DIMENSIONS FOR DEVELOPING SUPPLY CHAIN INTEGRATION SCENARIOS

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Abstract

The paper focuses on the issues of supply chain integration. The integration process is considered from the perspective of possible directions of its implementation. The choice of integration directions and types of actions is limited by space defined by: specific integration factors, their aggregate measure as well as assessment measures applicable to supply chain operation. The space in question determines the dimensions for developing supply chain integration scenarios. The authors undertook to verify this claim based on the 19 factors they had previously identified, their 4 described integration advancement levels, the supply model they had developed as well as using a series of simulation experiments. By applying process modelling and simulation methods, they managed to represent characteristic features of supply chain operation at each integration level for all identified factors. Empirical data necessary to verify the initial thesis were obtained by subjecting such model of supply chain to simulated material planning and flow in the option of dynamic changes resulting from the application of scholastic demand distribution. In doing so statistical methods were used for the general option (complete supply chain integration – all factors) and the specific option (for each factor individually). The authors found two issues to be particularly important – the correlation (established using binary methods) between supply chain performance and the integration level, or the lack of such correlation, but also regression power between these two variables.

Key words: SCM – Supply Chain Management, integration process

1. INTRODUCTION

Integration of supply chains is currently one of the key challenges for modern management in the global economy. Engaged in competition with one another, companies are looking for new conceptual ideas and methods of reducing operational costs and increasing their flexibility. Improved flexibility – in terms of the time needed to respond to current market needs and implementation of ambitious plans of product innovation – is impossible without progressive integration of supply chains. In recent decades supply processes have been evolving from little more than meeting of material demands to fostering close (oftentimes strategic) cooperation with suppliers. Cooperation between supply chain partners takes various forms; from framework contracts for supplies, to shared forecasting and planning, to concentration of reserves, to cooperation in design and launching production of new products, or of their key modules. The success of these practices offers tangible business advantages to each of partners, with the outcome being robust supply chains that are capable of competing globally. This fact gives rise to the widespread interest among management practitioners and the scientific world in the processes of supply chain integration.

This paper focuses on the aspect related to the formation of an adaptive scenario of supply chain integration. In the process of supply chain management, the leading company takes decisions on the directions of integration progress. Multidimensionality of the issue and the number of factors affecting the real level of integration force companies to carefully select the actions they should take. The choice of integration directions and types of actions is limited by space defined by: specific integration factors, their aggregate measure as well as assessment measures applicable to supply chain operation. The space in question determines the dimensions for developing supply chain integration scenarios. The authors, based on the studies on the multi-faceted conditions of supply chain integration, verified the assumptions presented above by simulation experiments performed using the created model.

