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RESEARCH ARTICLE

Perception of Economic, Social and Environmental Aspects of Modern Methods of Construction

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Abstract

Construction and operation of buildings are among the major consumers of material and energy resources and simultaneously contribute to the pollution of sustainable construction of buildings responds to the general requirements of sustainable development and qualitative represents a new approach to design, implementation and operation of buildings to meet the wide range of functional requirements, economic, environmental, social and cultural. Responses to the trend of sustainability are modern methods of construction (MMC). MMC are suggested to deal more effectively with uncertainties that construction commonly presents to clients and contractors, for example uncertainties inherent in traditional construction regarding than time, defects, safety, environmental impact, costs, profits and lifecycle performance. Regarding the MMC implementation in Slovakia, assembled buildings based on wood seem to be the most preferred construction system. In the study, presented in the paper, were searched already built and lived-in wood based family houses. The residents' attitudes to such type of buildings in the context with declared designing parameters of efficiency and sustainability are overlooked. The methodology of the research study is based on the socio-economic survey. A conclusion of this paper presents partial results concerning the investigation of selected aspects buildings based on wood, because these selected aspects are an important factor in the choice of the majority of clients in the choice of the construction system. Also important is the degree of compliance and the exploitation of the advantages of the individual systems, which are reflected in the cost, quality and speed of delivery building, but also its sustainability.

Keywords: *Wooden buildings, Economic, Social, Environmental, Socio-economic survey.*

Introduction

Sustainable development by Huttmanová [1] and Mederly [2] is a concept which came today in many spheres of economic and social life. Many still evaluated dimensions of development and growth, began to be recently supplemented the sphere of sustainability. However, the sustainability of development is quite difficult to quantify. It is particularly difficult to assess individual processes or phenomena in society, in the context of sustainability. The purpose of sustainability is not to restrict the development or slow the growth and development but also to find models of society development, not limiting for future generations. It comes to finding a new type of "healthy" development, which will be preserved longer, therefore a sustainable development. This was defined as a state of global equilibrium at which the global population and capital to maintain more or less constant level and trend of productivity growth, or decline these quantities must be kept under control. The terms sustainability and sustainable development were first used by [3] early 70s, particularly in relation to the knowledge contained in the report Club of Rome (1972), the uncontrolled growth of any type (whether stocks, production, consumption, pollution, etc.) it is not sustainable in an environment of existing limited resources. The very concept of sustainable construction term is not defined or interpreted clearly, so that neither its

principles and criteria are not easy to define precisely. Of the many previously published sources [1 - 9] after their summaries can be generalized aspects that the formulation of principles and criteria for sustainable buildings appear most frequently and which can be divided into three areas: environmental, social and economic.

Responses to the trend of sustainability are modern methods of construction (MMC). The modern methods of construction based on wood are the response to the above requirements as well as to trend of both, sustainable and effective construction. Manufacturing and construction of the wooden buildings, from applied materials and production technologies point of view, has definitely lower environmental impact compared to other traditionally preferred technologies (in Slovakia it is ceramic or silicate brickwork, monolithic reinforced concrete...). The MMC by Smith and Timberlak [8] presents the technologies that provide effective procedures of construction preparation and execution, resulting in a larger volume of production with higher quality and reduced time of their procurement. The advantages of the MMC are shorter construction time, fewer errors in construction, and reduced demands on energy consumption or reducing of construction waste generation. Their ambition by Burwood and Jess [9] is to enhance the construction efficiency through reducing of construction time, improvement of quality, sustainability and impact of the building and of the building process on environment. Lane [10] in its analysis of obstacles to greater use of modern methods of construction, represents MMC as products and processes designed to improve business efficiency, quality, customer satisfaction, impact on the environment, sustainability and predictability of the deadline set. MMC is engaged in looking at the possibility of improving the performance and effectiveness in building of construction as a whole. Authors Azman, Ahamad and Hilmi [11] maintains that the MMC in the construction industry have a higher productivity and better quality, as well as some benefits such as reduced construction time, lower overall construction costs, better quality, more durable and better architectural appearance, increased health protection at work and safety, conservation of materials, less construction waste, fewer emissions into the environment and reduce energy and water consumption. MMC represents, according to RNAO [12] better products and processes. Their aim is to increase business efficiency, quality and customer satisfaction, impact on the environment, sustainability and predictability of the delivery terms. MMC are therefore more focused on product. According to Burwood and Jess [9] are defined as MMC construction methods that provide efficient product management process to provide more and better products in less time, in different ways and also using different materials.

