Efficient Method of An Optimum Construction Company Supplier Selection Supported by Software

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Abstract-

An optimum selection of construction company suppliers is one of the most important processes of the top management. The most of construction processes are realised by many suppliers all over the world and during the process of construction planning it is necessary to find an optimum solution which would cover several criteria. Ensuring control over the outsourced processes does not absolve the organisation of the responsibility to meet all the customer, statutory and regulatory requirements. According to ISO 9001:2008 developed for Quality Management System the type and range of control to be applied to the outsourced process can be influenced by many factors such as a potential impact of the outsourced process on the organisation's capability to provide a product that would conform to the customer requirements and a degree to which the control for the process is shared.

There are several factors and criteria for the efficient selection of company suppliers. Our paper analyses these: quality management level of suppliers, an offered price of the construction process or product, time of construction process realisation and other specific criteria. Using the multi-criterion optimising method and scientific synthesis a method of the efficient selection of suppliers for construction processes is proposed: it relies on selected criteria and their importance.

The next part of our research results is a proposal of our original software which allows for an optimum 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 construction company supplier selection from the viewpoint of the key criteria of optimising: quality, time, cost and others. This efficient method and software can be applied in any construction company which cooperates with one or more suppliers in a building process. The optimum selection of suppliers can help construction companies save time and money which can be used for a useful company development process.

Keywords-

Effective selection; Multi-criteria optimization

1. 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 positive or 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 9001:2008 international standard dealing with implementation and certification of quality management system, section 7.3 and of practically each philosophy focused on quality management, i. e. total quality management (TQM) [1,2], KAIZEN methods [2], re-engineering methods [3] which deals with a radical reconstruction of company processes. External processes play an extraordinary role in the respective philosophy.

Many authors in the world deal with the selection of contractors. Ekambaram Palaneeswaran, Mohan M. Kumaraswamy were focused on developing a model for a contractor prequalification and bid evaluation in design-build projects. A study written by Bo Xia, Albert Chan, Jian Zuo, Keith Molenaar has summarized twenty-six selection criteria and it has shown that although price still remains an important category, its importance has declined in the last decade as other criteria have become more important. Also, we can find the application of selection based on fuzzy theory as described by D. Singh, Robert L. K. Tiong. Charles A. Weber, John R. Current and W.C. Benton describe vendor selection criteria and methods.. These include increased quality guidelines, improved computer communications, and increased technical capabilities. Specific attention is given to the criteria and analytical methods used in the vendor selection process. R.

Duolmin and V. Mininno analyzed supplier selection using a multi-criteria decision aid method and analyse how to allow for a simultaneous change of the weights (importance of performance criteria), generating results that can be easily analysed statistically, performing an innovative sensitivity analysis. The whole suppliers selection model presented (promethee/gaia techniques plus high-dimensional sensitivity analysis) can be a useful additional tool inside the final choice phase of a supplier selection process. According to the De Boer et. al. taxonomy, many decision models have been suggested for supporting the supplier selection process along its main steps (problem definition/formulation of the criteria, pre-qualification of suitable suppliers, final choice).

In the 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.

2. A Proposal of a Method of a Building Processes Supplier

Main construction contractors ensure several external processes in the course of the 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.

When selecting a building processes supplier, we propose a following method in accordance with the 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.
- 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 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 time 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 time schedule (yet, not at the expense of quality and technological requirements) is awarded with the highest amount of points. At this point it is vital that the main contractor prepare an optimum time 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, e. g. certified system of quality management, application of the total quality management (TQM), 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, negative assessment will lead to the supplier’s exclusion in future tenders.

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

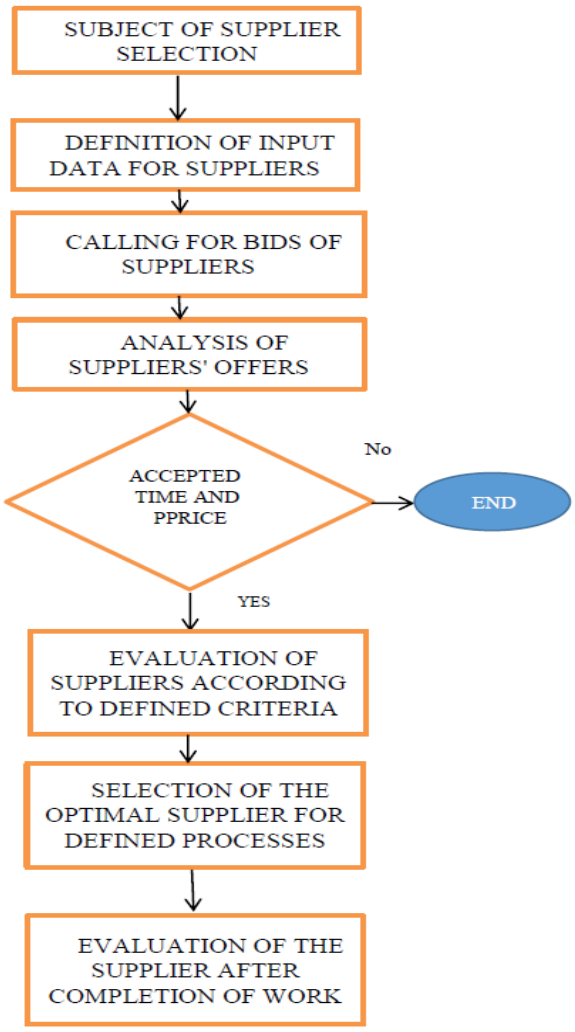

Figure 1. Method of a construction supplier selection

3. Structure of Criteria and System of Their Evaluation

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.

