ADDRESSING UNCERTAINTIES ABOUT TIMBER HOUSING BY WHOLE LIFE COSTING

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ABSTRACT

Increased cost and declining quality has resulted in a growing interest in industrialised construction. During the last twelve years around 20000 apartments have been built in Sweden using industrialized timber housing techniques. Still, potential clients and building owners are uncertain of long-term financial costs and functional performance of timber houses. The idea in this paper is to investigate if the use of whole life costing calculations might become a tool for addressing these uncertainties. For this purpose, a pilot interview study has been performed to obtain uncertainties expressed by Swedish building owners connected to multi-dwelling timber frame houses. In general, the results show that a tool must be able to handle not only economical factors but concurrently the effects of economical, technical, functional, cultural and human factors.

1. INTRODUCTION

In recent years, industrialization of construction is put forward as an aid to decrease the building costs. The challenge for the sector is to understand what industrialization implies in terms of management, actors' roles etc. Industrialization of construction is also debated in literature (e.g. London and Kenley, 2001). Multi-family timber frame housing has been pointed out as an area for industrialized process development in Sweden. However, uncertainties are expressed by clients and building owners concerning long-term financial costs, technical performance and management of prefabricated timber frame houses (Höök, 2005). The construction industry is to a high extent project oriented and construction is therefore, at times, criticized to lack a systematic and strategic approach to change because of the project nature (Saad et al., 2002). Since the project orientation/culture is so strong, a method that incorporates uncertainties caused by e.g. housing industrialization must be able to work on a project level and at the same time capture long-term behaviour of the facility. The aim of this paper is to identify uncertainties about timber housing and investigate if whole life costing can be used to address the uncertainties. In the context of this paper, timber housing is the industrialized production of multi-storey, multi-dwelling timber frame houses.

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2. BACKGROUND

Among Swedish contractors there is currently a specialization trend towards an increased use of prefabrication and industrialisation in housing construction. The Swedish regulations adopted in 1995 a functional view that allows timber in multi-storey buildings. Of a special interest for this research is therefore the development of timber housing.

Timber volume element (TVE) prefabrication is examined since it displays several of the attributes that are important in the industrialization approach. The TVE's are prefabricated as "ready-to-use" housing volumes complete with electrical installations, flooring, cabinets, and finishing etc. TVE prefabrication is competitive on the Swedish detached house market but much less on the multi-storey market (≤ 10 % market share). The basis for this low acceptance of the TVE prefabrication was examined by Höök (2005). The attitudes of 35 building owners' organisations were:

- *Historical prejudice:* TVE prefabrication was connected to barracks and simple movable houses and hence to a historical prejudice about poor performance and low quality.
- *Lack of required technical information:* Technical solutions of TVE's and timber in itself were not believed to be able to fulfil all code based functional demands such as adequate sound insulation etc.
- *Low long-term economical performance:* The TVE building system and their manufacturers' capacity and intention to fulfil long-time quality and life-cycle costs were questioned.
- *Organizational or project management change:* The TVE management is more related to process than traditional project management. This necessitates new co-operative patterns between the client and the manufacturer.

Hence, the presumed beneficial effects of industrialisation seem to be limited for TVE prefabrication due to two combined effects. Firstly, organizational and technological changes seem to outmode the traditional construction management practices and place greater demands on the coordination between different organizations. The client has to take a more active role in coordinating the industrialised process and he/she apparently lacks knowledge or trust if the TVE system leads to an optimal life cycle design. Secondly, in the eyes of the clients, there are too few actors to make the TVE system reliable comparable to other building techniques.

3. LITERATURE REVIEW

The research in this paper considers the basis and implications for the perceived uncertainties regarding timber housing. Literature on transaction costs is reviewed to address uncertainties, and literature on whole life costing (WLC) and whole life appraisal (WLA) is considered for life cycle design definitions and applications. The purpose is to give an explicit, not a comprehensive, literature review to explain the empirical results.