Sustainable and Modern Construction System Based on Wood

Generally, the modern methods of construction are technologies which make use of structures or their components manufactured in plants. The production of more or less completed components of building structures in the plants has a high potential for increasing the construction efficiency as at the production stage of building components as well as in the process of their integration in the site. In association with an increasing lack of building capacity, mainly skilled human resources real pressure on increasing the efficiency of the construction works. Therefore, also in areas where the not always effective procedures were preferred, are beginning to look and use innovative solutions. Responses to the demand for efficient, economic and sustainable solutions are modern methods of based on wood. Regarding the modern methods of construction implementation in Slovakia, assembled buildings based on wood seem to be the most preferred construction system.

One of the factors affecting the efficiency of the whole building is the speed of construction. Due to the shorter construction time of wooden buildings, the funds deposited begin to recover in a much shorter time than traditional masonry buildings. During the construction of wooden houses are used "dry" process, with the exception of the base plate, which allows for prefabricated houses in the winter months.

Prefabricated building requires almost no period of "maturation". This allows achieving a high productivity, in the manufacture of structural components, which takes place outside of the works in the production halls, as well as their subsequent assembling on site. When prefabricated houses is greater certainty that the price indicated in the contract will be respected as construction takes place in the short term and in relation to costs are not reflected effects such as price increases of materials, fuels or power, or redesigning, which usually occur with traditional technologies construction, which may result to the preceding construction and extension, as well as deterioration quality building.

Building constructions based on wood are capable of becoming economically interesting also in our regions, if they will effectively manage design, technology, logistics, quality management system in manufacturing and construction. One of the advantages of wooden houses by Cellar [13] is the variability of structures and composition of the walls, which can be designed as a low cost, low energy and passive models. This system is designed to build multi-storey buildings, apartment buildings, office buildings and houses. By Stefko [14] they can be divided into wooden buildings: prefabricated panel constructions, columnar constructions, timbered constructions, skeleton and half-timbered constructions. According to the Association of Wood Processors of Slovak Republic, the most widely used structural systems of prefabricated wooden buildings realized in Slovakia include panel constructions and columnar construction systems.

Off-site Construction Method Based on Wood - Panel Construction System

Structural elements - panels (wall, ceil, roof, gable, partition wall) are produced in different stages of completion in the production hall (Fig. 1) and subsequently transported to the construction site where are assembled to the structure. Build-up process is characterized by speed and precision. The panel generally consists of a wooden frame of profiled timber, covered on both sides with large-scale plates, filled with thermal insulation material. During the manufacturing, the panels are incorporated in the preparation for installation.

Fig. 1: Production hall of sandwich wall panels. (RD Rymarov [15])

Fig. 2: Construction of panel construction system. (HAAS Fertigbau [16])

Prefabricated construction panel system fully utilizes construction, manufacturing and assembly advantages of their production to the efficiency of the entire construction process. The key moment to increase the efficiency and degree of prefabrication is panel's finalization. Panel system has enormous potential for increasing efficiency in the design, production and construction phase. Manufacturing can be automated, thus increasing the quality of production and by re-implementation of the construction are obtained workmanship. Bearing system of prefabricated wooden houses is completed within a few days of starting the construction (Fig. 2). Other finishing and plumbing work ongoing after assembly of the individual elements.

