Life-Cycle Economics of Rentable Prefabricated School Facility Units in Municipal Real Estate Procurement

Life-Cycle Economics of Rentable Prefabricated School Facility Units in Municipal Real Estate Procurement

Jaakko Vihola and Harry Edelman

Tampere University of Technology, Finland
jaakko.vihola@tut.fi

Abstract

The purpose of this paper is to study the economic feasibility of rentable prefabricated spatial units as a part of the public real estate procurement strategy. Ensuring the resource effectiveness of the municipal real estate procurement is a matter of great significance. In 2013, the gross investments of the Finnish municipalities were approximately 4.7 billion euros from which the investments on real estate were 1.7 billion euros. Thus, the investment decisions should be made based on thorough life-cycle analysis. However, the prevailing practice of public real estate procurement weights strongly on initial costs.

Recently, there have been indications of interest toward industrially produced spatial units. Rapid product delivery times combined with the spatial flexibility provided by the systems can be considered as the main benefits when compared to more traditional forms of construction. Also, the diminishing quality risks made possible by the controlled facility environment in the production phase can be seen as a major advantage. Studied business model – which relies on renting – helps to transfer the risks related to functionality of the building from the municipality to the unit provider. The research hypothesis is that using rentable prefabricated spatial units helps municipalities to avoid costs related to difficulties in predicting future space requirements.

School properties where chosen for the analysis because of the ongoing public debate considering, for example, health hazards caused by mould and moisture damage occurring in this type of buildings. Net present value (NPV) method was used to compare the municipal life-cycle costs of two school property investment alternatives in Finnish context. The comparison was made between municipality developing and owning a school property and renting the wooden spatial units needed.

The results suggest that different kinds of municipalities can benefit from prefabricated rentable spatial units. The feasibility of spatial modules improves compared to the property built using traditional methods the more the amount of students fluctuates during the analysed time period. Additional benefits include the reduced need of school transportation as well as enhanced social cohesion made possible by children attending the school in local neighbourhood together with friends from the same area.

Keywords: Prefabricated spatial units, public real estate procurement, school facilities, municipal economics, life-cycle economics

1. Introduction

Enterprises should always aim to deliver products that meet the customer's needs as well as different legislative requirements as cost effectively as possible (Asiedu, 1998; Janz and Westkämper, 2007; Niazi et al., 2005). Similar thinking can be extended to the public sector and its services, such as education facilities or even entire residential areas. Efficient procurement practices are playing an essential role when striving to meet these goals. Both in the private and public sector, different investment options should always be evaluated using proper tools to guarantee as effective use of resources as possible. This particularly applies to real estate developments since those are recognised as capital heavy long-term investments. Thus, municipalities should be long-sighted when analysing the economic outcomes of these projects.

Recently, there have been indications of interest towards rentable industrially produced spatial units. Rapid product delivery times combined with the spatial flexibility provided by the systems can be considered as the main benefits when compared to more conventional building methods. In addition, the diminishing quality risks made possible by the controlled facility environment in the production phase can be seen as a major advantage. Studied business model – which relies on renting – helps to transfer the risks related to functionality of the building from the municipality to the unit provider. The amount of modules can be swiftly adjusted when there is a change in space requirements, for example, because of demographic changes in the area. Aforementioned leads to the following research hypothesis: Using rentable spatial units helps municipalities to avoid costs related to failures in predicting future space requirements.

In Finland, the school properties have been a topic of public debate in the past couple of years. According to Reijula et al. (2012) 12–18 % of the schools and day cares in Finland are affected by considerable moisture and/or mould damage. Because of this 172 000–259 200 children could be exposed to different health hazards. When thinking of how to replace the school properties that are damaged beyond the renovation threshold, the municipalities are forced to make a decision between renting and owning new properties. The economic impacts should be carefully studied especially when the population of the school-aged children in Finland is predicted to decline rapidly in the future (Official Statistics of Finland (OSF), 2015a). Thus, owning of a permanent solution with possible low utilisation rate in the near future is questionable to say the least.