3.1 Definition of uncertainty

Uncertainty is viewed in this paper as "*a business risk which cannot be measured and whose outcome cannot be predicted or insured against*". Uncertainty cannot be measured. However, two central contributors to uncertainty in a product development context are defined technology novelty/complexity and project complexity (Tatikonda and Rosenthal, 2000). Project complexity increases the degree of uncertainty as for a construction project with, e.g. new frame material, new actors or new type of co-operation. Technology novelty is, in a product development context, defined as *"the newness, to the development organisation, of the technologies employed"* (Tatikonda and Rosenthal, 2000). This opens the definition of technological novelty/complexity in construction e.g. to a broad range of attributes in industrialized timber housing. Knowledge about a new or altered production process and product design is needed as potential adopters' assumption of risk taking decreases with increased knowledge (Frambach, 1993).

Uncertainty has also been addressed in terms of the difficulties of task performance (e.g. Baccarini, 1996). Summing up, uncertainty is defined as "*the difference between the amount of information required to perform the task and the amount of information already possessed by the organization*" (Tatikonda and Rosenthal, 2000).The more uncertain the task, the greater the quantity and quality of information is needed to generate the knowledge necessary to complete the task.

3.2 Rationale for uncertainty

Transaction cost theory (TCT) was developed from transaction cost reasoning known through Oliver Williamson's *Transaction Cost Economics* (1975). The unit of analysis is the transaction, which "*occurs when a good or service is transferred across a technologically separate interface*" (Williamson 1985:1).

Two human and three environmental factors lead to transaction costs arising (Williamson, 1985:1). The two human/behavioural factors are:

- *Bounded rationality:* Humans are unlikely to have the abilities or resources to consider every state-contingent outcome associated with a transaction.
- *Opportunism:* Humans will act to further their own self-interests.

The three environmental factors are:

- *Uncertainty:* Uncertainty aggravates the problems that arise because of bounded rationality and opportunism.
- *Small numbers trading*: If only a small number of players exist in a market-place, there is little or no possibility of withdrawal and use of alternative players in the marketplace.
- *Asset specificity:* The value of an asset may be attached to a particular transaction that it supports. The possibility (threat) of a party acting opportunistically leads to a so-called "hold-up" problem. It refers to the extent to which a party is "tied in" a business relationship.

It is not until the human factors are combined with the environmental factors that problems arise (Williamson, 1975). Bounded rationality is a problem only when it is combined with situations perceived uncertain or complex for the party involved. As asset specificity and uncertainty increase, the risk of opportunism increases. Furthermore, human inclination for opportunism increases at a market with a small number of players, since opportunism brings its own punishment at a market with a large number of players (Williamson, 1975).

Transactions between organisations are controlled through contracts. This is especially true in construction since control of construction projects is based on firm contractual arrangements. However, the bounded rationality makes it impossible to regulate every matter within a contract, a phenomenon Williamson (1985:2) describes as contracts being unavoidably incomplete. In the relation between supplier and customer, trust will both facilitate the co-operation and prevent conflicts between the parties (Berggren and Lindkvist, 2005) and contracts can function both as a substitute and complement of trust (Klein Woolthuis et al., 2005). Prior experiences also play an important role in determining if and to what extent a partner can be trusted. Without long-term experiences it may not even be possible to submit the risk that one who is trusted may fail (Nooteboom, 2002).

3.3 Whole life concept

Traditionally, focus in construction is on minimising the initial building cost. It has, however, since the 1930s become obvious that it is unfavourable to base the choice between alternatives solely on the initial cost alone (Kishk et al., 2003). This philosophy is today globally denominated whole life appraisal (WLA) (Flanagan and Jewell, 2005). Several definitions of the WLA technique exist, of which many can be found in Flanagan and Jewell (2005), and the one we have chosen to use is: *"WLA is the total cost of a facility/asset over its operating life including initial acquisition costs and subsequent running costs"*. The terms whole life costing (WLC) and life cycle costing are differentiated by ISO (2004) defining WLC as a broader term including within it life cycle costing. The standard defines the term life cycle costing as more frequently used to describe a limited analysis of a few of the components within a constructed asset, rather than the whole building (ISO, 2004). We employ the above definition of WLC/WLA. The authors' comprehension of the whole life concept[2], including cost categories and cost variables, is illustrated in figure 1. In Sweden, taxes constitute approximately 50 % of the initial acquisition cost of a project and have to be accounted for, although the cost for taxes has not been included in figure 1.

