MAINTENANCE AND OPERATING COSTS IN OFF-SITE TIMBER FRAMED HOUSING

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Increased cost and declining quality have resulted in a growing interest in modern methods of construction (MMC) and, in particular, off-site production. Among Swedish contractors there is currently a specialisation trend towards an increased use of prefabrication and industrialisation in housing construction. The Swedish building regulations was altered in 1995 allowing timber as frame material in multi-storey buildings. Since then approximately 25 000 dwellings have been built using off-site timber framed housing techniques. Still, potential clients and residential property owner organisations are hesitant towards off-site multi-storey timber framed housing and express particular concerns about maintenance and operating costs (together called running costs). Therefore, the manufacturers of timber framed houses in Sweden have engaged in a number of projects which aim at identifying and exploring this uncertainty further. In this paper, maintenance and operating costs in off-site timber framed housing are examined and compared with running costs in traditionally built multi-dwelling buildings with concrete structure as well as average costs of comparable multi-dwellings in Sweden. The factors affecting maintenance and operating costs of residential properties are examined theoretically and empirically. To investigate whether timber frame is an influencing factor on the running costs, data has been collected from Swedish residential property owner organisations comprising economic data, interviews, documents and as well as questionnaires. Cost data on 19 properties, of which 11 are off-site timber framed properties, has been gathered and 16 personal interviews conducted to verify the results. Neither the results from comparative cost data nor interviews nor other documentation display cost differences between timber and other frame materials in housing. The findings should contribute to reduce the uncertainties about long-term costs of off-site timber framed housing.

Keywords: cost management, maintenance and operating costs, off-site production, timber framed housing, uncertainty.

INTRODUCTION

Industrialisation of construction, or off-site production[2], is often put forward as a solution to concerns over quality and cost, and a means by which future costs can be better controlled. None of this thinking is new, although interest has grown significantly over the past few years, partly after the publishing of the Egan Report (Egan 1998). In the UK, off-site production has been promoted as one of the solutions to the industry's performance problems (Pasquire, Soar and Gibb 2006, Goodier and Gibb 2007). Off-site multi-dwelling timber framed housing has been identified as one

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[2] Both terms describe the same method/phenomenon. Industrialised construction is the most frequently used term in Sweden whereas off-site production is used in the UK.

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area for further industrialised process development, particularly in Sweden and other countries where there is a tradition of this form of construction.

Against this encouraging background and the numerous works demonstrating the possible benefits of adopting the new methods (Naim and Barlow 2003, Roy, Brown and Gaze 2003, Jaillon and Poon 2008) uptake has been slow. Research conducted by e.g. Goodier and Gibb (2007) and Pan, Gibb *et al.* (2008) have identified the lack of transparent information about comparative costs as a factor that constrain the implementation of off-site production.

Among Swedish contractors there is a specialisation trend towards an increased use of off-site production in housing. Off-site production is competitive in the detached house market, but much less in the multi-storey market (around 15% of market share). The reason for this low acceptance was examined by Höök (2005). Her results showed that the presumed beneficial effects of off-site production are limited, in the case of timber framed modular building, due to the client lacking confidence in whether or not the system will produce optimal life cycle performance and due to the organisational and technological changes. Hence, the study by Höök (2005) revealed that uncertainties were expressed by clients and building owners over long-term costs, technical performance and the management of timber framed housing. A continuation of that study was conducted as an interview study within five residential real estate owner organisations, aiming to deepen the understanding of the expressed uncertainties. The study is presented in Stehn and Levander (2007). The results showed that most uncertainties or concerns were about costs; running costs (operations and maintenance), long-term performance and initial construction costs. Furthermore, the study revealed that cost is the decisive factor in design decisions, with shifting focus on short-term and long-term costs among the respondents. To address the concerns about costs and to reduce the knowledge gap, focus has been put on gathering empirical data on running costs and management of timber framed housing located across Sweden. The purpose of this paper is to address the uncertainties by examining whether the running costs of off-site timber framed residential properties differ from other residential properties in Sweden. Hence, the focus is to present the results of an empirical study of financial accounting on property level to examine the running costs of timber framed housing.

In the context of this paper, timber framed housing is the off-site production[1] of multi-storey, multi-dwelling timber framed properties.