2. DEVELOPMENT OF SUPPLY CHAIN INTEGRATION

In recent years, given the observable pressure on cutting costs of production activity along with reducing order implementation time, integration of processes has been a frequent topic of scientific papers, with particular attention being paid to planning processes (Daviaud, 2006, p. 33-34, Muzumdar & Fontanella, 2007, p. 35). In specialist literature, integration is often discussed in the context of supply chain management as an element required to secure high performance results. "The task of cooperating supply chain links is to attain high efficiency [...] through integration and coordination of all actions" (Łupicka-Szudrowicz, 2004, p.49). The papers examine the impact of integration on supply chain performance. In their paper, Lummus, Vokurka and Krumwiede showed that a higher integration level in supply chains makes it possible to attain better cost indicators (Lummus et al., 2008, p. 56-63). Many authors have made an attempt to identify the factors that affect the integration level. The study by Wong and Boon-itt concentrates on institutional standards and uncertain environment. They proved that standards intensify integration processes and that the integration level goes up as environmental uncertainty increases (Wong, & Boon-itt, 2008, p. 400-410). Based on the studies presented in specialist literature, one may say that soft integration factors obviously dominate over hard integration factors, which makes it harder to assess the phenomena in question objectively. Numerous papers emphasise that attaining full integration requires exchange of information about supply, production plans, distribution of benefits, as well as shared planning and implementation of strategies related to a physical product flow. Integration of product flows is a particularly difficult task given the presence of numerous models of material flow planning. The abundance of models results from customers' changing needs and constant attempts at costs rationalisation in production businesses (Stachowiak, 2003, p. 68-71). Specialist literature offers a number of papers tackling the issue of material flow planning models. Chronologically, the oldest are the models which assume inventory formation to facilitate smooth flow of material through the production system. The need to minimise costs and emergence of IT tools supporting performance of MRP algorithms contributed to broad application of that model. The development of computer hardware and software made it possible for users of the MRPII model to balance production tasks with available capabilities, as well as to integrate the production area with other company functions, such as accounting, finances, HR or distribution (Pająk, 2007, p.226). Further attempts at lowering the costs of operational activity bore fruit of the JiT model (Just in Time). The aim of JiT is to reduce the inventory level by organising just in time deliveries in the conditions of rhythmic production (Payne, 1993, p.304). Further integration within the supply chain resulting in coordination and optimisation of actions within the chain is known in specialist literature as the Supply Chain Management (SCM) strategy (Douglas & Griffin, 1996, p.1). Another noteworthy observation is the fact that most examinations of the integration of chain participants refer primarily to forward flows, performed from the producer to the consumer. What is more, a supply chain is often treated fragmentarily, as a relation between two participants: supplier-purchaser. Backward supply chains become more significant in the context of the quality of life of future generations. A pro-integration tool is tax reliefs and low interest loans as they provide financial spurs that encourage changes in the current production profile by facilitating the use of secondary raw materials (Bieda, 2007, p.28.). What is necessary is the transformation of logistic areas with more weight placed on the environmental protection aspect. Therefore second-hand products regain their value that was lost in the course of their operation, and they are remarketed. Given how limited resources are, reuse of products is economically attractive (Kruczek & Żebrucki, 2009, p.22) while the area related to waste may be perceived as an infinite plane offering the possibility to create added value (Brdulak & Michniewska, 2009, p.16).

Supply chain integration is an evolutionary process, namely the integration of specific participants proceeds in stages. For this reason integration can be accessed through determining its current level. The creators and advocates of the supply chain management concept tend to agree that achieving full integration of partners requires covering a challenging, long and multi-stage road. Specialist literature, however, presents diverse views on specific procedures that can be followed to reach higher levels of cooperation. For this reason the authors wish to describe and organise various opinions on reaching top partnership levels as part of integrated supply chains. Generally speaking, there is a common agreement about the fact that the supply chain integration process should start with improving internal logistics of the company that assumes the role of a change leader. An intermediate integration level is the implementation of a test programme of supplier development. Crucial for attaining the top development level, understood as an integrated supply network, is building true partnership with preferred suppliers and key clients as well as application of shared IT systems based on online solutions (Witkowski, 2010, p.73-75).

In structuring the knowledge of supply chain integration of the forward and backward type, the authors carried out a detailed analysis of four reference models used in this area. They are:

- three tier model by A.T. Kearney,
- four tier model by Ch.C. Poirier,
- five tier Compass model,
- SCOR model.

Since the models differ from one another, a decision was made to compare them. Ten criteria were established according to which scores were awarded to each model. The objective of the criteria was to identify the model offering the most comprehensive scope of the analysis of integration as well as finding possible research gaps. The results of the performed analyses can be seen in Table 1.

Table 1. Analysis of supply chain integration models

	Model by A.T. Kearney	**Model by Ch.C. Poirier**	**Compass model**	**SCOR model**
Quantifiable values of integration factors	-	-	-	-
Taking into account backward flows	-	-	-	+
Planning	+	+	+	+
Information flow	+	+	(+)	+
Material flow	+	+	(+)	+
Financial flow	+	+	(+)	+
Equity relations in the supply chain	-	+	-	-
IT in the supply chain	+	+	+	-
Competences of staff	+	(+)	-	-

	Model by A.T. Kearney	Model by Ch.C. Poirier	Compass model	SCOR model
Activities controlling in supply chain	+	(+)	(+)	+

Where:
\+ The model meets the criterion
(+) The model partially meets the criterion
– The model does not meet the criterion
Source: Hentschel, B., et al., 2015, p.120

An analysis of the summary presented in Table 1 suggests that no integration model presents quantifiable integration factors. The models presented in specialist literature are based on quantitative descriptions and lists used to verify specific statuses within supply chains. Moreover, only one model recognises the occurrence of reverse flows in supply chains.

