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An Architecture Framework for Open Building

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PAPER ABSTRACT Architecture has been described as frozen music. Alternatively, open building proposes an evolving collaborative symbiotic performance. However, current practice in the building industry is motivated by short term 'closed' (frozen) building perspectives. The uptake of BIM technologies challenges current practice in architecture by extending the dimensions of the building model from the spatial to include commissioning, occupation and decommissioning data. In this sense, BIM provides information systems that could support a vision of open building, but the relationship between the building stakeholders, their needs and the BIM model is unclear. An approach is therefore sort that will enable both the occupants and the building design team to design buildings that can be adapted to their contemporary and future needs.

In business, 'enterprise architecture' frameworks are often used to map the needs of an organization to its information systems. One of the earliest of these frameworks was based on observations of the design and construction of buildings. These frameworks are typically developed for use in a single organization. Alternatively, a 'community architecture' framework has been proposed that can model the relationship between information systems and loosely connected and diverse stakeholders such as that found in open building. This paper represents an inversion of the 'architectural framework' back to buildings from its previous incubation in business. Here, the multi-dimensional 'community architecture' framework is adapted to address the identified challenges of supporting open building through an 'open architecture framework' for itself and its stakeholders both now and in the future.

KEYWORDS: BIM; Enterprise architecture; Community architecture; Open architecture framework; Agile X Systems.

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Introduction

Habraken's 1972 call for open building proposes architecture as an evolving diverse stakeholder symbiotic performance. Habraken's ideas are sympathetic to contemporary concerns to extend our temporal consideration of buildings to include decommissioning and 'adaptive reuse' in a complete building life cycle model. Building information modelling (BIM) technologies promise a shared information system with stakeholder perspectives to support the orchestration of the information for a building's design, construction and maintenance. Additionally geographic information systems (GIS) technologies suggest that this is also possible or the wider urban environment and that links between these technologies and open building scales may be facilitated by precinct information modelling (PIM). However current BIMs do not model the requirements of the stakeholders and instead encode the artifacts of the design rather than the reasons and motivations for the artifacts. This can make it difficult for the stakeholders to understand the artifacts in the model. From a computer science perspective, enterprise architecture has been used to provide organizations with a model of the information assets of the organization as well the need and purpose of those assets from the perspective of their stakeholder owner. One of the most popular enterprise architecture frameworks, the Zachman Framework (Table 1), was based on the architectural design and construction process (Zachman, 1987). However these frameworks require some modification in order to adapt to the needs of open building.

	What	How	Where	Who	When	Why
Contextual						
Conceptual						
Logical						
Physical						
Out-of-context						

Table 1 The Zachman Framework

Previous adaptations of Zachman include (Boxer and Garcia 2009) and Martin et al. (1999) which extend the 2 dimensional matrix of cells into a three dimensional model. This is further explored in Morganwalp & Sage (2003) who explore a systems of systems (SoS) representation of the framework that they describe as a '3D enterprise architecture framework'. Based on this work, McGinley and Nakata (2016) propose a multi stakeholder 'community architecture' framework for use in the wicked problem of urban planning and smart cities. It works as an enterprise architecture framework that works 'outside the enterprise'. This paper aims to identify an appropriate architecture framework to support open building. Therefore the following section identifies the requirements for an open building architecture framework.

Background

Open building encourages designers to consider the provision of 'supports' which can be used by others to plug in their own designs (Habraken and Habraken 1972). From an information architecture perspective, this could involve the design of a core service layer onto which various functions can be supported by swapping in services as needed, without having to change the core building (support). The flexibility offered by open building is attractive today, by supporting diverse alternative future usage scenarios we could design building's to support future change whilst understanding their effects on their wider systems. A major difference between the time that Habraken originally wrote about open building and today is the potential of ubiquitous networked information systems and rapid prototyping technologies for instance to support this vision. However focusing on information systems, there are a number of challenges to developing an open building information system to support Habraken's vision, these include:

1. Managing diverse information systems (BIM, PIM and GIS);
2. Supporting Diverse stakeholder perspectives on the information systems;
3. Supporting unknown future use of buildings and requirements of users.

