METHODOLOGY FOR PRELIMINARY DETERMINATION OF THE COMPETITIVENESS OF METAL STRUCTURES

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Abstract. The present work shows a methodology for preparing an offer that outlines competitive advantages of the metal construction of overhead cranes when these cranes are considered as logistics machines. The competitiveness is determined by the framework construction principle of the machine.

Keywords: logistics, metal constructions, logistics equipment, competitiveness

1. Introduction

Logistics equipment consists of a multitude of material handling and storage machinery and facilities that are subsets of the logistics system. The machinery generally performs spatial movement of goods in a series of technological, handling, storage and other operations. Each of the subsets is characterized by its technical and economic parameters. The set of parameters of all these subsets (or subsystems) defines the properties of the logistics system as a coordinated system.

In today's open and globalized logistics equipment market, companies have to face tough competition and strive to offer the best to the customer requirements and parameters.

Bulgaria joined the European Union several years ago. In order to become EU member, the country had to conform to equalizing rules and regulations, concerning quality and finance, so as to become more competitive. The benefits that accrue from these prerequisite procedures applied to the work of designers and logisticians are indisputable, but these also bring much higher requirements to be followed. To be competitive, designers and logisticians have to be aware at any time of the status of major companies and competitors, and prepare such offers that are highly probable for selection by the customer.

The accurate approach for obtaining competitiveness is that the proposed facility be relevant not solely to the time of the offer but to the time of its application, i.e logistics equipment has to be up to date at the time of service and competitive at the time of order. But this is related to forecasting the parameters of the logistics equipment and its components. At present, leading countries (*UK, USA, Japan, Germany, etc.*) perform extensive work in determining the optimal parameters of future products, including the logistics equipment. Several authors like *F.M. Bass, S. Davie, N.R. Draper, S.B. Lawton, P. Charlton, R. Ahmadi, T.A. Roemer, R.H. Wang, T.R. Browning, V. Krishnan* are working on the problem, linking it to a shorter life cycle of the product and product strategy and utilizing various new computer tools and approaches for product strategy.

It is well-known [1] that when constructing and operating a logistics system, a major conceptual requirement is the high equipment independence, i.e. conformance of machines and facilities with specific process conditions. Such conformance is achieved through appropriately defined parameters, process servicing at minimal cost [2] and resource delivering at the right time, all accomplished by the corresponding equipment and logistics.

The selection of the optimal technique is an important point in the design of logistics systems. It depends on various factors and the main purpose is usually getting reasonable production and maximum profit. It could be achieved basically when applying the modular structure technique in which the design and construction of the new equipment is to be carried out in a new way, in full compliance with the requirements of the client.

In today's world, competition requires that the logistics framework valuation of a facility be the complement of the facility design process. This framework is a multidimensional architecture. *Fine* [3], established in 1998 an architecture that comprised of three areas: product, process and supply. The term "three-dimensional concurrent engineering" was coined later as *Fixson* [4] examined the impact of product characteristics on its design. It is illustrated in [5], the integration of product architecture and organizational structure with structural modelling approach in reference to the development of this architecture. Further studies [6] consider the development of the machine architecture in association with the prediction dependence on the time interval.

However, the principles of machine architecture do not apply only to the logistics facility as a whole, but also to its elements. This is an essential requirement by today's globalized market, where each basic logistics machine can be made in different countries and by different companies. As stated by *Anthony Giddens* [7], after the XIX century the transportation costs were significantly reduced and there was no need for most goods to be produced in close proximity to the place of consumption. During the 70's of the XX century, the manufacturing processes were already fragmented and took place in different locations. Since then, traditional concerns have structured the system of global division of labour in which the parts of a product are manufactured and assembled in different countries [8].

Metal structure is such a key part of logistics equipment. In many cases it is essential for the competitive advantages of the proposed machine. Its weight, shape and size direct the value of other characteristics. Cost, mass and operational reliability of handling trucks (from logistics point of view) is largely determined by their metal structure [9].