UNCERTAINTY

This research is part of a larger research project aiming to identify, explore and address the potential clients' and residential real estate owners' concerns and uncertainty about off-site timber framed housing. The definition and authors' understanding of uncertainty is: 'a business risk which cannot be measured and whose outcome cannot be predicted or insured against'. Two central contributors to uncertainty in a product development context are technology novelty/complexity and project complexity (Tatikonda and Rosenthal 2000). Project complexity increases the degree of uncertainty as would occur in a construction project where, for example, a new frame material, new actors or a new type of cooperation was involved. Technology novelty is, in a product development context, defined as ‘the newness, to

[1] More specifically, the type of off-site fabrication referred to is 'modular building', defined as units forming a complete building or part of a building, substantially complete in themselves leaving only a small amount of work to be completed on site, see (Gibb 1999)

the development organisation, of the technologies employed' (Tatikonda and Rosenthal 2000). This opens up the definition of technological novelty/complexity in construction to a broad range of attributes and possibilities including off-site timber framed housing. The continued development of this technology depends on information about its production process and product design being available to potential adopters so that their assumption of risk taking decreases with increases in knowledge (Frambach 1993). Uncertainty has also been addressed in terms of the difficulties of task performance (Baccarini 1996, 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.

MANAGEMENT AND RUNNING COSTS OF RESIDENTIAL PROPERTY

Literature on economic management of multi-dwelling buildings was reviewed to describe the main factors influencing the running costs of residential properties.

Economic management of residential real estate

As a real asset, housing exhibits several peculiarities, described by Moorhouse (1972) as being: longevity, immobility, having high fixed costs and that changes over time in supply and demand are optimally met by price (rent) adjustments.

Bejrum (1987) describes the characteristics of the economic management of multi-dwelling property as a complex business activity affected by many aspects and with influence from many different stakeholders. The economic management of real estate can according to Lundström (1986) to a great extent be equalled to common business. However, idiosyncratic are all the aspects and stakeholders that, together with the property features and the property market environment, are affecting the real estate company (Lundström 1986).

Factors affecting maintenance and operating costs

The long-range economic process and its consequences in multi-dwelling buildings have been studied at the Royal Institute of Technology in Sweden during the 1980s. They have shown that the costs of operation and maintenance have increased in comparison to the initial construction cost due to the change in building techniques and the advancement in information technology. The increased number of more complex installations and equipment have increased the costs for caretaking and control, as well as the costs for maintenance, as the economic life of these components are shorter than in older buildings. Hence, the building structure will constitute a less share of the total cost of the building over its life cycle (Lundström 1986, Bejrum 1987). In accordance to this reasoning, the frame material would not have a prominent influence of the running costs.

The long-range economic process of a multi-dwelling property is the result of several interacting and counterproductive factors (Bejrum 1987), primarily the:

- Physical characteristics and technical design of the property: including structural features and optional services (e.g. age, size and height of the building, type of structure, finishes, services, construction materials and number of functions)
- Condition and modernity of the building
- Utilisation and occupancy of the property: actual and alternative
- Geographical location of the property

- Real estate company (the owner): strategy, organisation, ambition and type of company
- Institutional framework: laws and regulations, norms, common practice.

El-Haram and Horner (2002) state that research have identified the age of the building as having a large impact on the maintenance expenses. Moreover, their study revealed that maintenance expenses are greatly influenced by the owner's budget constraints. The results from simulations show that the annual cost per square metre for residential buildings depends on geographical location of the property and that cost is decreasing with the number of floors of the building (Häkkinen *et al.* 2007). Al-Hajj and Horner (1998) identified the cost-significant items among running costs of buildings. They found that a small number of cost elements represent a high proportion of the running costs, such as; internal cleaning; heating; electricity; management; insurance; security; and rates.

RESEARCH QUESTIONS AND METHODOLOGY

Within this project, maintenance and operating costs of timber framed properties (T's) should be examined and compared to the running costs in traditionally built multi-dwelling properties, i.e. concrete properties (C's), as well as to the average running costs of multi-dwelling properties in Sweden. The purpose is to determine if the timber frame affect the running costs and we therefore pose the following research questions:

- What are the factors affecting operations and maintenance costs of residential properties?
- Are the factors the same for off-site timber framed housing as for other types of structures?
- Is there a difference in running costs for off-site timber framed housing, i.e. is frame material a factor influencing the running costs?