The first issue concerns the interest of open building in a variety of information scales. Secondly, the diverse stakeholders of the scheme need to be supported and finally the future use scenarios need to be considered and supported. Previous approaches to these challenges are discussed in the following sections.

Managing diverse information systems

It can be difficult to develop information systems to support wicked problem contexts such as the construction of the built environment because the goals of the various actors can be difficult to establish. Businesses use 'enterprise architecture' to model the needs of their business and their information system requirements. The Zachman architecture framework was based on real world architecture. However the abstraction of architecture into information systems has led to them operating in an 'idealised' context. Architecture is a significant component of the wicked problem of planning urban (Rittel and Webber 1973) and is often in the difficult position of providing a solution to potentially unsolvable wicked problems. Therefore an EA for open buildings would have to adapt to different stakeholder interests. Chourabi et al. (2012) suggest that enterprise architecture could be used in the design of smart cities for instance. However it is clear that such an approach would need to be adapted in order to represent the needs of diverse stakeholders.

The Zachman framework (ZF) is 'the de facto standard for classifying the artifacts developed in enterprise architecture' (The Open Group 2006). Zachman developed the framework based on observations he made of similarities in the developing field of information science to traditional (built environment) architecture and airplane design (Zachman, 1987). Zachman observed 5 perspectives in built architecture, which roughly follow the following design process: bubble chart; architect's drawings; architect's plans; contractor's plans; shop plans and finally the building. Zachman suggested that these could provide a 'generic set of architectural representations' that could be used in other disciplines, for instance information systems. To articulate these he proposed the Zachman Framework. Zachman describes the framework as a convenient classification scheme or 'periodic table' for information entities. The framework consists of a 6 x 5 matrix. Table 1 displays the column and row headings. By filling in its cells it is possible to specify the artifacts of the architecture and the relationship to each other. Each column represents a complete architectural 'model' which would be analogous to the stages of design he had observed in traditional architecture. The rows represent perspectives of the system. In contrast to the columns, the order of the rows is significant and represents an increasingly detailed view of the system. The columns are referred to as 'communication interrogatives' and each one represents a complete architectural model. The rows are referred to as 'reification transformations' (Zachman, 2008) and represent perspectives of the system. In contrast to the columns, the order of the rows is significant and represents the increasingly detailed view of the system.

Figure 1 Pruitt-Igoe Housing development in St. Louis, Missouri, U.S

The modernist movement in architecture and urban planning promoted the development of high rise social housing and inner city shopping centres by local authorities with minimal participation from local communities in the design of these urban environments. The demolition of the Pruitt-Igoe housing development in 1972 marked the end of the dominance of modernist planning, and is described by Jencks (1977) as 'the death of modernism in architecture'. Figure 1 describes the incongruity of the planners and architect's vision against the existing structure of the community. This image represents the challenge of applying a systematised approach to a wicked problem such as planning. In this case a standard solution 'the international style' has been imposed a set of interconnected and unique communities. The design decision has been imposed by the architect, and defined by a bureaucratic schema developed by the planners prescribing limitations to the zoning, heights and density of the layout. In response to similar projects in the UK, where projects were imposed on communities without their collaborative participation, a movement developed that drew inspiration from participatory design to involve the community directly in the design of their surroundings. The movement was called 'community architecture' and in 1987, when Zachman published his architectural analogy, a book was published called 'community architecture' which proposed a participatory model for architecture. It is therefore possible that if Zachman had explored a participatory (community) architecture analogy for his framework such as Wates and Knevitt's model of architecture, the Zachman framework might have supported different personas and conflict in design.

However Zachman choose a pragmatic view of architecture with the architect as the 'lead designer' dictating the design to the end users based on his interactions with the architecture firm Gaede and Larson, in Pasadena, California in 1985 (Zachman 1987). Zachman's view was constructed based on an approach he observed of the architect asking the client a series of questions about what they wanted. This approach works well when you have a single client that knows what they want, but complex projects typically have many actors that want different things. The Zachman Framework is therefore not a 'community architecture framework', it is an enterprise architecture framework and as such it requires a single source of authority to make decisions (based on client consultation) to develop an information system strategy. An alternative enterprise architecture framework is TOGAF (The Open Group architecture framework). TOGAF is divided into 10 components and defines rules for developing robust architecture principles rather than explicitly stating the principles in the framework (Urbaczewski and Mrdalj 2006). TOGAF and the Zachman Framework both contain elements that could be useful to design information systems for open building. However, the intuitive form of Zachman Framework's primary interrogatives (what, how, who, where, when and why) would be simpler to translate into a building analogy so in this paper, the Zachman framework is further explored. However for future approaches it would be interesting to also investigate TOGAF.

