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MULTIPLE CRITERIA EVALUATION OF ASSEMBLING BUILDINGS FROM STEEL FRAME STRUCTURES

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Steel frame structures are often used in the construction of public and industrial buildings. They are used for: all types of slope roofs; walls of newly-built public and industrial buildings; load bearing structures; roofs of renovated buildings. The process of assembling buildings from steel frame structures should be analysed as an integrated process influenced by such factors as construction materials and machinery used, the qualification level of construction workers, complexity of work, available finance. It is necessary to find a rational technological design solution for assembling buildings from steel frame structures by conducting a multiple criteria analysis. The analysis provides a possibility to evaluate the engineering considerations and find unequivocal solutions. The rational alternative of a complex process of assembling buildings from steel frame structures was found through multiple criteria analysis and multiple criteria evaluation. In multiple criteria evaluation of technological solutions for assembling buildings from steel frame structures by pairwise comparison method the criteria by significance are distributed as follows: durability is the most important criterion in the evaluation of alternatives; the price (EUR/unit of measurement) of a part of assembly process; construction workers' qualification level (category); mechanization level of a part of assembling process (%), and complexity of assembling work (in points) are less important criteria.

Keywords: Steel frame structure, Technological solution, Assembling work, Network model, Multiple criteria evaluation.

1 INTRODUCTION

Steel frame structures are often used in the construction of public and industrial buildings. Buildings from insulated metal structures have the following advantages: excellent architectural look that meets the strictest requirements for modern buildings; simple and fast mounting enabling to erect a big building in a very short time calculated in months or even weeks; good thermal-technical characteristics as modern metal structures enable to avoid thermal bridging at connections and the thickness of heat insulating layer is selected according to applicable standards; good operation characteristics as reliable elements ensure the required tightness of the building, metal elements are protected from corrosion by more than one layer of coating.

Modern steel frames are made of the following components: bearing metal elements of the structural framework (partitions and load bearing elements); roof, roof-wall and wall cladding; partition insulation packages (thermal insulation, noise insulation, wind and vapour barriers).

Elements of partitions structures and external wall insulation systems are presented in Figures 1, 2.

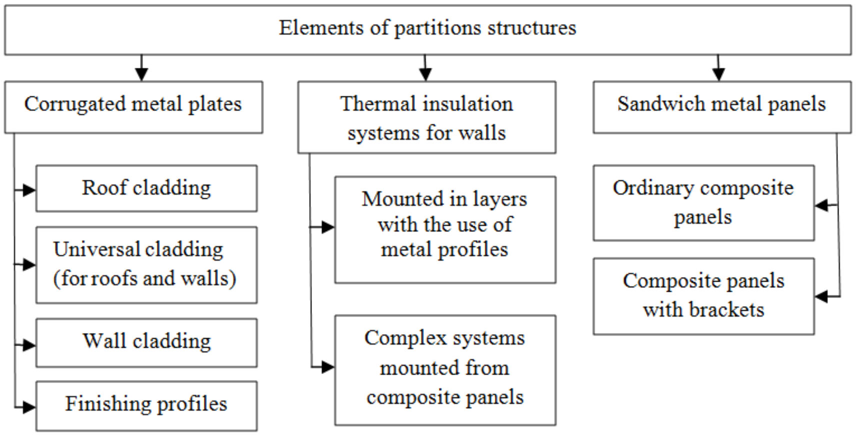

Figure 1. Elements of partitions structures.

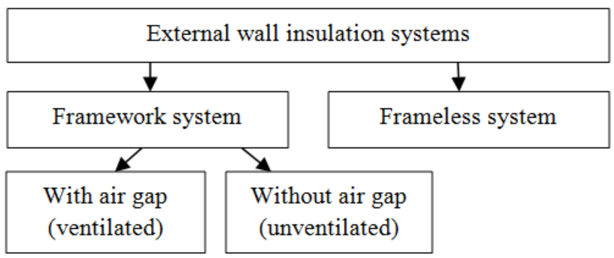

Figure 2. External wall insulation systems.

Methods of insulating walls of existing industrial buildings:

- Thermal insulating layer is fixed directly to the façade that is afterwards finished by reinforced (with mesh or fibre) plastering. It is a frameless insulation system.
- Wood or metal studs are fixed to the wall, thermal insulation is placed into the spaces between studs and various finishing panels are fixed to the studwork. It is a framework system (ventilated). It is a framework system (ventilated).
- Finished elements made of joined thermal insulation and finishing layers (composite panels) are fixed to the wall.

2 DESIGNING THE NETWORK MODEL FOR ALTERNATIVE MOUNTING SOLUTIONS IN STEEL FRAME BUILDING

2.1 Making Combinations of Complex Processes

The main stages for designing network models for steel frame building are as follows: buildings:

- making combinations of complex processes used in steel frame building;
- finding possible alternatives of partial processes in steel frame building;

- finding technological links between the alternatives of partial processes in steel frame building;
- drawing networks for steel frame building technology.

In terms of system approach, steel frame building is a complex process made of various partial (work) processes that can be completed by different working methods, which are determined by work object characteristics, construction materials, work tools, equipment, number of workers and their qualification. Each of the above factors is described by certain technical and economic indicators.

