Efficient Method of an Optimal Construction Company Supplier Selection Supported by Software

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Abstract

An optimal selection of production and services company suppliers is one of the most important processes of the top management. According to ISO 9001:2015 developed for Quality Management System the type and range of control to be applied to the outsourced process can be influenced by many factors. There are several factors and criteria for the efficient selection of company suppliers. Our paper analyses the following factors: quality management level of suppliers, offered price of the construction process or product and time of construction process realisation. Using the multi-criterion optimising method and scientific synthesis a method of the efficient selection of suppliers for external processes is proposed. In addition, we present our original software, which allows for an optimal selection of suppliers over a short course of time. This efficient method and software is implemented and verified on a real example from a real construction practice. Application of this method and software will increase the efficiency of the company supplier selection from the point of the key criteria of optimising: quality, time, cost and others. This efficient method and software can be applied in any company, which cooperates with one or more suppliers in a production and service process.

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Introduction

The question of efficient management of external processes for a construction organisation and an optimum selection of suppliers of construction materials, elements and processes is highly up-to-date virtually in every organisation of main construction contractors. An external subcontractor temporarily becomes part of the main contractor and may convey either a positive or a negative image. Moreover, with an optimum supplier selection, it is possible to save considerable financial resources, which might be utilised for the development of the organisation and improvement of the employees' living conditions. The issue of an efficient supplier selection is part of ISO 9001:2015 international standard dealing with implementation and certification of the quality management system, section 8.4 and of practically every philosophy focused on quality management, i. e. Total Quality Management (Oakland, 2003), KAIZEN methods (Gašparík, 2019), Re-engineering methods (Hammer & Champy, 2003) which deals with a radical reconstruction of company processes. External processes play an extraordinary role in the respective philosophy.

Many authors deal with the selection of contractors. Sawik (2013) deals with the optimal selection and protection of part suppliers and order quantity allocation in a supply chain with disruption risks. The protection decisions include the selection of suppliers to be protected against disruptions and the allocation of emergency inventory of parts to be pre-positioned at the protected suppliers. Palaneeswaran and Kumaraswamy (2000) were focused on developing a model for a contractor prequalification and bid evaluation in design-build projects. A study written by Xia et al. (2013) has summarized twenty-six selection criteria and it has shown that although price remains an important category, its importance has declined in the last decade as other criteria have become more important. Besides, we can find the application of selection based on fuzzy theory as described by Singh and Tiong (2005). Mwikali and Kavale (2012) identified key factors affecting selection of suppliers as; cost, technical capability, quality assessment, organizational profile, service levels, supplier profile and risk factors, in that relative order. This paper concludes that a cost criterion is a key factor affecting supplier selection for it dictates among many elements, the profit margins. Badorf et al. (2019) analyse the supplier selection decisions, while O'loughlin and Szmigin (2005) are interested in external and internal accountability of financial services suppliers and define paradoxes in managing expectations and experience. Rouyendegh and Erkan (2012) defined the analytic hierarchy process method concerning the selecting of the best supplier. Bhutta (2003) conducted the systematic literature review focused into supplier selection problems. Jantan et al. (2006) analysed impact of supplier selection strategy and manufacturing flexibility into quality of production.

In this paper, we aim for a complex approach, which addresses the question by listing specific real results and simultaneously gives a contractor an option to choose suitable criteria and determine their value according to a specific situation and significance of the construction.

Control of Externally Provided Processes and Products

The current standard ISO 9001:2015 includes requirements related to cases when external providers (suppliers) provide products, services or processes to the organization. The following main cases are distinguished:

- products and services delivered by an external provider that is considered to include them in products and services of the organization;

- products and services provided to the customer(s) directly by the external provider on behalf of the organization;
- process or part of the process is provided by the external provider as a result of the organization's decision.

The organization must ensure that externally provided processes, products and services conform to specified requirements. The organization is obliged to establish and apply criteria for evaluation, selection, performance monitoring and re-evaluation of external providers. The organization must retain documented information about these actions and of any measures resulting from evaluations (see Table 1, Table 2 and Table 3).

Externally provided processes, products and services must not affect the ability of the organization of continuous delivery of conforming products and services to its customers.

The organization must:

- ensure that externally provided processes are controlled following its Quality Management System (QMS) or Integrated Management System (IMS) related to quality, environment, Occupation Health and Safety (OHS);
- define control actions that are intended as applicable to both external provider as well as resulting outputs;
- consider the potential effect of externally provided processes, products and services on the ability of the organization to continuously meet customer requirements, applicable legal and regulatory requirements in the areas of quality, environment and OHS and effectiveness of control actions by an applicable external provider;
- establish verification or other actions necessary to ensure that externally provided processes, products and services fulfil requirements.