On-site Construction Method Based on Wood - Columnar Construction System

Columnar structural system originates from USA and Canada, where it is still the most widely used building system of builded houses. The basic element of such a construction is supporting frame perimeter and partition walls of various timber profiles (Fig. 3). Ceiling structure of the columnar construction is composed of different profiles of timber or wood beams form I. The stability of the columnar construction provides the cladding of large agglomerated materials such as OSB board or gypsum board. Thermal requirements are secured by inserting thermal insulation (Fig. 4). Standard construction of the walls is similar to panel construction system, but the individual elements and layers of walls are completed directly on site.

Fig. 3: Columnar construction system (Dubjel and Bobeková [17])

Fig. 4: Inserting thermal insulation of walls.

Construction and assembly of columnar structural system is less demanding on a large mechanization. All layers of the structure and operation of installations are carried out on site, resulting in higher labor intensity of their execution and a higher proportion of the works on site. This causes a greater likelihood of low quality work, including the impact of climatic conditions.

Sustainability Buildings from Point of Economic, Social and Environmental Aspects

In the states of European Union, but not only in them, is trend to construct economic and sustainable buildings that reflect not only on lowering operational costs but also the social need for sustainable development from the tenants, investors and government. Due to an objective assessment of the sustainability of buildings were created by various complex certification systems. These systems contain more or less different criteria of sustainability.

Over the past 15 years was created several certification systems. Most of countries have developed their own certification system, and therefore more than 60 exist today at the national level. Although the core of any certification is the same, they can be different in view of climate, geographic location, traditions of construction technology, material base etc.

In general, local evaluation methodology is used, but also in some countries the methodology of other organizations are used with corrections for the specific conditions of the country. The best known and most accepted certification systems include the American LEED, British BREEAM, German DGNB, internationally recognized, Australian Green Star, France HQE, Fin PromisE, European LEnSE, Italian Protocollo ITACA and Protocollo SBC.

Various evaluation systems differ by demands and evaluation criteria. According to Lupíšek [18] in almost of all investigated systems the greatest importance is on environmental criteria. The other two sustainability criteria - economic and social - are reflected in systems by larger (economic) or smaller (social) scales (Fig. 5).

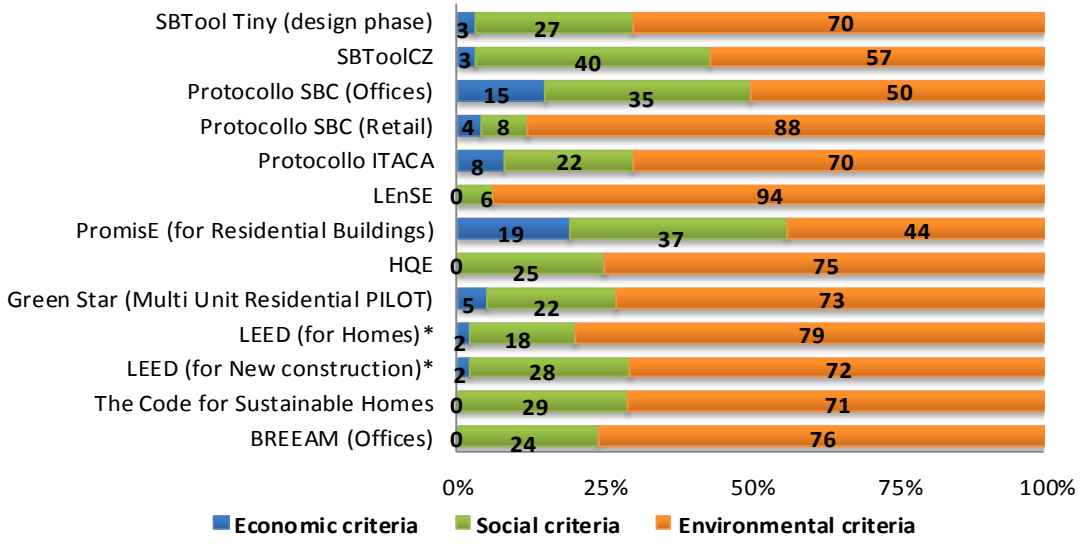

Fig. 5: Distribution of weights between groups of criteria in selected evaluation systems. (prepared according the source [18])

Despite the fact that the economic criteria in the evaluation systems have the smallest representation, most investors when choosing construction system is held in particular by economic aspects.