The complex process of steel frame building can be divided into the following partial technological processes: *F* – steel frame mounting, *B* – mounting of bearing structures (beams and trusses); *I* – installing connections (Figure 3).

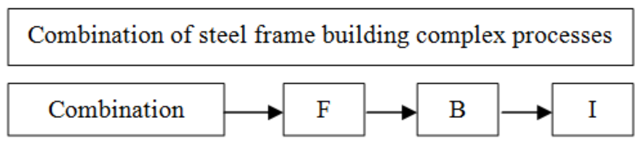

Figure 3. Diagram of steel frame building complex process combination.

The complex process of roof erection can be divided into the following partial technological processes: *P* – mounting of purlins, *IL* – inner layer mounting, *S* – sound insulation mounting, *T* – thermal insulation mounting, *W* – wind insulation mounting, *FL* – finishing layer (Figure 4).

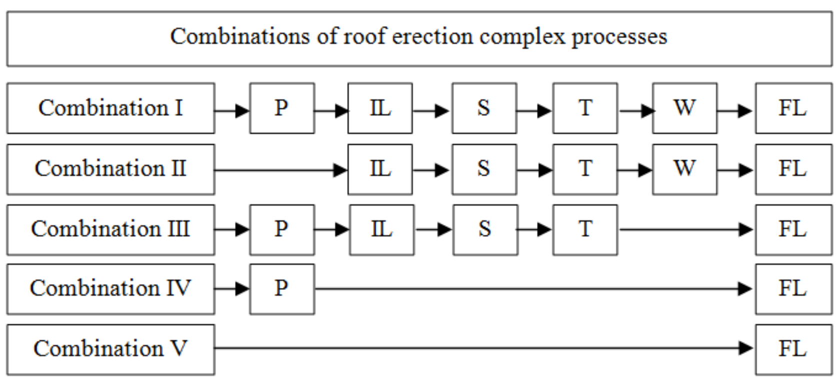

Figure 4. Diagram of roof erection complex process combination.

2.2 Alternatives of Partial Processes in Steel Frame Building

The analysis of steel frame building reveals many technological systems of this complex process. Many alternative solutions can be found by changing work methods. Different work methods result from the change of building structures, work tolls and mechanisms used.

Available alternatives of work processes used for the building a metal framework are presented in the Table 1 below.

Table 1. Alternatives of work processes used for the building a metal framework.

Partial process alternative code	Title of partial process in steel frame building: partial process alternatives (short description)
	Mounting of columns:
F1	manually, bolted connections
F2	manually, welding
F3	mechanically, crane lifting, bolted connections
F4	mechanically, crane lifting, welding
F5	mechanically, hoist lifting, bolted connections
F6	mechanically, hoist lifting, welding
	Mounting of bearing structures:
B1	mounting beams manually, bolted connections
B2	mounting beams manually, welding
B3	mounting beams, crane lifting, bolted connections
B4	mounting beams, crane lifting, welding
B5	mounting beams, hoist lifting, bolted connections
B6	mounting beams, hoist lifting, welding
B7	mounting trusses, hoist lifting, assembling on the ground
B8	mounting trusses at designated height, hoist lifting
B9	mounting trusses, assembling on the ground, crane lifting
B10	mounting trusses at designated height, crane lifting
	Making connections:
I1	making connections manually, welding
I2	making connections manually, bolting
I3	making connections, hoist lifting, welding
I4	making connections, hoist lifting, bolting
I5	making connections, crane lifting, welding
I6	making connections, crane lifting, bolting

2.3 Technological Links between Partial Processes in Steel Frame Building and Network Model Design

Network modelling of construction processes significantly improves operations management, work culture and efficiency, shortens the commissioning term, and reduces construction costs.

The method is beneficial only if the following conditions are met: well-organised data collection, transfer and processing; expedient system of decision making and task delegation to operators supported by computerised network and specialists highly competent in network planning and control.

The graphical representation of the variety of works in a construction process with marked technological and organizational links is called a network model (Janusaitis 1998). The network model with computed space, time and technological parameters is called a network. Alternatives of separate (partial) technological processes and dependency relationship between them must be set in the design of network technological model. Technological links are made for three building alternatives: steel frame (Figure 5) and roof (Figure 6). The quantitative and qualitative characteristics are shown in Table 2.

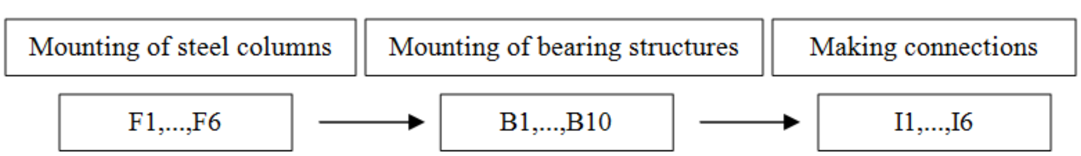

Figure 5. Technological links between partial processes in steel frame building.