In this study, the net present value method is used to compare the life-cycle costs of two different kinds of school property investment options from the viewpoint of municipality: First, where a municipality invests to a property which is built using traditional production methods mainly relying on prefabricated concrete sandwich wall elements and hollow core concrete slabs, and second, where the municipality rents the spaces required from the manufacturer of wooden spatial units. What makes this study unique is the fact that it is the first of its kind to combine the predictions of the student population development and the cost data of municipal real estate procurement and thus providing evidence how the variation in the demand of space over time impacts on the economic equation. The next section covers the relevant literature considering public real estate procurement and prefabricated spatial units. In the third section, the data for the analysis as well as applied research method are described. The fourth section presents the results of the LCC-calculations carried out. The final chapter includes conclusions and discussion about the relevance of the results as well as underlines the need for future research.

2. Background

It has been estimated that in 2011 the total expenditure of EU member states on education was on average 5.25 % of their GDP respectively. In Finland, the government carries an essential role in providing educational services thus the corresponding number is a bit higher being 6.76 % (Eurostat, 2015). In 2013, the investments of Finnish municipalities were approximately 4,7 billion euros from which the investments on real estate were 1,70 billion euros (Finnish Ministry of Finance, 2015). It is safe to say that municipal real estate procurement plays a major role from the viewpoint of national economy.

Statistics Finland has presented a projection that the population of children that fall into the category of compulsory education (aged 7–16) will decline rapidly in the upcoming decades *(Figure 1)*. The estimation was made based on the assumption that the birth rate remains constant in the future and the mortality continues to decline in a similar fashion as when comparing the data from 1987–1991 and 2010–2014. Migration is assumed to be 17 000 persons per year between 2016 and 2065. (Official Statistics of Finland (OSF), 2015a.) However, the areal differences in population development should not be overlooked. The demand for educational facilities is likely to continue to increase in the centres of growth and decline elsewhere.

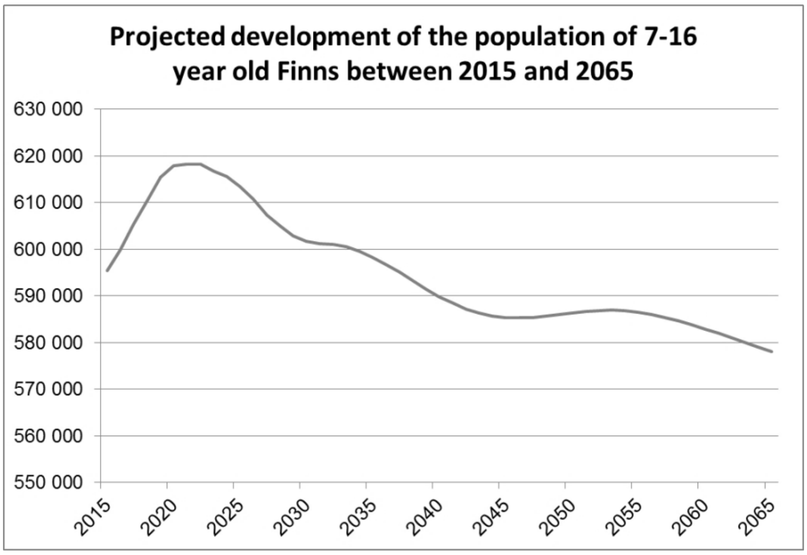

Figure 1: Projection of the development of the amount of children between 7-15 years old in Finland between 2015-2065 (Official Statistics of Finland (OSF), 2015a).

The amount of schools owned by the Finnish municipalities has declined rather rapidly since 2005 *(Figure 2)*. In 2005 Finnish municipalities owned approximately 3 300 school properties and that number has decreased to 2 400 by 2014. However Due to the increase in unit size of new school and tendency to close down the smaller units, this statistic can be deceiving because it does not take into consideration the actual volume of school buildings.