For input to the WLC calculation, future costs are converted to their current equivalent by using a suitable discount rate. A period of analysis is chosen and an appropriate investment appraisal technique is applied, of which the most employed in literature is the net present value method (Kishk et al., 2003). As WLC, by definition, deals with the future and the future is unknown (Flanagan et al., 1989), a risk analysis should be carried out after the performed calculation.

A review of different mathematical WLC models revealed that most of the models use the same basic equation. However, what separates them is the breakdown of cost elements. Concerning the suitability for the construction sector, each of the models seemed to have some specific advantages and some specific disadvantages (Kishk et al., 2003).

[2] A term mounted and used by the authors as an umbrella term for both of the terms WLC and WLA.

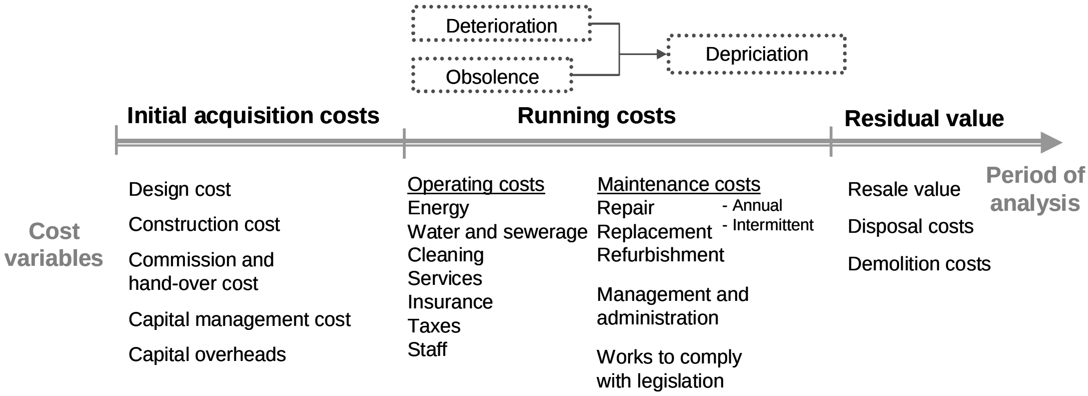

Figure 1. The authors' understanding of the whole life concept for buildings

The quality of decision-making derived from the use of WLA is constrained by the availability of appropriate and accurate data, which Flanagan and Jewell (2005) refers to as the "data problem". Additionally, the transition from understanding the theory of WLC to practising it is not easy (Flanagan et al, 1989). In many cases, the intangibles (such as aesthetics) are in conflict with the results from WLC calculations (Kishk et al., 2003), also contributing to the difficulties facing the usefulness of the technique. To conjoin these objective techniques with more subjective ones, Flanagan et al. (1989) suggest using weighted evaluation matrices to handle the intangible costs and benefits. Despite the above mentioned attempt, Öberg (2005) states that the majority of the tools, such as WLC, durability of materials and environmental assessment (LCA), are limited to their specific purpose and cannot provide a holistic view of the issue. A general and holistic model combining different tools for an optimal life cycle design has been denoted *integrated life cycle design,* Sarja (2002). The model, with methodology and methods linked to it, makes it possible to handle the multiple needs desired by the owners, users and society in an optimised way during the entire life cycle of the building. The main aspects included in the model are displayed in figure 2. The model might be able to address several facets of uncertainties, going beyond a traditional WLC model. Notable, and important, is that WLC calculations are included in this model.

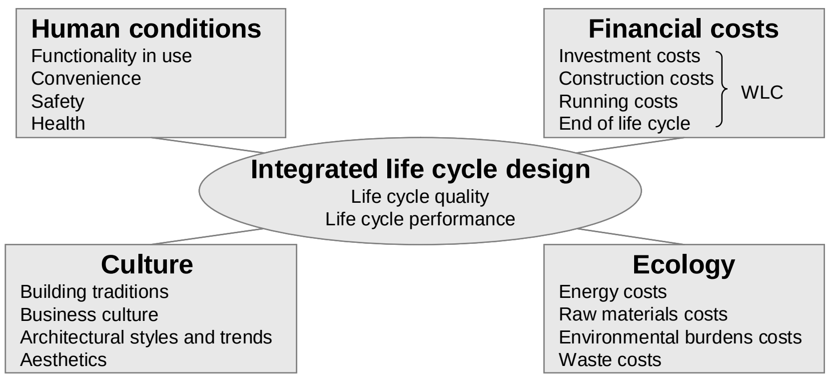

Figure 2. Main aspects of integrated life cycle design (after Sarja (2002))

