ARCHITECTURAL DESIGN OF VERTICAL EXTENSIONS OF BUILDINGS: A RISK PERSPECTIVE ON COMPLEXITY

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In Sweden, urban densification by vertical extension (VE) of buildings is one contemporary movement to meet the increasing urbanisation. The aim of this research is to increase the understanding of the complexity in architectural design (AD) of VE by applying a risk perspective. The proposition is that the uncertainties in the existing building (the host) create a demand for design adaptability of the extension and that this dependency, together with the inflexibilities in the extension, contributes to the complexity of VE. Empirical material was collected by in-depth interviews with eight experienced architects and followed by a theoretical analysis. The main contribution of this research is that it uses the complexity-uncertainty-risk interconnectivity to visualise the effect complexities in VE have on AD. The vertical interface is shown to be ambidextrous, both a difficulty and a solution. This adds managerial coordination complexity in the Swedish AD context that further the double-edged complexity of the vertical interface.

Keywords: architectural design, complexity, retrofitting, sustainability, urban

INTRODUCTION

This paper addresses architectural design of vertical extensions of existing buildings. The issue is that existing buildings put additional constraints on the extension. Developing heritage and urban form while being technically sound and cost efficient thus involves risks that usually are not managed in the early phases of new-build projects. The background is that Sweden is facing increased urbanisation in a time where sustainable urbanisation is a priority, e.g., in the 11th goal of the 17 Sustainable Development Goals (UNDP 2020) which concerns sustainable cities. Of the current urban planning and design issues, urban sprawl (e.g. increased city area) is recognised as the one of the most urgent problems to solve (COM 2004). Nabielek (2011) argues that the focus rather should be on urban densification, as a strategy for sustainable development of cities. Urban densification is shown to reduce ethnic and socio-economic segregation (Nabielek 2011). In addition, Dodman (2009) discerns benefits with urban densification through lower per capita emissions. Bolund and Hunhammar (1999) underpin opposing arguments to urban density by stating that urban ecosystems are threatened and (Jim 2004; Fuller and Gaston 2009) that green areas might be reduced by densification. There is a conflict between densification, land use and environmental impacts of densification. Campbell (2007: 307) writes: "Though we live in a three-dimensional world, land is a limited resource with essentially two

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dimensions" and that the potential for balance between economic and environmental interests exists in design itself.

In Sweden, urban densification by vertical extension (VE) of buildings is one contemporary movement to meet the increasing urbanisation without additional land usage. This is valid for both commercial and residential projects, including hybrids. Industrialised house building (IHB) is a commonly used option for the additional, new part of the extension, partly because of the light-weight structure and as a solution for logistics in constricted urban spaces.

In this research, VE is defined as: A vertical addition of a host building that creates new or extends existing functions, both technical and operational.

With this definition, vertical extension can be related to retrofitting as one of three options (Figure 1) to add functions (dotted lines) to a host building (solid lines). This research addresses only Vertical Extension (1), which is different from Horizontal Extension (2) and Renovation (3).

Figure 1: Three types of retrofitting, horizontal view

From an Architectural Design (AD) stance, retrofitting allows for the preservation of the morphological and architectural identity of the existing building and urban setting (Nilsson *et al.,* 2014). However, retrofitting projects are considered as more complex and uncertain when compared to new build (Ali 2014; Nibbelink *et al.,* 2017) and a retrofit will mean more unknowns and greater risks (Abdou 1996). Decisions made at the early stage of design have major influence on the overall design performance such as cost and time (Ali *et al.,* 2008). Poor decisions made early in the design phase might explain problems encountered in the construction or maintenance phase (Emmitt 2014). The early decisions and perceived values in house building projects are often influenced by an architect's design visions. Emmitt (2014) further states that the risks and uncertainties should be identified and managed to avoid compromising the projects' value. However, Uher and Toakley (1999) found that application of risk management in the conceptual design phase was relatively low, accounted to various structural and cultural factors. These studies point to a motivation for, but also lack of, early risk management generally in AD and specifically in high complexity and uncertainty situations. The aim of this exploratory study is to increase understanding of the complexity in architectural design of vertical extensions by applying a risk perspective.

