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THE USE OF AN ARTIFICIAL NEURAL NETWORK IN THE PROCESS OF CHOOSING THE PROJECT SUPPLY CHAIN BY THE PRINCIPAL CONTRACTOR

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Abstract: The project supply chain is characterized by many risks that expose the participating companies to bankruptcy, including primarily the principal contractor. For this reason, it is desirable to have a tool that will allow us to assess whether it is worth participating in such a chain without the risk of bankruptcy. The study showed that it can be an artificial neural network, whose support consists in indicating in which project supply chain the principal contractor should participate. In addition, it was shown which factors should be taken into account by them.

Keywords: risk, project, neural network, simulations, bankruptcy, supply chain

JEL classification: C45, G32

INTRODUCTION

The project supply chain is an issue which in Polish and foreign literature is characterized mainly in terms of logistics, without taking into account the risk and uncertainty. In addition, it is identified mainly with the construction industry [Sobotka, Wałach 2011], which can create such definition problems as well as problems with identifying factors that expose the entire project supply chain to risk. It is worth mentioning here that for the first time the concept of supply chain

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construction for the implementation of a construction project was relatively thoroughly characterized, only in the mid-90s [O'Brien 1998]. Although various aspects of the project supply chain have been already characterized, yet the fact that participation in it may expose the principal contractor, who is the most important element of such a chain, to the risk of bankruptcy, has not been taken into account. Such a study also causes problems because the number of projects implemented in such chains by enterprises is usually small, so there is a lack of historical data. Therefore, it should be assumed in the analyzes that knowledge about them is small, and the number of chains constituting the research base should also not be large.

Considering the above and wanting to fill the cognitive gap, it was decided to try to use an artificial neural network to support the functioning of the principal contractor, who may have a problem with identifying factors affecting the efficiency of the project supply chain, which means that he cannot assess in which chain he should participate, and which he should reject (at least because of the exposure to bankruptcy). All this is the main purpose of the publication, while the secondary goal is to determine such factors and express them in a numerical form for the use of an artificial neural network. The article uses a set of hypothetical data, using artificial neural networks and literature studies.

GENERAL PRESENTATION OF THE PROJECT SUPPLY CHAIN

There are few papers in Polish and foreign literature that precisely characterize the project supply chain, taking into account its most important features. After conducting literature research, it was found that the best definition was presented in 2007 and it describes the project supply chain as "(...) the global network used to deliver a project from raw materials to the final project customer through an engineered flow of information and physical distribution. The project supply chain thus involves the principal contractor who is in charge of the management of the project, the clients and their own clients, the suppliers and their own suppliers and subcontractors, the subcontractor and their own subcontractors [Parrod et. al. 2007]. Although the literature describing the presented matter is poor, however narrowing the considerations to the construction industry, it can be assumed that there are four most important areas concerning the management of such a supply chain [Vrijhoef, Koskela 2000]. However, emphasis should be placed on activities carried out on the construction site in order to minimize the costs and duration of the project. This can be done with the help of the correct relationship between the principal contractor and suppliers. One of the areas of management is related to integrated management and improvement of the entire supply chain as well as improvement of activities carried out at the construction site. All in all, such a chain is inseparably connected with the risk, the largest part of which the value cannot be precisely determined, is borne by the principal contractor. The latest research already includes the analysis of the risk of this chain, but most researchers examine it based on a demand assessment, or take into account its uncertain environment [Lian, Ke 2018]. However, there is a lack of research related to supporting the risk management process that would include assistance in the assessment of specific project supply chains. The problem, however, is that each of them is unique, so it's difficult to determine its most important features in detail. For this reason, five value drivers described in the literature were selected, which are strategic factors that significantly increase the value of such a chain and provide its competitive advantage [Venkataraman, Pinto 2008], and which can help build a tool supporting the assessment of this chain. These factors are:

- Customer - it is emphasized that the final recipient of the project resulting from the functioning of the chain is the most important value driver, here the project's value is determined;
- Cost - costs are also an important value driver of the chain, because there is a need to minimize and control them, because cost strategies may cause the need to make changes in the chain itself;
- Flexibility - is defined as the ability to respond quickly to changes in customer preferences, or to changes in the scope of the entire project. For example, it can be seen as giving the customer the freedom to make significant changes to the ongoing project;
- Time - this driver together with costs and quality represents the three most important constraints for projects, so if the project is completed on time or ahead of schedule, then the value of the project supply chain management can be expected to increase;
- Quality - there are many definitions of quality, however, in relation to the project, it can be defined in such a way that it means a situation in which the product of the project meets or even exceeds the expectations of customers. To sum up, quality as the last value driver is designed to ensure a certain level of functionality of the project result, its delivery at a reasonable price and at a given time, thus meeting customer's expectations.