4. RESEARCH QUESTIONS AND METHODOLOGY

The incentive to this study, aroused by the interview study by Höök (2005), is to deepen the understanding of the uncertainties and lack of trust expressed by building owners associated to timber housing. According to a market analysis presented by a Swedish commission, Industrifakta[3], clients are foreseen to receive increased power and a different role in a future industrialized building process in Sweden. A key factor for the clients is knowledge regarding long-term performance of the building systems. With a profound comprehension of the rationale for the uncertainties and lack of trust, the authors wish to investigate if and to what extent the uncertainties can be addressed by WLC/WLA considerations.

In this pilot study, we therefore formulated the following research questions:

- What are the uncertainties expressed by Swedish building owners related to timber housing and what are their rationale.
- If and to what extent can aspects in integrated life cycle design be used to address the uncertainties.

4.1 Research methodology

Considering the research questions, the investigation was designed as an exploratory study with a qualitative research approach. In-depth interviews are especially suitable when the problem is complex since the interviewer can rephrase the questions as well as pose related questions to penetrate the problem (Wiedersheim-Paul and Eriksson, 1989). With the possible difficulty involved concerning how to express uncertainties in mind, personal in-depth interviews were conducted. The possibility to adjust the questions to each individual was important in this case to reach the bottom of the viewpoints. The same questions, but from different angles, were asked thereby also reaching triangulation. In total, a number of seven in-depth interviews with five Swedish building owners were conducted. The interviews were held as semi-structured face to face-interviews.

The participating rental apartment building owners were selected from the features: geographical location of flats, size, type of ownership and whether they have experience of timber housing or not, see table 1.

Table 1. Characteristics of the participating companies

Location	No of rented flats	Ownership	Experience of timber housing
Luleå/Piteå	1100	Private-owned	Yes
Stockholm	5000	Cooperative economic association	No
Luleå	11500	Public-owned	No
All over Sweden	29000	Private-owned	Yes
Stockholm	43000	Public-owned	Yes

The interview data was analysed through *categorization*, taking into consideration the instructions by Dey (1993). Affinity diagram (Foster, 2004) was used for grouping the data and the aspects in Sarja (2002) to combine the groups.

[3] In Swedish: Industrifakta, 2006: Konsekvenser av industrialiserat byggande.

5. RESULTS AND ANALYSIS

A number of clusters of uncertainties were distinguished. Assorting the different groups of uncertainties under headlines constituted by the main aspects in of *integrated life cycle design* resulted in a number of groups falling outside the model by Sarja. These could, instead, be clustered under the headline technical solutions, identified by Höök (2005). The result of the categorization is displayed in table 2.

Table 2. The expressed uncertainties grouped and categorized

Financial costs	Technical solutions	Human conditions	Culture	Ecology
Energy consumption*	Motions*/Stability*	Sound insulation*/ perceived sound level*	Co-operation with partners*	Natural and sustainable materials
Long-term performance*	Risk of fire*	Security/ safety	Experience, history, tradition*	
Water damage, piping, installations*	Fulfilment of functional demands on actual location*	Comfort, well-being	Dry building process*	
Maintenance of wooden facades*	Timber as frame material*	Architecture, aesthetics		
Initial construction cost	Adaptability to new regulations and change			
Management- and life cycle economy*				
Stairwells and wooden staircases*				
Maintenance of: facades, roofs and windows				
Serviceability, accessability				
Wear				

The table shows the groups sorted under five headlines and divided into three levels. The groups in black squares are of highest importance as they are mentioned by four or more of the respondents. The groups on the second level, with grey filling, were mentioned by three or less and the third, the white, by one or two of the respondents. Notable is, no uncertainties were mentioned by four or more respondents under the headlines *culture* and *ecology*. The groups marked with an asterisk are uncertainties, or concerns, expressed especially about timber housing.