For this purpose empirical data has been collected from Swedish building owner organisations comprising economical data, interviews, documents and as well as questionnaires. This paper focuses on the results and analysis of the economical data for answering the questions above. However, to reach triangulation, interviews and other documentation will constitute the empirical base as a complement to the economic data. Recorded and transcribed interviews were analysed in search of perceptions of differences in running costs between off-site timber framed housing and other properties in the companies' portfolios. A total of 16 semi-structured personal interviews were conducted to verify the results from the cost data.

Economical data and selection of properties

The economical data used for analysis are annual costs for operations and maintenance. Excluded from the study are rental income, capital costs (interest costs and depreciation) and national real estate tax. All costs are expressed in SEK (Swedish kronor) per square metre dwelling space. Literally, total floor space equals dwelling space plus non-residential floor space. However, all of the selected properties included in the study have no non-residential premises making total floor space equivalent to dwelling space. The running cost data collected covers one to five consecutive years of each property. For the analysis, a database was created using Microsoft Excel spreadsheets.

Selection of residential timber framed properties
All properties included in the study are located in Sweden and are professionally managed by either municipal housing companies, larger private real estate companies or housing co-operatives within the nationwide HSB Association of housing co-operatives. The selection of T's was made with the objective of reaching a spread among the factors that theoretically affect the running costs of residential property (e.g. Bejrum 1987, Lundström 1986):

- Geographical location (Haparanda in the north to Helsingborg in the south)
- Category of ownership (Private bodies, Municipal housing companies, Housing co-operatives)
- Building characteristics (age, size, height, method of construction)
- Property owner/manager (14 different owners, 10 different property managers)

Selection of comparables
Comparable concrete properties (C's) were selected where obtainable and for their comparability to the T's to enable analyses of mean values. The properties are built on site with traditional methods and with all other parameters affecting running costs similar to a T for eliminating variation; property owner (company); geographical location; and technical design (size in square metres dwelling space, no of storeys, year of construction). Property number 12 (in table 1) enabled a paired comparison due to its characteristics with two identical buildings, one timber framed and one concrete structure. In paired comparisons variation is eliminated, or reduced to the minimum, by variations in the studied variable while all other influencing variables is held equal, e.g. property features, property company characteristics and tenant factors.

Indexation to Statistic Sweden's survey

To be able to answer research question no 3, but also for testing how representative the selection of properties is as to running costs of corresponding residential properties in Sweden, a comparison and indexation of the empiric material was made to Statistic Sweden's (SCB's) yearly published "The survey of receipts and costs for multi-dwelling buildings" (SCB 2003-2007). All studied properties, their features and annual running costs (expressed in SEK per square metre) as well as the result of the indexation to SCB are displayed in Table 1.

The parameters in Table 1 are representing:

Region:	Sthlm = Stockholm; Mun> and < 75'=Municipalities with > and < 75000 inhabitants
Type of owner:	HCO = Housing co-operative, MHC=Municipal housing company, P=Private company.
Manager of the property:	Data from 10 different property management companies.
Structure:	T = Timber frame, C = Concrete structure, T/C = One timber framed and one concrete building included in the property.
Size:	Dwelling space in square metres.
No of dwellings/buildings:	Total number of dwellings/buildings in the property.

Table 1: Studied residential properties, their parameters, actual running costs (expressed as SEK/sq.metre,year) and indexed cost mean

