Evaluation of Supply Chain Management Systems Used in Civil Engineering

Michał Tomczak[1], Łukasz Rzepecki[1]

[1] Faculty of Civil Engineering and Architecture, Lublin University of Technology, ul. Nadbystrzycka 40, 20-618 Lublin, Poland

m.tomczak@pollub.pl

Abstract. One of the most important factors which have an effect on the cost and time of the building process is the organization of physical resources and the information flow structure. Depending on how effective this system is, a building project may end with a success or a failure. Because of many conditions of the construction executing and different needs of the contractors, there are different Supply Chain Management (SCM) systems connected with supplying construction projects: single-stage, multi-stage or combined. The article presents a comparative analysis of construction SCM systems based on a modified fuzzy AHP.
The modification of this method is based on the use of interval type-2 fuzzy sets to aggregate evaluation according to the idea proposed by Mikhailov. The use of such a model of group preferences of decision-makers, makes it possible to take into consideration both the linguistic imprecision of an evaluation and the small number of experts. The weight values of specific criteria and the final scale vector of considered variants are obtained during the analysis. This may give a recommendation to general contractors in construction projects about which evaluation criteria and supply systems are preferred.

1. Introduction

An effective realisation of construction projects requires an efficient and coordinated action from all participants. Keeping balance among all organizational units of a construction company largely reduces the risk connected with organization and investment planning. Widely understood logistics plays an important role in the proper functioning of modern construction enterprises [1, 2]. Among other factors, a guarantee of a successful construction process depends on the appropriate management of the supply chain with the flow of physical resources and information. Construction logistics mainly includes delivering necessary raw materials and products to a construction site as well as the time and place management of a delivery. The processes connected with buying construction goods and their delivery to the destination is important to continue the investment realisation without disturbances. Proper resource management, the effectiveness of supply units and the ability to deliver on time are among many factors which make works efficient, on time and which optimize the realization cost of construction works.

Knowing that every construction project has an individual character and unique conditions of task realization, it is impossible to find a universal system, which would offer service to different investments in an efficient way [3–6]. Because of this, a proper configuration and a specialist service for the structure connected with supply chain management is necessary owing to the comprehensive range of its tasks and a big potential to make the construction costs lower.

2. Logistic supply systems

An SCM system should be understood as an intentionally organized and connected set of subsystems related to production, distribution and warehousing which include some interdependencies occurring between their specific properties. In this way generally, the logistic processes connected with time-space transformation of physical, information and financial resources happening between specific sectors of a company are known as Supply Chain Management [7–9]. The following article concentrates only on those logistic structures which are connected with the flow of material goods. If we consider the structure, purpose, relations and interactions between the elements of a system, it can be classified according to different criteria. When it comes to the management of the supply chain process, the most important criterion will be the institutional one, which classifies the systems according to the type and number of units employed in the realization of its tasks. Because of that, it is possible to distinguish types such as macro-logistic systems, which are connected with state economy; micro-logistic systems, which can be found inside single organizations and meta-logistic ones, which generate connections between multiple companies [8, 10].

The meta-logistic system comes from the connection of micro-logistic subsystems of different institutions by creating common supply and distribution structures. If we consider the number and type of supply chain links, it is possible to divide meta-logistic systems into:
– single-stage (direct flow of resources),
– multi-stage (indirect flow of resources),
– combined (both direct and indirect flow possible), [7].

In single-stage systems, we observe a simple flow of resources, without any additional logistic processes occurring in the links or enterprises which participate in commodity dealing. This makes the logistic costs lower and the service less labour-consuming. The biggest limit in using this type of a system is an undesirable localization of a supplier, which makes it difficult to fulfil the demands of the receiver on time. Multi-stage systems have additional intermediaries through the channel used to transfer goods from a sender to a receiver. The intermediaries are responsible for additional product service. This includes proper distribution of goods between the right receivers, excess warehousing, storing supplies and making material reloading possible. What is better about multi-stage systems is the possibility to bring closer specific stakeholders which have common distribution structures by creating a cooperation centre. The combined systems are the connections of the properties of the single and multi-stage systems. They make both the direct and indirect types of resource flow possible with the use of cooperation and dividing centres [11–13].