Supporting diverse user perspectives

In organizations that include an authority to define the strategy, goals and vision of the organization, it would be possible to use unaltered enterprise architecture (EA) frameworks. However in an open building context there are many competing actor interests. Therefore there is a need for a participatory or 'community' architecture framework, based on an appropriate enterprise architecture framework that is flexible enough to incorporate the multiple perspectives, visions and strategies present among community stakeholders. Multi-dimensional stakeholder models (Innes and Booher 2004) are required to support diverse stakeholder participation in the design of cities and their component open buildings. Therefore whilst Zachman is appropriate for this study due to its architectural origins, it needs to be adapted to support diverse stakeholder engagement. Based on a proposal by Nyerges & Drew (2001) who mapped the Zachman column models to the use case of developing a public participation geographical information system (PPGIS), McGinley and Nakata 2016 propose a community architecture framework that supports diverse stakeholder perspectives (Figure 2). They define community architecture as: *of the relationship of the community stakeholders' perspectives to the processes and data that support them.* The community architecture Framework is an augmented version of the existing 2d Zachman framework with an additional row to represent the different requirements of the stakeholders. Indeed it is possible that only the first row of the framework require a multi-dimensional stakeholder model. Boxer and Garcia's additional 'collaborative' row provides a multi-dimensional stakeholder perspective as suggested by Innes & Booher (2004). Therefore this research proposes to use the 2d approach of the additional row of Boxer and Garcia without the additional columns. This approach is described in Figure 3 with the additional alteration that instances of the term 'business' have been replaced with 'community'. This results in several new terms including 'community process model' and 'community logistics model'. The traditional enterprise framework represents the holistic vision and processes of a single organization. In contrast, the community architecture framework proposed in Figure 3 describes each instance of the collaborating perspective of each stakeholder.

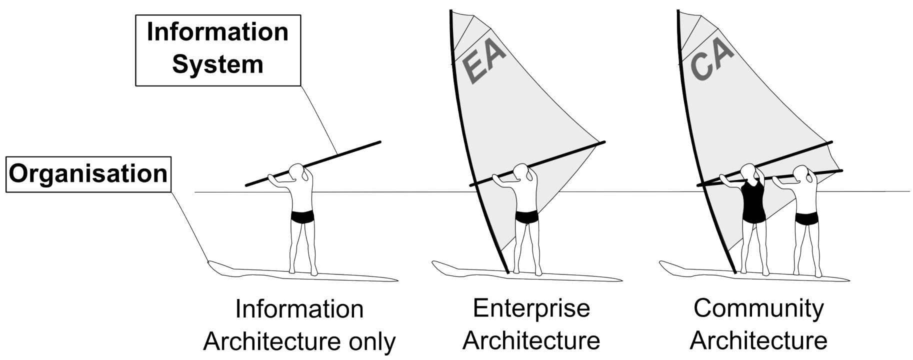

Figure 2 A comparison of information, enterprise and community architecture

	What	How	Where	Who	When	Why
Scope *Contextual* Planner (A)	List of things important to the community	Community processes	Stakeholder locations	Stakeholders	Community cycles	Community goals
Collaborative Model *Collaboration* Stakeholder (B)	$S_{1:WHAT}$	$S_{1:HOW}$	$S_{1:WHERE}$	$S_{1:WHO}$	$S_{1:WHEN}$	$S_{1:WHY}$
	$S_{2:WHAT}$	$S_{2:HOW}$	$S_{2:WHERE}$	$S_{2:WHO}$	$S_{2:WHEN}$	$S_{2:WHY}$
	$S_{n:WHAT}$	$S_{n:HOW}$	$S_{n:WHERE}$	$S_{n:WHO}$	$S_{n:WHEN}$	$S_{n:WHY}$
Community Model *Conceptual* 'Owner' (C)	Semantic Model	Community process model	Community logistics network	Workflow model	Community events	Community vision
Systems Model *Logical* Designer (D)	Logical Data Model	Applications Architecture	Distributed Systems Architecture	Human Interface Architecture	Process Structure	Community Rule Model
Technology Model *Physical* Implementer (E)	Physical Data Model	System Design	Technology Architecture	Presentation Architecture	Control Structure	Rule Design
Detailed Representation *Out-of-context* Subcontractor (F)	Data definition	Program	Network Architecture	Security Architecture	Timing Definition	Rule Definition
Generic	**Data**	**Function**	**Network**	**Organisation**	**Schedule**	**Strategy**

