Supply chain efficiency analysis in innovative company based on MCC-3C methodology

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ABSTRACT: The expansion of three-circuit Matrix of Core Competencies (MCC-3C) methodology aimed at improving supply chain (SC) efficiency in an innovative company is examined. It is demonstrated that analysis of production and development factor groups as part of the MCC-3C model, when analysing the supply chain structure, makes it possible to distinguish the criteria for decision-making on allocation and optimising the utilisation of competencies involved in the company's activities. Approaches for determining the applicability limits of qualitative theories and formation of quantitative assessments are proposed that allow justifying the structure of internal SC and positioning in external ones. An example of the MCC-3C methodology application in the SC design of an international company producing final hi-tech products is provided.

1 INTRODUCTION

The resulting (basic target) indicators (BTI) of the activities of economic entities are largely due to the adopted structure of the target indicators (TI) of internal subsystems and the effectiveness of their achievement (Podchufarov 2013, Samoylov & Podchufarov 2016). Supply Chain Management (SCM), irrespective of the breadth of interpretation of this concept, is an important factor for success in a market economy. In this regard, the credibility of the assessment of the significance and effectiveness of internal and external elements of SCM largely determines the rationality of the involvement and use of resources, both in the implementation of operational and strategic development plans.

The methodological basis for the development of a balanced SC structure can be the provisions of the theory of system interaction, which, based on the principles of the system approach, provides an effective tool for finding the best ways to achieve the resulting target indicators. Over the past few years, this direction has been actively developed by specialists of the Faculty of World Economy and World Politics at the Higher School of Economics, Moscow based on the Department of foreign economic association "Avtopromimport" "State and Corporate Management Systems".

When formulating justified solutions in the field of socio-economic interaction, a significant role is played by the availability of adequate models of the objects under consideration. The complex nature of the field of research has determined the development of a wide range of approaches to its analysis and forecasting. However, despite the high interest in this subject, there is still lack of practice-oriented methods that combine the depth of analysis with the visibility and convenience of their application in the stages of preparation and adoption of managerial decisions. To date, one can note the prevalence of two approaches in this field:

- the use of detailed mathematical models that require specialized knowledge in the theory of exact sciences and modern software-analytical tools;
- decision making on the basis of qualitative estimates and generalized characteristics of the object under study with minimal involvement of the mathematical apparatus.

Typical examples of the first approach, as a rule, include VAR-modeling (Vector AutoRegression), system dynamics model, DSGE models, etc. Examples of the second approach include the structural and strategic analysis methods (the five-factor model, the diamond model of competitive advantage, the value chain of M. Porter), the methods of expert evaluations (evaluation of competitive strength by A.A. Thompson and A. J. Strickland), matrix methods (BCG, GE/McKinsey, ADL) and many others.

Relevant situation is in SC sphere. The specific nature of SCM activities has determined the range of methods that take into account its features. As a rule, more sophisticated methods are provided by integral approaches aimed to analyze performance measurements and overall efficiency of SC based on relatively complicated methodologies: system dynamics, DEA, etc. Methods that use quite simple mathematics are available as well: SCOR model, methods based on balanced scorecard and benchmarking methodologies, etc. Comprehensive reviews of the SCM concept and respective methods can be found in Goedhals-Gerber (2010), Pettersson (2008), Sillanpää (2010).

There is also a range of methods aimed to analyze specific SC problems: cost and cost-benefit analysis emphasized on assessing logistics costs and ways to reduce them; ABC-analysis – a method of classifying resources by significance; XYZ-analysis – a method of classifying resources by characteristic trends in consumption; RFM-analysis – a method of customer segmentation based on the nature of consumption of the products produced by the company. The underlined methods are practice-oriented, are based on relatively simple mathematical models, give clear and easily interpreted results.

However, the above mentioned approaches do not fully bind SC elements with overall competitiveness of the company, which makes it difficult to obtain an integral assessment of their influence on the company's activities as a whole and take into account the significance of every single of them in achieving it.