The attempts to evaluate and choose an optimal SCM system, which often appear in publications [10], [14–16] are mostly based on cost, multi-criteria and also on simulation analyses. When choosing the right SCM system for an enterprise executing construction works under specific conditions, the economic, physical and organizational character of every investment must be considered. Because of this, it is very important to choose the right criteria and factors when evaluating logistic systems.

3. The Analytic Hierarchy Process

When decision-makers choose the best possible solution, they generally select the decision variant which will meet their preferences in the highest degree. One of the most popular methods for variant and criterion prioritization is the Analytic Hierarchy Process (AHP), which was created by T.L. Saaty [17]. In the AHP, a problem is organised according to a hierarchical structure. It is understood in such a way that the general objective a decision-maker (or decision-makers) intends to reach is positioned at the highest hierarchy level. A general objective, in turn, is composed of subcriteria which may be subject to further partitioning. At the lowest level of the hierarchical structure there are the decision variants [18]. In this method, evaluations are made by creating matrices of comparisons. When evaluating criterion pairs, it is necessary to check if the evaluations are consistent. To control the consistency of a matrix, Saaty suggests calculating two coefficients: CI (Consistency Index) and CR (Consistency Ratio). A matrix which includes pairwise comparisons can be accepted as consistent enough if the CR coefficient

is not higher than 10 %. What comes from the evaluations made by the experts is a scale vector, which shows a numerical value representing how important each criterion or variant is.

This way, by confronting the criterion evaluation and decision making variants, a subjective solution which meets the decision-making criteria in the best possible way is shown.

4. Fuzzy sets

Generally, we can divide uncertainty into many different types, but the two most important ones are the linguistic uncertainty and the uncertainty connected with randomness. The first one comes from the fact that every word has a whole range of different shades of meaning, and one term may have totally different meanings for every person. The other kind of uncertainty is connected with the fact that an occurrence of events is difficult to predict. To deal with these uncertainties (where "dealing with" is understood as model building and maximizing its effects) one can use respectively: the fuzzy set theory and the probability theory [19].

Despite superficial similar elements, there is a significant difference between the probability theory and the fuzzy set theory, both when it comes to the nature of things considered and their formal properties. The most important difference between those concepts is that the events studied in the probability theory are crisp sets and the uncertainty is connected with the fact that events happen randomly. While in the fuzzy set theory, the uncertainty is connected with the membership of an element in a set. What is more, probability is a normalized measure, whose basic attribute is additivity and the sum of possibilities must equal 1. The fuzziness is an assessment, which is not additive or normalized [20].

The fuzzy set theory, announced by Zadeh in 1965 [21], has been criticized from the start for the fact that it needs a crisp membership function, which is not always possible to get and is somehow contrary to the very concept of fuzzy set theory itself. To meet the expectations, in 1975 Zadeh [22] expanded his theory with sets of the fuzzy membership function, which are called type-2 fuzzy sets. Thanks to those sets, it is possible to model the cases in which determining a crisp membership function is problematic. Type-2 fuzzy sets make it possible to model the linguistic uncertainty more precisely and deal with it better in the process of decision making than type-1 fuzzy sets [23–25].

In the probability theory, the whole data about the random uncertainty is obtained from the probability density function or the probability mass function. Unfortunately, in many real-life cases, it is impossible to determine the functions mentioned above, so in the practical use an average and a variance is used to describe the random uncertainty. Using an average alone does not tell much about the distribution of probability – the information about the dispersion of events around the average is delivered by the variance. It is similar in the fuzzy set theory – they require a dispersion measure which is the footprint of uncertainty of the type-2 fuzzy sets [22].