3.1. Determined Scoring System

Determined scoring system is based on knowing the content of each criterion and points assigned to it.

The scoring system in question was used with the criteria of quality and invoice due date. Table 1 and table 2 visualise the scoring system chosen for the model example:

Table 1. Qualitative criteria

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

3.2. Dynamic Scoring System

Dynamic scoring system lies in changing values which are unknown until their registration which derive from the bids of the rest of suppliers. The scoring system in question applies mainly to the criteria of price and time. In other words, we know both maximum and

minimum value we would assign the most or least points, yet it is unknown how many points would be assigned to other values so that proportional point distribution is kept. This point distribution may be reached with the help of an equation of a straight line.

Table 2. Criteria related to the invoice due date

No.	A criterion related to the invoice due date	Points
1.	A supplier requests payment in advance	0 pts
2.	Payment on the product delivery	1 pts
3.	Payment within 3 days from the invoice issuance	2 pts
4.	Payment within 14 days from the invoice issuance date	3 pts
5.	Payment within 1 month from the invoice issuance date	4 pts
6.	Payment after the 1st month, in instalments based on the contract	5 pts

Prices translated into the equation will result in prices lying on the x-axis, points lying on the y-axis. Thus the equation of a straight line will look like this:

$$y=kx+q \quad (1)$$

Subsequently, for the scale of 1 – 5 points we get the following equation:

$$y=4((max-x_i)/(max-min))+1 \quad (2)$$

Modifying the equation leads to the following:

$$y=(1+(4max/(max-min))-(4x_i/(max-min)) \quad (3)$$

where
max – the bid with the highest price,
min – the bid with the lowest price,
x_i – the price of the bid we seek the points for,
y – the number of points of each bid.

A very similar approach is applied with time. In this case, we need to imagine that delivery time lies on the x-axis, with points lying on the y-axis. Here, the equation of a straight line will look like this:

$$y=kx+q \quad (4)$$

Subsequently, for the scale of 1 – 5 points we get the following equation:

$$y=4((max-x_i)/(max-min))+1 \quad (5)$$

Modifying the equation leads to the following:

$$y=(1+(4max/(max-min))-(4x_i/(max-min)) \quad (6)$$

where
max – the bid with the longest delivery time,
min – the bid with the shortest delivery time,
x_i – the time of the bid we seek the points for,
y – the number of points of each bid.

3.3. Values of Individual Criteria

Values express the importance of individual criteria and subsequently influence the final number of gained points. For the need of supplier selection a percentage expression of values was used. A percentage scale is dynamic and depends on the provider's choice of a supplier.

4. Software for Selection of Building Processes Suppliers

The software in question operates in the Microsoft Excel environment and was created by means of 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 (Fig.2):

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

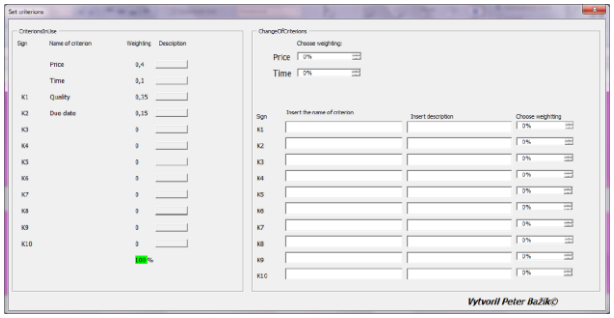

Figure 2. Part of program for setting criteria

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. Also, 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 are 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. When the button next to each criterion is pressed, a piece of information about the point assignment for a particular criterion is displayed. Figure 3 shows the bids of five suppliers which were analysed by applying the software.

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 (Fig.3).

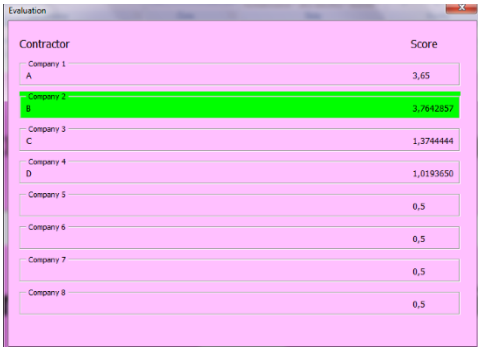

Figure 3. Evaluation of bids

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 a 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 dynamic scoring system and computational operations providing final number of gained points.

