10TH INTERNATIONAL DESIGN STRUCTURE MATRIX CONFERENCE, DSM'08
11 – 12 NOVEMBER 2008, STOCKHOLM, SWEDEN

USING DSM TO REDEFINE BUILDINGS FOR ADAPTABILITY

Robert Schmidt III[1], Syed Mohyuddin[2], Simon Austin[1] and Alistair Gibb[1]

[1] Department of Civil and Building Engineering, Loughborough University
[2] Department of Construction Services, Moulton College, Northampton

Keywords: adaptability, product architecture, sustainability, construction process, component, DSM

1 INTRODUCTION

As a society we suffer from the inclination to ignore the causes of problems and instead deal with the effects; this disposition to find a 'remedy' rather than a prevention bolsters our tendency to resist change. The current challenge which besieges the resilient construction industry, sustainability, finds a remedy on a project basis by lionizing buildings rather than addressing the actual haphazard construction process which continues to endure. We have instilled over time a bespoke industry of onsite construction requiring an array of sub-industries to deliver a skilled workforce and various raw materials at a particular site creating a unique prototype every time. Several influential, government-back reports have argued for more joined-up production, exploiting the underlying common processes [1].

One initiative held by the *Adaptablefutures* group looks to exploit the initial design chain of events to imbue adaptability into the building's lifecycle. This group is working with GSK (GlaxoSmithKline), a multi-national pharmaceutical company, to address their need to cut the construction time of their facilities from 24 months to 13 weeks. This project, *Newways*, looks to redefine the overall method of how buildings are assembled by standardizing all elements and creating a catalogue from which to design. Figure 1 shows the proposed system of parts (900), components (90), and assemblies (30) initially to be used for three types of their facilities (laboratories, primary and secondary production). The GSK facilities are needed in a very tight sequential timeline, and the use of standard design and construction methods creates an extensive period of overlap, creating a high level of risk due to the uncertainties of starting construction prior to knowing exactly what is needed. Shorter construction time means less risk and more control enabling the deferment of critical investment decisions, lower capital costs, and the ability to reconfigure facilities quickly during design.

