International Journal of Engineering & Technology, 7 (2) (2018) 449-452

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i2.9372
Research paper

Comparing of innovative and traditional technologies of wood houses for using the efficiency index

Jozef Švajlenka[1]*, Mária Kozlovská[2]

[1] Technical University of Košice, Faculty of Civil Engineering, Department of Construction Technology and Management
[2] Technical University of Košice, Faculty of Civil Engineering, Department of Construction Technology and Management
**Corresponding author E-mail: jozef.svajlenka@tuke.sk*

Abstract

Sustainable development is a term, which came in at present in many spheres economic and social life. Many of the development and growth dimensions that have been evaluated so far have recently been complemented by the sphere of sustainability. In the context of sustainable construction, there is a host of other environmental, social and economic criteria which show the extent to which a construction and its use affects its users' health, or even the health of the whole society. The aim of this paper is to present a comparing of innovative and traditional technologies of wood houses for using the efficiency index. Based on a comparison of generally defined formulations of efficiency, it was created through the authors of this manuscript the formula for efficiency evaluation, determining efficiency as a ratio of synthetic to analytic efficiency indicators. By comparative analysis we found that the panel construction system, representing off-site technologies, is considerably more efficient when compared with instances of traditional on-site technologies.

Keywords: *Efficiency index, Innovative technology, Wood construction*

1. Introduction

Sustainable development by Mederly [1] is a term, which came in at present in many spheres economic and social life. Many of the development and growth dimensions that have been evaluated so far have recently been complemented by the sphere of sustainability. However, the sustainability of development itself is relatively difficult to quantify. This is all the more difficult to judge individual processes, whether in society or in the context of sustainability. The goal of sustainability is not to limit development, slow down growth and development but also to find models of company development that will not be limiting for future generations. It is about finding a new type of "healthier" development, which will be maintained for a longer time, namely sustainable development. It was defined as the state of global equilibrium, in which the population of the Earth and the capital are kept at a more or less constant level and the tendencies for growth, whether the drop in these quantities must be under rigorous control.

According to Tywoniak [2] ways to improve the sustainability of buildings are very diverse. The common feature should be to comply with generally formulated sustainability requirements, where we can also include social and economic issues in addition to quality environment and low production of pollutants. A prerequisite for ensuring the functional, building-physical and cultural sustainability of buildings is the creation of a flexible strategy that could be applied in relation to the protection and renovation of works. The starting point for such a strategy will be the identification of time and functionality concepts in architecture and the categorization of technical and material solutions evaluated in terms of time, renewable and substitutability.

According to Kupkovič [3], efficiency is a synthetic and heterogeneous concept. Syntheticity manifests itself in the fact that the concept of efficiency comprises a substantial portion of the problems of a society's economic development, ranging from the discovery and use of resources (labour, work instruments and work artefacts), their transformation into utility artefacts, to their distribution (consumption) [4,5]. The heterogeneous character of the concept of efficiency shows in its multiplicity of meanings [6]. In actual practice, it is applied in various contexts. According to Kupkovič [3], efficiency, in a broader sense, can also be understood as successful production activity arising from implementing new technology or organisation of work, consistency of production and product quality, improved consumption standards, eliminating strenuous labour, etc [5,7]. Efficiency therefore conveys new qualitative elements of economic and manufacturing activities [8]. According to Pifko, Špaček et al. [9], efficiency is a ratio of incurred costs (construction funding, effort and time expended) to gained benefits (quality and comfort).

According to Vlachynský and Markovič [10], measuring efficiency presupposes a statement of criteria and selection of indicators. According to Sosedová [11], a criterion is a measure, rule or a 'standard' by means of which efficiency levels can be determined, that is, to what extent a given solution meets the requirements stemming from economic, social and environmental interests in the society, and hence from the basic aspects of sustainability. The criteria for judging efficiency may vary, as efficiency an aggregate measure of all factors which affect the results of any activity [5,6]. They depend on specific conditions and goals in terms of which an efficiency assessment is performed. An efficiency criterion must be identified according to specific intentions and conditions [12,13]. An efficiency criterion is expressed by means of indicators. A choice of a criterion involves the setting of a goal, and we therefore need to pay sufficient attention to it. As a result of this, a criterion also serves as a means of discovering and exploiting reserves and forms a basis for measuring efficiency [14,15].