When planning the fabrication of metal frame facilities, the business offer always has to take into account the frame optimal mass that results from proper frame shape and material used. In this study, metal structures are formally divided into linear and areal. All, primarily horizontal structures, are assumed linear such as the structures of bridge cranes, conveyors, etc. Areal structures are assumed those, that except for the general horizontal orientation, also have additional elements like columns, feet, etc., such as the structures of gantry cranes, harbour cranes, container cranes etc.

The purpose of this work is to develop a methodology for preparing a competitive offer for a linear structure logistics machine. The development process is clarified with tips for the construction of particular machines - bridge cranes.

2. Methodology and algorithm for preparing a competitive offer for steel structure

The competitive advantages of the steel structure of a given logistics machine are determined by using the structural principle, the theory of forecasting, *Fuzzy logic* and model of *Nonaka & Takeuchi*. Figure 1 shows a methodology for preparing a competitive offer for steel structure:

1. Block ***"Logistics machine"***. Determining the specific logistic machine, the particular market and its requirements.

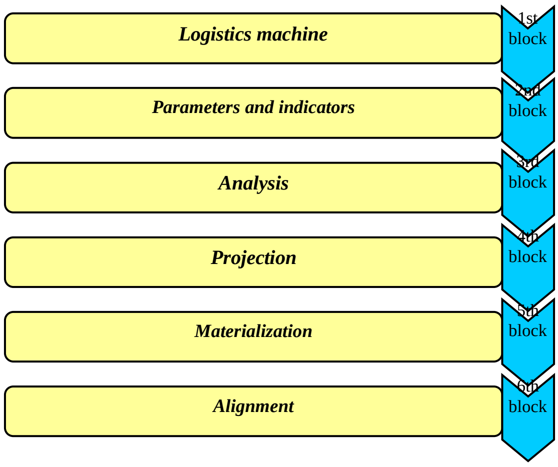

Figure 1. Methodology for the preparation of a competitive offer for a steel structure

2. Block ***"Parameters and indicators"***. Generating the basic parameters of the machine and its metal construction. These parameters will serve as indicators when comparing the proposed metal structure to competitive designs. Decomposition is performed, at the same time, for each frame in accordance with the components responsible for the competitive advantage (section type, type of the profiles that make up the section, materials, production technology).

3. Block "***Analysis".*** Benchmarking to competitors based on selected (created) indicators for the range of indicator variation.

4. Block "***Projection***". Selection of indicator values and their ranges of possible variation for the company.

5. Block ***„Materialization".*** The developed indicators are materialized with particular machines and logistics solutions. Synthesis of possible configurations of specific solutions for each variant is made by the principle of minimum total cost.

6. Block ***„Alignment"***. All variants of the metal structure are ranked according to the minimum cost of a particular decision.

There are many different engineering parameters necessary for forecasting and building of a comprehensive strategy for the development of a logistics process or machine. Some of them have to be studied in more details because they aim to reveal the objective trends and possible contradictions of processes.

This work focuses only on certain parameters that are essential for the metal structure since they help validate the quality of the machine design under different conditions. These parameters are particularly relevant because of the contemporary complex situation of crisis, changes in metal prices and increasing energy prices.

Cranes are undoubtedly essential logistics machines. It is well-known that there is immense variety of literature that deals with the topic of improving the metal structure. In [10], a forecasting of the values of the mass ratio of bridge cranes with lifting capacity of five tons was performed, based on data collected for their parameters variation in past years. The resulting forecasts are presented in graphs and tables. In [11], the authors have considered crane design from the viewpoint of reliability.

In short, there are various types of cranes, but their common feature is the heavy metal structure. The surplus weight becomes obvious when taking a look at the mass ratio which is closely monitored in this work.

The present study begins with the selection of several bridge cranes by the following parameters:

- Year of production;
- Capacity;
- Span;
- Crane mass.