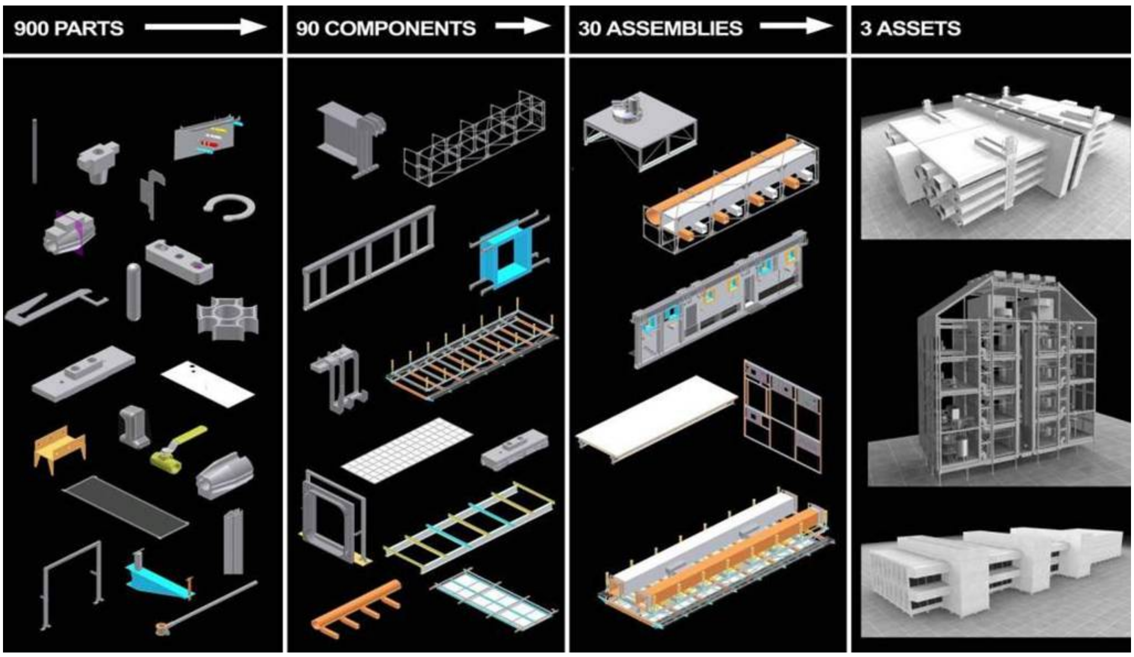


Figure 1. Newways concept

2 MOTIVATION

Throughout modern history there have been countless attempts at standardising components for a variety of modular systems, but most have failed to sustain replication or cross into the wider industry. On the other hand, an ideal example would be the use of USB ports in today's personal computers as a universal interface for any external device independent of the specific manufacturer or function. There remains a need in the construction industry to identify basic interfaces which can span across a variety of systems increasing compatibility and adaptability between buildings systems [2].

Adaptablefutures looks to generate an open building system [3] from a kit of parts approach coalescing with the already established *Flexilab* system. *Flexilab* is GSK's moveable furniture and modular service system which is able to adjust to evolving work demands by allowing users to 'adapt' their environment through a 'plug and play' approach producing flexible research spaces. The work will establish a base building approach which will allow for a level of infill, for example *Flexilab*, to take place creating variety within the products.

3 APPROACH

DSM can be used as a learning tool which can help analyze the effects of changes in a powerful visual format, exploring the commonality across a spectrum of parts, components, and assemblies [4]. Currently, there is a paucity of research when it comes to analyzing component-based DSMs related to the construction of buildings. Previous research has focused on the process architecture related to building design [5] , [6]. We believe there is huge potential in the construction industry to benefit from component-based DSM analysis identifying systems, subsystems, components and interfaces, understanding the interactions between them, and the use of appropriate clustering algorithms to provide insights into the architecture. The following questions arise:

a) Optimum level of standardisation
b) The best combinations of components
c) Identification and definition of interfaces
d) Performance assessment of the proposed design

These questions have a circular logic and hence iteration is required. The question of performance is particularly challenging because of the difficulty that clients have in assessing long-term needs and hence benefits. The initial aim of the research is to disentangle the design complexities embedded in a bespoke product, and to add clarity to the boundary between the base building (standardized) and fit-out (unique) in an open building system.

To start with, a product model has been constructed for a single assembly, the Floor Cassette, using a parameter as well as component-based DSM. Binary DSMs as well as numerical DSMs are being used in line with the approach of Pimmler & Eppinger [7] and Helmer [8] to indicate strengths and weaknesses of dependencies. Both manual [9] and automated clustering algorithms have been used to identify optimal product architectures. This will help to identify potential modules and interfaces and hence would be a step forward towards standardization. Identification of modules will help later in platform development as modules could be categorized as core or common and differentiating. The trade-off between modularized or standardised components and components that add variety or individualization can then be investigated.

4 REPLICATION

Once an initial catalogue of parts is identified through a product model building, replication can begin to take place, creating a product platform to allow for greater customization while maintaining low costs [10]. The commonality amongst parts would develop a modular or scaleable product, while other unique components offer differentiation to occur at the fit-out level creating a family of products (buildings, building typologies). A modular architecture can address functions, interfaces, or modules. Identification of modules can be done using a variety of DSM models to identify highly interactive elements allowing for small variances to be identified and separated into either common or unique components. The *Newways* project uses a 10/80/10 approach. Ideally 80% of 'construction' would be replicable leaving 10% to specific program enhancements and 10% to site context.

5 CONCLUSION

Identifying an established system of parts (varying from Newways specific (proprietory) components to open-market commodities) would help form a consistent supply chain which will increase delivery efficiency allowing for better cost predictability and commonality of interfaces. Critically, this could in turn create a more stable, continuous flow of work in the supply chain and hence encourage companies to make the necessary long-term commitment. Offsite construction will spawn a quicker and more predictable outcome embodying parallel processes and reduced waste, allowing the site to become an assembly line rather than a construction site increasing productivity and quality.

The *Newways* project is a method for GSK to better understand their building assets enabling them to increase capital efficiency and get more out of what they have. Industry-wide questions of applicability remain debatable. Can a system architecture cross building typologies and/or structural typologies? Can a common interface be developed and permeate through the construction industry as a catalyst for system integration? In the end, the *Newways* model hopes to serve as an archetype for an evolutionary change which can burgeon within the larger construction industry.