The significance of efficiency indicators, according to Maříková and Mařík [16], also lies in the fact that they can be used in comparing the efficiency of different variants. Indicators allow measuring the degree of fulfilling a criterion's requirement, determining the size and cause of deviations and proposing a method of their elimination [17].

According to Huttmanová [18] and Mederly [19], permanently sustainable development is a concept which has entered into many areas of economic and social life [20,21]. Many previously assessed development and growth aspects have recently been extended to include the dimension of sustainability. However, development sustainability itself is relatively hard to quantify. It is all the more difficult to judge individual processes and occurrences in the society in the context of sustainability (or permanent sustainability) [22,23]. The purpose of permanent sustainability is not restrict development or slow down growth and progress, but to find such models of the society's development which will not be restrictive for future generations. It is a matter of finding a new, 'healthier' type of progress which can be maintained over the long term. This new type of progress was defined as a state of global balance in which the global population and capital are maintained at a more or less constant level, while trends affecting the increase or decrease of these variables must be thoroughly kept under control [4,24,25,26].

2. Methodology

The subject of our work was the real use of wood-based constructions. In the analysis, we compared the efficiency of two wood-based construction systems. The evaluation was aimed at evaluating effectiveness in the context of the underlying principles of sustainability.

Based on a comparison of generally defined formulations of efficiency, relation (1) was established to evaluate and demonstrate wooden buildings' construction systems' efficiency, determining efficiency as a ratio of synthetic to analytic efficiency indicators expressed in terms of an efficiency index (within the considered interval). Efficiency measurement in our case is a ratio of gained benefits (by means of evaluating sustainability, the so-called sustainability index, quality and comfort of living, expressed as a synthetic indicator) to incurred costs and time required for acquisition (acquisition costs, operating costs and construction time, expressed as analytic indicators).

$$E_i = \frac{\mathrm{SI_i}}{\mathrm{TC_i} + \mathrm{AC_i} + \mathrm{OC_i}} \quad [-] \qquad (1)$$

where:

Ei – Efficiency of construction system (Efficiency of construction system - Ei) [efficiency index]

SIi – sustainability index of construction system 'i' recalculated as percentage points

CTi – average construction time of construction system 'i' recalculated as percentage points

ACi – average acquisition costs calculated per m2 of useful area of construction system 'i' recalculated as percentage points

OCi – average monthly operating costs for heating calculated per m2 of useful area of construction system 'i' recalculated as percentage points

Several evaluation and standardisation systems (norms) were used in selecting user parameters: STN EN 15978, 15643-3, 15643-4, LEED, BREEAM, DGNB and SBTooL [27-32], which comprehensively evaluate the sustainability of constructions in terms of design and execution (Table 1). The aforementioned evaluation systems are analysed in more detail in the theoretical part of this work. In further research, the parameters listed in Table 1 are incorporated into a socio-economic research focused on examining the extent of fulfilling the declared user parameters of prefabricated wooden constructions in use. Due to the various structures of classifying criteria and parameters in the individual evaluation systems, even the selected parameters are impossible to match to a single set of criteria.

Table 1: Selection of user parameters of construction in the context of sustainability systems

Selected criteria	Assessment systems							
	STN EN 15978	STN EN 15643-3	STN EN 15643-4	LEED	BREEAM	DGNB	SBToolCZ	CESBA Tool SK
applied building materials	x						x	
visual comfort inside building		x		x	x	x	x	x
visual comfort of building exterior		x		x	x	x	x	
spatial solution		x					x	
housing quality		x					x	
healthiness of building		x		x	x	x	x	
investment cost on building procurement			x				x	
service cost			x	x	x	x	x	x
acoustic comfort in building		x		x	x	x	x	x
lighting comfort in building		x		x	x	x	x	x
indoor air quality in building		x		x	x	x	x	x
construction quality		x	x					
defects at the beginning of building use		x	x					
defects during building use		x	x					
construction time	x	x	x					
thermal comfort in wintertime		x		x	x	x	x	x
thermal comfort in summertime		x		x	x	x	x	x

Note: x - Occurrence in assessment systems

The above user parameters formed a basis for measuring construction efficiency, or efficiency of construction systems based on wood, and will also help to discover any shortcomings in the individual construction sustainability criteria in this segment of modern constructions. Efficiency measurement is evaluated using specified criteria.

