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Measuring the level of integration in a sustainable supply chain

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Abstract: This article presents a system for measuring the level of integration of a sustainable supply chain. A supply chain involves both forward and backward flows and is related to S&OP model. The paper features also the methodology for developing a system for evaluating and validating the measurement system along with its application guidelines. A comprehensive list of 19 integration categories subject to evaluation is supplemented with the description of the integration levels pertaining to selected categories.

Keywords: supply chain management, measurement of integration assessment, forward and backward supply chain

1. INTRODUCTION

The transformation of production and logistics systems in both individual companies and across entire supply chains requires an in-depth diagnosis and a framework for putting its guidelines into practice. The Authors put forward a comprehensive system for evaluating the level of the supply chain integration, which has been based on their extensive first-hand experience in diagnosing company logistics systems (Cyplik and Hadas, 2011) and in developing dedicated hybrid solutions (Hadas and Cyplik, 2012), as well as on detail research into the integration barriers in the industry. Integration has been viewed as a means of achieving sustainable development and meeting business objectives set for the supply chain.

2. THE MODELS OF INTERNAL AND EXTERNAL INTEGRATION

The supply chain integration is an evolution process – the integration of respective chain actors is gradual. The point of departure for measuring the level of integration is establishing the degree / level, at which it is performed. The most interesting integration model concepts include:

- SCOR – Supply Chain Operations Reference model,
- 4-tier Poirier model,
- agility – the chain's capacity to meet the ever-changing demand,
- 4-tier compass model,
- 4-tier Stevens model,
- 3-level A.T. Kearney model.

In order to streamline the functioning of logistics chains, the Supply Chain Council has formulated the Supply Chain reference model (SCOR, 2010). The process description consistent with the SCOR model consists of three levels:

1) top level – at this level the scope of the SCOR is defined, objectives related to gaining competitive advantage are being established;
2) configuration level – at the second level the methods of customer order processing are being selected;
3) process element level – at the third level the company's capacity to compete on the market is being defined, as well as the process elements, inputs and outputs, process metrics and good practice regarding its implementation.

SCOR metrics play key role. They apply to all the levels are focused around 5 areas:

- reliability – providing top quality customer service,
- on-time response – time required for responding to customer queries,
- costs – assessing the costs of the supply chain functioning,

- resources – the evaluation of the resources used for meeting customer requirements.

In line with the initial version of Ch.C. Poirier (Poirier, 1999) model, the supply chain matures in 4 phases: there are two phases of internal integration and two phases of external integration. Advancing to the next level is always predicated on achieving the preceding stage. In the Poirier model, in each maturity level the focus is on a given category of tasks, which are measured and tracked. In the first phase of the integration the tasks are related to internal conditioning, which are in the second phase expanded by external conditioning. Satisfactory results obtained at the current integration level (one of four) serve as a point of departure for moving towards the next maturity level.

The founding fathers of the 5-level model of development in the supply chain - the Compass model - condition reaching subsequent stages on the application of more and more advanced IT technologies (Poirier, 1999). Changes in these technologies are aligned with ever-changing chain objectives and should be matched to existing organizational and planning solutions.

A.T. Kearney distinguishes 3 levels of the supply chain maturity, which are suited to the level of integration between the supply chain links. In this case the number of distinguishing features, describing the subsequent levels of supply chain maturity, is greater than in the Compass model. They are as follows:

- consistency in meeting customer expectations,
- the scope, integration level and planning horizon,
- the level of partner relationships with the suppliers,
- the methods and objectives for continuous process improvement,
- involvement and competency of human resources,
- the scope of application of IT technologies,
- tracking system and the opportunity for taking correction measures.

Each of the above mentioned models is focused on the selected aspects of integration or on IT tools which support this integration. The grasp of the subject matter varies: starting from the models based on a set of recommendations up to models based on project management properties. The system for measuring the supply chain integration presented in the paper is a manifestation of the holistic approach, which brings together a comprehensive diagnosis with a reference roadmap for integration. The purpose underlying the work undertaken by the Authors was to expand the classic model of integration. In order to enhance the model usability, its validation has been based on the diagnosis of the integration barrier in business conditions and on the modelling of the supply chain in simulation applications.