Taking into account the features of the project supply chain and its value drivers mentioned in the work, an attempt was made to build an artificial neural network, which can be an important element supporting the principal contractor within such a chain.

ARTIFICIAL NEURAL NETWORK IN THE CONTEXT OF DETERMINING THE SELECTION OF THE PROJECT SUPPLY CHAIN

The paper attempts to configure an artificial neural network in order to serve as a tool supporting the determination of the selection of a specific project supply chain. It is created by a large number of neurons [Tadeusiewicz 1993] processing information, they can also be called a binary element [Arbib 2003]. They are connected into one network with specific weights, modified during the learning process, which is divided into three types: supervised learning with the teacher (the set of learning pairs includes the input vector and the correct answer vector, i.e. the correct answer for given vectors from the input space is known [Ghosh-Dastidar, Adeli 2009], unsupervised learning (it does not allow the possession of information that would describe the correctness of the answer that would result from the operation of the network, reinforcement learning (it does not assume the existence of a teacher, but only a criticism, assessing the correctness of the tendency to answer.

The use of artificial neural networks in the context of choosing a given supply chain can be treated as a method based on a computer pattern recognition. This network generates correct answers based on input data, even for data that was not provided in the learning process, so it can generalize the knowledge acquired during learning to generate the correct answers. When analyzing specific project supply chains, the objects are those chains. This solution, however, requires assigning specific features to the chain objects so that artificial neural networks recognize specific types of chains when learning, which will be the basis for their proper classification. The article proposes the use of artificial neural networks that require the designation of features of project supply chains. Therefore, 8 universal features based on the listed value drivers have been proposed, which are training data for artificial neural networks. The set thus proposed may allow two classes of decisions to be generated. The first would include the project supply chain in which the principal contractor should not participate (based on the expert's suggestion, the value of the standard in this case is "0"), and the second - in which he can participate (the value of the standard is "1"). Adoption of such a division is made on the basis of expert suggestions, and the above two decisions result from the separation of chains in terms of assessing their attractiveness and the possibility of exposing the principal contractor to bankruptcy. The most important assumptions about the empirical study are as follows:

- A single supply chain is a tested object, and its attractiveness is examined from the perspective of the value of the twelve proposed features (in the form of expert suggestions), so the value of the standard is "0" or "1". This will allow learning of an artificial neural network to assess hypothetical project supply chains;
- The study has used a "supervised" learning, the learning process involved analyzing 12 hypothetical cases of project supply chains, while after teaching the network, an experiment was carried out for an additional 6 potential chains, with possible values of features that can be assessed ambiguously by the principal contractor. The number of cases has been deliberately limited because the principal contractor cannot use historical data when analyzing the project supply chain, and each case should be treated as unique;

- The experiments were related to the assumption of the number of inputs equal to 8 and the changing multiple of the learning process, while the number of neurons in the hidden layer - ranged in the range of 2 – 9;
- The finally adopted network architecture consisted of a hidden layer covering 6 neurons, as well as an output layer, while the function of the transition in the hidden layer was sigmoid function (TANSIG), and in the output layer - linear (PURELIN);
- The multiple learning process of the network was 40 and it was taught by the Back Propagation method according to the L-M algorithm (Levenberg-Marquardt);
- The ultimate goal of network learning was to obtain the smallest value of the sum of squares of the difference between the output signal and the value of the standard proposed by the expert.

The proposed and possibly considered a universal set of 8 features was characterized in tabular form (Table 1.) Additionally, it was explained which indicator was used to calculate the value of the feature, taking into account the reference to the assessment of the project supply chain.

Table 1. The feature set developed for the assessment of project supply chain

Feature name	Indicator/Feature	The Essence in relation to value driver
Duration of the project supply chain	T (in years)	The feature relates directly to the value driver - time. However, it cannot be assumed that, along with a longer chain, it is very risky as it might turn profitable.
The probabilities (p_i) of obtaining specific revenues from the project at the end of a of a given period, which result from the occurrence of four assumed scenarios, were multiplied by the assumed revenues (g_i)	$p_1 \times g_1$ (monetary value)	The feature refers to the value driver - client, because at the end of the project, he can generate different revenues with certain probabilities, depending on the client's financial situation. The specified revenues were multiplied by the probabilities assigned to them, because such a set allowed to teach the network more effectively than in the case of providing single values.
	$p_2 \times g_2$ (monetary value)	
	$p_3 \times g_3$ (monetary value)	
	$p_4 \times g_4$ (monetary value)	
Foster-Hart measure of risk	$R(g)$ (monetary value)	The measure applies to value driver - cost, because as the costs increase, the principal contractor may be increasingly exposed to the risk of bankruptcy, which is why this value should be compared with the level of the principal contractor's assets. If the contractor's assets are too low in relation to the $R(g)$ value, then the project should be rejected.

