# DESIGNING ADAPTABLE BUILDINGS

**Robert Schmidt III[1], Simon Austin[1], and Dave Brown[1]**

[1]Department of Civil and Building Engineering, Loughborough University

*Keywords: DSM, adaptability, time, layers, building decomposition, component interactions*

## 1    INTRODUCTION

This paper builds on the introductory paper (Schmidt et al., 2008) submitted for the 2008 DSM conference.

### 1.1    Adaptability

This investigation looks to make clear ***adaptability*** as a definable design characteristic with a principle consciousness towards *time* and *layers*.

*Time* - the design consideration that buildings are dynamic systems that interact with a set of evolving endogenous and exogenous demands that require a capacity to accommodate change (space, function, and componentry) over time.

*Layers* – the design consideration regarding the organization and interfaces between components of varying life spans and functions.

As a result, ***adaptability*** increases the capacity for change over time while *reducing the efforts and expenditures to do so* through the way the building is designed, increasing the longevity (i.e. sustainability) of our built stock.  This represents a fundamental change in the way we perceive our buildings and the composition of them as static constructions to dynamic systems.  In his book, How Buildings Learn (Brand, 1994), Brand clarifies his understanding of buildings as a composition of shearing layers (Figure 1).  Table 1 shows a brief comparison of Brand's layers with other literature which have broken buildings into a series of 'layers'.  A fundamental question became, with the use of DSM, how would the building components cluster?  Would they cluster into these varying layers of time and function or would there be strong dependencies between short and long-life components?
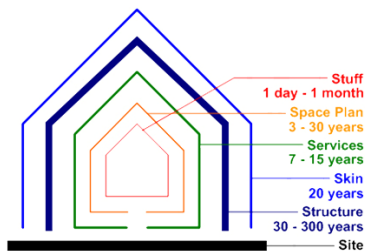


*Figure 1. Brand's layer diagram*

| Building Decomposition | | | |
|---|---|---|---|
| **Brand 1994** | **Slaughter 2001** | **Rush 1986** | **Duffy 1990** |
| Site | | | |
| Structure | Structure | Structure | Shell |
| Skin | Exterior enclosure | Envelope | |
| Services | Services | Mechanical | Services |
| Space plan | Interior Finish Systems | Interior | Scenery |
| Stuff | | | Set |

*Table 1. Building decomposition comparision*

### 1.2    Building Decomposition

In order to begin our process of abstraction, a classification of building 'parts' was considered to help decompose the artefact into three distinct classes:  components (the bytes), spaces (the large voids between the bytes), and systems (a combination of components + space).   This provided us with an initial rationale for the items to be listed in the matrix.  To help determine the relationships between 'parts',  in conjunction with previous literature – Table 2 (see also Helmer et al. 2007), three general dependency types were identified: spatial (e.g. adjacency, contraint), service (e.g. energy, water), and structural (e.g. gravitational, lateral) flows.  Service flows regard the transferring of a material element which services the habitability/ function of the building; spatial flows are concerned with the spatial relationship either through adjacency, constraint, boundary, or visualization; while structural flows pertain to the transferring of a physical load either vertically/ horizontally or directly/ indirectly. Lastly, a simple (structural/ spatial) weighting system was developed to bolster manipulating the data.

A weight of 1.0 was given to a *structural load transfer*, .75 to a *physical connection*, .50 to a *spatial adjacency*, and .25 to a *spatial constraint*.

**TYPES OF INTERACTIONS**

| Pimmler & Eppinger 1994 | | Rush 1986 | | Slaughter 2001 | |
|---|---|---|---|---|---|
| Spatial | need for adjacency | remote | do not physically touch (coordinated functionally) | Physical | connection, intersection, adjacency |
| Energy | need for energy transfer | touching | Contact without a permanent connection | Functional | enhance, complement, degrade function |
| Information | need for data or signal exchange | connected | two systems are permanently attached (e.g. welds) | Spatial | independent but in the same room |
| Material | need for material exchange | meshed | systems interpenetrate and occupy the same space | | |
| | | unified | share the physical form and is no longer distinct | | |

*Table 2. Types of Interactions between parts*

## 2 PROJECT SNAPSHOTS

### 2.1 Newways

The Newways project entails developing a minimum number of standard parts, while maximizing variety, and looking at the ramifications of the subsequent changes (e.g. what is good for the speed of construction, may not be good relative to future adaptability).