2 MCC-3C METHODOLOGY

For a comprehensive analysis of the activities of market relations in modern conditions, a methodology for assessing and managing competitiveness based on the three-circuit MCC-3C model, proposed by the authors of the article, is widely used at present. In general, competitiveness in the approach has three circuits for consideration, reflecting the interconnection of its components. In the first circuit, consumer quality indicators are analyzed, in the second – the competitiveness factors and in the third – the core competencies (CC). In the first circuit, the optimization problem is solved based on the requirements for external consistency, in the second – internal consistency and in the third – consistency in the subsystems of the life cycle (Podchufarov 2018).

Within the framework of the approach, the object under study is represented in the form of a system of interconnected segments, refer to Figure 1, and is characterized, on the one hand, by an integrated competitiveness indicator, determined by the joint influence of the competitiveness factors included in the segments under consideration, on the other hand, by indicators of the position of the object on the market.

As a result, the mechanism of the iterative verification (sequential refinement) of the received estimates is laid in the methodology, which ensures the convenience of using MCC-3C models when developing algorithms and coordinating management decisions. Analysis of the effectiveness of the use of competitiveness factors and their significance in achieving the resulting (target) indicators is carried out on the basis of Matrices of Core Competencies (Podchufarov 2013).

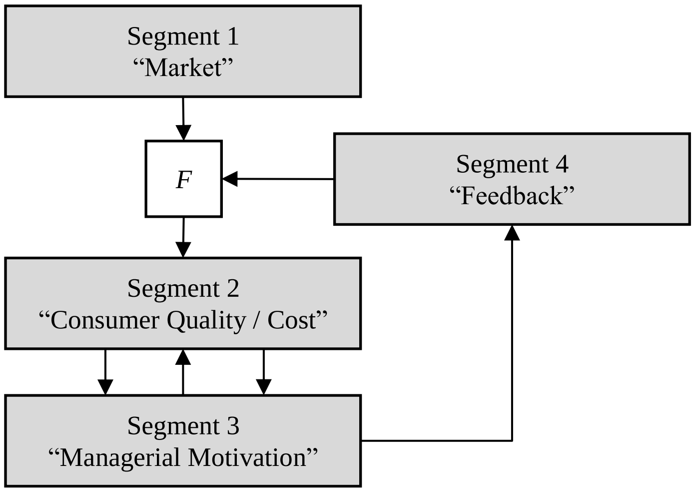

Figure 1. MCC-3C model segments and their interaction.

The model considers the structure and the assessments of the competitiveness factors linearized close to the equilibrium trajectory, where each factor is described by its comparative indicator (*CI*) and the significance indicator (*SI*):

- *CI* is a nondimensional value that determines the level of the current comparative state of the factor with respect to the competitor in question, the valuation of which is assumed to be 1;
- *SI* is a nondimensional value that determines the degree of influence (lag / advance) of the considered factor value on the basic target indicator.

The *CI* and *SI* are defined by assessments of variables or functional dependencies in the planning interval under consideration. Calculation of resulting indicators is made in accordance with the economic interpretation of this concept and the rules applied in the Control Systems theory to the transfer functions.

The generalizing indicator K_i for the *i*-th factor in static case (the coefficient of the transfer function) and generalizing indicator K_n for the *n* sequential elements are determined by the formulas:

$$K_i = 1 - (1 - CI_i) \times SI_i; \quad (1)$$

$$K_n = \prod_{i=1}^{n} K_i, \quad (2)$$

where *n* – total number of factors.

For example, if specified factor for the object under investigation has *CI* = 1.2 and *SI* = 0.5 when it means that we assess it by 20% better than the same factor of our competitor (which equals to 1). From (1) and (2) follows that it defines 10% (20% × 0.5) increase in K_n (as compared to *CI* = 1).

The indicator of competitiveness (*CMPI*) in case of direct circuit:

$$CMPI = K_{MR} \times K_{CQ/C} \times K_{MM}, \quad (3)$$

where K_{MR} – coefficient of the transfer function for Segment 1, $K_{CQ/C}$ – for Segment 2, K_{MM} – for Segment 3.

The proposed approach in many ways makes it possible to combine the depth of the mathematical apparatus of the model with an intuitive interpretation of the intermediate and final results. To increase the reliability, methods of harmonizing evaluations with statistical results of the analysis of significance of factors can be used based on the VAR analysis of the relevant time series.