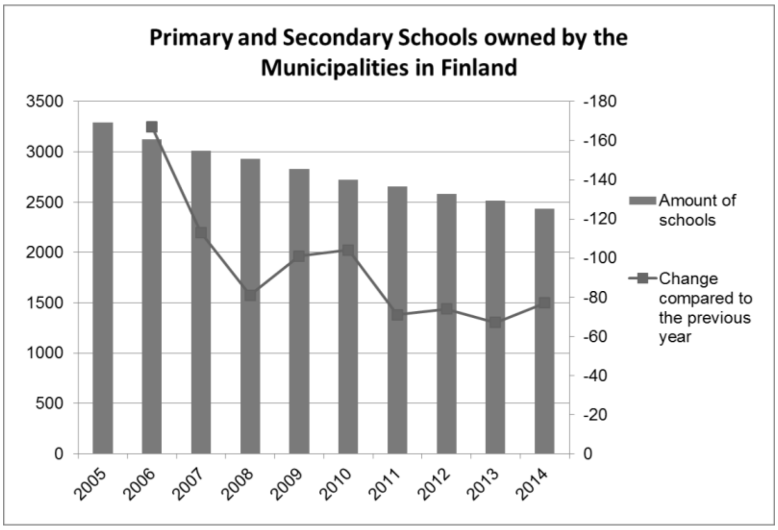

Figure 2: Primary and secondary school buildings owned by the municipalities in Finland between 2005–2014. The line graph presents the annual change (vertical axis on the right).(Official Statistics of Finland (OSF), 2015b)

Public procurement has been covered from many different angles in the existing body of literature. Most countries have a strict legislation considering public procurement of services and goods. Public tendering procedures have been a predominant mechanism for granting construction contracts in municipal sector. Usually the choice between the bidding contractors is made weighing strongly on the tender price. However, there are some studies showing that this practice leads to lacking quality and prolonged project deliveries (Cheng et al., 2000; Drew and Skitmore, 1997). Because public procurement is responsible for significant share of demand of goods and services, it is often seen as major source for potential innovations (Aho et al., 2006; European Comission, 2005; HM Treasury, 2004). However, Edler and Georghiou (2007) argue in their article how despite public procurement representing a key source of demand for the firms, for example, in construction, health care and transport industries, the potential of using public procurement for source of innovation has been largely ignored conceptually as well as in practice.

Environmental and sustainability related aspects of prefabricated buildings are well documented. Jaillon et al. (2009) investigated in their study how utilising prefabrication in building construction could help to mitigate the growing problem of building waste generation in Hong Kong area. They found out that the average waste reduction level was about 52 % compared to the conventional on-site construction projects. Bonamente et al. (2014) used LCA approach to model carbon and energy foot prints for different size buildings. The results indicate that the main environmental impacts arise from the operational phase of the buildings. Similar results were found by Faludi et al. (2012) who studied the life cycle impacts of a 5000 ft^2 prefabricated commercial building constructed in San Francisco. However, it was also stated that in the case of nearly zero energy buildings impacts from manufacturing are the most dominant. Pons and Wadel (2011) concentrated specifically on the environmental impacts of prefabricated school buildings in Catalonia. Using simplified LCA modelling, they compared the CO_2-emissions of four technologies; non-prefabricated building technologies as well as prefabricated school facilities made out of wood, steel and concrete. The results show that prefabricated solutions have lower environmental impacts through analysed time period. However, according to the study there is still room for improvement in the processes to further reduce the CO_2-emissions and especially the waste generation related to manufacturing and recycling.

The economic literature considering prefabricated spatial units is very limited. The report of National Audit Office (2005) claims that in British context construction projects carried out using modern methods, such as modular spatial units, are usually more expensive than the ones applying the more conventional methods. However, there is an overlap in the price ranges thus in certain conditions modern techniques could prove to be more cost effective. Pan et al. (2005) argue in their study which is based on survey of the top 100 housebuilding firms in UK that the cost savings of the off-site manufacturing are achieved, for example, in the areas of reduced risks and maintenance costs, shorter construction times and cost certainty.

This study contributes to the existing body of literature by being the first to focus on the municipal school property investment in Finnish context by combining the official cost data from various sources and the student population projection provided by Statistic Finland. The result is the most comprehensive analysis yet regarding the subject and can be used as a starting point when aiming for decision-making based on facts in the field of public real estate procurement.