To sum up, the methods of assessing supply chain integration levels put forth in specialist literature usually depend to a large extent on identified integration stages, with integration itself being divided into internal and external. The internal integration stage is mostly characterised by attempts to reduce costs, while the external integration stage – by maximising profits and market share (value increase). To each integration stage a set of specific characteristics is assigned being subject to measurement and assessment. The main drawback of the solutions in question is inaccuracy of proposed characteristics, resulting in ambiguity of notions and subjectivity of awarded scores.

3. CATEGORIES OF SUPPLY CHAIN INTEGRATION

As part of the authors' research on multi-aspect conditions affecting supply chain integration, a grading system for integration levels was developed as well. The assessment of supply chain integration level is based on the analysis of the integration level for each identified factor. By using this solution it is possible to comprehensively analyse supply chain integration levels. For each of the 19 identified integration levels 4 levels were described – assessment grades (see more: Hadas et al., 2014a, p.59-78). Each of the levels (A, B, C, D with A being the top one) has a defined performance characteristic which facilitates performance assessment within a supply chain (by being assigned to a specific level). The authors, when describing specific integration levels, focused on:

- integration symptoms,
- symptoms of absent integration,

which made it possible to make assessments based on a typical operation characteristic of a given chain obtained, e.g., during interviews with managerial staff. Table 2 presents 19 categories of integration operations, without their detailed description.

Table 2. Categories of supply chain integration

1. Sales support	5. Transport operations	9. Financing of supply chain operation	13. Recycling cooperation	17. Characteristics of secondary raw material availability
2. R&D	6. Unified packaging	10 Inventory management in supply chains	14. Response to internal supply chain disruptions	18. Ability to accept returns from the market and information flow on secondary raw materials
3. Investments	7. Information flow integration	11. Information quality, accuracy and standards	15. Reduction of material losses	19. Monitoring of the performance of supply chain links
4. Demand forecasting	8. Material flow optimisation	12. Leading cooperation areas	16 Supply provision and secondary raw materials storage	----

Source: Hadas et al., 2014b, p.6

Moreover, based on the aforementioned factors, the authors developed the methodology of determining the integration index for a given supply chain. The methodology of determining the integration index for a given supply chain assumes that full integration of all links within a supply chain is not possible due to (Hadas et al., 2014a, p.59-78):

- its natural dynamics (variability over time),
- assumed strategies of performing specific functions (e.g. short term agreements concerning distribution and sales, or purchases compliant with the "multisourcing strategy", a prerequisite of which is an extensive supplier base with poorly developed cooperation).

Furthermore, as it was assumed in the course of work on the assessment model, integration – rather than being a goal in itself – is a tool that can improve company's operating indicators. For the abovementioned reasons it is necessary to (Hadas et al., 2014a, p.59-78):

- asses the level of supply chain integration for a selected group of key entities (links)
- relate the selection of key links to the rank of a supply item (category) and the chosen strategy used in selecting the number of supply sources for an individual supply item,

- the adopted measure of link significance assessment should include the ranks (managerial decision) and value (measurable in currency units) of supply value stream,
- assessment of integration level should not affect company's sourcing strategy, but be a result of it; it should provide information to support activity at the tactical and operating level.

The supply chain integration model developed at later stages of work, as well as its representation in the application performing process simulations, was meant to facilitate verification of the accuracy of integration level characteristics assumed for selected (quantifiable) integration factors.

4. SUPPLY CHAIN MODEL AND ITS REPRESENTATION IN THE SIMULATION APPLICATION

The authors of this paper created their own supply chain model, based on forward flows (primary raw materials) and backward flows (waste, secondary raw materials).

The model implies a 5-level structure of the supply chain. It includes (see Figure 1):

- suppliers of primary raw materials – e.g. entities offering raw materials,
- intermediaries involved in the trading of secondary raw materials – e.g. entities collecting and offering secondary raw materials, waste stock exchange,
- manufacturer – an entity producing finished goods and their components both from primary and secondary raw materials,
- distributors – entities responsible for the storage of finished goods and supplying them to the sales network,
- sales networks – entities which supply the goods directly to the final customer.