Architectural Design

Alharbi *et al.,* (2015) describe an architect's three core areas as: design, technology and management, and how these interrelated areas depend on communication. However, the role and responsibilities of an architect is contingent on the specifics of each national building conditions and sector culture. Grange (2005) believes that Swedish architects wish for a stronger role. Emmitt *et al.,* (2009) mention that in the Swedish context the architects are quite invisible. Arguably, compared to other European architects, Swedish architects generally have much less managing responsibilities over parameters as economy and technology. In Sweden, the roles of the architect and the project manager are two different professions. A Swedish architect is more concerned with quality parameters such as the aesthetical and the functional perspective whereas the project manager has the overarching responsibility with primary control over project objectives, like time and cost, on behalf of the client. This separation of roles has developed over time with the increasing demand for niche knowledge (Hansson *et al.,* 2015), resulting in the two professions becoming more specialists than generalist. This research follows the Swedish approach to the architects' profession (Figure 2). Based on management of the majority of Swedish house building construction project in all types of stages in design and with any contract, this interpretation defines the role of the project manager and the architect. Technology expertise lies with consultants e.g., structural or HVAC designers.

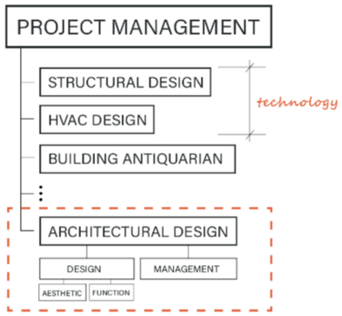

Figure 2: Scoping this research by defining architectural design in the Swedish context

Complexity, Uncertainty and Risk

As defined above, VE is a vertical addition of a building volume that creates new or extends existing functions, both technical and operational. Following the argumentation of Kivelson and Kivelson (2018), VEs can be considered complex systems since at least two parts interact dynamically to function as a whole and the parts are interconnected. Therefore, a complexity perspective is adopted, to portray and position vertical extension projects among other retrofitting or new built projects. Qazi *et al.,* (2016) ague that it is not only important to understand and evaluate project complexity but also to visualise the complex interaction between project complexity and complexity-induced risks. Chapman (2016: 938) argues for a link between complexity and risk and proposes that "a complex project is one which exhibits a high degree of uncertainty and unpredictability, emanating from both the project itself and its context". Abdou (1996) characterizes a complex project as when new approaches paves for uncertainty. In addition, Botchkarev and Finnigan (2015) characterize it as when interactions of structural and dynamic elements occur across the broad categories of technical, organisational and environmental domains. Finally, Baccarini (1996) considers a complex project to be when many interrelated parts can be described as their degree of differentiation and interdependency. The construct in Figure 3 is used in this research to address complexity as an integrated component in the risk-uncertainty interconnectivity.

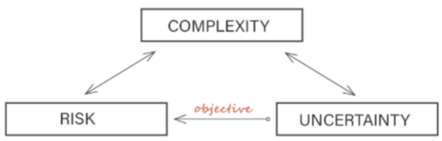

Figure 3: The complexity-uncertainty-risk interconnectivity

A risk is an effect of uncertainty on objectives (ISO 2018). In the context of projects, risk is associated with an uncertain event or condition that if it occurs possibly has an effect on the project's objectives (Chapman 2001; Zou *et al.,* 2007; Ayyub 2014).

These objectives can be described by fixed measurable terms often as cost, time and quality (Hillson 2002). Consequently, risk cannot be defined without a relation to an objective. Furthermore, if objectives are flexible rather than fixed, and if objectives could be varied to cope with the effects of uncertainty, then risks wouldn't exist (Hillson and Murray-Webster 2017). This indicates that the possibility for flexibility or adaptability of objectives could affect risk management.

Uncertainties in risk analysis are often divided into two types; (1) aleatory (random) uncertainty and (2) subjective, epistemic uncertainty (Ayyub 2014). Epistemic uncertainties arise from lack of knowledge or understanding (Hillson 2004) while aleatory variability are not dependent on knowledge. Epistemic uncertainty is the most dominant type in risk analysis (Ayyub 2014) and the one that this research focuses on.

Vertical Extensions - A Matter of Adaptability?