Figure 3. Community architecture framework.

In this way the framework builds a picture of a 'unified community' of stakeholders from the presentation of the multiple perspectives, interests and requirements of diverse autonomous stakeholders. Having established the requirements of the models, a series of approaches are proposed for each of the columns based on the framework. Figure 3 describes the community architecture framework which includes an additional row, named 'S' to represent the community architecture collaborative model. This reveals some interesting challenges such as how to model an uncertain 'future vision' for diverse stakeholders for open building. This is discussed in the following section.

Supporting unknown future uses

'[if] you want to change this building, you want flexibility. If you want to change this building [..] then don't hard bind the wall to the floor. Separate the independent variables. If you want flexibility, you separate the independent variables. By the way, we learned about that a long time ago, those of us who are in IT; separate the independent variables. I haven't heard this for 30 or 40 years, but it's like binding. You don't want to bind anything together.'

(Zachman, 2015)

Supporting future unpredictable use in buildings requires a multi-dimensional vision from the design team that incorporates at least the current needs of the stakeholders *and* their future needs. One approach to address this would be to decouple the information systems of the building. This could enable the building design process to be 'debugged' and or reconfigured 'on the fly' to make it possible to step forwards and backwards in the design process to change material systems and spatial utility attributes thereby creating what would be called in computer science an 'agile' approach (Figure 4) for an open building that is designed to adapt to its user's needs over time. These systems could be decoupled so that we end up with three discrete systems, 'design', 'material', fabrication', which would act as layers of an 'Agile 'X' system.

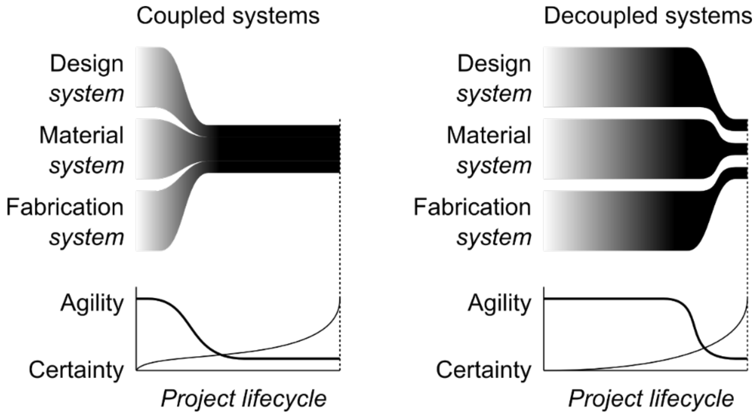

Figure 4. Comparison of coupled and decoupled systems

This could be explored by decomposing the information systems of the design or 'support' file from the specification of their material manifestation for instance. This provides an appropriate perspective to the changing nature of open building. In the left hand diagram of Figure 4, both approaches converge into a coupled system, although the decoupled system following agile fabrication principles, remains flexible for longer. In this case an 'Agile X framework' could be imagined as a series of three layers (design, material, construction) stacked on top of each other. This could be extended to include for instance a contextual / policy layer into the framework which would demonstrate why future adaptions decisions have been made to satisfy project and contextual specific requirements. This would fit in the 'why' column of the relevant architecture framework.

These sections have described previous approaches to the three main challenges of developing an architecture framework to support open building. Based on this discussion it is clear that the main problem is to develop a framework that is multi-stakeholder, can support multiple conceptual model scales and protocols and be flexible to adaptation in the future. This is addressed in the following section with the proposal of an architecture framework for open building.