The Newways system is unique because we were given a prescribed kit to work with consisting of parts, components, and assemblies. This is inherent to understand because the established kit drove the initial clusters/ analysis. The initial matrix using the WBS order was comprised of parts and their dependencies (Figure 2 left image). The first manual manipulation placed the parts sequentially to their final assemblies (Figure 2 center image). Further manipulation optimized the parts into larger families of assemblies (Figure 2 right image). Seven families of assemblies were identified within the kit.
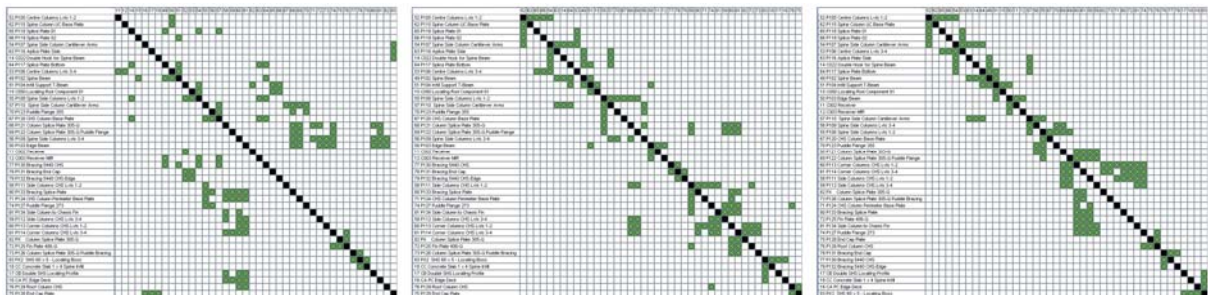


*Figure 2. From Initial DSM to optimal clustered families*

Initial modelling showed a clear design tendency for strong bus parts (column and beam) as system integrators which diagrammed as palpable groups of assemblies. A subsequent step would be to see how the kit assembles as a complete structural asset and integrates as a finished building.

### 2.2 Verbus

The Verbus system is a modularized structural system that currently integrates with other systems through conventional methods (interior and exterior). Thus, the question arose, what opportunities are available for the module to interface better with other modularized systems (e.g. windows, exterior panels)?