The organization must **communicate, with the external provider**, its requirements on:

- processes, products and services that it will provide;
- product and service approval, methods, processes and devices, the release of products and services;
- competence, including any required qualification of persons;
- relations of external provider with the organization;
- performance control and monitoring of external provider applied by the organization;
- verification or validation actions that the organization or its customer intends to carry out at the premises of the external provider.

Table 1

Form for evaluation of external material provider before realized delivery

Questions (criteria)	Record	Points (0-5)
Is the supplier a holder of a certificate according to ISO 9001:2015 or, at minimum, holder of a certificate of material conformity?		
Can the supplier meet our required delivery dates?		
What is the price of goods offered?		
What is the cost of transport to the destination?		
Has our organization a positive experience with the supplier?		
What is the term of payment of invoices?		
Has the supplier good references for its operation?		
Has the organization set up a QMS or IMS? Are its products dangerous to health and safety during use?		

Source: Gašparik (2019)

Table 2
Form for evaluation of external construction works provider before realized delivery

Questions (criteria)	Record	Points (0-5)
Is the supplier holder of the certificate for the QMS according to ISO 9001:2015 or the IMS according to ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018 or do they have such systems set up?		
Does it have technological procedures and inspection and test plans for construction processes?		
Can the supplier meet our required delivery dates?		
What is the offered total price of delivery?		
Has our organization a positive experience with the supplier?		
What is the term of payment of invoices?		
Has the supplier good references for its operation?		
Does it observe legislation in the areas of environment and health occupation and safety?		

Source: Gašparik (2019)

Table 3
Form for evaluation of external material or construction works provider after realized delivery

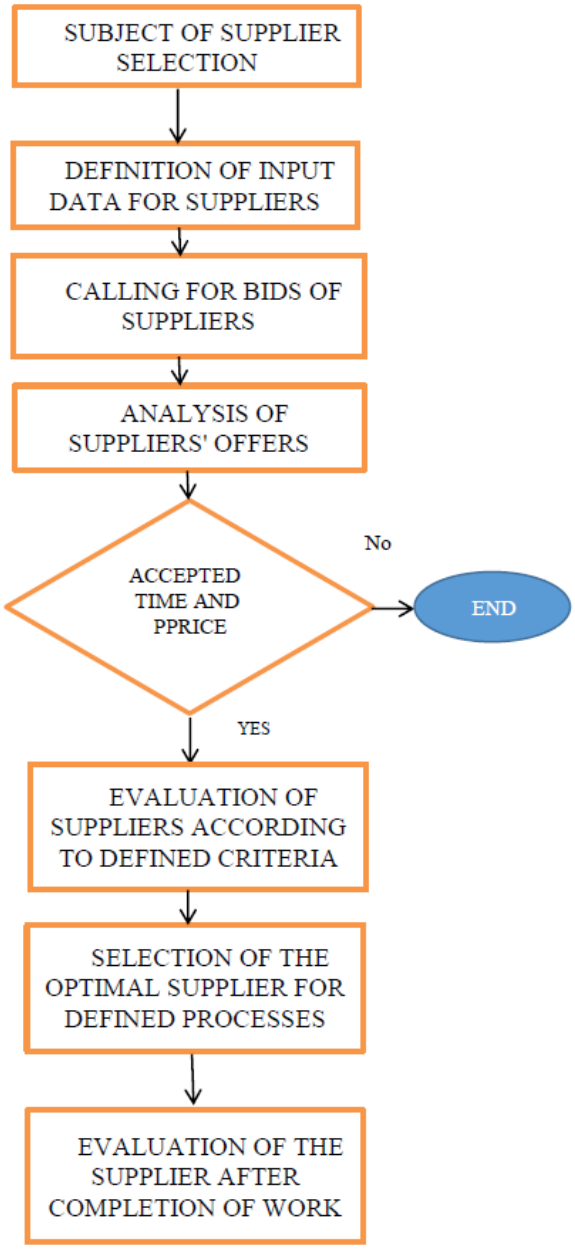
Questions (criteria)	Record	Points (0-5)
Did the supplier fulfil all quality requirements in line with contract or order?		
Were there any problems with delivery acceptance?		
Are all necessary records about delivery quality available?		
Did the supplier meet the required delivery dates?		
Did supplier meet the price agreed in contract?		
What was the level of cooperation with the supplier?		
Did the supplier implement effective corrective actions for nonconformity cases?		
How professional was the supplier?		
Has supplier had problems related to environment and health occupation and safety?		