A special case of type-2 fuzzy sets are interval fuzzy sets, where the third dimension of a membership function is ignored because it has the same value in each point. Calculations made on the models described using interval type-2 fuzzy sets are much simpler and need much less computing power than in the case of problem calculation presented using generalized type-2 fuzzy sets. Because of that, the interval type-2 fuzzy sets are the most popular kind of type-2 fuzzy sets used in practice [23].

Firstly, a type-2 fuzzy set $\tilde{A}$ will be defined: a type-2 fuzzy set $\tilde{A}$ in the universe of discourse X can be represented by a type-2 membership function $\mu_{\tilde{A}}$, shown as follows [26]:

$$\tilde{A} = \{((x,u), \mu_{\tilde{A}}(x,u)) \mid \forall x \in X, \forall u \in J_X \subseteq [0,1], 0 \le \mu_{\tilde{A}}(x,u) \le 1\}, \tag{1}$$

where J_X denotes an interval $[0,1]$. The type-2 fuzzy set $\tilde{A}$ also can be represented as follows [26]:

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_X} \mu_{\tilde{\tilde{A}}}(x,u)/(x,u), \tag{2}$$

where $J_X \subseteq [0,1]$ and $\iint$ denotes the union over all admissible x and u.

Let $\tilde{\tilde{A}}$ be a type-2 fuzzy set in the universe of discourse X represented by the type-2 membership function $\mu_{\tilde{\tilde{A}}}$. If all $\mu_{\tilde{\tilde{A}}}(x,u) = 1$ then $\tilde{\tilde{A}}$ is called an interval type-2 fuzzy set [27]. An interval type-2 fuzzy set $\tilde{\tilde{A}}$ can be regarded as a special case of a type-2 fuzzy set, represented as follows [26]:

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_X} 1/(x,u), \tag{3}$$

where $J_X \subseteq [0,1]$.

The upper membership function and lower membership function of an interval type-2 fuzzy set are type-1 membership functions, respectively [24]. A triangular interval type-2 fuzzy set, which is used in this paper (Fig. 1.), is explained as a $\tilde{\tilde{A}}_i = (\tilde{A}_i^U; \tilde{A}_i^L) = ((a_{i1}^U, a_{i2}, a_{i3}^U; 1), (a_{i1}^L, a_{i2}, a_{i3}^L; 1))$ where $\tilde{A}_i^U$ and $\tilde{A}_i^L$ are type-1 fuzzy sets, $a_{i1}^U, a_{i3}^U, a_{i2}, a_{i1}^L, a_{i3}^L$ are the references points of the interval type-2 fuzzy set $\tilde{\tilde{A}}_i$. is the membership value of element a_{i2} in the upper and the lower triangular membership function $\tilde{\tilde{A}}_i, 1 \leq i \leq n$ [23], [24], [28].
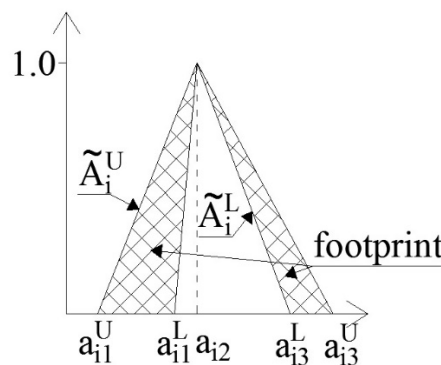
Figure 1. Example of triangular fuzzy type-2 set $\tilde{\tilde{A}}$

5. A description of the used group multi-criteria decision making support method

To compare the supply chain management systems in construction, we used the method which is a variation of the AHP method as taken by Mikhailov [29], in which the group preferences of the decision-makers are modelled with the use of triangular interval type-2 fuzzy sets. In the same way, as in the original AHP, in this method the scale vector is received by comparing the decision variant pairs according to consecutive criteria and by comparing the criteria among one another. The components of the vector make it possible to rank the decision variants and select the best of them. The first stage of this method is to calculate the arithmetic mean and the standard deviation of the evaluations:

$$\overline{a}_{ij} = \frac{1}{K} \sum_{k=1}^{K} a_{ijk}, \quad i = 1,2,...,n-1, \ j = 2,3,...,n, \ j > i, \tag{4}$$

$$\sigma_{ij} = \frac{\sqrt{\frac{\sum_{k=1}^{K}(a_{ijk} - \overline{a}_{ij})^2}{K-1}}}{c_4}, \quad i = 1,2,...,n-1, j = 2,3,...,n, j > i, \tag{5}$$

where:

K – the number of experts who take part in the decision making,

n – the number of decision variants according to the established criteria,

a_{ijk} – the evaluation coming from the comparison of the decision variant i with the decision variant j made by the expert k,

c_4 – is the coefficient used for calculating the estimator of the unbiased standard deviation $(c_4 \approx 1 - (1/4K) - (7/32K^2))$.

The values m_{ij}, l_{ij}, u_{ij} are calculated in the same way as in the Chang's method [30]:

$$l_{ij} = \min_{k=1,2,...,K}\{a_{ijk}\}, \tag{6}$$

$$m_{ij} = (\prod_{k=1}^{K} a_{ijk})^{\frac{1}{K}}, \tag{7}$$

$$u_{ij} = \max_{k=1,2,...,K}\{a_{ijk}\}, \tag{8}$$

and those values on a given α-level are determined in the following way:

$$l_{ij}(\alpha_l) = l_{ij} + (m_{ij} - l_{ij}) \cdot \alpha_l, \tag{9}$$

$$u_{ij}(\alpha_l) = u_{ij} - (u_{ij} - m_{ij}) \cdot \alpha_l. \tag{10}$$

Contrary to type-1 fuzzy sets, the end-points of the α-cuts of type-2 fuzzy sets are not points but intervals of the length:

$$d_{ij}(\alpha_l) = \sigma_{ij} \cdot (1 - \alpha_l). \tag{11}$$

The interval $d_{ij}(\alpha_l)$ can be divided into two subintervals: the inner one of the length $d_{ij}^I(\alpha_l)$ and the external one of the length $d_{ij}^E(\alpha_l)$ (Fig. 2), and their lengths will be determined as follows:

$$d_{ij}^I(\alpha_l) = d_{ij}(\alpha) \cdot c_4, \tag{12}$$

$$d_{ij}^E(\alpha_l) = d_{ij}(\alpha) - d_{ij}^I(\alpha_l). \tag{13}$$

In a similar way to the Mikhailov's approach [29] the membership function is decomposed using α-cuts and it is accepted that the crisp preference evaluations of the decision-makers are located within the end-points determined by these α-cuts:

$$l_{ij}(\alpha_l) \mathrel{\widetilde{\leq}} \frac{\omega_i}{\omega_j} \mathrel{\widetilde{\leq}} u_{ij}(\alpha_l), \alpha \in [0,1]; i = 1,2,...,m-1; j = 1,2,m; i < j; l = 1,...,L, \tag{14}$$

where the „$\widetilde{\leq}$" means "fuzzy less or equal to zero". The relation (14) can also be expressed as:

$$\begin{aligned} \omega_i - \omega_j u_{ij}(\alpha_l) &\mathrel{\widetilde{\leq}} 0, \\ -\omega_i + \omega_j l_{ij}(\alpha_l) &\mathrel{\widetilde{\leq}} 0. \end{aligned} \tag{15}$$

When it comes to the above relation of inequality, it can be described a matrix form:

$$\mathbf{R}(\alpha_l)\boldsymbol{\omega} \overset{\sim}{\leqq} 0, \quad i < j; i, j = 1, ..., n. \tag{16}$$