The Verbus volumetric system lead to another approach by having two explicitly distinct constructions being integrated. Data for the building was entered initially (Figure 3 left image) as either part of the conventional system of construction (baby blue) or part of the Verbus system (magenta). This lead to the initial decision to split the large matrix into two smaller matrices allowing for each 'system' to be optimized individually and then recombined (this also made the 110 parts easier to work with). The data was entered sequentially relative to building subsystem composition (e.g. structure, roof, floor, walls), thus, some clustering could be seen immediately. Optimization tightened the clusters and pulled 4 integrating parts outside of the modules. There were six general clusters identified (finishes, interior walls, exterior walls, floor roof, and connections).
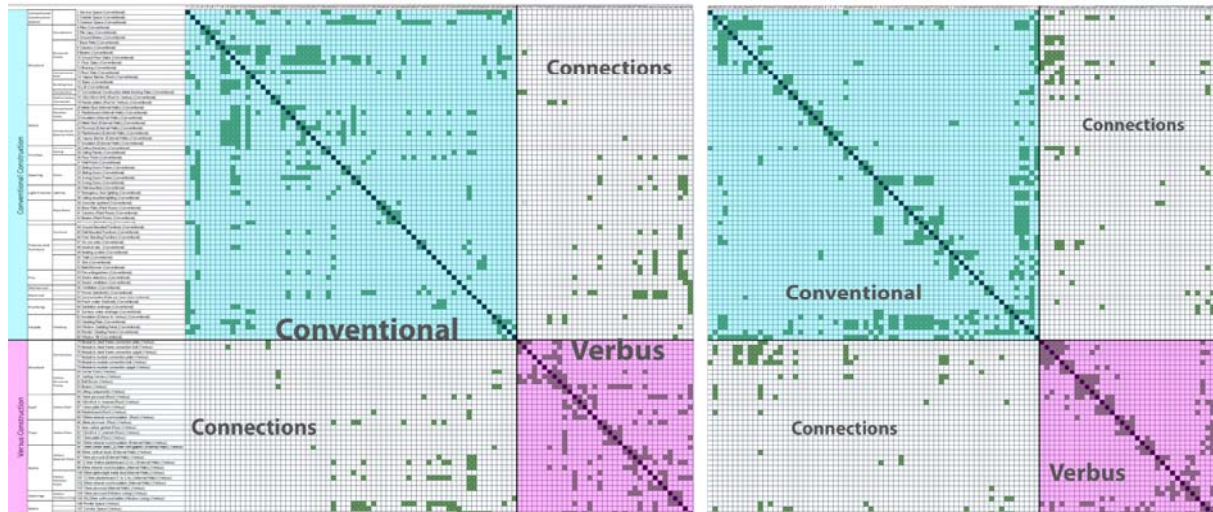


*Figure 3. Initial and Recombined Models*

Slabs and spaces acted as the integration parts. After optimization of both systems, the matrices were recombined to see where the dependencies between the two 'optimized' systems now occur (Figure 3 right image). Further manipulation of the systems as a single entity needs to be undertaken.

## 3    CONCLUDING THOUGHTS

Initial differences between the systems clearly showed the dependency structure is highly dependent on designers' thinking. The categorization of dependencies made the initial understanding of relationships between parts easier (i.e. helped build the initial matrix), and allowed for further analysis to be conducted in regards to a specific type of dependency (i.e. helped filter the matrix). It became apparent quickly that the size of the matrix (over/ under 60) dictated initial manipulation techniques. It was often easier to gather clues from running an algorithm, and then manually manipulating the matrix from that point; however, using intuition tends to cluster components based on a more traditional understanding of which parts should cluster together (lose of potential insight).

In conjunction to these analytical studies, the development of a generic building model looks to identify all potential design permutations between 'parts'. The intent of this model is to serve more as a development tool to suggest and map a 'dependency strategy' which can then capture designers subsequent decisions as products manifest as part of the design process highlighting for example where the strategic rules have been broken. The focus on adaptability has given preference in regards for future work to try and synthesize both time-based and product-based studies (i.e. looking at a product at various stages in its life and considering the evolving dependencies and changes).

## 4    ACKNOWLEDGEMENTS

## REFERENCES

Brand, S. 1994. *How buildings learn: What happens after they're built*. New York: Penguin.

Duffy, F. 1990. Measuring building performance. *Facilities* 8, (5): 17.

Helmer, Robert, A. Yassine, and C. Meier. 2007. Module and interface identification and definition - A comprehensive approach using DSM.

Pimmler, T. U., and Steven D. Eppinger. 1994. Integration analysis of product decomposition. Paper presented at ASME 6th International Conference on Design Theory and Methodology, .

Rush, R. D., ed. 1986. *The building systems integration handbook*. New York: John Wiley & Sons.

Schmidt III, R., S. Mohyuddin, and S. Austin. 2008. Using DSM to redefine buildings for adaptability. Paper presented at 10th International Design Structure Matrix Conference, Stockholm, Sweden.

Slaughter, E. S. 2001. Design strategies to increase building flexibility. *Building Research & Information* 29, (3): 208.

Contact: Robert Schmidt III
Loughborough University
Department of Civil and Building Engineering
r.schmidt-iii@lboro.ac.uk