Source: Gasparik (2019)

Method of optimal external provider selection

Main construction contractors ensure several external processes in the course of construction preparation and performance. Mostly these include a supply of building materials and products or building processes. The paper is focused on the selection of building processes suppliers.

Figure 1
Construction supplier selection method



Source: Author's illustration

When selecting a building processes supplier, we propose the following method following Figure 1:

- defining the building processes to be provided by an external supplier,
- preparing the input data of the construction contractor for the needs of potential external suppliers: (planned construction time-schedule, construction project, bill of quantities etc,),
- defining the building processes to be provided by an external supplier,
- a call for bids (on the Internet and in other media),
- collecting bids, analysing them from the viewpoint of pre-defined criteria (see the following chapters),
- setting the most favourable bid for the realisation of building processes,

- signing the main construction contractor's contract with an external building processes supplier based on the supplier's bid,
- monitoring the works of an external supplier in correspondence with the contract; and continuous invoicing of the works.

What plays a significant role in the selection of a building processes supplier is a selection of criteria and their values. The first suggested criterion is a supplier's capability to perform the work in time as defined in the construction schedule. The suppliers who are not able to start performing in the required time shall be excluded from the tender. Eligible suppliers are evaluated according to a certain point system where the bid with the shortest schedule (yet, not at the expense of quality and technological requirements) is awarded the highest amount of points. At this point, the main contractor must prepare an optimum schedule of building processes performance and set their minimum as well as maximum requirements regarding the provision of quality of the processes.

The second suggested selection criterion is the price of the works. In this case, the main contractor and their costing clerk should establish an optimum price and set a minimum and maximum limit, e.g. 20 % from the optimal price using suitable software (CENKROS, CENECOM, CONTEC). The bids exceeding these limits would be excluded; the rest of bids would be evaluated in points and mathematically in the way that the lowest accepted price gains the highest number of points, while the highest accepted price gets the lowest number of points. Other price offers between these extreme limits are to be determined by interpolation.

The third selection criterion is the quality level of a particular building processes supplier. The most suitable method appears to be the assessment of the level of Quality Management level; e.g. certified Quality Management System (QMS), application of the Total Quality Management (TQM) philosophy, KAIZEN system, Re-engineering methods, EFQM model, the best building of the year award or previous experience with realising similar constructions etc. The next suitable criterion appears to be the invoice due date. The later the invoice due date, the more favourable the situation for the construction contractor from a financial point of view.

The software to be described in the next part of the paper enables contractors to suggest more criteria deemed significant by them. Setting values for the criteria may allow considering the priorities which are important for individual contractors. Thus, contractors may objectively evaluate the best supplier for selected. As a result, the negative assessment will lead to the supplier's exclusion in future tenders.

Thus, the contractor has an option to create their database of the most suitable suppliers based on optimal selection and supplier's assessment, which may lead to future offers of cooperation.

Definition and Structure of supplier selection criteria

It is necessary to set the key criteria for every activity, hence for the selection of building processes suppliers, too. Among them are undoubtedly the quality of performed works, duration of the processes and their price. These basic criteria may be extended by additional criteria such as an invoice due date which may play a significant role in the financial management of the construction. Within the framework of a model application example, this paper is focused on the abovementioned four criteria.

The scoring system of the criteria is based on the possibility or impossibility to assign points regardless of knowing the offers of other potential suppliers. Hence, the scoring system stems from two approaches of assigning points to individual criteria. In both cases, a 0 – 5 scoring scale was used where 0 stands for the worst and 5 for the

best variant. The determined scoring system is based on knowing the content of each criterion and the points assigned to it. The scoring system in question was used with the criteria of quality and invoice due date. Table 4 and Table 5 visualise the scoring system chosen for the model example and software implementation.