In order to account for the quality of the crane metal linear structure, the "metal capacity factor" is introduced:

$$k_K = \frac{M_{KP}}{L \cdot M_T} \cdot Z\,, \qquad (1)$$

where:

L - crane span;

M_{KP} - crane mass;

Z - relative price of the used material and production of the metal construction (expressed in BGN/m).

It is known that the metal structure depends on the crane operating mode and formula (1) is used when comparing cranes under identical conditions.

Otherwise, formula (1) is transformed into:

$$k_K = \frac{M_{KP}}{L \cdot M_T} \cdot Z \cdot K_r\,, \qquad (2)$$

where K_r is a coefficient taking into account the working regime of the machine.

This indicator considers the quality of the machine and depends on the material used. The relative costs of materials and production (defined by the production technology) of steel structures are a prerequisite for the preparation of comparative tables and graphs and for selection of competitive production.

On the other hand k_K = F(Θ, Ω, Ψ, Δ) where:

Θ - section type (Θ = 1, 2, …, Θ);

Ω - type of the profiles which constitute the section; ($\Omega = 1, 2, \dots, \Omega^{\nabla}$)

Ψ - constructing material; ($\Psi = 1, 2, \dots, \Psi^{\nabla}$)

Δ - production technology. ($\Delta = 1, 2, \dots, \Delta^{\nabla}$)

After substitution and transformation, the following is obtained:

$$k_K = F(\Theta, \Omega, \Psi, \Delta) = \frac{M_{KP}}{L \cdot M_T} \cdot Z \cdot K_r\,. \qquad (3)$$

It is obvious that this indicator captures the elements of the metal structure providing competitive advantage with respect to the cross section shape, its constituent elements and material. As shown, the coefficient in (3) is common and reflects trends in the metal structures for the given company product. It can be applied to specific groups of machines that are separated by certain parameters. When it comes to a particular machine, some of the parameters in (2) are fixed and constant. This greatly simplifies the coefficient solution as well as helps obtain ideas of specific designs.

Let n (n = 1 … N) be the number of competitors, continuously monitored and analysed. Let each of them be identified with estimated coefficient of metal capacity k_K^n n (n = 1 … N) for a period of T years in the future. Then the relative coefficient ${}^{o}k_K^n$ will be:

$$ {}^{o}k_K^n = \frac{k_K^{\min}}{k_K^n} = \frac{\dfrac{M_{KP}^{\min}}{L^{\min} \cdot M_T^{\min}} \cdot Z^{\min} \cdot K_r^{\min}}{\dfrac{M_{KP}^n}{L^n \cdot M_T^n} \cdot Z^n \cdot K_r^n}\,, \qquad (4)$$

where $k_K^{\min}$ is the metal capacity factor of the competitive firm with the lowest cost.

The set ${}_K^n M$ of k_K^n solutions will be limited in the interval $[k_K^{\min}, k_K^{\max}]$.

But the set ${}_K^n\Phi$ of ${}^{o}k_K^n$ coefficients is defined within the interval (0, 1]. The coefficient for company mentioned belong to the interval ${}_K^n\Lambda$. This interval consists of the values ${}^{o}k_K^n$ that are of the set ${}_K^n\Phi$ (${}_K^n\Lambda \in {}_K^n\Phi$). The particular interval of ${}_K^n\Lambda$ is determined using Fuzzy logic [12, 13] where the *terms* appear as *high, average and low competitiveness*. The solution is prepared by using the algorithm described in [14]. The boundaries of ${}_{K}^{n}\Lambda$ are within 1 and a value determined by the company policy.

The chosen ${}^{o}k_{K}^{n}$ helps define the value of our coefficient k_{K}^{n}. Using this coefficient for the predetermined (estimated) time T, the cost of production, operating costs E and the possible costs related to a more expensive, but lighter machine or vice versa i.e. compared to alternative capital ΔZ, can be found.

$$\Psi = Z + E + \Delta Z \, , \qquad (5)$$

The exact value of the coefficient is selected by the total cost equation (5), which is solved either for the cheap metal structure with large mass and operating costs or for expensive structure, but with low operating costs. The solution of k_{K}^{n} yields a value, where $\Psi = \Psi \min$, with the following limitations:

- $Z > 0$ - real machine
- $E > 0$ -working machine
- $\Delta Z > 0$ - There is a difference between the lighter and the heavier machine.