5. Application of the Method and Software on a Particular Model Example

Stage 1:
Input definition:

- type of construction: multi-function building,
- stage of works: processes of structural works,
- expected price: 30 mil. EUR,
- required construction time-schedule 1st March 2014 – 1st March 2015 (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 3).

Table 3.The bids of suppliers for software evaluation
S – supplier

S	Performance time (dd.mm.yy)	Price mil. EUR	Quality	Invoice due date
A	1st March 2014 – 1st December 2014 276 days	28	ISO 9001 Certificate	14 days
B	1st March 2014 – 1st March 2015 366days	31	ISO 9001 Certificate + EFQM Model	1 month
C	1st March 2014 – 1st February 2015 338days	35	Technical standards	3 months
D	1st March 2014 – 15th February 2015 352days	33	15 years of experience	Payment in advance
E	1st March 2014 – 25th February 2015 362days	20	10 years of experience	2 months

4. Stage:

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%,
– quality 35%,
– due date 15%,

Figure 4 shows the suppliers' point values based on the analysis of their bids, the offered price and performance time schedule. Figure 4 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 4. Figure 5 shows final results and implies that the best building processes supplier for the need of the order appears to be the supplier B.

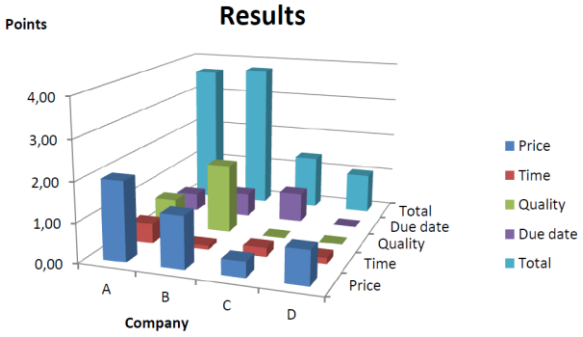

Figure 4. Results according to criteria

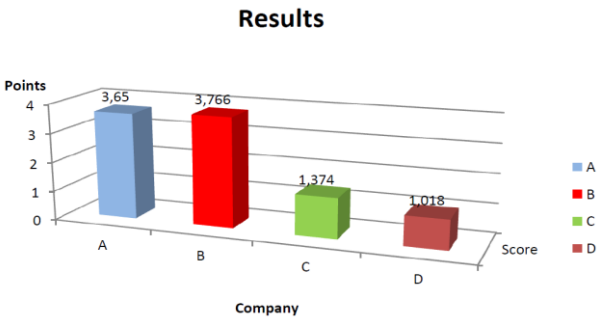

Figure 5. Final results

Conclusion

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. Bazik) leads to a transparent and objective supplier selection in the 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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References:

[1] Paulová, I., Hekelová, E., Šatanová, A.,Šalgovičová, J.: *Metódy zlepšovania efektívnosti a účinnostiTQM.* Vydavateľstvo STU Bratislava, Radlinského 121, 813 68 Bratislava, 2008

[2] Oakland, J. S.: *Total Quality Management*. Oxford, Elsevier Ltd., 2003

[3] Hammer, M. and Champy, J.: *Reengineering – a manifesto for Business Revolution.* New York: Harper Collins Publisher Inc., 1993

[4] Porter, L. J. and Tanner, S. J.: *Assessing Business Excellence: A Guide to Business Excellence and Self- assessment.* Burlington: Butterworth-Heinemann, 2004

[5] Hakes, C.: *The EFQM Excellence Model to Assess Organizational Performance: A Management Guide*. Zaltbommel: Van Haren Publishing ,2007

[6] Palaneeswaran, E. and Kumaraswamy, M.: *Contractor Selection for Design/Build Projects*. J. Constr. Eng. Manage., 126(5), 331–339.2000

[7] Xia, B., Chan, A., Zuo, J., and Molenaar, K. : *Analysis of Selection Criteria for Design-Builders through the Analysis of Requests for Proposal*. J. Manage. Eng., 29(1), 19–24. 2013

[8] Singh, D. and Tiong, R. *A Fuzzy Decision Framework for Contractor Selection.* J. Constr. Eng. Manage., 131(1), 62–70.,2005

[09] Ch.A., Current,J.R. and Benton,W.C. Vendor selection criteria and methods. European Journal of Operational Research. Volume 50, Issue 1, 21991, p. 2-16

[10] Duolmin,R. and Mininno,V. *Supplier selection using a multi-criteria decision aid method.* Journal of Purchasing and Supply Management. Volume 9, Issue 4, 2003, p.177-187

[11] **L.**de Boer, E.Labro and P.Molrlacchi. *A review of methods supporting supplier selection.* European Journal of Purchasing and Supply Management, 7 (2001), pp. 75–89