Uncertainties in Retrofitting

In terms of the interconnectivity between complexity-uncertainties-risk, retrofitting stands out regarding the AD compared to new build. For example: "The development of design for refurbishment most likely depends on designer's endeavours to gather information from the exiting building" (CIRA 1994 as cited in Ali *et al.,* 2008: 390). Factors that contribute to complexity and uncertainty in retrofitting are identified by Ali (2014) to be e.g., unforeseen site conditions and lack of information during design stage, low quality of information feeding into the design process (Nibbelink *et al.,* 2017) and the fervently changing time-design equation (Abdou 1996). Consistently, Ali *et al.,* (2008) states that the uncertain conditions of the existing building limits in the available design information that consequently creates uncertainties in the design process causing high risk in decisions.

Inflexibilities in Industrialised House Building

Industrialised House Building (IHB) firms in Sweden organise their operations around total deliveries, structured into platforms. Their platforms use high degrees of both prefabrication and standardisation of components, and processes for building and logistics (Lessing *et al.,* 2015). IHB is the pre-dominant choice in Sweden for the extension part of the VE, partly because of the lightweight structure, partly because of the logistics solution offered. Arguably, the IHB solution offers predictability concerning delivery speed and dependability.

Based on the Swedish context, the position taken in this research is to consider VE as a retrofit with an extension of a pre-constructed (IHB) structure. Consequently, the inflexibilities of IHB must be considered. The level of flexibility in design adaptation to building specifications decreases with a high level of predefinition (e.g. Jansson *et al.,* 2014). IHB platforms do not support generality, while host buildings cannot be controlled to suit IHB platforms. Here is a possible conflict that this research addresses. The reduced design flexibility inherent in IHB can increase risks when confronted with functional and technical requirements and conditions of the host. The complexity-uncertainty-risk interconnectivity can increase even further because of the difficulties to determine the host conditions, in turn caused by lack of as-built information of the host. In the VE setting, the balance between prefabrication and standardization imposed by IHB limits the adaptability of the extension in relation to a required adaptability to the host.

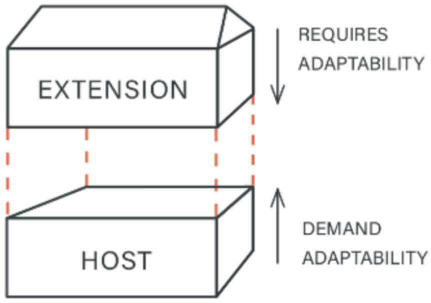

Figure 4: The adaptability dependency between a host and an extension

The proposition that this research intends to evaluate is that there is demand for design adaptability of the extension which generates a design adaptability dependency, and that this dependency contributes to the complexity of VE (Figure 4).

METHOD

Context-specific data collection from VE-projects was considered essential to increase understanding of the complexity from an AD point of view. This speaks in favour of a qualitative method since the intention was to study the phenomena in its real-life context (Yin 2011). To address the aim and specifically how adaptability contributes to the complexity of VE, an exploratory and qualitative design was considered suitable. To gather deep empirical material the method of qualitative in-depth interviews was preferred, an approach that aims to depict a complex phenomenon by the respondent's viewpoint (Yin 2011). These were conducted with an open approach where there was only an outline of subjects prepared. Supplementary questions emerged along the interview and thus varied based on respondent's story. The interviews were held March-May 2019 with eight architects from different companies, all with experience of recently completed VE projects in Sweden. The selection of respondents was made so that their projects' character varied based on place (urban density), function/operation and material for the extension (Figure 5). Large variety was important, from the representative projects, to be able to characterise complexity in AD of VE in general, regardless of these variations. The respondents' involvement in the design phase narrate what content this research is based on.

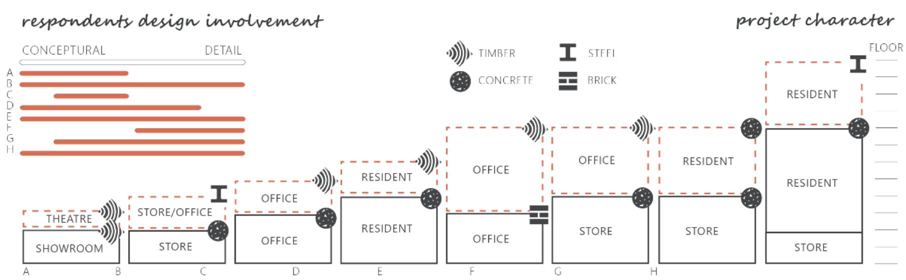

Figure 5: Respondent overview

Based on the complexity-uncertainty-risk interconnectivity (Figure 3) the interview subjects were centred on the quality objective related to AD (Figure 2). Design issues or problems that occurred in real projects were identified, relating to risks as an certainty that has effect of objectives, a risk that has happened (Hillson 2017). The interview subjects were put together in a two-dimensional logic: first about positive insights covering AD issues from the real projects, second zooming out to vision opportunities and obstacles for vertical extensions in general to detect opportunities for sustainability drivers of VE and for insights into further research.