Taking into account the dynamics of factors and their cross-influences, it is possible to generate dynamic MCC-3C models in which the interaction with internal subsystems is represented as an oriented graph. In such a model, the competitiveness indicator of the subsystem of a lower level determines the *CI* of the corresponding factor in the higher-level subsystem, and its SI is an estimate of the cross-influence between the specified subsystems (Podchufarov 2018).

The decomposition of the basic system into internal subsystems and the methodology for assessing the cross-influence of factors proposed by the MCC-3C approach allow us to construct an "end-to-end" scheme for the formation of competitiveness, to identify its most significant elements and to set requirements for the values of their indicators. The implementation of a set of inter-system interaction measures eliminates sources of imbalance in the systems under consideration, which are the cause of unsustainable or inefficient development, and allows the formation of proposals aimed at their further improvement. However, practice shows that the results acceptable for application in some cases can be obtained on the basis of simplified MCC-3C models that consider the first two interaction circuits and do not include the analytical instrument of cross-influence accounting.

It is important to note that the proposed approach allows linking indicators of various functional directions determining the achievement of BTIs and taking into account the potential of core competencies structured in accordance with the MCC-3C.

3 MCC-3C IMPLEMENTATIONS IN SUPPLY CHAIN MANAGEMENT

Considering SCM as one of the important components of management, which in many cases encompasses the complete circuit of the life cycle of the products, it is logical to adopt the prevailing opinion about the high relevance of the task related to the choice of the methodological basis of the SCM analytical apparatus as an element of the overall management system.

Using the MCC-3C models in SCM makes it possible to identify problem factors and to form the structure of cause-effect relationships that determine the achievement of the resulting indicators. Analysis of the effectiveness of SC allows to identify the criteria that justify the decision-making about business models of participation in external SC and the transfer of internal SC elements to the external interaction circuit.

As noted above, the application of the MCC-3C approach allows us to determine the competitiveness factors and obtain their numerical estimate. Also, the functionality of MCC-3C model makes it possible to evaluate groups that characterize certain areas of activity. Analysis of the importance of groups of factors and their correlation with the CC structure forms the basis for the preparation of conclusions about the feasibility of developing certain competencies in the internal or external circuits of SC.

Introducing the concept of significance indicator of the k-th group of factors (SIG_k):

$$SIG_k = \sum_{i \in F_k}(SI_i), \quad (4)$$

where F_k – the subset of factors in the k-th group, and the significance indicator of the k-th group of factors in the two-dimensional state-space with coordinates SIG^D – significance indicator of the development factors and SIG^P – significance indicator of the production factors:

$$SIG_k^{(D;P)} = (SIG_k^D; SIG_k^P), \quad (5)$$

$$SIG_k^D = \sum_{i \in D_k}(SI_i),\ SIG_k^P = \sum_{i \in P_k}(SI_i),$$

where D_k and P_k – the subsets of factors belonging to the k-th group and referring to "development" and "production" respectively ($D_k \cup P_k = F_k$), it is possible to form an array of data characterizing the groups of the object under investigation. It is convenient to project them on the coordinate plane with the X axis corresponding to the SIG^P and the Y axis corresponding to the SIG^D, referred to as the "area of specialization", Figure 2. Groups on the figure are represented by points in the first quadrant of the plane.

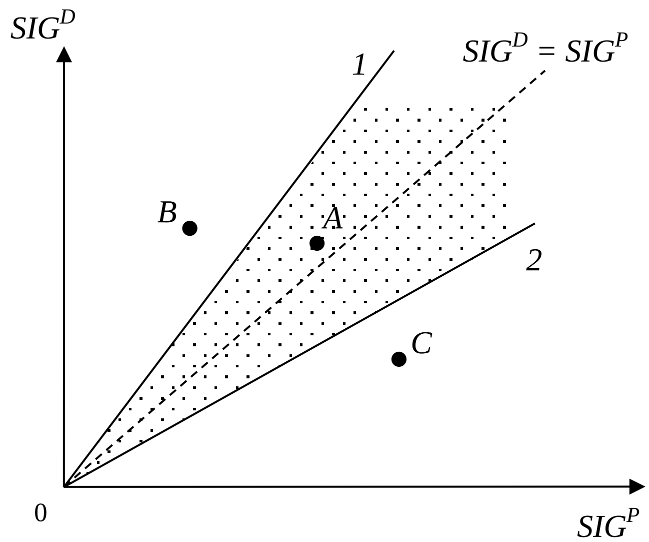

Figure 2. Factor groups representation in the area of specialization.