3. Analysis of selected wood-based construction systems

In further research, we analysed two groups of wooden construction systems. The groups of off-site technologies and on-site technologies:

- Panel construction system (off-site - modern construction system) (45 buildings)
- Log construction system (on-site - traditional construction system) (23 buildings)

3.1. Characteristic of Panel construction system

Panel construction system is a typical off-site modern building construction. One of the expanded wooden building systems in practice is a panel construction system. This is actually a modified column system when a panel is made in a special factory rather than a building site. The reason for the extended application of the panel construction system is its design, manufacturing (Fig.1), assembly and finishing advantages. The panel construction system is based on the production of individual types of panels of the building structure (floor, perimeter, partition, ceiling, gable and roof) in the production hall, their transport to the site and rapid assembly by the technician.

The main advantage of the panel construction system is the possibility of maximum preparation of the construction parts of the building in the production, quick assembly and completion of the construction on the building site (Fig.2), which lasts in standard conditions for a maximum of 3 months. The panel construction system allows the use of modern production technology lines with automation nodes and the efficient capacity of truck tractors. The panel construction system is used as an integral part of the fast and efficient installation of modern mobile cranes, able to manage the construction of the building even in the most demanding field conditions, which ultimately shortens construction time at the building site. Characteristic features of the panel construction system are: the frame structure makes the frame, the higher demands for transportation and manipulation of the structural parts of the building (all-wall panels), the need for manipulation technically during construction, very fast construction time.

Fig. 1: Manufacture of panel construction system [33].

Fig. 2: Example of panel construction system [34].

3.2. Characteristic of Log construction system

Log construction system is a typical on-site building construction. Log constructions are the followers of the traditional architecture of the Central Europe countryside, especially in the mountainous parts where there was enough wood. The perimeter walls of these structures are made of machined tree trunks - log cabins (prisms, pillows and others). The wall joints are bonded by carpentry joints, which ensures the overall stiffness of the structure.

The characteristics of log construction system are: High craftsmanship, special selection of wood, high wood consumption, solid ground plan, volume and shape changes of the building, building siting (Fig.3,Fig.4). Rough construction creates a unique atmosphere with its architectural expression and provides full use of wood as a natural material (material cleanliness). Compared to lightweight skeletal structures they provide higher thermal accumulation capability. This property positively affects the overall energy balance of the log structure. From the point of view of the environment and the energy load it is beneficial to use so-called false log cabins that use only locally available renewable materials where wood is not chemically protected, with the least possible natural-dry treatment. By using alternative (natural) thermal insulation such as sheep's wool, hemp, it is possible to minimize the associated energy, in the energy required to operate with a reduction in CO_2 emissions.

Fig. 3: Realization of log construction [35].

Fig. 4: Example of log construction [35].

3.3. Analysis of examined parameters

Overall, we analyzed 68 buildings actually used. The individual answers to the questionnaire correspond to the number of constructions, as one representative filled in the questionnaire for each construction and his answers included opinions of the other users of the given construction.

The respondents' previous housing significantly affects the comparison with the current wooden construction housing. The majority of respondents (60.3%) stated a block of flats as their previous housing, 27.8% of respondents stated a traditional masonry family house, and 11.9% of respondents even stated a wooden construction as their previous housing. It follows from the findings that the respondents can compare traditional housing with living in a wooden construction based on their experience with other housing construction solutions.

The periods of use of the individual wooden constructions were also surveyed. Constructions with a period of use of one year were the largest group. Groups with a period of use between 2 and 5 years and over 10 years were more or less equally large. The period of use of the individual wooden constructions is a sufficiently long period of use for an objective evaluation of the constructions by their users.

Figure 5 illustrates the effectiveness of the compared construction systems.