3. Data and Methodology

In this paper, life-cycle cost (LCC) analysis is carried out to compare the economic feasibility of two different educational facility investment alternatives from the perspective of a municipality. The analysis was made between renting a school property built using prefabricated spatial modules, and the traditional alternative, in which a municipality invests to a new property and owns a building after development is finished. The analysed investment alternatives are not based on real-life counterparts. However, the cost data used in the analysis is gathered from different official sources. The main purpose is to provide information about the economic feasibility of rentable spatial units compared to more conventional method of construction by taking into account differing costs of the investments throughout their life-cycle. Also, the presented approach makes it possible to figure how the changes in the student population impact on the economic feasibility of the studied alternatives.

3.1 Data

For the purposes of the LCC calculations the data was acquired from various official sources to perform a comparison between the studied investment alternatives. The values of different variables and the data sources are listed in *table 1*.

Table 1: The municipal expenditures of the analysed investment alternatives.

Municipality invests to a new school property			**Municipality applies rentable prefabricated spaces**		
Variable	**Value**	**Source**	**Variable**	**Value**	**Source**
Amount of students	250/214	Official Statistics of Finland (OSF), 2015a	Amount of students	250/214	Official Statistics of Finland (OSF), 2015a
Required floor area	4 500 m^2	Finnish National Board of Education, 2012	Required floor area	4 500 m^2	Finnish National Board of Education, 2012
Investment cost	2 308 €/m^2	Haahtela and Kiiras, 2015	The costs of foundations and utilities	103 €/m^2	Haahtela and Kiiras, 2015
The cost of maintenance	8,2 €/m^2	Lonka et al. 2012	Transportation and installation	250 €/m^2	Parmaco Ltd., 2015
The annual growth rate of real maintenance costs	2,8 %	Official Statistics of Finland (OSF), 2015c	Monthly rent	14 €/m^2	Parmaco Ltd., 2015
Annual inflation rate (15 year average)	1,8 %	Official Statistics of Finland (OSF), 2015d	Annual inflation rate (15 year average)	1,8 %	Official Statistics of Finland (OSF), 2015d
The annual cost of technical deterioration	2,3 % of the investment cost	Nippala et al. 2006	The annual real increase of the rent	1,2 %	Parmaco Ltd., 2015

City of Kouvola was chosen as the location for the theoretical example for a school facility investment. Kouvola is situated in southeast Finland about 140 kilometres northeast from the Finnish capital Helsinki. In the end of 2013, the population of Kouvola was 86 926. Kouvola was chosen for the study area because in 2014 a school for approximately 250 students situated in the city was closed down. Another reason for the selection is the fact that according to Statistics Finland the population of the city is declining (Official Statistics of Finland (OSF), 2015e) which supports the assumptions made in the analysis. All of the expenditure variables are presented in the current price-level of Kouvola region.

Only the costs differing between the two investment alternatives were taken into account. In Finland, the technical quality of the new production practically always follows the requirements set in the part D3 of the National Building Code (Finnish Ministry of Environment, 2011). It defines the minimum requirements considering the energy efficiency of new buildings. Thus, the specific heating energy consumption (kWh/m^2) can be assumed to be similar between the two studied alternatives. When combining this fact with the predominant position of the district heating in the Finnish building stock, the utility costs in the both alternatives are very similar and thus are omitted from the analysis. Land value is not considered in the analysis based on the fact that comparison is made between two exclusionary investment alternatives for the same geographical location. In both cases, the floor area of space required is expected to be the same 15 m^2/student. The main differences between the investment alternatives are the large initial capital cost and the cost of maintenance and technical deterioration included in the alternative where municipality invests to a new school property. The costs of maintenance as well as the cost of deterioration are included in the monthly rent in the second alternative. However, also in the case of rentable spatial units there are some initial construction costs including the building of foundations and surrounding utilities as well as the costs of transportation and installation of the units. The cost information regarding the rentable spaces was provided by Parmaco Ltd. (www.parmaco.fi) which is one of the few manufacturers in Finnish real Estate market producing and renting spatial units aiming to reach similar architectural and technical quality as more conventional developments.