Line $SIG^D = SIG^P$ divides the allocated quadrant into two equal parts. In the case where the indicators of the groups lie above this line (for example, groups *A* and *B*), the significance of the production factors for them is higher than the significance of the development factors. Consequently, for the indicators of the groups lying below the line (for example, group *C*) the situation is reversed, and the significance of the factors of production will be lower than the significance of the development factors. In practice, it is convenient to single out a "sector" of values, in which these indicators are comparable, that is, their ratio is close to one. The given region is bounded by arrows 1 and 2 (highlighted by dotted lines).

Of particular interest is the analysis of significance indicators of the resultant groups of factors characterizing the objects in question as a whole (resulting significance indicator of the group, SIG_{res}). This indicator is calculated using formula (4), where the whole set of factors formed by MCC-3C model for the object under investigation is considered.

In the case the SIG_{res} areas on the figure fall outside the shaded segment, decisions about the inclusion of SC elements in the external or internal contour, as a rule, with acceptable reliability can be justified by qualitative estimates, and in many cases it is sufficient to use the provisions of the theory of transaction costs (Coase 1988). For example, in the case of an arrangement above arrow 1 (point *B*), it is logical to transfer to the external contour the links that based on R&D activities, and transfer the production of the main components to the internal contour. Otherwise, when objects lie below arrow 2 (point *C*), it is advisable to include the elements responsible for the production of components of the final product in the external contour, while the R&D activities are carried out in-house.

In the case when SIG_{res} is placed in the allocated segment, between arrows 1 and 2, in order to work out a decision on the structure of SC, a more detailed analysis of the group indicators, as to their mutual location in the area of specialization and relationship with the core competencies (Podchufarov & Senkov 2017) is required.

Particular attention should be paid to the situations when the companies under consideration are characterized by the SIG_{res} placed within the allocated segment, and belong to a class of high-tech enterprises focused on producing end products. As a rule, they are characterized by active interaction of production units and R&D, and in many cases small- and medium-term specialization.

Below is an example of an analysis of the SC structure based on the MCC-3C model for a high-tech company (an international machinery holding), whose feature is the active interaction of R&D and production-related units both at the development stages and support in the manufacturing of the final products, specializing in medium-series production.

The use of the MCC-3C model in the analysis of the activity of this enterprise made it possible to identify the factors of development and production and obtain estimates of the comparative and the significance indicators (an extract for aggregated groups of factors is provided), refer to Table 1.

Table 1. Indicators of the factors of the MCC-3C model for international machinery holding (extract).

Consumer quality factors	*CI*	*SI*	*K*
Production			
Components of own production	1.10	0.15	1.015
Components of external manufacturers	0.80	0.15	0.970
Assembling the final products	1.10	0.10	1.010
Ensuring product lifecycle	0.50	0.15	0.925
Other	0.85	0.15	0.978
Development			
Components of own production	1.30	0.10	1.030
Components of external manufacturers	0.80	0.20	0.960
Integrated solutions (complexes)	1.05	0.10	1.005
Processing and management algorithms	0.90	0.20	0.980
Technological processes	0.80	0.20	0.960
Other	0.85	0.20	0.970

Cost factors	*CI*	*SI*	*K*
Production			
Components of own production	1.20	0.20	1.040
Components of external manufacturers	1.10	0.20	1.020
Assembling the final products	1.20	0.20	1.040
Ensuring product lifecycle	1.10	0.10	1.010
Other	1.05	0.10	1.005
Development			
Components of own production	1.30	0.20	1.060
Components of external manufacturers	1.10	0.10	1.010
Integrated solutions (complexes)	1.10	0.10	1.010
Processing and management algorithms	1.20	0.10	1.020
Technological processes	1.10	0.10	1.010
Other	1.05	0.10	1.005

In the case under consideration, the estimates of the significance of the resulting factors of production (1.5) and development (1.7) are comparable, which corresponds to the shaded segment of the area of specialization on Figure 2. An analysis of the position of the group indicators in this area presented in the table and their relationship to the core competencies (Podchufarov & Senkov 2017) made it possible to formulate the requirements for the SC structure of the enterprise under study aimed at balanced utilization of its own CCs, significance indicators limits, as well as the development of cooperative ties and strategic partnerships in justified areas of activity, refer to Figure 3. Radius of each circle on Figure 3 is proportional to the utilization of respective CC. Factors that form groups placed inside circles are treated as activities developed inside the company. To design efficient SC other factors are more likely to handle on "outsource" basis.