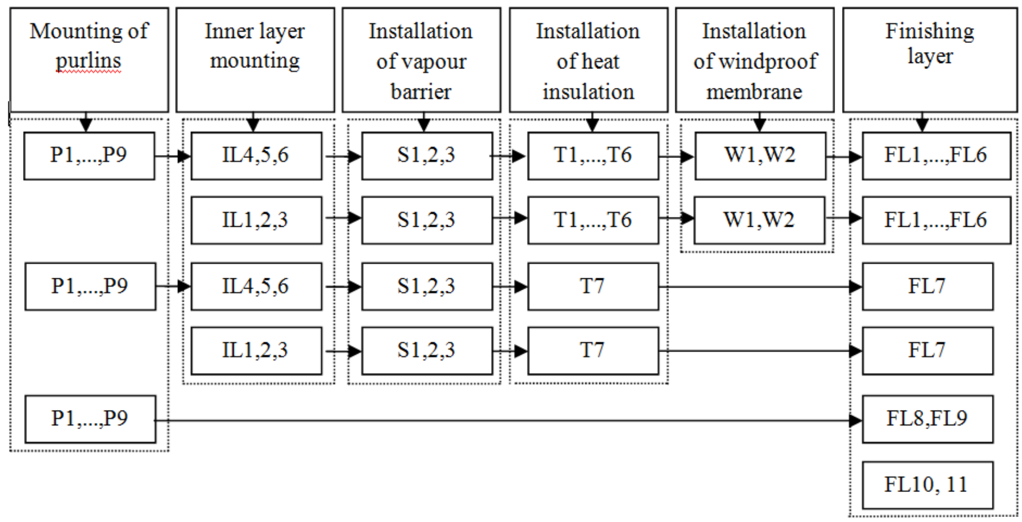

Figure 6. Technological links between partial processes in roof building.

Table 2. Quantitative and qualitative characteristics.

Criteria	**Unit of measurement**	**Definition**
The price of a part of assembly process	(EUR/unit of measurement)	Price (in EUR) per conventional unit of measure of the analysed partial process alternative
The qualification level of construction workers	category	Evaluation criterion indicating the workers' ability to do the work of the relevant complexity
Mechanization level of a part of assembling process	%	
Durability	in year	Life cycle of steel frames
Complexity of assembling work	in points	Complexity of work evaluation criterion

3 MULTI-CRITERIA EVALUATION OF ALTERNATIVE SOLUTIONS IN STEEL FRAME BUILDING

The rational alternative for steel frame building is found from the diagram presented in Fig. 7:

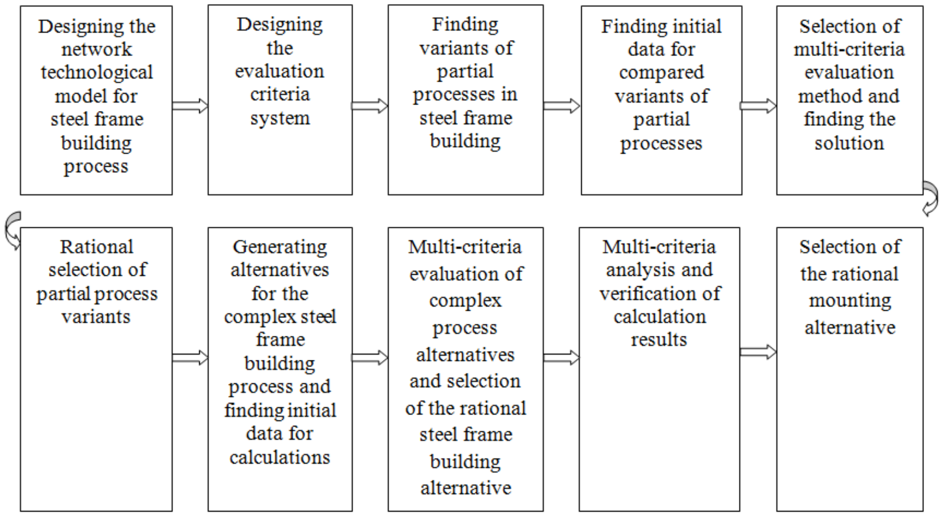

Figure 7. Algorithm for the selection of the rational alternative for the complex process.

The method of proximity to an ideal point can be applied to finding the most effective engineering solution alternative (Miniotaite 2016).

4 CONCLUSIONS

Taking into consideration the factors that affect the rationality of steel frame building process solutions it is feasible to do the technological modelling of multi-criteria evaluation of alternative buildings.

A criteria system for the evaluation of alternative partial processes must be designed in order to find the rational steel frame building alternative. Criteria values and importance may be subsequently adjusted taking account of priorities and the current situation.

In practice it is possible to find the most rational technological alternatives for metal framework, roof and wall structures separately with the help of network technological model and multi-criteria analysis of steel frame building solutions.

In multiple criteria evaluation of technological solutions for assembling buildings from steel frame structures by pairwise comparison method the criteria by significance are distributed as follows: durability is the most important criterion in the evaluation of alternatives; the price (EUR/unit of measurement) of a part of assembly process; construction workers' qualification level (category); mechanization level of a part of assembling process (%), and complexity of assembling work (in points) are less important criteria.

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