The Selection of Usage Parameters of Wooden Buildings

Currently, the sustainability criteria, divided into three groups, associating the economic, social and environmental criteria, are mostly used to assess buildings. These criteria are linked to each other; respectively some criteria underlie other ones. This resulted in existence of many different sustainability assessment systems [19 - 21].

In the social area, for example thermal comfort, acoustic and visual comfort, level of daylight, indoor air quality or space adaptability is assessed. In the environmental area, in particular application of renewable resources for energy or water providing is assessed. Even

though, the environmental parameters of building materials, waste generation (within manufacturing and construction) or the whole environmental impact of the building are also rated. Although the proportion of economic criteria has the lowest representation in assessment systems, just that criteria mostly influence investors "attitude" to sustainability in building procurement.

To select the usage parameters, several assessment systems respectively standardized systems as STN EN 15978, 15643-3, 15643-4, LEED, BREEAM, DGNB and SBTooL were applied. The systems assess buildings sustainability comprehensively from designing and construction point of view. In the further research, these parameters are incorporated into socio-economic exploration. The exploration is aimed at investigating the extent of declared usage parameters meeting in case of using phase of assembled wooden buildings. Given the different segmentation of criteria and parameters in different assessment systems, the selected parameters cannot be clearly attributed to one single area of criteria.

Despite the undeniable advantages widely associated with construction systems based on wood, the wooden buildings are not equally enforced in Slovakia. This is due low level of awareness and knowledge on the part of potential customers and investors as well as distrust of new, unverified construction technologies.

Therefore, the study is focused on a group of users of already settled buildings. The residents have the real practice of several years living in and so, they are able to appreciate the benefits of the wooden buildings on the basis of their experiences. It is one of the possible motions that should influence potential customers and satisfy them of generally declared benefits. It is through experience of customers, who have already used given "product".

Research Materials and Methodology

The research methodology is based on the socio-economic survey. The research subject is represented by already lived in wooden family houses and the matter of the survey consists in residents' feelings in the context of the level of meeting the initially declared usage parameters. The results should confirm or refute the initially declared parameters of wooden buildings from selected sustainability criteria point of view.

The socio-economic survey was conducted by questionnaire and quantitative methods of evaluation (in the form of multiple choices or scaling) as well as qualitative methods (through open responses by personal contact with respondents) were used.

The survey have run from the beginning of 2015 and given the still running research activities in this segment of construction, more data will be achieved in the future. The respondents, i.e. owners of wooden buildings were identified with the support of companies specializing in the manufacturing and construction of assembled wooden buildings in Slovakia. This fact should contribute to impartiality; the respondents did not feel the "pressure" from building contractors side.

Since in Slovakia the wood-based family houses are the most common from all the segment of wooden buildings, the respondents were owners or users of already lived in wood-based family houses. The questionnaire contains more than 50 questions divided into five parts: information on respondent, the origin of references on wooden building, data on the building, selected parameters of customer efficiency in the context of building sustainability, advantages/disadvantages – resume of respondent experiences. Answers to questions combined methods of choice, scaling and open responses.

Up to now, more than thirty wooden buildings were explored through the mentioned survey. The sample consisted of panel construction system and columnar construction system. In the paper are presented the results from 38 wood-based family houses. The using period of the surveyed buildings was from 1 year to 8 years. The age distribution of the wooden

houses demonstrates sufficiently long time for the real evaluation of the buildings from their users' side. Due to the large extent of data collected through questionnaire, only selected parts of the survey results are evaluated and discussed in the paper. The presented parts of the survey are focused on priority of selected criteria users before to the procurement of wooden building. Views of users were divided according to the construction system of wooden building in they are living.