Using the Zimmermann transformations [31], the fuzzy membership function of the relation "less or equal to zero" for the line j can be described as (Fig. 3):

$$\mu_{x\overset{\sim}{\leqq}0}(x) = \begin{cases} 1, & x \leq -d_{ij}^{E}(\alpha_l), \\ 1 - \dfrac{x + d_{ij}^{E}(\alpha_l)}{d_{ij}(\alpha)}, & -d_{ij}^{E}(\alpha_l) < x \leq d_{ij}^{I}(\alpha), \\ 0, & x > d_{ij}^{I}(\alpha). \end{cases} \tag{17}$$

In the applied method, the issue is formulated as a fuzzy problem of linear programming with the maximization of satisfaction of the whole group of decision-makers marked as the λ symbol:
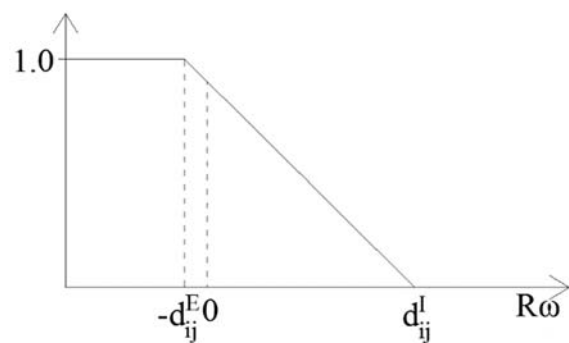
$$\begin{aligned} & \max \lambda \\ & d_{ij}(\alpha_l)\lambda + \mathbf{R}_j(\alpha_l)\boldsymbol{\omega} \leq d_{ij}^{I}(\alpha_l), \\ & \sum_{i=1}^{m} \omega_i = 1, \\ & \omega_i > 0, \\ & i = 1, 2, ..., m, \\ & j = 1, 2, ..., 2p. \end{aligned} \tag{18}$$

m – the number of evaluations which are the coefficients reflecting the preference intensity of a single compared decision variant in respect to the other one ($m = n(n-1)/2$).

p – the number of pairwise comparisons, $p \leq m(m-1)/2$.
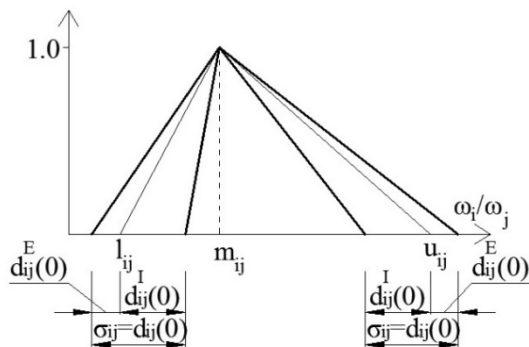
Figure 2. The aggregation of the assessments of a group of decision-makers using the type-2 fuzzy set

Figure 3. The fuzzy membership function of the relation "less or equal to zero"

The degree of the evaluation consistency is determined using an optimal value of the $\lambda^{\star}$ parameter. The $\lambda^{\star}$ parameter with a value higher than one means a full consistency of evaluation, while less than zero a total lack of consistency.

After solving the linear programming task for all of the selected α-levels, the outcome values should be weighted using the following formula:

$$\omega_i = \frac{\sum_{l=1}^{L} \alpha_l \cdot \omega_i^*(\alpha_l)}{\sum_{l=1}^{L} \alpha_l} \ . \tag{19}$$

6. An example of evaluation of selected SCM systems in civil engineering

The method shown above was used to hierarchise the selected SCM systems used in construction. The evaluated SCM systems are considered in relation to the situation of supplying a construction project with materials necessary to complete the investment which involves erecting a 4-storey office building up to the point of the construction shell. The construction site, situated on the city outskirts, is very large and there is a road infrastructure next to it. The building under construction has a mixed construction method, where the masonry walls are supported with reinforced concrete pillars, while the floors are made of prefabricated elements. The works are carried out by 5 independent subcontractors and the completion must not take more than 6 months.The structure of each considered system includes logistic processes connected first of all with the choice of suppliers and taking orders from the customers, completing and preparing them for sending (packing, describing and checking if they match the order). Another element of the supply chain is the transportation and in some cases warehousing of the ordered products in the cooperation and division centres. The ending phase is related to providing the contractors with specific materials.