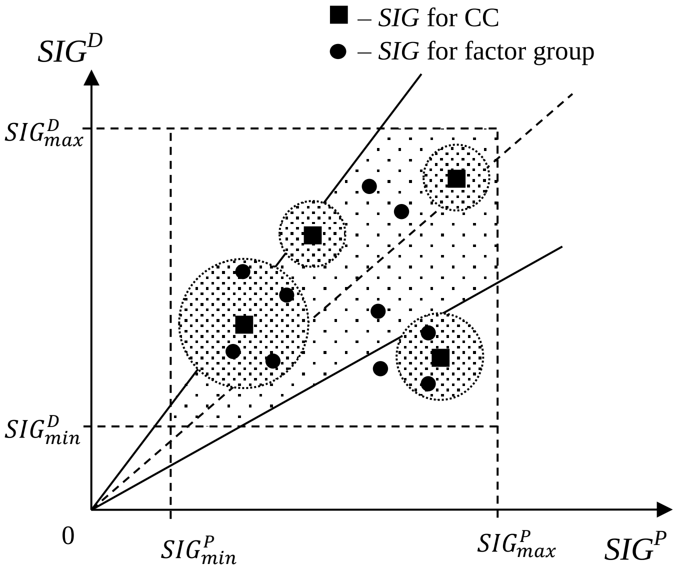

Figure 3. Analysis of core competencies in the area of specialization for international machinery holding (extract).

Taking into account the specifics of the enterprise, determined by the big role of R&D and the limited serial production of end products, additional requirements were determined for SCM processes in terms of their flexibility and adaptability to changes. Special attention was paid to SC in the R&D sphere, which is due to the need for deep immersion in the subject area when placing orders in the external circuit for components of newly developed products and quality control of their execution. Also, the features of the external cooperation factors were taken into account. In the case examined, the cost of the purchased products was largely determined by the conditions of the relations between the counterparties at the product development stage and the indicators of mutual interest in a long-term partnership, which is characteristic of the specific nature of the company under study.

Situations similar to those considered in the terminology of the XYZ analysis are characterized by the nomenclature of the category Z, which significantly exceeds the number of values corresponding to large-series production enterprises. As a consequence, in many cases, the top management of the enterprise assumes the processes for its formation and control over execution, with institutional support from the competent collegial bodies, including representatives of owners and counterparties, and, in the presence of state orders, regulating and controlling authorities. The units that support SCM processes associated with the nomenclature corresponding to categories X and Y generally have a negligible amount of output in terms of money.

Features of the case are quite common in the production of critical components and products for long periods of use. Examples of sectors of the economy that are consumers of this class of products include shipbuilding, machine-tool construction, aviation, space, chemical, power industry, and others.

4 CONCLUSIONS

A high level of competition in the modern market dictates the need to build effective supply chains. A typical trend in such conditions is the management's desire to increase the reliability of analytical information for making decisions about the development of its internal core competencies and the transfer of non-core SC elements to the external contour within the framework of strategic partnerships and external cooperation.

The extension of the MCC-3C approach presented in the article includes a methodology based on an analysis of the significance of development and production factors, which makes it possible to identify the composition and obtain quantitative assessments of the criteria that justify the development of requirements for the SC structure. The class of companies in which the specified groups of factors have comparable indicators of significance is investigated. Special attention is paid to enterprises specializing in medium- and small-series production of high-tech end products. The essential features of the SC of such companies are indicated.

In general, the principles of the system approach, the theory of interaction of systems and the MCC-3C models developed on their basis allow to do quantitative assessments of the influence of the SC structure on the achievement of the BTI of the subjects of economic relations being investigated, to set requirements for SCM processes and to develop an informed decision on their internal or external implementation. At the same time, the joint use of the proposed approaches with specialized methods of analysis and forecasting, according to the authors, can provide the maximum positive effect when planning the company's activities in the SCM field.

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