When preparing an offer for a certain crane L, M_T, K_r are defined in advance and formula (4) becomes:

$${}^{o}k_{K}^{n} = \frac{k_{K}^{\min}}{k_{K}^{n}} = \frac{M_{KP}^{\min} \cdot Z^{\min}}{M_{KP}^{n} \cdot Z^{n}} . \qquad (6)$$

For cranes with the same L and Z (the relative cost of materials and production of the steel structure is the same for two comparable cranes), formula (3) becomes:

$$k_K = \frac{M_{KP}}{M_T} . \qquad (7)$$

Equation (7) is the reciprocal of the known mass ratio. This mass ratio is studied in [10] where it is concluded that the mass ratio of the machinery increases in time, i.e., there is a trend that machines with the same capacity tend to have lower mass. This is due to new developments and research, new methods of calculating machines, new lighter materials, reducing the uncertainty of the period of service and reducing energy consumption. It is obvious that all this is reflected by formula (3) and shows the correctness of the approach in determining competitiveness.

As to the cranes, the necessity of calculating the alternative remains because they consist of large metal construction so when using only a slightly lighter material, the total mass is largely reduced. In the abovementioned study [10], it is shown that the observed trend in the change of the mass ratio over the years allows us to predict with some degree of accuracy the mass ratio in the future. Thus some of the characteristics of a future machine can be defined so that it meets the competitive advantage condition. Based on this, this work also offers a way of forecasting k_{K}^{n} for the competitive companies.

The components of formula (3) are considered so that dependencies $k_K = F(\Theta) = \frac{M_{KP}}{LM_T} Z$ are prepared with constant other parameters, i.e. the change of the coefficient k_{K}^{n} is considered at different forms of the sections during time. The same is conducted for: Ω - the types of profiles which constitute the section; Ψ - the material of which they are made; Δ - the technology of production. Then the solutions $x_{\Theta\Omega\Psi}^{\Delta}$ for k_{K}^{n} $(\Theta = 1,2,...,\Theta^{\nabla})$, $(\Omega = 1,2,...,\Omega^{\nabla})$, $(\Psi = 1,2,...,\Psi^{\nabla})$, $(\Delta = 1,2,...,\Delta^{\nabla})$ will be:

$$\left\| x_{\Theta\Omega\Psi}^{\Delta} \right\| = \begin{vmatrix} x_{\Theta\Omega 1}^{1} & \cdots & x_{\Theta\Omega\Psi}^{1} & \cdots & x_{\Theta\Omega\Psi^{\nabla}}^{1} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{\Theta\Omega 1}^{\Delta} & \cdots & x_{\Theta\Omega\Psi}^{\Delta} & \cdots & x_{\Theta\Omega\Psi^{\nabla}}^{\Delta} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{\Theta\Omega 1}^{\Delta^{\nabla}} & \cdots & x_{\Theta\Omega\Psi}^{\Delta^{\nabla}} & \cdots & x_{\Theta\Omega\Psi^{\nabla}}^{\Delta^{\nabla}} \end{vmatrix} . \qquad (8)$$

The decisive algorithm methodology for preparing a competitive bid is the principle of "top - down design" i.e. starts from the particular market and competitors and includes the main steps shown in Figure 2:

Step 1. Choice of a particular market. Determination of the specific market where our facility will participate, including metal construction and customer needs. The necessary restrictions and regulations of this market and logistics requirements are determined.

Step 2. Identification of possible competitors. Identify potential competitors and offers that are available on the market. Identification is based on experience and observation of the behaviour of competitors along with market analyses.