3. THE METHODOLOGY FOR BUILDING A SYSTEM FOR MEASURING THE LEVEL OF INTEGRATION IN THE SUPPLY CHAIN

Works on the system for measuring the integration of the supply chain were initiated by setting the primary and secondary guidelines, which identify the tasks to be fulfilled by the model and way in which the entire issue of integration is defined. The primary assumptions behind the measurement system:

- Classifying the measures taken be supply chain agents into previously defined integration levels, with each factor (category) subject to individual classification,
- Evaluating the aggregated level of the supply chain integration,
- Identifying „Achilles' heels" – the supply chain bottlenecks,
- Producing recommendations on the tools and activities leading to enhancing performance in individual categories.

The next step consisted in defining the supply chain performance indicators at the operational level, intended to measure the simulation results.

At the same time, the analysis of the results of surveys (general and detailed) and existing integration models provided the grounds for systematizing:

- Integration factors (the description category of the integration level),
- Integration levels for each description category of the integration level.
- Description of features characterising the integration levels for each class,

Such a procedure was adopted when preparing the project of the evaluation system. It was followed by defining the system verification guidelines through:

- Dividing integration factors into:
    - simulated – mappable for simulation purposes.
    - Non-simulated – non-mappable (exceedingly difficult or impossible to be mapped for simulation purposes).
- Description of simulation experiments (process- and structure-related changes) for each integration factor susceptible to mapping (and its level).

Subsequent stages involved the development of:

- A methodology for using the integration system in business environment:
- A simulation model and a procedure for validating its correctness
    - Simulation experiments, outcome analysis, corrective feedback.
    - Validation (verification) of the evaluation model through analysing the impact that individual integration factors and their integration levels have on the simulation results
    - Feedback – correcting the activities at particular integration levels for individual integration characteristics
- Laying down the guidelines and setting the direction for further research.

4. A SYSTEM FOR MEASURING THE LEVEL OF INTEGRATION IN THE SUPPLY CHAIN AND ITS APPLICATION IN PRACTICE

4.1 Survey into the barriers to the integration of the supply chain processes

The system for measuring the integration level has been developed in line with the methodology mentioned above (see fig.1.) and is based on:

- The analysis of the results of survey (general and detailed).
- The analysis of selected models of internal and external integration.