The first of the evaluated SCM models (single-stage) deals with individual process of supply to independent construction contractors (V1). Each of the subcontractors is individually responsible for placing orders directly at the selected supplier and for organizing transportation using their own transport equipment or the measures which belong to the supplier in charge of the order. The role of the general contractor is limited to organizing and sharing place necessary for unloading the delivered materials and raw materials.

The second model is an example of multi-stage SCM system, in which the logistic service of supply is provided by a specialized department of the general contractor (V2). The subcontractors communicate the need for the building materials in proper advance and at the time demanded by the management of the logistic department. The general contractor is responsible for the realization of delivery through ordering proper goods, setting the delivery time and organizing a place for unloading. In addition to this, after arriving at the construction site, the delivery must be controlled to ensure that it matches the order and then directed to the final recipient.

The third system model uses the support of an external institution specializing in complex logistic service to investments (V3). A logistics centre, which is the middle link of the supply chain and where all of its streams intersect is a unit which offers a wide range of logistic functions and processes. It is a unit which has machines and equipment of the highest quality as well as a very large warehousing area that is able to store different sorts of goods, thanks to which it is able to offer service to many investments at the same time. The centre also has a specialized information system used for transferring data between the suppliers, the centre and the recipients. A management unit is placed inside the construction site area, whose task is to take orders from the construction contractors and forward them to the centre. The centre employees, who have the construction work schedule, are responsible for fulfilling orders and the organization of deliveries so that they meet the needs.

During the evaluation of selected SCM systems, the following criteria were considered:
- timeliness of deliveries,
- the possibility to fulfil emergency orders,
- crediting of expenses,
- the number of reloadings (when it comes to wastage of materials),
- warehousing infrastructure costs.

Four civil engineers with several years of experience were asked to assess the presented variants of SCM systems for the considered investment. The result of the experts' assessment is shown in Table 1.

Table 1. The matrices of the pairwise comparisons of the criteria weight

	Expert 1					Expert 2				
	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
C1	1.000	2.000	1.000	5.000	2.000	1.000	1.000	2.000	3.000	4.000
C2	0.500	1.000	0.500	3.000	1.000	1.000	1.000	2.000	3.000	4.000
C3	1.000	2.000	1.000	5.000	2.000	0.500	0.500	1.000	2.000	3.000
C4	0.200	0.333	0.200	1.000	0.333	0.333	0.333	0.500	1.000	2.000
C5	0.500	1.000	0.500	3.000	1.000	0.250	0.250	0.333	0.500	1.000
	Expert 3					Expert 4				
	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
C1	1.000	1.000	0.500	3.000	3.000	1.000	1.000	0.500	5.000	0.500
C2	1.000	1.000	0.500	3.000	3.000	1.000	1.000	0.500	4.000	0.500
C3	2.000	2.000	1.000	4.000	4.000	2.000	2.000	1.000	5.000	1.000
C4	0.333	0.333	0.250	1.000	1.000	0.200	0.250	0.200	1.000	0.200
C5	0.333	0.333	0.250	1.000	1.000	2.000	2.000	1.000	5.000	1.000

The calculations showed the final weights of individual criteria for the evaluation of the SCM systems to construction site (Table 2). The experts assessed timeliness of delivery, and the possibility of crediting of expenses the most highly, with the latter criterion receiving a little higher score. The criteria connected with the number of reloading and warehousing infrastructure costs were assessed as the least important.

Table 2. The obtained criteria weights of the SCM systems based on the assessment given by the experts

Criterion	C1	C2	C3	C4	C5
Criteria weights	0.283	0.240	0.275	0.074	0.128

Also, the experts made pairwise comparisons of SCM system variants with respect to specific criteria. The results of this assessment are in Table 3.