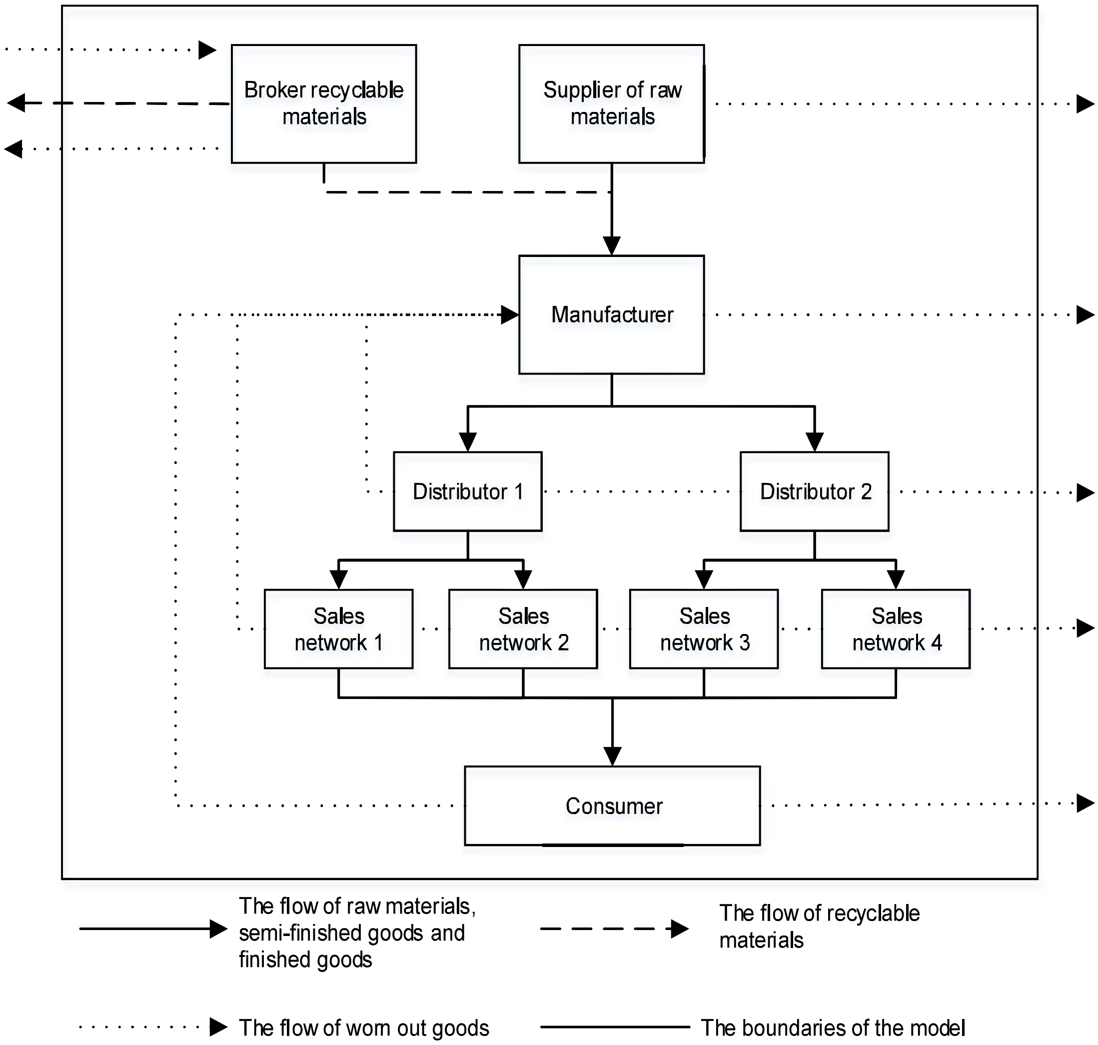
Main input and output data for the model include:

- forecast demand,
- estimated costs,
- actual demand,
- waste stock exchange bids.

Main controlling parameters in the model:

- the prices of raw materials, the prices of finished goods,
- stock maintenance and replenishment costs,
- transport costs,
- material flow times,
- properties of raw materials,
- cash flow times,
- profit margins,
- minimum levels of customer service,
- maximum production capacity and potentials of the partners in the supply chains.

Figure 1. Structure of the supply chain mod



Source: own study

Three metrics have been identified for the purposes of assessing the supply chain within the developed model:

- service level – the ratio of the number of delivered items to the number of items ordered by these customers,
- profitability – a ratio of the achieved material flow as controlled by the profit plan to the generated profit,
- cash flow – identified with an average amount of cash available to the company in the months under inspection.

The presented metrics enable the evaluation of the streams flowing in the supply chain: material stream and financial stream (the perspective of costs and cash).

A model thus developed makes it possible to analyse the impact of selected integration factors and their levels on supply chain performance.