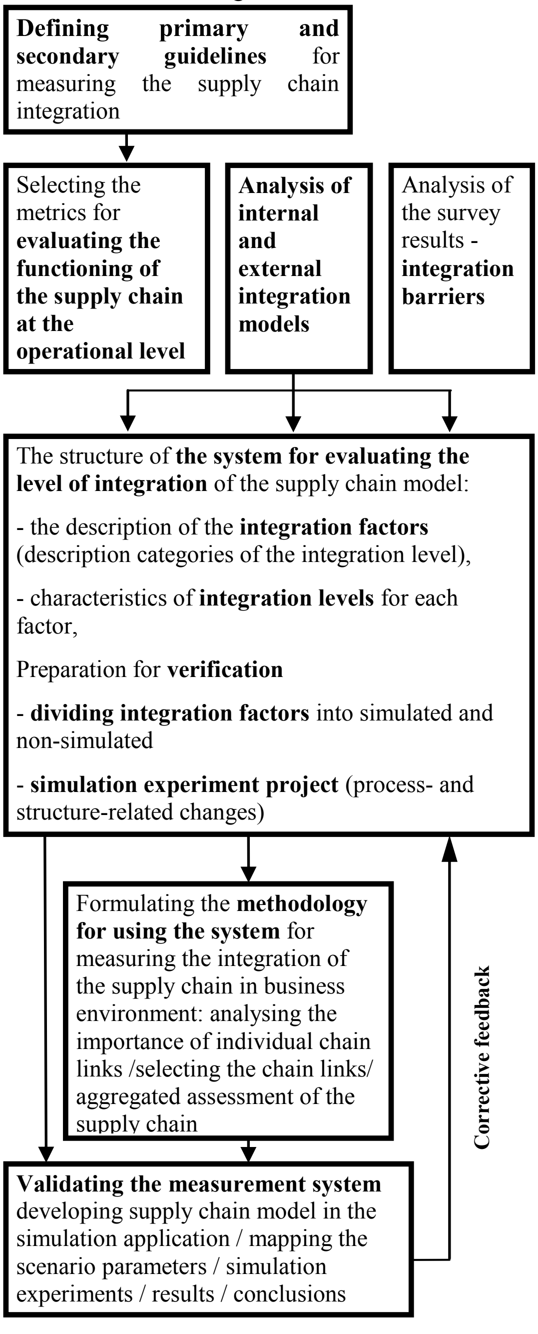

Fig. 1. A methodology for building the system for measuring the integration level in the supply chain.

The survey aimed at identifying the barriers to the integration in the supply chain had 392 respondents representing various enterprises and management levels. After a preliminary selection (rejecting incorrectly completed surveys) as many as 372 questionnaires were duly analysed. The survey results included:

- A standard structure for enterprise employees (higher level management ca. 5%, medium level management ca. 38%, employees ca. 57% of the respondents),
- The most important departments and functions (stock management / warehouse ca. 22%, production/assembly 18%, sales ca. 17%, distribution/transport ca. 17%, finance ca. 6%),
- Small and medium-sized enterprises (189 respondents) and large enterprises (126 respondents).

The issues and detailed questions were arranged into 17 groups and allowed for identifying the categories of internal and external problems, which pose barriers to enhancing the cooperation between the enterprises. The survey findings were not analysed in depth (due to paper length restrictions), it should be noted, however, that provided answers fall into the following categories:

- Supply chain structure (quantity and the type of links),
- The type of integration measures undertaken by enterprises,
- Barriers which hamper the enhancement of the integration level,
- The characteristics of reverse flows,
- Barriers to increasing the amount of recyclable materials,
- Problems, which are perennial in planning production and logistics processes.

The findings of this research provided an important input to the categories of activities evaluated in the integration process. The end result of the works is a system for measuring the level of the supply chain integration, highly relevant for the management issues under investigation.

4.2 Supply chain integration factors

The Authors' system for measuring the integration level in the supply chain is based on the analysis of the integration level of individual factors that have been previously identified. Such a solution enables a comprehensive analysis of the supply chain integration levels.

The following factors / integration activity categories were taken into consideration when evaluating the level of integration in the supply chain (see Table 1.).

Integration factors denote the categories of the functioning of the supply chain, which have been characterised and grouped in the proposed measurement system. It has been assumed that the supply chain integration may take place by way of process and / or structural changes

- **Process changes**, which refer to a change in the functioning of the supply chain as regards the mechanisms governing and steering the material stream flows, the exchange of information and the means of executing planning functions,
- **Structural changes**, which refer to a change in: the type, quantity, location or capacity (throughput) of particular links (resources) creating the supply chain.

Table 1. Integration factors and the type of integration activities in the supply chain

Factor name / Categories of integration activities	Type of integration activities	
	Process changes	Structural changes
Sales support	X	
Research & development works	X	
Investment activities	X	
Demand forecasting	X	
Transport activities	X	X
Packaging unification	X	
Integration of the information flow	X	
Optimisation of the material flow	X	X
Financing the supply chain functioning	X	
Inventory management in the supply chain	X	X
Quality, accuracy and information standards	X	
Major areas of collaboration	X	
Collaboration in recycling	X	X
Response to internal disruptions in the supply chain	X	
Reducing material losses	X	
Delivery performance and the storage of recyclable materials	X	X
Recyclable material availability characteristics	X	X
Handling returns and recyclable materials information flow	X	X
Tracking performance results for the supply chain links	X	

Four levels - grades have been identified for each of the 19 integration factors. Each level (level A B C D, where A means the highest level) comes with a clearly defined characteristics, based on which the supply chain activities can be measured (by assignment to an appropriate category). When characterising the integration levels, the Authors kept in focus:

- manifestations of integration,
- or the symptoms of their absence,

which facilitates the evaluation based on the typical characteristics of the functioning of a given supply chain, obtained during, e.g. interviews with managers.