In this study, the residual value of the investment alternatives was ignored. This is mainly due to the fact that if municipality procures the spaces using the renting model the ownership of the modules stays on the manufacturer who will reclaim them after the service agreement ends (if there is no redemption rights clause in the contract). In the case of municipality developing and owning a new facility, the residual value is really hard to define. Technical value based on the age of the building can be quantified using various methods but the specific characteristics of education facilities make this problematic. Large school facilities are not often appealing from the perspective of real estate investors. Usually they require significant amount of alterations to modify the spaces to support other possible activities. In the case of demolition, residual value can even thought to be negative if the costs of the demolition process and waste management are taken into consideration.

3.2 Net Present Value method

Net present value method (hereinafter referred to as NPV) can be used to estimate the life-cycle costs of the investment alternatives. The NPV method is based on the time value of money, meaning that a cash flow in the future is less valuable than an identical cash flow today. The two most central reasons behind this phenomenon are inflation/deflation and a simple fact that a present cash flow can be invested immediately to earn future returns, whereas a future cash flow cannot be invested yet. The NPV method takes the time value of money into consideration by discounting the future cash flows by an appropriate discount rate. The mathematical form of the NPV equation used in our model can be written as follows:

$$NPV = \sum_{t=0}^{n} \left(\frac{Expenditures_t}{(1+r)^t} \right) \qquad (1)$$

Where: t = cash flow period
r = the chosen discount rate
n = calculation period

In the model the cash flow period (t) is one year, whereas the analysed calculation period of a development project (n) is 26 years. Choosing a proper discount rate (r) is one of the most crucial elements in any type of medium- to long-term investment calculation. The discount rate describes the yield requirement for the investment, including the perceived risks, capital costs as well as desired profits. As a rule of thumb, the minimum discount rate should be at least high enough to cover the financing costs of an investment. A high discount rate gives more weight to cash flow events at the beginning of the analysed life-cycle. Thus, usually investments with low initial capital costs seem more tempting when using high discount rates. Instead, the lower the discount rate, the more the impact of the cash flow events occurring further in the future will have on the results of the analysis.

There is an extensive academic literature on the uncertainty related to public investments and selection of a proper discount rate (e.g. Arrow and Kruz, 2013; Arrow and Lind, 2014). Woodward (1997) states in his article that the appropriate discount rate in LCC analysis varies from 3 percent to over 20 percent depending on the nature of the investment and investor. For the purposes of this analysis, a real discount rate of 5 percent is used. A real discount rate does not include inflation/deflation, whereas the so-called nominal rate does. Whenever a real discount rate is used, the cash flows discounted must be presented in real values as well. The utilisation of real rates and costs is chosen because it is really hard to predict the inflation for long calculation periods. The significance of this matter grows the longer the calculation period is.

4. Results

The economic feasibility of school facility investments was studied comparing two alternatives: First, where a municipality invests to a property which is built using conventional construction methods, and second, where the municipality rents the spaces required from the manufacturer of wooden spatial units. In addition, two alternative student population development scenarios were studied. One where the amount of students stays constant through the studied time period and other where there is a decline in student population. The decline was modelled based on the estimation presented by Statistics Finland.

The results based on the calculation scenario where the amount of students is assumed to stay constant throughout the calculation period (2015–2040) are presented in *Figure 3*. It is noteworthy that the renting model does not include costs for the first year of the studied time period. This is based on the assumption that after the foundations and other preliminary works are finished the modular building system is really fast to put together. However, when building using more traditional methods, the development will take at least a year for the project of this scale. From the figure can be seen that the cumulative discounted costs of the renting model by pass the ones caused by owning the property in 2037 (22 years after the start of the development). In other words, if the purpose of the municipality is to own and use the property longer than 22 years it is more cost effective to develop and own the property. Alternatively, if the strategy is to keep the property only as long as the students can be located to other facilities in the area and the required time is shorter than 22 years the renting model will be a better choice from the viewpoint of economics.