Feature name	Indicator/Feature	The Essence in relation to value driver
Flexibility	F (numerical value)	The feature directly relates to flexibility, which is one of the value driver. It was assumed that if the flexibility is the smallest, then the value of the feature is "1", and when it is the highest - "10". The higher it is, the more risky the project becomes.
Quality	Q (numerical value)	The feature also refers to quality, which is the last value driver. It was assumed that if the quality required by the customer is the lowest, then the value of the feature is "1", and when it is the highest - "10". The higher it is, the more cost-intensive the project becomes.

Source: own study

The set of features presented is intended to generally reflect the situation of a given project supply chain. All feature values were built based on expert suggestions, because each project is unique and the company is not able to characterize projects based on historical data. It should be added that the Foster-Hart risk measure, which was used, was each time calculated on the basis of specific probability and income values using a commonly known formula presented in 2009 [Foster, Hart 2009]. An example period with actual data is presented in Table 2.

Table 2. Sample hypothetical data for eight features

Indicator	Value
T (in years)	4
$p_1 \times g_1$ (monetary value)	-56.25
$p_2 \times g_2$ (monetary value)	-31.5
$p_3 \times g_3$ (monetary value)	42.75
$p_4 \times g_4$ (monetary value)	67.5
$R(g)$ (monetary value)	919.49
F (numerical value)	3
Q (numerical value)	2
Z (value of the pattern)	1

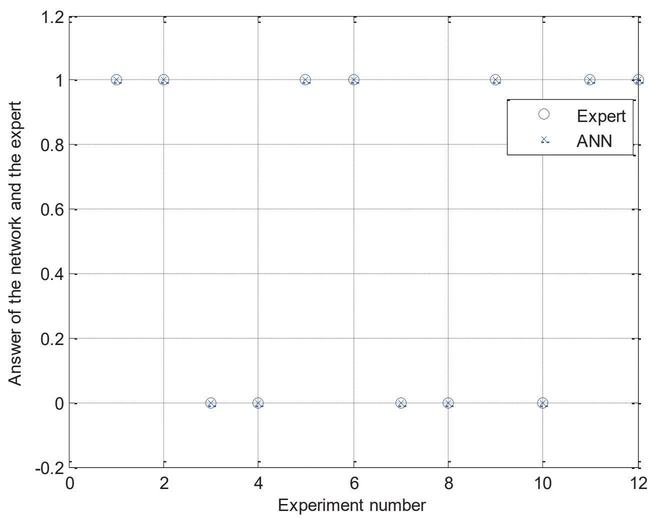
Source: own calculations

It is easy to see that the expert must be able to accurately classify chains, because they are always unique, and the number of completed projects in the enterprise may be small. This issue is the most problematic, which is why artificial neural networks seem to be an indispensable tool that is able to support the principal contractor.

APPLICATION OF ARTIFICIAL NEURON NETWORKS FOR THE PURPOSE OF DEFINING BY THE PRINCIPAL CONTRACTOR THE DECISION ON THE PARTICIPATION IN THE PROJECT SUPPLY CHAIN

The simulation tests carried out at work in MATLAB programming environment were designed to obtain simulation results in line with the expert's suggestions. In the initial phase of the study, the neural network obtained unsatisfactory results due to the determination of incorrect weights, so the learning process was changed, assuming that the result of each learning is the beginning of the next. The number of such repetitions was chosen experimentally until the network generated satisfactory results. The result of the study was an effective network learning, which is reflected in Figure 1, in which the OX axis means the number of the project supply chains examined, while the OY axis - the value of decisions. It is easy to see that the standard values are always "0" or "1". In contrast, the network results were marked in the form "X" and the suggestions of the expert were marked in the form "O".