Below you will find integration activities selected (due to paper length restrictions) from among 19 categories:

Integration category: R&D works

Being successful on the market nowadays is often predicated on offering innovative products, tailored to meet customer needs. Conducting research development works is a costly and risky venture. When acting in isolation, companies do not have sufficient funds at their disposal and in case of the research failure the risk of falling into financial problems is quite high. Undertaking R&D works within the framework of the supply chain considerably reduces the risk of failure and fosters the economies of scale, which brings down unit costs of developed solutions. A detailed description of particular integration levels is presented in the table 2.

Table. 2. Research & development works – performance characteristics at particular integration levels

Integration level	Performance characteristics
A	A centralised system for planning and coordinating R&D works (related to the issues consistent with the adopted competing strategy), taking into account the strengths of each partner in the supply chain; the reverse chain and related material feeds are taken into account in the process of designing products and processes
B	Research projects are run within supply chains, they are aimed at delivering innovations of key importance for the chain's competitiveness, more than two partners are engaged in the project
C	Incidental research projects initiated between two partners in the supply chain
D	R&D works conducted in isolated links are based on individual know-how demand forecasts

Integration category: Investment activities

Investment activities related to building production facilities, warehouses and to the development of the distribution network determine the expansion of enterprises and supply chains. Running investment projects requires collecting a sufficient amount of funds. Acting in isolation is not conducive to attracting and raising capital. Making a concerted effort not only facilitates the acquisition of capital (greater assets), but also allows for a more effective use of new investments, which reduces ROI. Investment activities for particular integration levels are presented in the table 3.

Table. 3. Investment activities - performance characteristics at particular integration levels

Integration level	Performance characteristics
A	Centralised decision making related to investment activities, of key importance for the chain's competitiveness, the scope of the investment project applies to production facilities, warehouses and distribution channels
B	In the supply chain we can distinguish the investments undertaken jointly by more than two partners, which are aimed at enhancing chain's competitiveness, decisions taken at the level of the agreements between the chain's links, the scope of the investment project involves warehouses and distribution channels
C	Isolated joint investment projects (aimed at increasing competitiveness) undertaken by two partners from the supply chain, the scope of the investment project involves distribution channels
D	No joint investment activities

Integration category: Demand forecasting

Forecasting demand is a key information input in the supply chain. Errors in forecasts have their consequences for the material flow, inventory volume and the level of customer service. All of the above mentioned consequences trigger extra costs of the supply chain's functioning. It can be therefore concluded that forecasts with lower error rates will have a beneficial impact on the supply chain return. One of the conditions of precise forecasting is the origin of the information source and the length of the forecast period. If the data is derived from a source that is close to the customer and the final end user, then the error rate is lower. On top of the above, if the data is processed (forecast preparation) by fewer entities, then the cumulative forecast error rate is lower. This is what makes the cooperation between the supply chain partners so vital. A detailed description of the activities undertaken on the four identified integration levels is presented in the table 4.

Table. 4. Demand forecasting - performance characteristics at particular integration levels

Integration level	Performance characteristics
A	Forecasting at the level of the entire supply chain with the time horizon covering cumulative lead time and the absolute forecast error per each link being no less than 90%.
B	Forecasting at the level of the entire supply chain on condition that the time horizon covers cumulative lead time and with the absolute forecast error per each link being no less than 90%.
C	Irrespective of the forecasts for individual links in the supply chain (no exchange of the information, trend-based, etc.
D	No formalized forecasting procedure

Packaging unification

Packaging performs various functions. In view of the integration of the supply chain, the focus is on the logistics functions. The primary purpose of the packaging from the point of view of the supply chain is protecting the product from any losses (damage) and reducing packaging handling costs in storage (all phases) and in transit. Packaging unification is intended to bring to a minimum any operations involving packages, in particular at the stage of warehouse receipt and issuing. Standardising packages in the supply chain may effectively rule out the need for repacking or changing the shapes of logistics units. Such a unification is also likely to bring down inventory levels in the supply chain, which may lead, in consequence, to further operational cost cuts. The measures taken at integration level are presented in the table 5.