5. SUPPLY CHAIN INTEGRATION MODELLING – SELECTED SIMULATION RESULTS

5.1. Supply chain results for change of the total index of integration level

Before the results of supply chain can be analysed, one should introduce the assessment method in the condition of having six functioning (selected for simulation experiments) integration factors, each of which may assume 4 states (A, B, C, D). The following factors and levels of their integration were analysed:

- Availability of secondary raw materials,
- Integration of planning processes,
- Inventory management,
- Transport operations,
- Unified packaging,
- Material flow optimisation.

For the purpose of a synthetic analysis, one indicator was created as a source of information about the state of supply chain integration. The indicator was formed as a total of numbers representing the levels of integration of each of the selected factors. The following values were adopted for transcription: level A = 4 points , B- = 3 points, C =2 points, and D = 1 point. The aggregate result of integration level assumes 19 various states (from 6 to 24 points - the highest level of integration for all the six factors).

In the next step was done, a number of statistical analysis (Table 3) to verify the dependence between levels of integration and performance of the supply chain (cash flow, profitability, Service level (OTIF – On Time In Full delivery)

Table 3. Summary results of statistical analyses carried out to verify the total integration level

Integration level / **Performance of the supply chain**	**Changes in the total index of integration level** (based on the calculation of selected factors; the results are in ascending order)
Correlation analysis	Between levels of integration and performance of the supply chain
Cash flow	Correlation exists
Profitability	Correlation exists
Service level (OTIF)	Correlation exists
Analysis of regression (for integration level change)	
Cash flow	Large impact (ascending direction)
Profitability	Large impact (ascending direction)
Service level (OTIF)	Large impact (ascending direction)
Analysis of variance significance (ANOVA)	
Cash flow	Significant
Profitability	Significant

Service level (OTIF)	Significant
Analysis of change dynamics (average % of change between integration levels)	For four levels: A, B, C and D for all 6 factors under analysis
Cash flow	14.58%
Profitability	5.30%
Service level (OTIF)	3.41%

Source: Own study

The obtained results confirm that the assessment model of integration level, i.e. a model of characteristics of particular levels for given factors, is correlated with supply chain performance. This means that as the integration level increases, the supply chain performance under analysis changes; moreover – most significantly – these correlations are statistically important.

5.2. A summary analysis of the results of integration level verification carried out for selected factors

On the basis of the results obtained during the previous phase of work, three key factors were qualified for the purpose of detailed analyses of the assessment of impact exerted by a single factor on supply chain performance:

- Secondary raw material availability,
- Integration of planning processes,
- Inventory management.

These are three critical factors that exert the greatest impact on supply chain performance.

The analysis contains an assessment of impact exerted by particular integration factors attributable to various integration levels. The results for the remaining factors are presented in Table 4. The summary of results for each of the factors under analysis demonstrates the correlations and regression power related to specific changes of integration levels and their impact on supply chain performance. Statistical significance of variances was also analysed along with change dynamics with respect to: cash flow, profitability and service level (OTIF). The presented list of results provides an answer to the basic questions concerning verification of correctness of adopted integration levels for each of the factors under analysis.

Finding a correlation between an integration level and supply chain performance is something very much desired. No correlation between the performance and changes in integration levels means that the division (differentiation) into these levels in not important (and hence pointless). In this way one may verify the adopted characteristics of integration levels. The analysis of variance significance helps in drawing conclusions in statistical assessment. Moreover, the analysis of regression and change dynamics allows one to determine the strength of impact exerted by changes in a given integration level on supply chain performance. Thus presented set of results is a valuable material for reaching conclusions.

Table 4. Summary results of statistical analyses carried out to verify integration levels for selected factors

Factor	Secondary raw material availability	Integration of planning processes	Inventory management
Analysis of correlations (between integration level change)			
Cash flow	Correlation exists	Correlation exists	Correlation exists
Profitability	Correlation exists	Correlation exists	Correlation exists
Service level	Correlation exists	Correlation exists	Correlation exists
Analysis of regression (for integration level change)			
Cash flow	Very low change dynamics (very small impact)	Large impact	Very large impact
Profitability	Very large impact	Small impact	Very large impact
Service level	Small impact	Very large impact	Average impact
Analysis of variance significance (ANOVA)			
Cash flow	Significant	Significant	Significant
Profitability	Significant	Significant	Significant
Service level	Significant	Significant	Significant
Analysis of change dynamics (average % of change between integration levels)			
Cash flow	Small significance (1.84%)	Significance (7.42%)	Large significance (25.37%)
Profitability	Significance (3.75%)	Small significance (1.37%)	Significance (3.18%)
Service level	Insignificant (0.72%)	Significance (5.01%)	Significance (6.92%)