Step 3. Analysis of competitors. This step builds knowledge base of the company (*firm's knowledge base*). Possibility to create, transfer, collects, integrate, protect and use of knowledge assets is the primary factor in achieving and maintaining the competitiveness of modern companies. Effective knowledge management in companies is achieved by applying the model of *Nonaka & Takeuchi* [15, 16], which takes into account the interaction between the hidden and explicit knowledge. When analysing competitors' metal structures, hidden knowledge (*tacit knowledge*), that includes subjective insights, intuitions and hunches, plays an important role. It is deeply rooted in individual action and experience, as well as ideas, values and emotions.

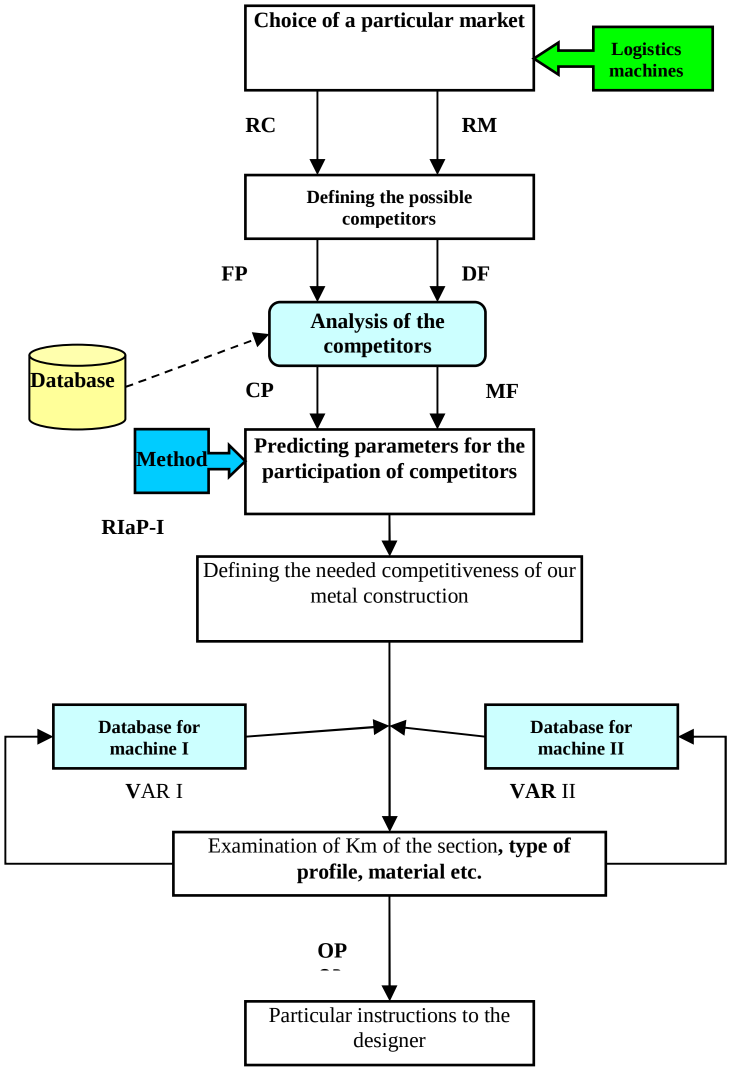

Figure 2. Calculating algorithm – structure scheme
RC-requirements of the client; RM-requirements of the market; FP-producer company; DF-database of the company; CP-competitiveness of the companies; MF-parameters of the construction; RIaP-I- solutions for the metal construction of the competitors; VAR-I R VAR-II-l variants of solutions; OP- optimal values of the elements.

The third element of the model of *Nonaka & Takeuchi* for creating knowledge are assets of knowledge. According to *Nonaka et al.* [17] these are the resources that form the basis of the process of knowledge creation and are necessary for its maintenance. These assets of knowledge include knowledge of competing companies such as companies' technological skills, products, timing, innovations supplies, etc., separated in module "competitors."