Table. 5. Packaging unification - performance characteristics at particular integration levels

Integration level	Performance characteristics
A	Packaging unified across the entire reverse chain, matched to the transportation fleet and the material movement technology. Returnable packaging in use to a large extent (over 75% in total for the chain) with closed loop, no repacking except for packaging purposes
B	Packaging unification and the application of closed loop of reusable packaging between more than two partners including the supply chain leader
C	A section unification of selected types of packaging between the closest partners in the supply chain
D	Internal (one link) packaging unification

Integration category: Integration of the information flow

Information availability mentioned in the chapter on forecasting as a factor behind lower forecast error rates is not the only that an uninterrupted flow brings. If we assume that inventory in logistics may take a material or a time-related form, then the more time is lost in the course of the information flow in the supply chain, the greater inventory levels it requires. It can be inferred, therefore, that accelerating the information flow may lead to reducing the operational costs of the supply chain. Potential benefits go beyond the flow time. Up-to-date information usually has a lower error rate and enables a more precise identification of further measures to take. A detailed description of activities in the supply chain at each of the 4 integration levels is presented in the table 6.

Table. 6. Integration of the information flow - performance characteristics at particular integration levels

Integration level	Performance characteristics
A	Information available in real time across the entire supply chain
B	Information available in real time between selected supply chain partners, including the chain leader
C	Information available in real time between two selected supply chain partners
D	No tools which reduce the information transfer time

4.3 Selected guidelines for using the system for measuring the level of integration in the supply chain

A complete integration of all the links in the supply chain is not possible due to its dynamics (variability) and the strategies put in place for individual functions (e.g., short-term agreements on distribution, sales or purchase in line with the „multi sourcing" strategy). On top of the above, integration is not an objective as such, but rather a tool for improving the functioning of the chain (according to the evaluation criteria that have been adopted). It should be therefore taken as a point of reference for measuring the level of integration in the supply chain in the selected group comprising key entities (links). A quantitative approach (the number of supply chain links) does not deliver in this respect on account of various roles and different sizes of the entities which form the supply chain. The perspective of the values of the material stream flowing through individual links is much more relevant here. To merit classification into particular groups, the analysis must involve:

- 50% of values (for group C),
- 70% of values (for group B),
- 90% of values (for group A),

of material stream in the supply chain.

Such a measurement method determines integration activities as well. As the value of material streams increases downstream, (values are added), the integration which is closer to the customer is more effective and more economically justified (high inventory costs, diversified goods), not upstream (unprocessed raw materials).

The stream value is measured based on the period of time which is longer than stock replenishment cycle in the supply chain in order to avoid a situation, in which a given link weighs more at the measurement time due to a blockage in the flow or due to speculative stock accumulation.

The allocation to the supply chain integration level depends on the lowest performance result (the so called „Achilles' heel") for factors under investigation.

Table. 7. Integration level matrix – the scope of integration

Integration scope	Integration factors							
Stream value	Integration levels	1	2	3	4	5	….	19
A (>90%)	A			√				√
B (70%)	B	√	√		√		√	
C (>50%)	C					√		
D (<50%)	D							

CONCLUSION AND FURTHER RESEARCH

The system for measuring the level of integration in the supply represents a holistic approach towards the management of the integration process. Nineteen integration and 4 integration levels combine into a 76 – dimensional matrix, which allows for evaluating a supply chain with forward and backward flows and to coordinate at S&OP level. The assessment of the aggregated level the supply chain integration provides the grounds for identifying weak links in the integration process. The recommendations pertaining to the tools and activities aimed at improving individual evaluation categories and the entire management system, which have been included in the presented model, serve as a path towards transformation. Further works will be focused on case study projects and supply chain modelling in simulation applications and analysing the results, with the use of developed evaluation methodology.

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