REFERENCES

[1] Egan, J. Rethinking Construction: Report of the Construction Task Force, HMSO, London, 1998.

[2] Larson, K., S. Intille, T. J. McLeish, J. Beaudin, and R. E. Williams. Open source building - reinventing places of living. *BT Technology Journal*, 2004, 22, 187-200.

[3] Kendall, S. Open building: An approach to sustainable architecture. *The Journal of urban technology,* 1999, 6 (3), 1-16.

[4] Browning, T.R. Applying the design structure matrix to system decomposition and integration problems: a review and new directions. *IEEE Transactions on Engineering Management.,* 2001.

[5] Austin, S. A. Baldwin, B. Li, and P.Waskett. Application of the analyticl design planning technique to construction project management. *Project Manage. J*, 1996, 7, 48-59.

[6] Austin, S. A. Baldwin, and A. Newton. A data flow model to plan and manage the building design process. *J. Eng. Des.,* 1996, 7, 3-25.

[7] Pimmler, T.U, and Eppinger, S.D. Integration analysis of product decomposition. *ASME 6th International Conference on Design Theory and Methodology,* 1994.

[8] Helmer, R., Yassine, A., and Maier, C. Module and interface identification and definition – a comprehensive approach using DSM's. *9th International Conference on Engineering Design, ICED'07,* 2007.

[9] Sharman, D.M., and Yassine, A.A. Characterizing complex product architectures. *Systems Engineering,* 7(1), 2003.

[10] Vuuren, W. and J. Halman. Platform-driven development of product families: linking theory with practice. *Conference "The Future of Innovation Studies"*, Eindhoven, September 2001.

Contact: Robert Schmidt III
Loughborough University
Department of Civil and Building Engineering
Loughborough, Leicestershire
LE11 3TU, UK
+44 (0) 1509 222897
r.schmidt-iii@lboro.ac.uk
www.adaptablefutures.com

10TH INTERNATIONAL DSM CONFERENCE

Using DSM to redefine buildings for adaptability

Robert Schmidt III, Syed Mohyuddin, Simon Austin and Alistair Gibb

Adaptable Futures Research Group

Department of Civil and Building Engineering

Loughborough University

Index

- A product-based architecture
- The Newways system
- Initial DSM ideas/ analysis
- Development of a product family
- Conclusions/ Questions

FOLLOW THE FLOW OF INFORMATION!

MANAGE COMPLEX SYSTEMS

Technische Universität München

FOLLOW THE FLOW OF INFORMATION!

MANAGE COMPLEX SYSTEMS

Motivation

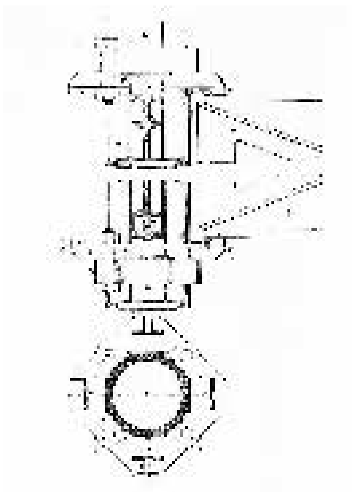
- The current challenge for construction is sustainability
- Need to identify basic interfaces which can span a variety of systems increasing compatibility and adaptability between buildings systems
- There is a demand for the economic life of a building to equal its technical life.
- We believe DSM can be used as a learning tool to help give insight into these challenges