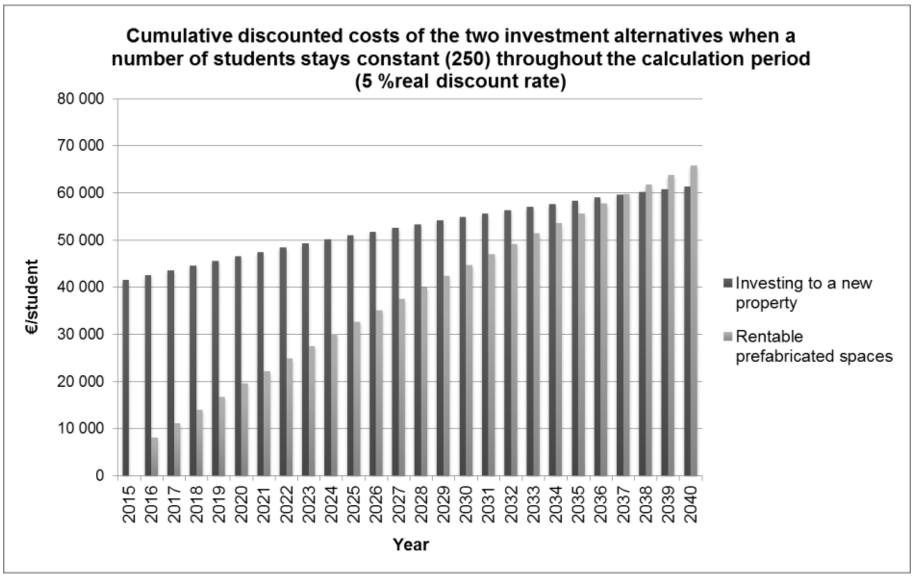

Figure 3: Cumulative discounted costs of two studied investment alternatives assuming that the amount of students stays constant during the calculation period.

One benefit of the rentable prefabricated modules is the fact that the system is spatially very flexible and responses well to changes in space demand. The calculation results presented in Figure 4 support this claim. This scenario is based to a projection made by Statistics Finland about the population development of school-age children in Kouvola, Finland. In 2015, the student population is assumed to be 250 and according to the projection it decreases to 214 by 2040. In addition, the amount of spatial units is adjusted in every ten years (2024 and 2034) by removing the units not needed anymore because of the decline in the student population.

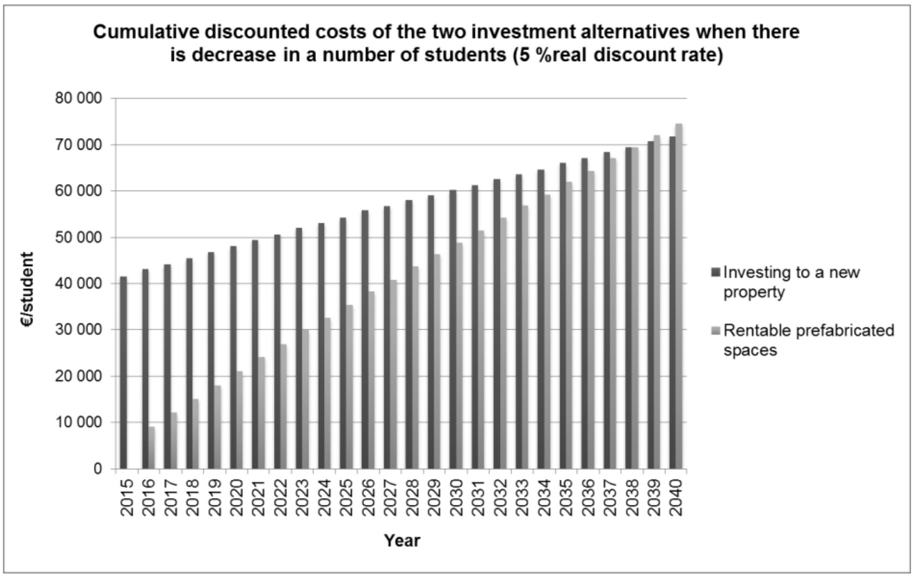

Figure 4: Cumulative discounted costs of two studied investment alternatives assuming that the amount of students declines during the calculation period according to projection made by Statistics Finland.