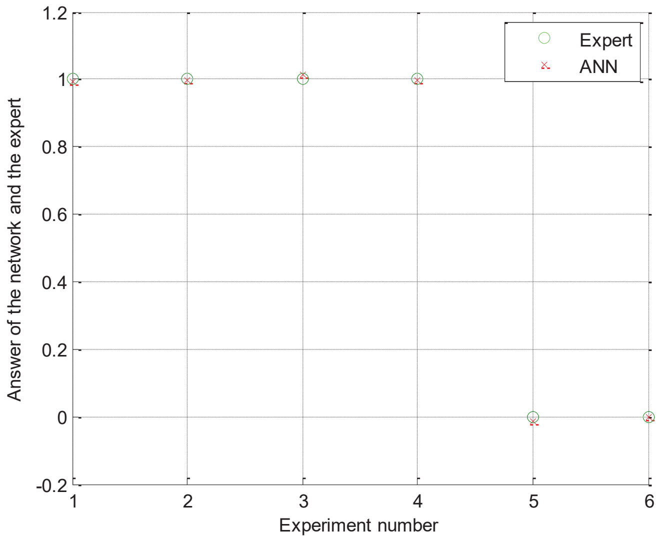
Figure 1. Example of network response for multiple learning on theoretical values in a training set for twelve project supply chains



Source: own preparation based on the MATLAB program results

Figure 1 presents the results of simulation tests, which visually can be considered as very satisfactory, because in all cases the positions of "O" and "X" are almost identical. The network taught in this way allowed for an effective use to assess the hypothetical six project supply chains that constituted the testing set. The usability of the already configured network has also been confirmed by obtaining satisfactory results, which was also illustrated by the location of "O" and "X" in Figure 2.

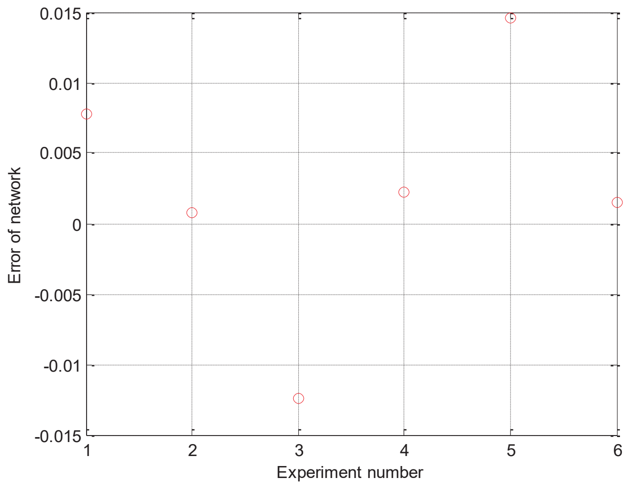
Figure 2. The results of network learning on theoretical values in a test set consisting of six hypothetical project supply chains



Source: own preparation based on the MATLAB program results

The utility of the network and the quality of the results obtained for the test set were also assessed by calculating the difference between the standard value and the value generated by the network for six hypothetical cases. Individual differences are presented graphically (Figure 3) to reflect the fact that they are relatively small.

Figure 3. Values of differences between expert and network values in the test set for hypothetical project supply chains



Source: own preparation based on the MATLAB program results

The final result of the simulation study was to obtain a network configuration that would allow the assessment of various project supply chains, which by their characteristics may expose the principal contractor to bankruptcy. It is also important that he can compare his property value with the value analyzed by the network in order to avoid the risk of bankruptcy. This aspect was not found in the Polish and foreign literature.

SUMMARY

The research was carried out to solve the research problem posed, because poor literature devoted to the project supply chain does not present how to solve it. When analyzing this chain, the first thing to consider is the fact that each one is unique. Secondly, historical data cannot be analyzed, which makes it difficult to draw conclusions about its functioning. Thirdly, in the literature on the subject, the most important value drivers regarding the project supply chain have been characterized too generally, which makes it difficult for the principal contractor to conduct analyzes. Therefore, to solve the research problem, a universal set of 8 features was proposed, referring to the value driver presented in the literature, on the basis of which the artificial neural network could be subjected to the learning process by analyzing 12 project supply chains. The learning process was the most effective when the network consisted of two layers: a hidden (consisting of 6 neurons) and an output layer (1 neuron), while the function of the transition in the hidden layer was "TANSIG", and in the output layer - "PURELINE". It was

assumed that the values of possible revenues generated by the chain were multiplied by the probabilities of achieving them and the learning multiple was 40.

In summary, satisfactory research results were obtained because the artificial neural network obtained results in line with the expert's suggestions, based on the hypothetical data of the teaching set. This way, the network also generated correct results for the test set, which is why it can be considered as an expert advisory system, supporting decision making for the principal contractor, wishing to participate in the project supply chain. The number of cases analyzed has been intentionally reduced, because each of them is unique and in business practice the enterprise may not have experience of project implementation. In addition, it seems reasonable that the proposed set of 8 features is so universal that the presented network configuration along with this data set can be useful for assessing any chain. Considering the above, it can be a comprehensive expert system supporting the risk management by the principal contractor who wants to implement a large project without any bankruptcy risk.

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