Table 4
Criteria of Quality Management level

Criterion-related to the Quality Management level of suppliers	Points (0-5)
The organisation has no QMS in accordance with ISO 9001:2015	0 pts
The organisation has QMS in accordance with ISO 9001:2015 without the certificate, yet they have positive references	1 pts
The organisation has the QMS certificate in accordance with ISO 9001:2015	2 pts
The organisation has the QMS certificate in accordance with ISO 9001:2015. Also, they have implemented an Integrated Management System (IMS) – quality, environmental, occupational health and safety in accordance with ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018	3 pts
The organisation has the IMS certificate in accordance with ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018	4 pts
The organisation has either QMS or IMS certificate and applies higher forms of quality management (TQM, KAIZEN, business process re-engineering, EFQM model of excellence etc.	5 pts

Source: Gašparik (2019)

Table 5
Criteria related to the invoice due date

Criterion-related to the Quality Management level of suppliers	Points (0-5)
A supplier requests payment in advance	0 pts
Payment on the product delivery	1 pts
Payment within 3 days from the invoice issuance	2 pts
Payment within 14 days from the invoice issuance date	3 pts
Payment within 1 month from the invoice issuance date	4 pts
Payment after the 1st month, in instalments based on the contract	5 pts

Source: Gašparik (2019)

Software Implementation

The software in question operates in the Microsoft Excel environment and was created utilizing VBA (Visual Basic for Applications). At the beginning of the software development, it was necessary to define basic functionalities of the whole system. Therefore, four basic system parts were created, namely:

- setting criteria,
- setting suppliers,
- showing results,
- printing results.

The main parts were created in object-oriented programming. It means that objects were created to which commands were programmed. The software contains various text fields which had to be programmed in a way that the set data remained in the program memory and could be used in computations at the same time. Besides, it was necessary to find a way which would enable certain data to be highlighted.

Part 1: Setting criteria

This part contains units for setting the information needed for the supplier selection. These units are:

- highlighting criteria,
- names of criteria,
- values of criteria,
- description of point assignment to individual criteria.

This part is secretly linked to a calculation part where the calculations, which use the set data, take place. One of the curious properties of the programme is its ability to warn a user about the failure to fulfil the needed 100 % value of criteria. The programme warns a user by colouring certain fields in red; this indicates that the sum of all the values does not equal 100 %. It is possible to write information about the names of criteria and description of how points are assigned to given criteria into empty fields in this part. The description will be consecutively shown in the information section in the 'setting suppliers' part. The user's advantage is always having an up-to-date description of point assignment to any criterion.

Part 2: Setting suppliers

This part includes eight tabs. Each tab is meant for one company. The required data are then written in the tabs. These data are related to the supplier selection and they are written into the 'evaluating criteria' part. Besides, the company's identification data such as name and contact details can be found here. In the 'evaluating criteria' part, the companies price offers and time needed for a service or product delivery is put in. There are also 10 criteria, which a user has set in advance with an option of point selection on a 0 – 5-point scale.

Part 3: Showing results

This part contains a total evaluation of individual suppliers showing the number of gained points. The most favourable offer is in green colour.

Part 4: Printing results

Printing serves as a well-organised and well-documented evaluation of suppliers with a complex report on individual suppliers; it also serves for printed output.

Part 5: Calculation

The invisible part comprises computations into which the data from the 'setting criteria' and 'setting suppliers' sections are entered. All the mathematical formulas are translated into computations. Among significant elements in the computational part are functions seeking maxima and minima, computational model creating a dynamic scoring system and computational operations providing the final number of gained points.

Model Example

The method and software-defined in the paper were implemented and verify at the model example.

Stage 1

Input definition:

- type of construction: multi-function building,
- stage of works: processes of structural works,

- expected price: 30 mils. EUR,
- required construction time-schedule 1st March 2019 – 1st March 2020 (1 year).

Stage 2

Publishing the call for bids and providing the main contractor's documents for the competing suppliers:

- construction project,
- overview of building processes of structural works,
- bill of quantities etc.,
- required construction time-schedule.

Stage 3

Presenting five bids of the competing suppliers (see Table 6).