By comparing the previous two figures it can be seen that the decline in the student population favours the rentable spatial units because of the system's ability to adapt to a new situation. The break-even point moves to year 2039 which means that that renting the facility is now more profitable if municipality plans to own the property 24 years or less. It should also be noted that the selection of the discount rate affects a great deal to the results. The higher the discount rate, the more it favours the renting model. This is due to the fact that high discount rates favour the investments with low initial cost, and the significance of the future renting costs diminishes.

5. Conclusions and Discussion

It is foreseeable that different kinds of municipalities can benefit from prefabricated rentable spatial units. The results presented in this paper suggest that rentable prefabricated spatial units should be considered as an option especially in municipalities that have an uncertain future and thus will have a decrease in population of school-aged children in forthcoming decades. The same phenomenon is present also in growing cities where the amount of children may vary drastically by city districts. The feasibility of rentable spatial units improves when comparing to a property built using traditional methods the more the amount of pupils fluctuates during the analysed time period. Also it is worth mentioning that avoiding the unnecessary transportation of children brings many economic benefits, reduces the environmental impact, and may even enhance social cohesion when the children may attend the school in local neighbourhood together with friends from the same area.

It should be noted that the holistic economic analysis considering the procurement of any public construction project is far more complicated issue than just an LCC-calculation covering the variables related to building and maintaining properties. Every project is its own unique entity requiring customized analysis to determine the best performing procurement method. Regarding the educational services, there are many real-life cases where municipalities have tried to achieve budgetary savings by closing out schools and locating the students to other schools in the region. Usually the savings have not been reached because of the analyses are not including all of the externalities caused by the change. For example, closing down a school usually leads to costs in other areas such as transportation, re-establishing the teaching groups elsewhere, the necessary spatial modifications in substitute school, lost state subsidies, etc. Evaluating different alternatives is a complicated task. However, because of the long lasting effects and capital heavy nature of these investments, the tools and decision-making should be approached with the significance of the matter in mind.

One interesting, yet underexplored, area is so-called hybrid-models where permanent parts of the property are complimented with the prefabricated spatial units. This would enable to capitalize on the benefits related to both systems. This kind of system when in balance would make the use of the cost effectiveness of conventional construction methods and the spatial flexibility of prefabricated spatial units. However, if the Finnish municipalities continue to rely heavily on owning the public properties and procurement procedures emphasising strongly the role of the initial investment costs, the focus should be on flexible designs where the alteration of use can be carried out with minimal changes leading to increased resource effectiveness.

References

Aho, E., Cornu, J., Georghiou, L., Subirá, A., 2006. Creating an Innovative Europe. Luxembourg: Office for Official Publications of the European Communities.

Arrow, K.J., Kruz, M., 2013. Public Investment, the Rate of Return, and Optimal Fiscal Policy. Routledge.

Arrow, K.J., Lind, R.C., 2014. Uncertainty and the Evaluation of Public Investment Decisions. Journal of Natural Resources Policy Research 6, 29–44. doi:10.1080/19390459.2014.867640

Asiedu, Y., 1998. Product life cycle cost analysis: state of the art review. International Journal of Production Research 36, 883–908. doi:10.1080/002075498193444

Bonamente, E., Merico, M.C., Rinaldi, S., Pignatta, G., Pisello, A.L., Cotana, F., Nicolini, A., 2014. Environmental Impact of Industrial Prefabricated Buildings: Carbon and Energy Footprint Analysis Based on an LCA Approach. Energy Procedia, International Conference on Applied Energy, ICAE2014 61, 2841–2844. doi:10.1016/j.egypro.2014.12.319

Cheng, E., Li, H., Love, P., 2000. Establishment of Critical Success Factors for Construction Partnering. J. Manage. Eng. 16, 84–92. doi:10.1061/(ASCE)0742-597X(2000)16:2(84)

Drew, D., Skitmore, M., 1997. The effect of contract type and size on competitiveness in bidding. Construction Management and Economics 15, 469–489. doi:10.1080/014461997372836

Edler, J., Georghiou, L., 2007. Public procurement and innovation—Resurrecting the demand side. Research Policy 36, 949–963. doi:10.1016/j.respol.2007.03.003

European Comission, 2005. Public Procurement for Research and Innovation - Developin Procurement Practices Favourable to R&D and Innovation. Luxembourg.

