.

How far could this be taken? Just the shell, or the fit-out and services as well? Would standard foundations prove economic?

3. NEXT STEPS – BIM AND E-TRADING OF COMPONENTS

Building Information Modelling (BIM) is still in its infancy in the construction industry. Until the material suppliers begin to offer digital, information-rich tags for their products, it will not be possible for designers to harness the full potential of the BIM methodology and really move the industry forward. In traditional buildings, this is hampered by the huge number of components used to construct the building, often in a bespoke arrangement. With an Öppen system building, the number of components is much reduced and the same components are repeatedly used on many projects. This will encourage suppliers of products used in the Öppen system to become early adopters of information-rich tags. This in turn might open up the opportunity for e-trading of Öppen system building components.

4. NEXT STEPS – OTHER BUILDING TYPES

In addition to the typology already described, the following are being developed:

- Öppen4labs. This variant accommodates the need for large vertical services risers at regular intervals across the floor plate. It also has a lower threshold of floor vibration to meet the needs of the sensitive equipment.
- Other options to consider may be:
  - Öppen4health, both administration and clinical building.
  - Öppen4prisons, category D, low-risk detention centres.
  - Öppen4students, this is a big market in the UK.

5. NEXT STEPS – GREATER COLLABORATION

To date, the Öppen system has been developed by the designers (architects and engineers) and the Tier 1 suppliers (Main Contractors), with only limited involvement of Tier 2 suppliers (specialist trade contractors) and Tier 3 (material suppliers).

6. NEXT STEPS – QUILTING RATHER THAN WEAVING

Quilting, the on-site assembly of off-site manufactured components, could be taken further. How much of the services installation and fit-out could be made off-site?

7. NEXT STEPS – A ZERO-CARBON IN-USE BUILDING

The Öppen system is inherently a low energy building: good levels of insulation, airtight, high floor to ceiling, exposed thermal mass, ample natural ventilation, good natural light. In addition, we are working on a heating/cooling system that requires no external heating source.

CONCLUSION

We believe that through the application of lean thinking, open building theory and the benefits of prefabrication it is possible to simultaneously reduce time and cost, increase long term adaptability, all while maintaining a bespoke appearance, long term value and robust durability. Öppen intends to deliver targets of 50% time reduction and 30% cost reduction, possibly better.

ACHIEVEMENTS

This hypothesis has been tested on a university research building, and then refined and further tested on a health sector administration building. It has been proved that the buildings delivered can be constructed more quickly and at lower cost.

It is now possible to identify the challenges that have prevented this outcome before. Perhaps this conundrum could be summarised as the client's desire to ask for everything, and in response the design team's willingness to provide everything asked for, and, to suit their creative instincts, to do so in a novel fashion.

John Harbraken's concept of 'levels' begins to indicate what buildings should allow to change in the future: principally the interior rather than the skeleton or skin. Then by segmenting the market to a typology with common characteristics, the problem becomes more manageable by reducing the breadth of the variables.

It has been understood how on-site assembly of systems rather than raw materials – quilting rather than weaving – reduces time and craft skills, helps achieve some of the goals. However this understanding has to be tempered with the knowledge that wholesale use of volumetric modular components increases cost and reduces adaptability.

The perceived brand-weakness in the UK of any building system has been overcome by the Öppen system by thinking of buildings as having 'Öppen inside', while having a unique external and internal appearance.

Having cracked the problem with one typology, Öppen is now looking to apply this thinking to other typologies.

A real building as a commodity. Just as cars moved from being hand-built, to mass-produced, to mass-customised, so Öppen is moving construction from hand-built to mass-customisation, the mass-produced phase having proved not to work.

A proven zero-carbon building is still a target. Many supposedly low-energy buildings fail to achieve their claimed performance and, as one-offs, there is no opportunity to improve (Curwell 1999). Öppen has the opportunity for learning. This coupled with what is an inherently low energy building, should mean that demonstrable zero-carbon is achievable.

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