Technische Universität München

FOLLOW THE FLOW OF INFORMATION!
MANAGE COMPLEX SYSTEMS

adaptablefutures

The Crystal Palace



Technische Universität München

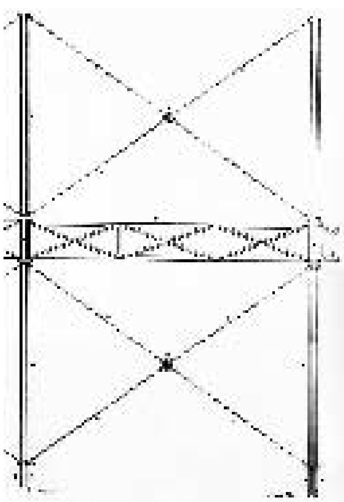
JÖNKÖPING INTERNATIONAL BUSINESS SCHOOL

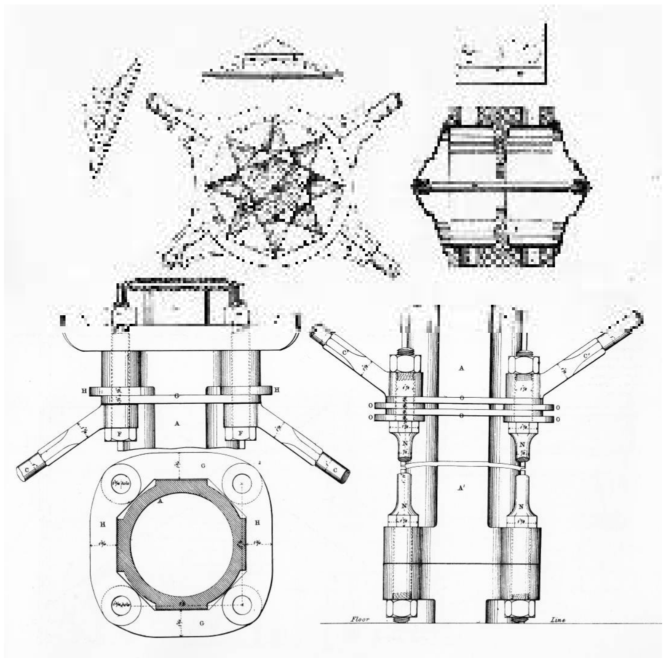
10th International DSM Conference 2008- 5

FOLLOW THE FLOW OF INFORMATION!
MANAGE COMPLEX SYSTEMS

adaptablefutures

Component-based Architecture





Technische Universität München

JÖNKÖPING INTERNATIONAL BUSINESS SCHOOL

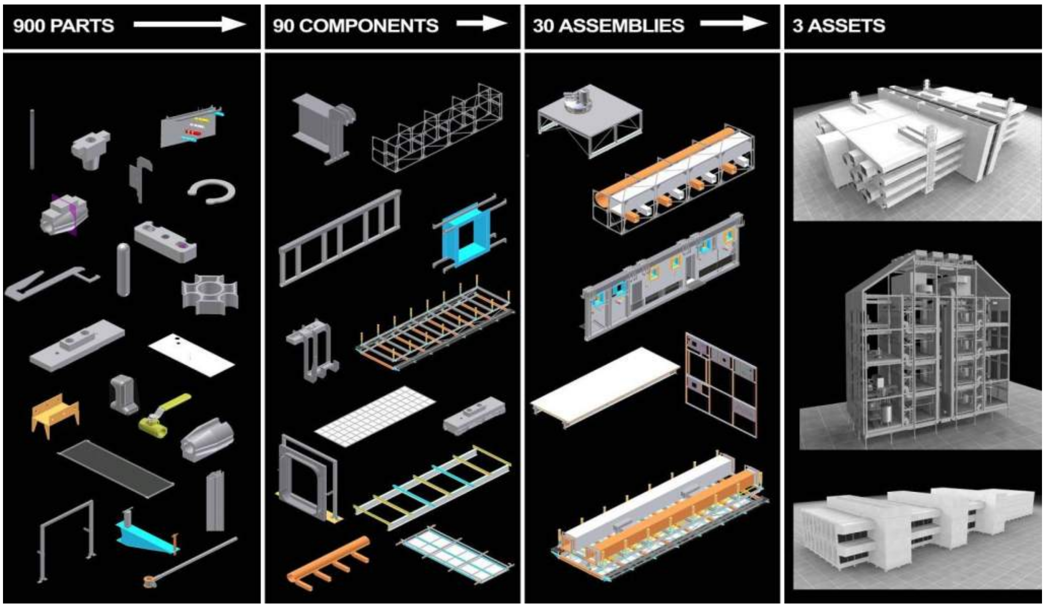
10th International DSM Conference 2008- 6

What is Newways?