Eurostat, 2015. Public expenditure on education.

Faludi, J., Lepech, M.D., Loisos, G., 2012. Using life cycle assessment methods to guide architectural decision-making for sustainable prefabricated modular buildings. Journal of Green Building 7, 151–170. doi:10.3992/jgb.7.3.151

Finnish Ministry of Environment, 2011. D3 Energy Management in Buildings, Regulations and Guidelines 2012. Department of the Built Environment, Helsinki.

Finnish Ministry of Finance, 2015. Kuntatalousohjelma 2016-2019 (No. 16a/2015), Valtiovarainministeriön julkaisu. Helsinki.

Finnish National Board of Education, 2012. Perus- ja esiopetuksen tilantarpeen tunnusluvut [Characteristics of space requirements in educational facilities].

Haahtela, Y., Kiiras, J., 2015. Talonrakennuksen kustannustietoa 2015 [The costs of construction 2015]. Haahtela-kehitys Ltd., Helsinki.

HM Treasury, 2004. Releasing Resources for the Frontline (Gershon review). London.

Jaillon, L., Poon, C.S., Chiang, Y.H., 2009. Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. Waste Management 29, 309–320. doi:10.1016/j.wasman.2008.02.015

Janz, D., Westkämper, E., 2007. Design to Life Cycle by Value-Oriented Life Cycle Costing, in: Takata, S., Umeda, Y. (Eds.), Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses. Springer London, pp. 461–466.

Lonka, H., Lallukka, V.-V., Romppainen, S., 2012. Itä-Uudenmaan kuntapalveluverkkoselvitys - Kuntien toimitilaverkoston ja siinä tapahtuvan toiminnan selvitys [Assessment of the service network in Eastern Uusimaa Area in Finland]. Helsinki.

National Audit Office, 2005. Using Modern Methods of Construction to Build Homes More quickly and Efficiently. London.

Niazi, A., Dai, J.S., Balabani, S., Seneviratne, L., 2005. Product Cost Estimation: Technique Classification and Methodology Review. J. Manuf. Sci. Eng. 128, 563–575. doi:10.1115/1.2137750

Nippala, E., Vainio, T., Nuuttila, H., 2006. Rakennustyyppikohtainen peruskorjaustarpeen arviointi kuntien rakennuksissa [Assessment of renovation needs in municipal buildings]. The Membership of the Association of Finnish Local and Regional Authorities, Helsinki.

Official Statistics of Finland (OSF), 2015a. Population projection 2015-2065. Helsinki.

Official Statistics of Finland (OSF), 2015b. Providers of education and educational institutions.

Official Statistics of Finland (OSF), 2015c. Real Estate Maintenance Price Index. Statistics Finland, Helsinki.

Official Statistics of Finland (OSF), 2015d. Consumer Price Index. Statistics Finland, Helsinki.

Official Statistics of Finland (OSF), 2015e. Population projection 2015 according to age and sex by the area 2015-2040. Statistics Finland, Helsinki.

Pan, W., Gibb, A., Dainty, A., 2005. Offsite Modern Methods of Construction in Housebuilding: Perspectives and Practices of Leading UK Housebuilders. Loughborough University, Department of Civil and Building Engineering.

Parmaco Ltd., 2015. Winning offer of Lauritsala’s school facility.

Pons, O., Wadel, G., 2011. Environmental impacts of prefabricated school buildings in Catalonia. Habitat International 35, 553–563. doi:10.1016/j.habitatint.2011.03.005

Reijula, K., Ahonen, G., Alenius, H., Holopainen, R., Lappalainen, S., Palomäki, E., Reiman, M., 2012. Rakennusten kosteus- ja homeongelmat (No. 1), Eduskunnan tarkastusvaliokunnan julkaisu.

Woodward, D.G., 1997. Life cycle costing—Theory, information acquisition and application. International Journal of Project Management 15, 335–344. doi:10.1016/S0263-7863(96)00089-0