For the assessment of significance of selected parameters we choose method of weighted average was used. The method uses the response rate and the distribution of respondents opinions to signification (+) or not signification (-) of selected criteria. For comparative assessment, the significance was determined:

The criterion is completely no significance (-2 weight)
The criterion is little significance (-1 weight)
The criterion is a moderately significant (0 weight)
The criterion is very significant (+1 weight)
The criterion is a highly significant (+2 weight)

The mean of each parameter was calculated by:

$$\overline{x_i} = \frac{\sum_{j=1}^{5} w_j * f_{ij}}{\sum_{j=1}^{5} f_{ij}} \quad (1)$$

where Wj is weights of the degree of significance j (-2, -1, 0, +1, +2)

where fij is corresponding frequencies of the degree of significance j of parameter i
and where $\sum_{j=1}^{5} f_{ij}$ is total number of respondents.

In the survey were evaluated these aspects: time of construction, Investment cost on building procurement, operating costs of the building, quality and comfort of living, ecological aspects, reference of companies and construction technology.

The mean $\overline{x_i}$ of each parameter represents the significance criterion, i.e. how significantly prefer users of selected criteria (Fig. 6, Fig. 7).

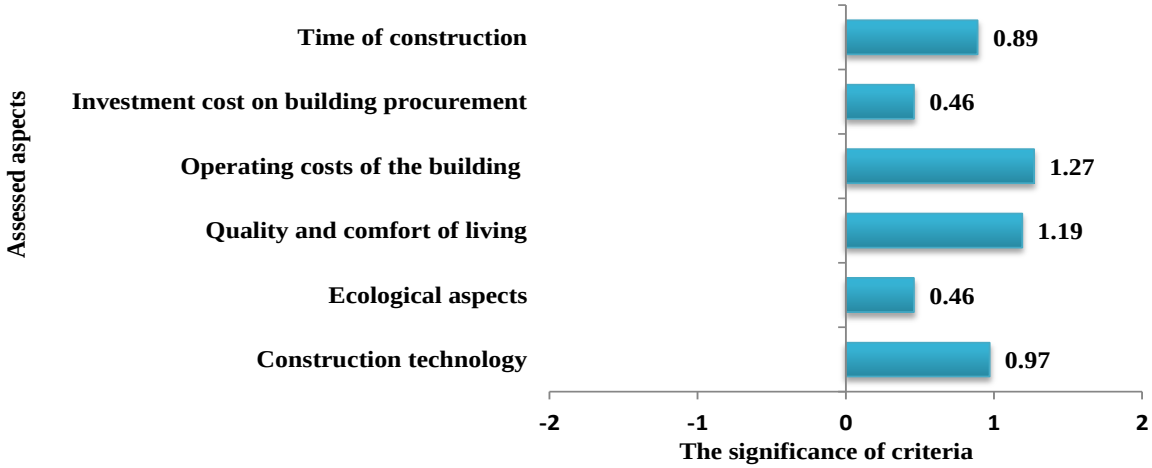

Fig. 6: Assessing the significance of selected aspects of wooden buildings

The same analysis we used in assessing the views of separately for the both technologies (columnar construction system and panel construction system). Significant differences with regard to different construction system appeared only on three parameters: time of construction, investment cost on building procurement and ecological aspects (Fig. 7).