Source: Own study

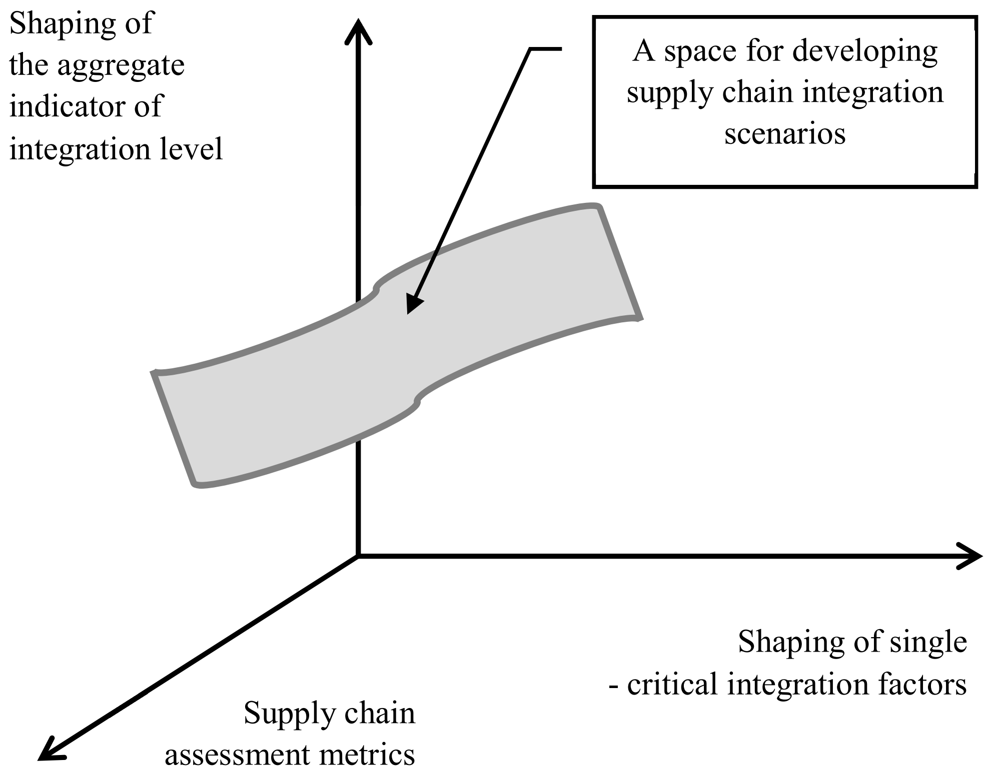
The analysis of correlation and variance significance is of basic character, namely it verifies the validity of one's reasoning. Conversely, the analysis of regression and change dynamics goes much deeper and may be used to build a scenario of supply chain integration.

6. DIMENSIONS FOR DEVELOPING SUPPLY CHAIN INTEGRATION SCENARIOS

When formulating general correlations in the studied area, one may conclude there are three dimensions when it comes to the development of integration scenarios for forward and reverse supply chains (namely choosing integration directions) (Figure 3):

- the first dimension is shaping of single - critical integration factors,
- the second dimension is shaping of the aggregate indicator of integration level,
- the third dimension are supply chain assessment metrics.

Figure 3. Dimensions for developing supply chain integration scenarios



Source: Own study

The dimensions of the supply chain management system form the space for developing a scenario of improving the integration level. The first dimension (X axis) refers to the shaping of single integration factors. The plane is therefore oriented to searching for leading (critical) factors affecting the integration process. Therefore it is in that direction that the plane should be explored. The authors of papers, based on distinguished integration factors, developed supply chain model and a series of simulation experiments, highlighted the abovementioned factors: „inventory management", "integration of planning processes", "availability of secondary raw materials". As regards the process of supply chain management (and the process of increasing its integration level) one should look for critical factors that affect supply chain performance the most. The critical factors presented herein are definitely not all the items in their catalogue (set). Nevertheless, the factors verified herein (through a series of experiments) may be a natural axis of integrating activities. This fact is confirmed by the results of simulation experiments, especially in the context of adopted assessment metrics of supply chain functioning. The potential development of the measurement system of supply chain performance will surely be accompanied by extending focus of managers' activity on other factors.