The interviews lasted 70-150 minutes and were all recorded and transcribed. Data analysis was done in two steps. The first step was thematic coding, which can provide a rich and complex data and generate unanticipated insights (Braun and Clarke 2006). The codes used to filter the data originated from the theory presented above and are listed in Figure 6. Braun and Clarke (2006) argue that this theoretical thematic analysis is driven by the researchers' analytical interest and tends to generate less description on the overall data. The choice between data-driven or analysis-driven coding depends on the question. Since the question here is to investigate complexity in AD of VE by adding a risk perspective the logical choice is to begin with risk-theory and then look at risk-theory in the context of retrofitting and IHB. The second step in the analysis was interpretation, which is essential when aiming to understand the data (Flick, 2014), by adding the complexity-uncertainty-risk interconnectivity (Figure 3) when viewing the data.

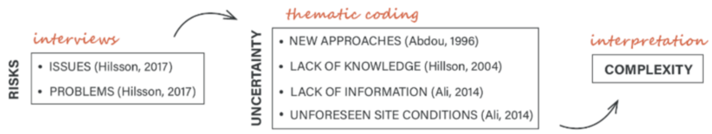

Figure 6: Research approach

Architectural Design of Vertical Extension as a Complex System of Components

The following findings are the main take away from the interviews. They are presented to illustrate the complexity in AD of VE projects. The intention in all eight VE projects was to extend or create new functions. In all eight projects IHB was used for the extension. Here the findings from occurred issues (risk) regarding uncertainty are themed as derived from different components in VE-projects, altogether leading to complexity by interpretation (Figure 6).

The Host / Extension Adaptability Dependency
Many of the uncertainties in the VE projects studied originated from lack of information about the host's condition. ["It is a never-ending detective work and some guesswork if the information is correct"]. Due to this, late changes were imposed when updated information of the host was provided. When conditions in the host became known, the new frame of requirements sometimes largely changed the AD possibilities that also needed to correspond to the IHB extension adaptability requirement to accommodate changes in layout. In many projects, due to lack of knowledge or/and information regarding the host condition or the IHB extensions adaptability requirements, the structural designers underestimated the task for proper structural design and thereby gave the architect incorrect information for the possibilities in AD. ["They promised a little too much in the beginning, and then they realized that there were some limitations."]. It was also brought up that new building approaches like IHB timber structures added problems, ["Few structural designers know how to deal with timber"] which according to Abdou (1996) generates uncertainty that contributes to complexity. In some cases, the updated information of technical or functional requirements of the host demanded that adaptation of the IHB extension to the new conditions. The host / extension dependability illustrated above adheres to the complexity-uncertainty-risk interconnectivity in Figure 3, the interdependency as a factor for complexity described by Baccarini (1996) and that lack of knowledge adds to complexity and uncertainty in projects (Hillson 2004; and

Ayyub 2014). Consequently, flexibility and adaptability are essential characteristics of the extension (cf. Figure 4).

In summary: The combination between lack of information and knowledge (uncertainty) and constantly changing information of conditions in the host requires adaptive visions (objective) and a flexible design of the extension to prevent the system from locking. The factors leading to uncertainty do all contribute to complexity of AD in the case of VE.

The Vertical Interface - a Possible Solution

Figure 7 conceptualises the architectural design risks in the form of interacting components (host, interface and extension) that together generate complexity. The main uncertainty factors are the uncertainties in the host that combined with the adaptability dependency in the interface generate large risks. Many of the AD challenges originated from what can be called the interface between the host and the extension consisting of a technical and a design dimension.