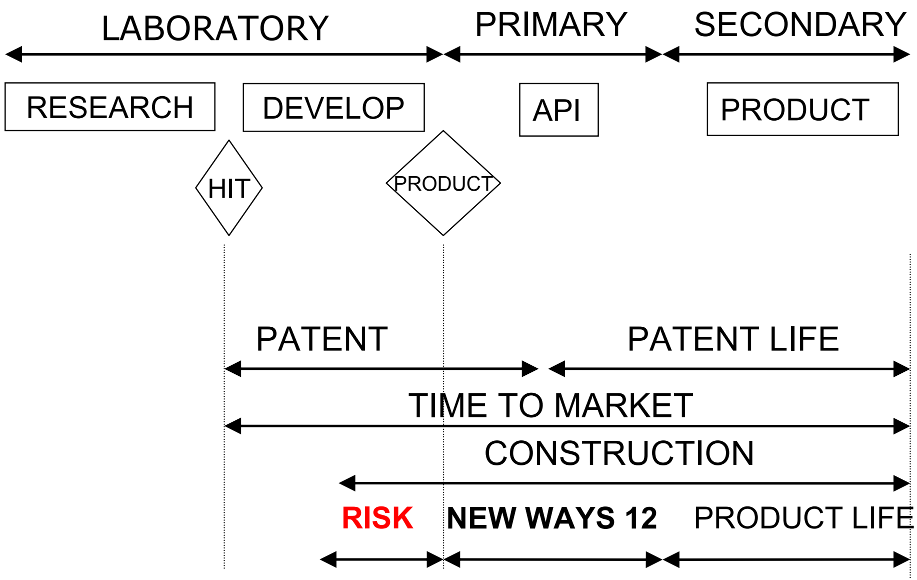
- GlaxoSmithKline initiative to radically reduce the construction and commission time of their built assets
- Future-proofing and flexibility of manufacturing drugs
- Modular design and off-site assembly
- Every GSK asset constructed from a part catalogue
- An established supply chain to remove process ‘gaps’
- Map depreciation level to business activity
- Become the ‘asset of the future’

FOLLOW THE FLOW OF INFORMATION!
MANAGE COMPLEX SYSTEMS

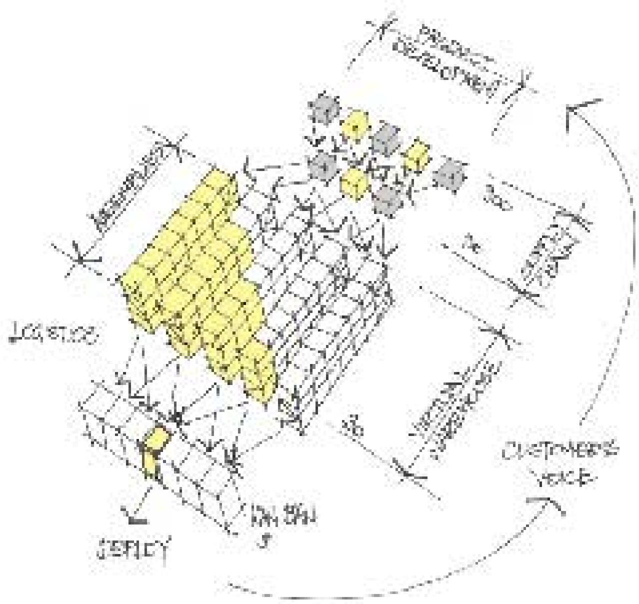
Newways product concept



Why 3 months?



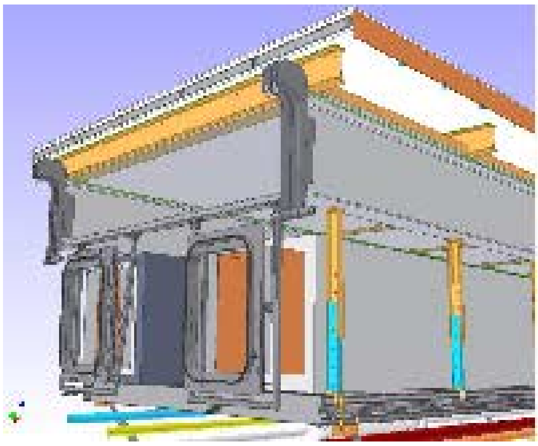
Create a supply chain



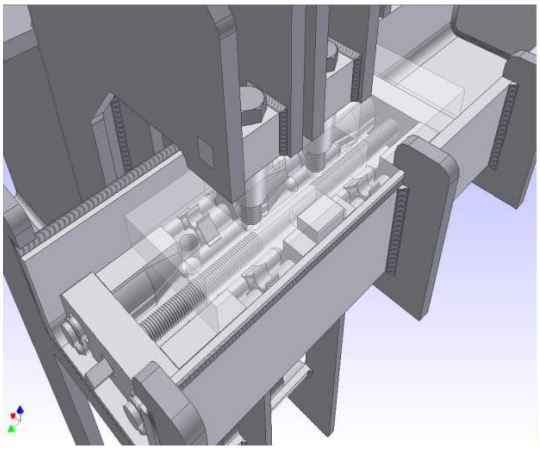
"Assembling a jigsaw"