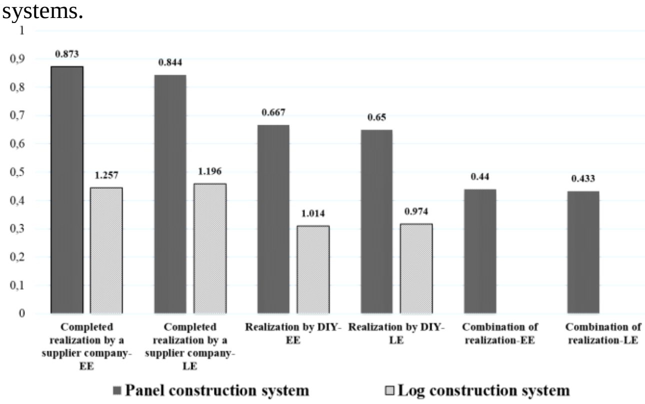

Fig. 5: Efficiency of the compared wood constructions' construction systems. Note: EE – energy-efficient, LE – low-energy house

Based on the resulting comparison (Fig. 5) and conclusions, we may state that the panel construction system, representing off-site technologies, is considerably more efficient when compared with instances of on-site technologies.

Findings drawn from the individual variants show that:

- panel constructions based on wood completed by a supplier firm are the most efficient,
- constructions where there was a combined execution method are the least efficient (a combination of execution by a supplier firm and DIY execution),
- DIY execution was not as efficient as execution by a supplier firm, although it was still more efficient than a combined execution method,
- efficiency in terms of meeting energy standards was by far the highest in the case of panel wood constructions and the lowest in the case of log constructions,
- in terms of energy standards, execution by a supplier firm achieved the highest efficiency, but in the case of DIY execution and a combined method, the resulting efficiency is comparable.

It is also interesting that from the point of view of sustainability, we would expect a better rating for log constructions, which are the most suit-able environmentally. However, it is precisely the synthetic indicator, which also took account of other sustainability criteria that revealed their shortcomings, especially regarding construction use comfort and quality.

4. Conclusion

It follows from the comparison of the efficiency of construction systems in the context of selected sustainability parameters that panel constructions based on wood executed by a supplier firm are the most efficient. Constructions executed using a combined construction method are the least efficient (a combination of execution by a supplier firm with DIY execution). Efficiency in terms of meeting energy standards is by far the highest in the case of panel wood constructions and the lowest in the case of log constructions. A higher energy standard (low-energy), as opposed to an energy-efficient one, was only reflected in a moderate increase in efficiency. Based on the resulting comparison and conclusions, we may state that the panel construction system, representing off-site technologies, is considerably more efficient when compared with instances of on-site technologies.

Acknowledgement

This contribution is a partial output of the VEGA - 1/0557/18 "Research and development of process and product innovations of modern methods of construction in the context of the Industry 4.0 principles" project solution.