Property	Location	Region	Type of owner	Property manager	Struc-ture	Year of occupancy	Square metres	No of dwellings	No of buildings	Annual data	2003	2004	2005	2006	2007	2008	Index mean
1	Stockholm	Sthlm	HCO	1	T	2001	1290	24	4	2003-2007	320	360	441	404	486		1,399
2	Stockholm	Sthlm	HCO	2	T	2002	755	14	3	2003-2007	395	353	337	325	336		1,154
3	Stockholm	Sthlm	HCO	2	T	2003	2533	36	3	2004-2007		305	349	338	358		1,152
4	Stockholm	Sthlm	HCO	3	C	2002	916	10	2	2003-2005	173	209	248				0,798
5	Stockholm	Sthlm	HCO	3	C	2001	7185	73	5	2003-2005	254	234	249				0,886
6	Stockholm	Sthlm	HCO	1	C	2001	9033	128	4	2004-2007		252	254	327	324		0,985
7	Stockholm	Sthlm	HCO	2	C	2004	4680	70	2	2005-2007			324	329	299		1,049
8	Linköping	Mun>75'	MHC	4	T	1996	2492	36	1	2005-2006			211	220			0,995
9	Linköping	Mun>75'	MHC	4	T	2003	8570	206	2	2005-2006			152	201			0,814
10	Linköping	Mun>75'	MHC	4	C	2001	8810	96	2	2005-2007			233	246	272		1,106
11	Helsingborg	Mun>75'	MHC	5	T	1999	594	8	1	2003-2007	237	190	195	179	268		0,864
12	Vindeln	Mun<75'	MHC	6	T/C	2001	846	12	2	2003-2006	191	216	200	246			1,111
13	Luleå	Mun<75'	P	7	T	1999	3026	60	6	2006-2007				330	396		0,943
14	Luleå	Mun<75'	P	8	T	1997	2786	104	6	2005-2007			298	340	335		0,866
15	Växjö	Mun>75'	P	9	T	1996	3124	55	3	2004-2008		303	308	369	376	352	1,001
16	Haparanda	Mun<75'	P	10	T	2006	3710	69	2	2008						475	No stat
17	Haparanda	Mun<75'	P	10	T	2007	2073	39	2	2008						246	No stat
18	Luleå	Mun<75'	P	10	C	1980	7379	179	6	2006-2007				367	591		1,196
19	Luleå	Mun<75'	P	10	C	1985	679	10	1	2006-2007				436	580		1,270

The survey conducted by SCB covers real estate of multi-dwelling buildings in Sweden. The statistics are based on a total survey of municipal housing companies, and on a sample survey of real estate belonging to private bodies and housing co-operatives. In total, the total survey consist of 300 municipal housing companies with data on company level whereas the sample survey include 1900 housing co-operatives and 2800 properties belonging to private bodies with data on property level. The indexation to SCB enables calculating mean values of the data over different years and different number of years, and comparison of properties with different features. Furthermore, an analysis of the SCB statistics was made with the purpose of identifying the cost drivers for running costs. After standardisation of the cost data through indexation, analyses of indexed means were made. No statistical methods were used since the empiric data does not contain enough properties to make a statistically robust analysis.

RESULTS AND ANALYSIS

For enabling indexation (or normalisation) of the collected cost data, an initial analysis was made of the cost drivers in the survey by SCB (2003-2007). The main cost drivers in the statistics are:

- Type of owner (Private bodies, Municipal housing companies, Housing co-operatives)
- Year of construction
- Region (Metropolitan area versus smaller municipality)

The empiric cost data were indexed to; type of owner; region and; (where possible) year of construction. Cost data from municipal housing companies (MHC's) is on company level, not property level, hence making indexation to year of construction unfeasible. Instead, municipal housing companies were indexed to size of company in terms of number of dwellings in portfolio. Since year of construction is the most prominent cost driver (running costs are rising with increasing age of the property) and indexation to this cost driver was not possible for MHC's, it required us to multiply the indexed costs for properties belonging to MHC's with the factor 2.457. This since the studied properties are quite newly built (1990s to 2007), thus having lower running costs than average properties in the portfolios of MHC's.

Running cost means of timber properties versus concrete properties and Swedish residential property statistics

The mean value of the indexed cost data for all properties included in this research, 1.035, indicates that the selection of properties is fairly representative of the mean in Sweden, only deviating 3.5 % (see table 2).