Stage 4

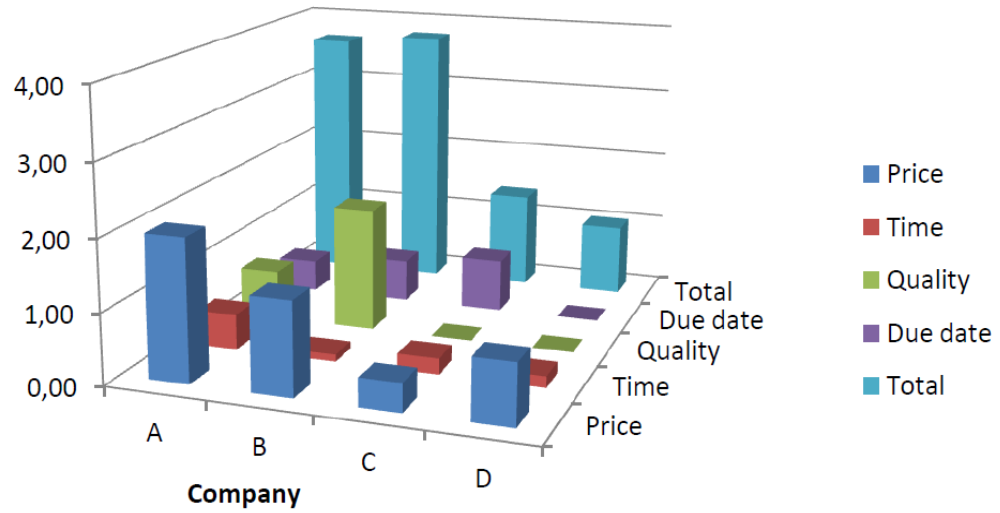
Evaluating the bids through the software according to the defined criteria, setting the winning bid and conclusion of the contract with the winning supplier. In our model example, the values of criteria were used in the following manner: price 40%, time 10%, and quality level 35%, invoice due date 15%. Figure 2 shows the suppliers' point values based on the analysis of their bids, the offered price and performance schedule. Figure 2 depicts a graphical evaluation of the suppliers' bids. One of them was excluded due to the undervalued price, the other four suppliers were analysed according to the criteria based on the input data stated in Figure 2. Figure 3 shows the final results and implies that the best building processes supplier for the need of the order appears to be the supplier B.

Table 6
The bids of suppliers for software evaluation

S	Offered time date	Price(mil.EUR)	Quality level	Invoice due to date
A	1.3.2019-1.12.2019	28	ISO 9001 Cert.	14 days
B	1.3.2019-1.3.2020	31	ISO 9001 Cert Model EFQM	1month
C	1.3.2019-1.2.2020	35	Technical Standards	3 months
D	1.3.2019-15.2.2020	33	15 years experience	Payment in advance
E	1.3.2019-25.2.2020	33	10 years experience	2 months

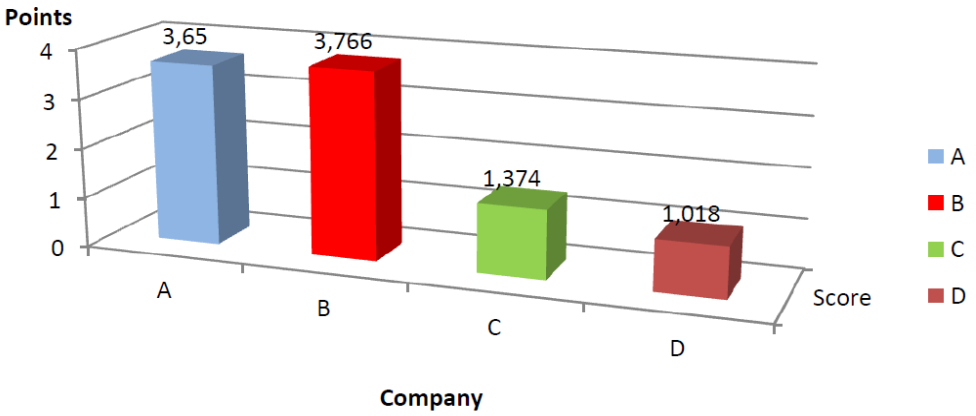
Note: S - Supplier
Source: Authors

Figure 2
Results according to criteria



Source: Authors

Figure 3
Final results



Source: Authors

Conclusion

An optimal selection of products and services company suppliers is one of the most important processes of the top management. The most of processes in production and service sector are realised by many suppliers all over the world and during the process of products' planning, it is necessary to find an optimal solution, which would cover several criteria

The research paper was focused on the increase in efficiency of external processes and optimum supplier selection according to defined criteria. The method of supplier selection and automatized system of bids evaluation through the proposed software (author: P. Bažík) leads to a transparent and objective supplier selection in a short time. Many construction companies approach this process spontaneously and mostly consider only the price. Their records on the selection process are partially kept in secret, which sometimes leads to corruption and biased evaluation. The method of supplier selection supported by the software was met with great reception and interest in the programme in the organisations with an

implemented Quality Management System. The results of our research work are also applicable to public procurement tenders regarding buildings. In the future research work, it might be possible to develop the question of extending the selection criteria and accurately defined scoring system which would best reflect the quality of bids.
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