Another dimension of integration (Y axis) refers to the shaping of the total level of supply chain integration as a complex assessment of all the 19 factors and their levels. The analyses performed with respect to four levels of supply chain integration showed that an increase of the level entails better assessment metric values (chapter 5.1.). Selected assessment metrics show positive tendencies (increase in metric value reflects better functioning of supply chain), so one may conclude that supply chain integration is a way to improve its competitive edge.

The scenario of improving the integration level will be developed on the basis of the assumption that the increase in the integration level of all factors is conducive to better supply chain performance and attaining a synergy effect. The synergy effect, so sought after by managers, is possible to achieve when interaction of particular factors is ensured. In practice, various configurations of integration levels for each factor are possible. The synergy effect most certainly will not exist in each configuration. What is more, the so-called negative feedback may occur, which will affect supply chain performance in an adverse way. In order for this plane to be used in the development of an integration scenario it needs to be adapted so that the negative phenomenon could be avoided. The key issue here is the analysis of logical cohesion between particular solutions used at a given integration level for each of the factors. It is obvious that apart from contradictory solutions, which should not be difficult to eliminate, there are a number of configurations that can be used to create solutions the efficiency of which is hard to predict. The authors – in the assessment model of the aggregate integration level indicator – assumed that the aggregate assessment depends on the weakest link. The only parameter that may be influenced (through making a choice) during assessment is the width of integration understood as a percentage share of partners in the supply chain subject to assessment (degree of coverage of supply chain). Such freedom to choose the degree of supply chain coverage with the integration process is a consequence of the need to take into account various strategies of sourcing in everyday management. For example, the implementation of multi-sourcing strategy, which may be optimum for many product items, does not assume progressing integration but rather large flexibility and no dependence on suppliers. On the other hand, the assumption that the result of integration level assessment depends on the weakest results (for factors with the lowest integration levels) means that attempts should be made to achieve a balanced integration increase. Neglecting the selected factors may lead to unfavourable configurations in which the level of one factor is blatantly different than the level of another. In such configurations "bottle necks" may occur as well as the negative feedback mentioned earlier. As it has already been pointed out, this fact needs to be considered by managers developing an adaptive integration scenario. More importantly, not only the starting configuration of integration level should be analysed, but also the target condition as well (in a given cycle of change project management). In the process of implementing work-intensive and long-term changes, the intermediate states are equally important, as they create the "road map" for the implementation. The negative supply chain performance in the intermediary phase is a threat to partners in the chain. Therefore the threats should be limited by proper – flexible management of change project.

The third dimension of integration (Z axis) refers to the impact of particular actions on the assessment metrics of supply chain operation. As a result of the performed analyses, certain generalizations were made with respect to particular supply chain assessment metrics:

- cash flow grows fastest with low values of integration aggregate measure,
- profitability increases in a linear way as the chain integration level goes up,
- the level of customer service grows fastest once a certain level of integration is exceeded making use of the synergy effect.

On the one hand, the general statements identified herein allow one to formulate forecasts of the impact that potential actions may have on the improvement of: profitability, customer service level or cash flow; depending on the integration level at which the factors under analysis are. Such knowledge is particularly important for managers who need to bring about an "immediate" improvement of the selected assessment metrics. From such perspective, one may say that this dimension has the largest impact on shaping the adaptive integration scenario. On the other hand, the nature of this plane is auxiliary when compared to the two other as it is used to verify efficiency of actions taken on the basis of the two dimensions presented above.

7. CONCLUSIONS

Dynamic development of supply chain integration scenarios against quickly changing external conditions allows one to attain the assumed competitive position.

What is crucial to make it happen, however, is the knowledge of basic dependencies affecting the formation of economic phenomena in such entities. Integration factors and opportunities for shaping thereof are subject to strong internal and market conditions in which the "leading" companies operate, i.e. the entities which have the causative power to build stable supply chains and initiate the process of their integration. The presented papers show that the development of supply chain integration scenario is affected by both actions leading to an increase in its aggregate indicator and the impact on critical factors, as well as those directly contributing to improving the assessment metrics of its functioning.

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