Open building architecture framework

The background identified previous approaches that could be brought together to address the information system requirements for the design, construction and maintenance perspectives required by open building. This section investigates how the community architecture framework be augmented to support both diverse perspectives and adapt to multiple scenarios in an open building context. To address this an open building adaptation of the community architecture framework (Figure 3) is presented in Figure 5. The cells of the framework remain largely unchanged to reflect their technological relevance for the hybrid (traditional / digital) open building architecture framework for use in future work.

- Row A is changed from 'scope' to focusing on the stakeholder attributes.
- Row B uses the multi stakeholder model of the community architecture framework to capture the requirements for the stakeholders. Indicatively 3 sub rows are shown but this could be increased or reduced in response to the needs of the project identified in row A.
- Row C uses the same terms as the community architecture framework for its cells but the row has been renamed to 'utility' referring the utility or function of the building.
- Row D has been renamed interaction and describes how the utility systems will interact with the users and other stakeholders.
- Row E has been renamed BIM and describes the final representation of the open building component artifacts in construction drawings for instance.
- Finally, row F is redefined as realization and describes the open building as built artifacts.

	What	How	Where	Who	When	Why
Stakeholder description (A)	Stakeholder interests	Stakeholder processes	Stakeholder locations	Stakeholder personas	Stakeholder cycles	Community goals
Stakeholder Requirements (B)	$S_{1:WHAT}$	$S_{1:HOW}$	$S_{1:WHERE}$	$S_{1:WHO}$	$S_{1:WHEN}$	$S_{1:WHY}$
	$S_{2:WHAT}$	$S_{2:HOW}$	$S_{2:WHERE}$	$S_{2:WHO}$	$S_{2:WHEN}$	$S_{2:WHY}$
	$S_{n:WHAT}$	$S_{n:HOW}$	$S_{n:WHERE}$	$S_{n:WHO}$	$S_{n:WHEN}$	$S_{n:WHY}$
Utility (C)	Semantic Model	Community process model	Community logistics network	Workflow model	Community events	Community vision
Interaction (D)	Logical Data Model	Applications Architecture	Distributed Systems Architecture	Human Interface Architecture	Process Structure	Community Rule Model
BIM (E)	Physical Data Model	System Design	Technology Architecture	Presentation Architecture	Control Structure	Rule Design
Realization (F)	Data definition	Spatial Program	Network Architecture	Privacy	Timing Definition	Rule Definition
Generic	**Data**	**Function**	**Network**	**Organization**	**Schedule**	**Strategy**

Figure 5. An open buildings architecture framework.

This provides a model to develop open buildings however it is difficult to model multi-dimensional future scenarios of use as required by open building. It may be that this would involve manipulating one of the linked cells in row B which could act as stakeholder specific interfaces in the development of open building. Following the uptake of these frameworks it would be possible to link them to each other to develop open building models at different scales. For instance a number of these frameworks could be combined to provide an idea of how they work together at a neighbourhood, city or region scale. This could ultimately provide a link between building BIM, PIM and GIS models thereby addressing the first challenge to developing information systems for open building identified in this paper.

Conclusion

This paper proposed an open architecture framework for architecture by identifying and addressing the three main challenges of developing an information architecture to support open building. The first is addressed through the identification of a need for an architecture framework to address the challenges of diverse information systems in open building. In this context the Zachman framework is suggested as a suitable basis for an open building architecture framework due to its built environment origins, although TOGAF is also discussed. It is interesting that a tool that was developed outside of the building industry but was inspired by it could be reintroduced to architecture. The second (supporting diverse stakeholders) could be addressed using the community architecture framework to provide a representation of the relationship of the community stakeholders' perspectives to the processes and data that support them. This could make a difference and open up the BIM model to more participants through appropriate perspectives. To address the final challenge of supporting uncertain futures, this paper proposed an approach that investigate the unknown futures of open building. The open building framework proposed here is currently being applied to 3 buildings on a university campus in Australia. It will be exciting to see how these frameworks interact at the different scales and ultimately the result of reintroducing architecture frameworks back into architecture. It is certain that there will be lots to learn from this approach and hopefully this can support the aims of open building.

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