Table 2: Mean cost values after indexation to SCB statistics (Scb 2003-2007)

SCB statistics	Timber properties	Concrete properties	All studied properties
1	1.030	1.041	1.035

Mean values of the indexed data for T's versus C's show only an insignificant difference in running costs, -1.1 %, in favour for T's. The difference of T's to the mean of multi-dwellings in Sweden is only +3 %. The fact that the structure has no or little impact on the running costs is also supported by literature (Lundström 1986, Bejrum

1987) and by interviews with property managers, building managers and maintenance personnel within the property owner organisations. They either express that there are no differences in costs due to building technique (off-site versus on-site) and structure (timber versus concrete), or they express an opinion of higher running costs for T's but do not have any real evidence to support it, such as specific actions or cost data, i.e. the opinions are unsubstantiated.

Comparison of identical timber and concrete buildings

An interesting case for a paired comparison is property no 12 (see parameters and running costs in table 1) located in the north of Sweden. The property consists of two buildings and the only feature that differ the two is type of structure; one of the buildings has a timber frame (TF) and one a concrete structure (CS). Hence, the two buildings are identical in all other terms, e.g. owner, property manager, year of construction, size, number of dwellings, age of tenants (only a 0.5 difference in mean), number of tenants, location and direction in point of the compass.

Table 3: Heating and estimated maintenance for identical timber and concrete buildings

	Timber building (T)	Concrete building (C)
Energy expenditure (for heating)	81 kWh/year,sq.metre	103 kWh/year,sq.metre
Estimated maintenance (in maintenance plan)	665 400 SEK	692 400 SEK

The running cost data is on property level and therefore it cannot be discerned for the two buildings. Interesting is however that energy expenditure for heating is registered on each of the buildings showing a higher expenditure for the CS, in average approximately 27 % higher per year than for the TF (see table 3). This is a result contradicting the opinion of potential clients and building owner organisations, the common belief of higher energy expenditure for heating in timber framed housing. With heating as one of the main factors affecting the operating costs of residential buildings, e.g. Al-Hajj and Horner (1998), this is a result pointing at lower operating costs for the TF. The maintenance actions carried out do not differ between the two buildings. Furthermore, examining and comparing the maintenance plans for the two buildings, i.e. the estimated costs for planned maintenance during the first 25 operating years, they show no difference in expected external maintenance. However, the maintenance plan show a slightly higher cost (in total 27 000 SEK higher) for internal maintenance of the CS. The cost difference originate from the different floor finishes in the buildings, i.e. a higher cost for exchanging the floor covering of U.P.V.C. in the CS than sanding and lacquering the parquet flooring in the TF. In interviews with the vice president of the company, the property manager and the building manager they only confirm the findings. Nether one of the respondents sees any differences using TF compared to CS, on the contrary they express advantages with the choice of TF. To sum up, the paired comparison display a negligible difference in running costs due to structure of the building with a slightly lower cost for the TF.

Factors affecting running costs in timber framed properties

T's included in the study deviating upwards from the cost mean in statistics are all housing co-operatives, of which all are located in Stockholm. All other T's, i.e. the

average of all rental properties owned by either private or municipal property companies, show a lower indexed cost than the Swedish average.

The empirical material is too small to draw robust statistical conclusions. However, the factors primarily affecting the running costs of the T's are:

- Number of floors (decreasing cost with increasing height of the buildings)
- Size of buildings (decreasing costs with increasing no of square metres/building)
- Type of owner

Neither of these results are specific for off-site timber framed housing but common for all residential properties, (see e.g. Bejrum (1987), Häkkinen (2007)) indicating no differences in cost drivers. Since all T's are built quite recently (1996-2007) no conclusion can be drawn about the impact of age on the running costs.

Furthermore, the conclusion drawn by El-Haram and Horner (2002) about budget constraints greatly influencing the maintenance costs is supported by the interviews with respondents within private and municipal housing companies. The annual maintenance expense is said to be determined from the remaining margin within the net operating income. Another prominent theme from the interviews is that the property companies do not analyse the financial accounting for each property. This fact might contribute to the perceived uncertainty about the running costs of timber framed housing, or at least does not increase the knowledge about the long-term economic outcome of the T's in their portfolio.

For a deeper understanding of the cost elements contributing to a sound life cycle economy it is interesting to further analyse T's deviating more than ten per cent from average, i.e. indexed mean>1.100. The properties differing are property number 1, 2 and 3, all of which are housing co-operatives located in Stockholm. The reason for this deviation needs further examination by a more thorough analysis of cost elements in the financial accountings.