- Built in controlled accessible environment
- Components constructed in parallel to building fabric
- Improved productivity
- Less manpower on site + reduced risk
- Higher quality
- Opens up work areas quickly
- Reduction in schedule
- Improved H&S on Site

PAM design



Quick connection of services



'Hook and Eye' connection for flooring assemblies allows accurate and fast construction of flooring

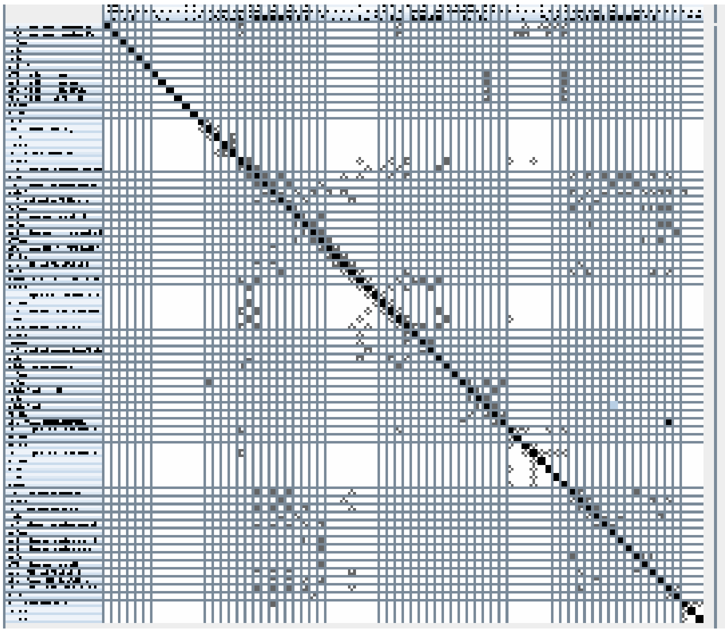
DSM in the construction industry

- Previous research focused on information flow through the design/ construction process
- Shift focus to a component-based DSM analysis, similar to other product-based industries, e.g. automotive, mobile
- Understand the system as a product - identify hierarchy of subsystems and components and hence disentanglement strategies

DSM as a learning tool

- Identify modules and interfaces
- Identify/compare clusters
- Identify and remove redundancies
- Explore commonality across a spectrum of parts, components, and assemblies
- Eliminate small variances with similar components
- Identify a hierarchy amongst components
- Ease the coordination demands (interfaces) between subsystems by identifying critical points
- Analyze effects of changes

Initial clustering



The following questions arise

- What is the optimum level of standardisation?
  - Where does the base building finish and the infill start?
- What are the best combinations of components?
  - How can we better assemble our buildings?
- What kind of and how many interfaces are optimal?
  - How can we ease assembly and reduce long-term maintenance?
- How will the proposed design perform?
  - How can we assess long-term value and needs?

Product architecture

- Create a system architecture (catalogue of parts) through a product model
- Idealize a system where 80% of 'construction' would be standardized
- Create a product family using an open building system approach, establishing a consistent boundary between a base building and infill
- Create a modular and/ or scalable product

FOLLOW THE FLOW OF INFORMATION!
MANAGE COMPLEX SYSTEMS

Mass customization

- Study the adaptability of the model system to other building/ structural typologies
- Identify sub-systems which can be common amongst the various product types – structure, services, public spaces…
- Users become designers, personalizing the space based on needs and functions restricted only by the configuration of the components not by a pre-designed arrangement

Conclusions

- Identify an established system of parts to form a consistent supply chain increasing delivery efficiency allowing better cost predictability and a commonality of interfaces.
- Can a system architecture cross building typologies and/or structural typologies?
- Can a common interface be developed and permeate through the construction industry as a catalyst for system integration?