The database has a tree structure and is suitable for an *XML* representation (*W3C* Recommendation, 2006). Information in the XML structure has to meet the standards of the World Wide Web Consortium (*W3C*) syntax, which corresponds to the information structure of the above system.

This database is used to analyse each of the identified potential competitors and to identify possible characteristics and parameters of the metal structure. Thus it is possible to calculate and monitor the coefficient, including its absolute changes and the growth rate, adjust the hidden knowledge database, etc.

Step 4. Predicting parameters for the participation of competitors. After performing analysis of possible competitors, it is possible to predict the coefficient k_K^n for every competing company. The result is the set $^n_K M$ of the forecasted k_K^n. The required prediction accuracy is achieved by comparing each estimated coefficient with its subsequent actual value and adjustments of the participating variables and coefficients.

The prediction is carried out by the known methods for 2 to 3 year period estimation [18]. In its treatment of statistical data the forecast submitted as a set of classes, each representing a temporary time series of a particular parameter. At this point all parameters (base and chain indices) must be set. The processed information is presented graphically, providing meaningful analysis and comparative assessment of changes of the analysed dynamic index.

Evolution of dynamic indices is shown with a gradual increase or decrease of their values, characterized by monotonous nature of the change in time. The proposed methodology includes a graphical mathematical processing, variance and comparative analysis of the results suggests high professional qualifications and provides great amenities on automated processing and decision making during the design development through appropriate dialogue mode.

Based on the resulting estimated coefficient k_K^n a prediction of the parameters of the metal structure, which firms would offer in the offer to the customer is carried out. This is achieved by following the trends of the metal structures of competitors.

Step 5. Defining the needed competitiveness of our metal construction. To establish the necessary competitiveness of metal constructions, the corporate knowledge base should contain the following components [15]:

- Module competencies of the company - technological and intellectual capacity and potential of the company;
- Customer module - needs, desires and advices of the client;
- Supplier module - supplier capabilities and other information.

On the basis of the existing database the value of the necessary competitiveness is determined, which value is determined by $k_K \cdot k_K$ varies in the interval [$k_K^{\min}, k_K^{\max}$], where $k_K^{\min}$ is the minimum value amongst the analysed competitor companies, and $k_K^{\max}$ is the maximum value amongst the analysed competitor companies. The desired value for k_K, are choose (define) using the described method by using the relative coefficient $^o k_K^n$ and regarding the politics of the company and the design conditions.

Cost of individual solutions for the metal construction of a logistics machine having N number of models, each model is designed for Ñ ranges are shown in Table 1.

Table 1. Cost of individual decisions

Elements		Solutions for the metal construction									
		Model 1			Model 2			…	Model N		
		Range 1	Range 2	Range Ñ 1	Range 1	Range 2	Range Ñ 2	…	Range 1	Range 2	Range Ñ N
№	Name	value	value	value	value	value	value	…	value	value	value
1	Type of section	C_{11}^1	C_{11}^2	$C_{11}^{\tilde{N}1}$	C_{12}^1	C_{12}^2	$C_{12}^{\tilde{N}2}$	…	C_{1N}^1	C_{1N}^2	$C_{1N}^{\tilde{N}N}$
2	Type of profiles of which the section is constituted	C_{21}^1	C_{21}^2	$C_{21}^{\tilde{N}1}$	C_{22}^1	C_{22}^2	$C_{22}^{\tilde{N}2}$	…	C_{2N}^1	C_{2N}^2	$C_{2N}^{\tilde{N}N}$
3	Used material	C_{31}^1	C_{31}^2	$C_{31}^{\tilde{N}1}$	C_{32}^1	C_{32}^2	$C_{32}^{\tilde{N}2}$	…	C_{3N}^1	C_{3N}^2	$C_{3N}^{\tilde{N}N}$
4	Technology of production	C_{41}^1	C_{41}^2	$C_{41}^{\tilde{N}1}$	C_{42}^1	C_{42}^2	$C_{42}^{\tilde{N}2}$	…	C_{4N}^1	C_{4N}^2	$C_{4N}^{\tilde{N}N}$

Step 6. Examination of Km of the section, type of profile, material etc. Based on the chosen value of k_K the various section options are examined. The result is a list of possible configurations of the metal structure. Based on the obtained value we define different variants for obtaining this value by

changing the section type profile, the materials and the technology of production.