CONCLUSIONS AND FURTHER WORK

The results from the comparative cost data, the interviews and other documentation do not display any significant cost differences between residential timber framed properties and concrete properties. On the contrary, the empirical material exhibit a minuscule cost advantage for the studied timber framed properties in comparison to the concrete properties.

Interestingly, there seems to be a discrepancy between clients' opinion of higher running costs and the actual running costs for timber framed properties as presented in this study. Since clients' opinion differs from our results, uncertainty may be reduced by providing this information about comparative costs and thereby possibly change clients' opinion. Hence, the boundary of knowledge can be pushed forward and contribute to increase the uptake of off-site timber framed housing.

An additional analysis of the empirical data, i.e. of the cost elements constituting the total running costs, could provide knowledge for further improving the life cycle economy of timber framed housing.

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REFERENCES

Al-Hajj, A and Horner, M (1998) Modelling the running costs of buildings. *Construction Management and Economics*, **16**(4), 459-70.

Baccarini, D (1996) The concept of project complexity—a review. *International Journal of Project Management*, **14**(4), 201-4.

Bejrum, H (1987) *Long-range maintenance policy in multi-family rental buildings (In Swedish)*, Stockholm: Royal Institute of Technology.

Egan, J (1998) *Rethinking construction*, Construction Task Force Report for Department of the Environment, Transport and the Regions, HMSO, London.

El-Haram, M and Horner, M (2002) Factors affecting housing maintenance cost. *Journal of Quality in Maintenance Engineering*, **8**(2), 115-23.

Frambach, R (1993) An Integrated Model of Organisational Adoption and Diffusion of Innovations. *European Journal of Marketing*, **27**(5), 22-41.

Gibb, A (1999) Off-site Fabrication–Pre-assembly, Prefabrication and Modularisation. In: John Wiley and Sons, New York, NY.

Goodier, C and Gibb, A (2007) Future opportunities for offsite in the UK. *Construction Management and Economics*, **25**, 585-95.

Häkkinen, T, Vares, S, Huovila, P, Vesikari, E, Porkka, J, Nilsson, L, Togerö, Å, Jonsson, C and Suber, K (2007) *ICT for whole life optimisation of residential buildings, VTT Technical Research Centre of Finland*,

Höök, M (2005) *Timber Volume Element Prefabrication - Production and market aspects*, Licentiate thesis 2005:65. Luleå University of Technology, Department of Civil and Environmental Engineering, Division of Structural Engineering–Timber Structures, Luleå.

Jaillon, L and Poon, C S (2008) Sustainable construction aspects of using prefabrication in dense urban environment: a Hong Kong case study. *Construction Management and Economics*, **26**, 953-66.

Lundström, S (1986) *Management of rental properties: influencing factors and long range planning. (In Swedish)*, Stockholm: Royal Institute of Technology.

Moorhouse, J (1972) Optimal Housing Maintenance under Rent Control. *Southern Economic Journal*, **39**(1), 93-106.

Naim, M and Barlow, J (2003) An innovative supply chain strategy for customised housing. *Construction Management and Economics*, 21(6), 593-602.

Pan, W, Gibb, A and Sellars, A (2008) Maintenance cost implications of utilising bathroom modules manufactured offsite. *Construction Management and Economics*, **26**(10), 1067-77.

Pasquire, C, Soar, R and Gibb, A (2006) Beyond pre-fabrication - The potential of next generation technologies to make a step change in construction manufacturing. In: *IGLC*, Santiago, Chile.

Roy, R, Brown, J and Gaze, C (2003) Re-engineering the construction process in the speculative house-building sector. *Construction Management and Economics*, **21**(2), 137-46.

SCB (2003-2007) The survey of receipts and costs for multi-dwelling buildings in 2003-2007. In: SCB, Statistics Sweden.

Stehn, S and Levander, E (2007) Addressing uncertainties about timber housing by whole life costing. *In, 4th Nordic Conference in Construction Economics and Organisation*, 14th-15th June, Luleå, Sweden.

Tatikonda, M and Rosenthal, S (2000) Technology novelty, project complexity, and product development project execution success: a deeper look at task uncertainty in product innovation. *IEEE Transactions on Engineering Management*, **47**(1), 74-87.