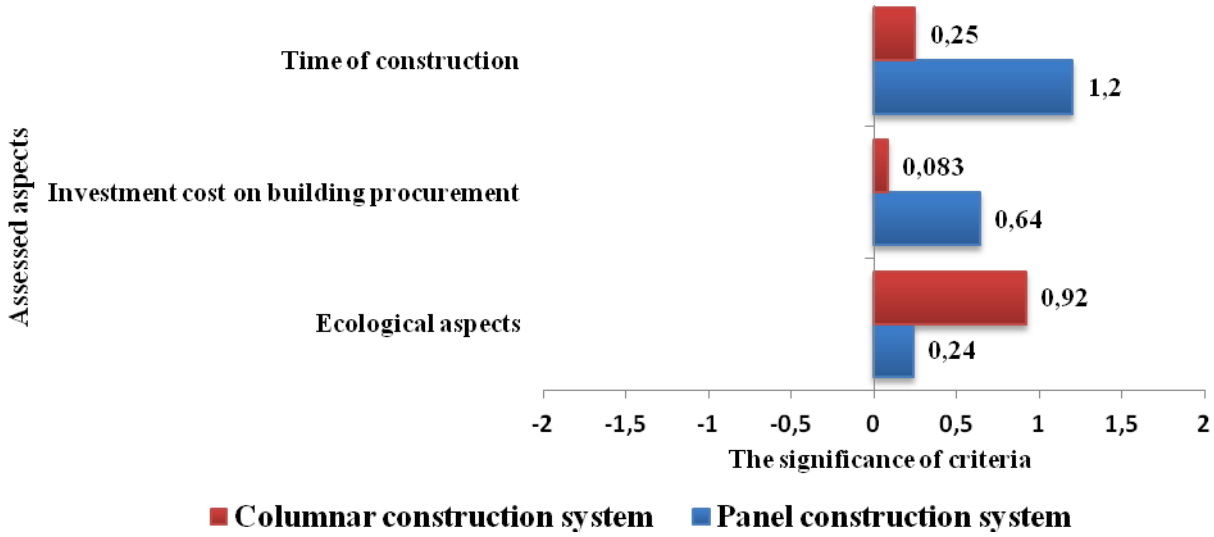

Fig. 7: Assessing the significance of selected criteria for both construction systems

Based on users experience with the use of wooden buildings there are also evaluated advantages and disadvantages of wooden buildings (Table 1).

Table 1: Evaluation of advantages and disadvantages of wooden building through users (in percentage of respondents)

Type of construction system	Columnar system construction		Panel construction system	
Assessed aspects	Advantages	Disadvantages	Advantages	Disadvantages
Time of construction	100%	-	100%	-
Investment cost on building procurement	80%	20%	87%	13%
Operating costs of the building	100%	-	100%	-
Quality and comfort of living	100%	-	96%	4%
Ecological aspects	100%	-	100%	-
Construction technology	100%	-	100%	-

Conclusion

According to image 6 users give the greatest significance on operating costs of the building and quality and comfort of living. Less significance was observed on construction technology and time of construction. The least significance for users places on ecological aspects and Investment cost on building procurement.

According to image 7 significant differences was in time of construction, investment cost on building procurement, Ecological aspects and reference of companies. User's columnar construction systems give the smallest priority to the time of construction because of realization of the columnar system lasts longer than a construction panel system. As for the investment cost on building procurement greater emphasis has been observed in user's panel construction system because a panel construction system can better monitor time of construction to which it relates accurately determined investment cost on building procurement. At prefabricated houses is greater certainty that the price indicated in the contract will be respected as construction takes place in the short term and in relation to costs are not reflected effects such as price increases of materials, fuels or power, or redesigning,

which usually occur with columnar construction systems, which may result to the preceding construction and extension, as well as deterioration quality building. In contrast, user's columnar wood buildings prefer ecological aspects of more than user's panel construction system because they see an on-site working with wood. Structural elements - panel construction systems are produced in different stages of completion in the production hall and subsequently transported to the construction site where are assembled to the structure and users are not directly visible production elements. In the other evaluated aspects were not significant differences.

According to table 1 significant difference was in investment cost on building procurement and it was little difference in quality and comfort of living. User's columnar systems were not very satisfied with the investment cost on building procurement because the price is influenced by many factors, especially time of construction. At the other side of the user panel construction systems have been more satisfied with the investment cost on building procurement because thereby it is the shorter construction time is can better predict the final cost of construction. Only 4% of user's panel construction systems were dissatisfied with the quality and comfort of living. In the other parameters were not differences and users were generally satisfied with the aspects evaluated.

From the analysis results show that the modern methods of wood-based offer many advantages and benefits. The benefits concern all major areas of sustainability such as environmental, social as well as economic sphere because all areas are mutually conditional. The survey shows that users before building of procurement give the greatest significance of operating costs of the building and quality and comfort of living. The main advantage of wood building that is used as the main building material wood which is a renewable and sustainable building material. As confirmed by the users of these buildings. Users evaluated as additional benefits mainly time of construction, operating costs of the building and construction technology. This survey can serve companies that sell wooden houses as a model which prefer their potential investors.

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