References

[1] Mederly, P., Environmentálne indikátory trvalo udržateľného rozvoja, Disertation thesis, 2009. (online), [cit 2017-09-05], < https://lnk.sk/rGQS >.
[2] Tywoniak, J., Nízkoenergetický dom. Praha, (2005).
[3] Kupkovič M *Ekonomický podnikový slovník*, Vydavateľstvo Ekonomickej Univerzity, Bratislava, (1994).
[4] IEA (International Energy Agency, Technology Roadmap - Energy efficient building envelopes. OECD, (2013).
[5] Alchian AA, Demsetz H (1972) Production, Information Costs, and Economic Organization, *Am Econ Rev* 62 (5), 777-795.
[6] Ruuska A, Häkkinen T (2016) Efficiency in the delivery of multi-story timber buildings, *Energy Procedia* 96, 190 – 201.
[7] Pifko H. *NEED – Navrhovanie energeticky efektívnych domov*, Vydavateľstvo Eurostav, Bratislava, (2017).
[8] Gašparik J, Gašparík M (2012) Automated quality excellence evaluation. *Gerontechnology* 11 (2), 84.
[9] Pifko H, Špaček R. *Efektívne bývanie*, Vydavateľstvo Eurostav, Bratislava, (2008).
[10] Vlachynský K, Markovič P. *Finančné inžinierstvo*, Vydavateľstvo Ekonómia, Bratislava, (2001).
[11] Sosedová J. *Towards efficiency in Logistics Parks*, Acta Logistica Moravica, (2013).
[12] Finch G. *Energy Efficient Building Enclosure Design Guidelines for Wood-Frame Buildings*, RDH Building Engineering Ltd, (2013).
[13] Minarovičová K, Antošová N. (2016) Sustainability of ETICS maintenance technologies, *Applied Mechanics and Materials: Advanced Architectural Design and Construction* 820:194-199.
[14] Gibberd J. (2014) Sustainability impacts of building products: An assessment methodology for developing countries, *Acta Structilia* 21 (2), 69-84.
[15] Pošiváková T, Hromada R, Veszelits Laktičová K, Vargová M, Pošivák J, Molnár L. (2018) Selected Aspects of Integrated Environmental Management, *Ann Agr Env Med*.
[16] Maříková P, Mařík M. *Moderní metody hodnocení výkonnosti a oceňování podniku*, Vydavatelství EKOPRESS, Prague, (2005).
[17] Zuo J, Zhao ZY. (2014) Green building research – current status and future agenda: A review, *Renew Sust Energ Rev* 30, 271-281.
[18] Huttmanová E. Selected aspects and problems of evaluation of sustainable development. http://www.pulib.sk/elpub2/FM/Kotulic14/pdf_doc/11.pdf , 2017 (accessed 2 October 2017).
[19] Mederly P. *Environmentálne indikátory trvalo udržateľného rozvoja*. Dissertation thesis, (2009).
[20] Tambouratzis T. (2016) Analysing the construction of the environmental sustainability index 2005, *Int J Environ Sci Technol* 13, 2817–2836.
[21] Korytárová J, Hromádka V, Dufek Z. (2012) Large city circle road Brno. *Organ Technol Manag Constr Int J* 2012, 3, 584–592.
[22] Jain RK, Taylor JE, Peschiera G. (2012) Assessing eco-feedback interface usage and design to drive energy efficiency in buildings, *Energ Buildings* 48, 8-17.
[23] Lupisek A, Nehasilova M, Mancik S, Zelezna J, Ruzicka J, Fiala C, Tywoniak J, Hajek P. (2017) Desighn strategies of building with low embodied energy. *P I Civil Eng-Eng Su* 170(2):65-80.
[24] Zgutova K, Decky M, Sramek J, Dreveny I. (2015) Using of Alternative Methods at Earthworks Quality Control. World multidisciplinary earth sciences symposium, *WMESS 2015*, 15:263-270.
[25] Sebok T, Vondruska M, Kulisek K. (2001) Influence of MSFC-type dispersant composition on the performance of soluble anhydrite binders. *Cement Concrete Res* 31(11):1593-1599.
[26] Katunská J, et al. (2014) Diagnosis of elected industrial hall object and idea for its reconstruction. *Advanced Materials Research* 1057, 19-26.
[27] EN 15643-3: (2012) *Sustainability of Construction Works – Assessment of Buildings – Part 3: Framework for the assessment of social performance*, prepared by CEN/TC 350/WG 5.
[28] EN 15643-4: (2012) *Sustainability of Construction Works – Assessment of Buildings – Part 4: Framework for the assessment of economic performance*, prepared by CEN/TC 350/WG 4.
[29] STN 73 0540 *Tepelnotechnické vlastnosti stavebných konštrukcií a budov. Tepelná ochrana budov*. Bratislava: SÚTN (2002).
[30] STN EN 15643-3. (2012) *Sustainability of Construction. Assessment of Buildings. Part 3: Framework for Assessing Social Performance*.
[31] STN EN 15643-4. (2012) *Sustainability of Construction. Assessment of Buildings. Part 4: A Framework for Assessing Economic Characteristics*.
[32] STN EN 15978. (2012) *Sustainability of Construction. Assessment of the Environmental Performance of Buildings. Calculation Methods*.
[33] La Vardera, Letters from Sweden – panel building in Sweden vs the USA. (2008). (online), [cit 2018-01-05], <https://lnk.sk/lmn0>.
[34] Green Building Advisor. (2018). (online), [cit 2018-01-05], <https://lnk.sk/sRSV>.
[35] Handcrafted. (2018). (online), [cit 2018-01-06], <http://handcrafted-logs.com/services/>.