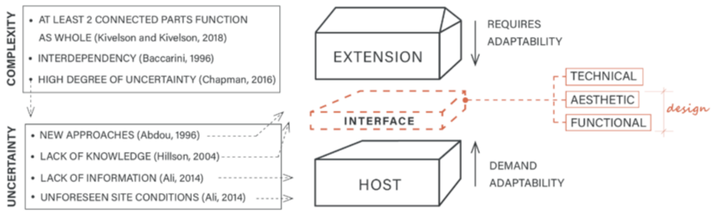

Figure 7: Architectural design of vertical extension as a complex system of components

The Technical Interface

The technical interface includes demands for connecting the structural systems of the host and the IHB extension and services systems (e.g. HVAC). In some projects specific physical interface structures were designed, called a waist by the architects. ["We had a waist, as we call it, an installation floor of about a meter high that is in the transition between the existing and new building where we can distribute installations horizontally"]. This interconnected solution loosened flexibility requirements on the IHB extension and opened for AD, e.g., more freedom in the layouts. The waist can be viewed as an adaptability zone that minimized the interdependency between the extension and the host. However, the waist led to increased total building height. Since the detailed development plan often have restrictions on maximum building height (meters) based on standard floor height this creates a problem. Consequently, this not only added technical complexity to the VE project but also created a time-consuming iterative process with the municipality and within the design team. However, flexibility in the development plan objectives could reduce risks emanating from the vertical interface, as described by Hillson and Murray-Webster (2017).

The Functional and Aesthetical Design Interfaces

The functional interface regards the communication service as well as the intersections of the layouts. Earlier functional standards utilized for the host are not compatible with the accessibility requirements needed for the VE which sometimes led to design changes in the host to meet contemporary requirements of communication and fire safety. ["The challenges are always communication; can you use the same stairwell? The elevator is outdated, does not meet today's requirements for accessibility and it may not be so easy to extend the stairwell"]. Issues also arose in some VE projects with multi-functional purposes, which entail heterogeneous functional interfaces. One example of incompatibility was when apartments in the extensions were placed on top of an office host building ["When the existing building was not intended for housing, there are divisions of the supporting structure that can pose problems. The dimensions were not equivalent to what we have as IHB housing module measures."].

The challenges in the aesthetical interface were mainly concerned with bringing the two facades together aesthetically. Proportions were mentioned as one of the main concerns from the municipality (the local planning authority) and spoken of as a great challenge for the architects. ["I think the proportions are very difficult.", "It was very much the municipality that wanted three distinct bodies to break up the scale."] This can be managed by working with the waist, or using tools like colour, shape and material to contrast or integrate. One example was to let materials converge in the waist. ["The idea was to be able to respect the existing tile through this waist and at the same time disconnect these two building parts from each other."].

In summary, the interface, not the host and extension per se, induces the most architectural design complexity to the system of components. The extent of the challenges in the aesthetical and functional interface seems mostly to be linked to the rationality of the technical interface, thus a possible solution for AD complexity. However, the design of the technical interface is not traditionally the (procured) responsibility for architect in the Swedish AD context which then required a lot of coordination and information management by the architects (Figure 2). ["Formally, it falls to the project management, but we had many visible installations and suddenly it became an issue of aesthetics, so we tried to manage those issues as well"] The importance of managing the risks in the interface reoccurred in many interviews. ["We have seemingly a lot of responsibility in the coordination, but we have no power over the consultants."]. Arguably, the possibilities for architects to manage AD risks lie in taking on a complex coordination and communication task between technical consultants, the municipality (as the local planning authority) and the IHB system supplier.

CONCLUSION

The aim of this research is to increase understanding of the complexity in architectural design of vertical extensions by applying a risk perspective. In this paper, this has been met by viewing VE as a system of uncertain components and by highlighting the adaptability dependability concentrated in the interface between the host and the extension as the main complexity. The vertical interface is ambidextrous since it is both a unique AD difficulty in VE and a possible solution for the adaptability dependency. Flexibility in architectural design in VE is dependent on technical solutions of the interface that in the Swedish AD context adds managerial coordination complexity which in turn further the double-edged linkage complexity of the vertical interface. The research also points out that there potentially is a gap in the Swedish architect's authorised management responsibilities and those unofficially taken on.

Moreover, in VE projects, sustainability goals for urban densification imposes additional complexity-uncertainty-risk interconnectivity. To reach such goals, it is important to understand and manage this interconnectivity. Consequently, future research will investigate those risks further, using risk identification techniques.

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