Determining the cost of material used (steel sheet or profiles) plays an important role when building the supply chain. Our studies indicate that for the current task a "*maximum supply chain*" is suitable, where integration is such that avoids critical management situations, such as deficiency or excess inventory in the chain as a result of whiplash effect (*"Forrester effect*").

There are many management concepts designed to address problems arising in supply chains with metals (e.g., shortening delivery time, an adequate response to market changes, etc.). Our research has shown that a proper way of simulating similar situations is possible through the software *AnyLogic 6.9.0*. Using *AnyLogic 6.9.0.* different models of manufacturing, logistics, supply chain, market, competition, etc. are developed. These models are based on the basic paradigms of imitation modeling, agent modeling, modeling of discrete events and system dynamics.

The ability to mix different approaches allows for the easily and accurate description of real-world processes. This is done through *AnyLogic* standard libraries: *Enterprise Library, Pedestrian Library, Rail Yard Library* [19] for metal constructions. The proposed simulation software helps in the analysis of the two known major policies for the management of stocks:

1) A system of inventory management with a fixed interval between orders – where the current stock is equal to the projected demand, the order is made in a given period of time.
2) Management system with a fixed quantity of stocks for ordering at the maximum volume of the stock (system type (*s*, *S*)) - where the stock is periodically checked at regular intervals, and the new order is placed when the volume drops to critical point of order (fallback stock). The amount of the contract is determined as the difference between the maximum and current stock inventory for a fixed time interval. This type of system is characterized as a mixed between systems with fixed-point and fixed time contract, it is considered that combines the main characteristics, taking advantage of the strengths and overcome their weaknesses.

In the current case, the focus is mainly on stochastic search. Beyond the specified dimensions (as planned orders for finished products) the demand cannot be considered permanent, since real-world conditions of uncertainty as economic conditions, competitive actions, changes in regulation held, market conditions or consumer tastes cannot be ignored. In this sense the application of the *EOQ* model for most of the stock is not appropriate in the case of a production logistics system for metal constructions. Other important factors are unknown (sought) - optimal amounts for each of the stocks, unknown time of placing an order to a supplier for an indefinite amount of costs.

Due to the strong probabilistic nature of the initial conditions, the optimal setting of specific values is achieved by simulating different situations and searching for optimal values of the desired outcomes, expressed by the total cost and percentage of successful orders. An indicative comparison between the two policies for stock management is performed by *AnyLogic 6.9.0* academic version. The comparison proves that while maintaining the same high quality service to customer orders (less than 1% unfulfilled orders) for the management of stocks with a fixed quantity to order at maximum volume of the stock (system type (s, S)) the economic result is better - the costs are about 30% lower.

It is recommended when setting a new search for stochastic parameters (the number of outstanding orders, total expenditure and number of orders) that the parameters vary from the mean of the normal distribution by up to 50%.

Step7. Particular instructions to the designer. Based on the resulting variant of the preceding paragraph, the designer selects a particular section and prepares an offer to the clients. The result is a ready configuration of the metal structure at the lowest acceptable cost.

3. Conclusions

An approach and methodology for preliminary determination of the competitive advantages of the metal structures of logistics machines are worked out. Both could be used in developing an attractive business offer or in designing the construction of these machines.

It has been attested that the presented model provides wide opportunities for research and analysis as well as for subsequent optimization. When optimization is to be performed, there must be enough clarity about the laws of the involved changes and the parameters selected, so as to facilitate the selection of the most suitable option for optimization.

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