The most frequently mentioned uncertainties regarding *financial costs* are energy consumption, long-term performance and water damages. The respondents expressed a belief of higher energy consumption with a timber frame than for a traditional (concrete) frame, questions about the length of the building's physical life and particular concerns about the consequences of a water leakage in a timber frame house. All building owners, except one, expressed perceptions about motions (a technical solution) in the wooden frames causing, for example, cracks in wall paper.

All respondents expressed doubts that the sound insulation, found under *human conditions*, is not good enough for timber housing. Their impression was that the living environment would be disturbed by noise making the building less attractive.

Most of the uncertainties are about financial costs. This finding clearly, and maybe not surprisingly, indicates that the long-term financial cost is the most crucial uncertainty to address. Furthermore, a salient observation from the interviews is that cost is the decisive factor in design decisions, but with shifting focus on short-term and long-term costs among the respondents. A difference could be discerned between private and public building owners. Consequently, many of the uncertainties of highest importance can be addressed by WLC calculations, although not all.

A conclusion drawn from table 2 is that the main grounds for the uncertainties about *technical solutions* originate from the TVE houses being a new product offer, a new frame material, with a novel construction method (industrialized production), all of which can be referred to as *technology novelty*. The technology novelty added with the facts that construction encompass high project complexity and that buildings incorporate a high degree of asset specificity and are of high economic value for the client makes it evident that human bounded rationality will influence the client's understanding of the transaction. Uncertainties concerning the technical solutions must therefore be addressed for the product to be trusted.

A building is a complex product delivered long after the contract has been signed. Due to this project complexity, the human bounded rationality is high in this type of transaction making trust an essential ingredient in the choice of contractor. No prior experience of the contractor will lead to an even higher perception of risk-taking from the client. Even more, if the client in addition has no prior experiences of either industrialised production or timber housing, there will be poor trust for all three inherent components in the choice of timber housing and little motivation to take the risk. The small number of manufacturers on the timber housing market further increases the perception of risk-taking. This can be explained by the increased inclination for opportunistic behaviour by the contractor, inevitably making the contractor perceived as less trust-worthy. Thus, creating distrust for the product and uncertainty about the delivery since the client has no possibility of withdrawal when there are no alternative contractors to engage.

To sum up, one can clearly derive many of the grounds for the expressed uncertainties related to timber housing, especially for the ones under the headlines *financial costs* and *culture* from Sarja (2002) and *technical solutions* coined by Höök (2005). Visible is, however, that most of the uncertainties can be embodied in the main aspects in *integrated life cycle design* by Sarja (2002). Though, with diverse weight given to the aspects since this study takes into consideration solely the perspective of the client resulting in the high importance given to the economical aspect and insignificant consideration of ecology. However, to address *all* uncertainties requires augmenting Sarja's model with the aspect *technical solutions*.

6. CONCLUSIONS

The most important features of timber housing, as a new product on the construction market produced with a new production process by relatively small and unknown manufacturers, generate uncertainties and scepticism among the potential clients and building owners. The grounds for the uncertainties related to timber housing are shown to a large extent to be found in the transaction cost theory and in the notions of technology novelty and project complexity. Knowledge of the rationale behind the perceived uncertainties makes it possible to address them. The study does, however, not reveal how this should be achieved since it was outside the scope of this paper.

The interviews in this pilot study show that uncertainties related to financial costs constitute the great majority of the uncertainties emphasized by building owners. Hence, a conclusion drawn is that WLC calculations will be able to address a large number of the perceived uncertainties about timber housing. Although, for the calculations to be applicable and accepted, the model must be broadened to include all aspects in integrated life cycle design. The characteristics of timber housing make it crucial to address the uncertainties about its technical solutions for the new product to be trusted by the clients.

Further research will be directed towards finding methods to meet the concerns related to timber housing. Since uncertainties about financial costs and long-term performance represent the majority of uncertainties mentioned, the research will focus on addressing these by applying WLC methods. However, the long-term objective is to tackle this subject with a holistic approach, creating a tool for addressing uncertainties related to new construction products from a general point of view and to facilitate the use of integrated life cycle design models.

7. ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support of from Trä Centrum Norr, an R&D centre at LTU, and the interview respondents for providing the data.

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