Based on the experts' assessment, the SCM system for construction which used a logistic centre received the score of 0.398 and was found the best in the final ranking. The worst, however, was the system with direct supplies (0.286). A detailed ranking of SCM systems for construction is in Table 4. It must be noticed that the differences between individual variants are not so big (the difference in the assessment of the best and the worst system is 0.112) and even the smallest changes of the performance conditions could make a difference in the final ranking.

The calculations were done using Microsoft Excel 2013 and LINGO 14.0.

Table 3. The decision-makers' preferences connected with SCM systems shown in a nine-point scale

C1	Expert 1			Expert 2			Expert 3			Expert 4		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
V1	1.000	0.200	0.167	1.000	0.250	0.200	1.000	0.250	0.167	1.000	0.200	0.200
V2	5.000	1.000	0.333	4.000	1.000	0.500	4.000	1.000	0.500	5.000	1.000	1.000
V3	6.000	3.000	1.000	5.000	2.000	1.000	6.000	2.000	1.000	5.000	1.000	1.000
C2	Expert 1			Expert 2			Expert 3			Expert 4		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
V1	1.000	0.167	0.143	1.000	0.250	0.125	1.000	0.333	0.111	1.000	0.250	0.200
V2	6.000	1.000	0.500	4.000	1.000	0.333	3.000	1.000	0.250	4.000	1.000	0.500
V3	7.000	2.000	1.000	8.000	3.000	1.000	9.000	4.000	1.000	5.000	2.000	1.000
C3	Expert 1			Expert 2			Expert 3			Expert 4		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
V1	1.000	5.000	7.000	1.000	2.000	0.167	1.000	0.167	0.167	1.000	6.000	7.000
V2	0.200	1.000	3.000	0.500	1.000	0.125	6.000	1.000	1.000	0.167	1.000	2.000
V3	0.143	0.333	1.000	6.000	8.000	1.000	6.000	1.000	1.000	0.143	0.500	1.000
C4	Expert 1			Expert 2			Expert 3			Expert 4		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
V1	1.000	3.000	8.000	1.000	2.000	7.000	1.000	1.000	6.000	1.000	1.000	8.000
V2	0.333	1.000	4.000	0.500	1.000	5.000	1.000	1.000	6.000	1.000	1.000	7.000
V3	0.125	0.250	1.000	0.143	0.200	1.000	0.167	0.167	1.000	0.125	0.143	1.000
C5	Expert 1			Expert 2			Expert 3			Expert 4		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
V1	1.000	1.000	8.000	1.000	1.000	7.000	1.000	3.000	8.000	1.000	2.000	8.000
V2	1.000	1.000	7.000	1.000	1.000	7.000	0.333	1.000	5.000	0.500	1.000	5.000
V3	0.125	0.143	1.000	0.143	0.143	1.000	0.125	0.200	1.000	0.125	0.200	1.000

Table 4. The preference values of the group of experts

System variant/ Criterion	C1	C2	C3	C4	C5	ω_i
V1	0.091	0.080	0.477	0.545	0.544	0.286
V2	0.367	0.274	0.250	0.381	0.388	0.316
V3	0.542	0.646	0.273	0.074	0.069	0.398

7. Conclusion

The choice of system has a significant effect on the course of executing and the cost of a construction project. It shows how important it is to deliver suggestions to general contractors about the weak and strong aspects of particular SCM systems for construction based on an objective and detailed analysis. In this paper, through the use of the assessment based on group decision making, it became possible to reach the synergy effect of several experts' knowledge and experience. Thanks to the modified AHP it was possible to take into consideration both the differences among the experts' assessments and the small number of decision-makers. In this way, we obtained the scale vector, which arranges particular SCM systems in the order reflecting their usefulness in respect to the established assessment criteria.

The authors can see a need for a further development of the topic discussed in the paper. It seems that the most interesting way to develop the topic would be to carry out an analysis based on the evaluation provided by many experts. Also, the assessment should concern not only a single case, but the organization of wider construction supply process in general. This would involve the consideration of a higher number of aspects connected with the functioning of logistic systems of construction.

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