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PROBLEMS OF SUPPLY PROCESS RELIABILITY ASSESSMENT AT SMALL AND MEDIUM-SIZED ENTERPRISES

Abstract: In the paper, the basic objectives of supply process are discussed. The importance of reliability assessment for the supply and procurement process is mentioned and some basic factors are described. The example of supply process analysis for SME is shown. The most important faults/errors of the process are described. The low costs of the faults/errors counteractions are underlined.

Keywords: supply process, reliability analysis, small and medium-sized enterprises.

1. Introduction

The supply process was formerly perceived exclusively as obtaining materials essential to satisfy customer needs. In (Twaróg 2003), delivery is defined as "...activity of gaining something by any way, also by violence or by robbery". Contemporary, in (Ballou 2004), delivery is described as "a complex of activities which are indispensable for acquisition of materials needed to ensure an enterprise activity taking into consideration all factors influencing on rationalization of supply process". So, broadly understood supply process includes acquisition of raw materials, semi-finished products and ready-made products, as well as providing an enterprise with investment goods and everything what is necessary for effective functioning of a firm. Supply process includes a number of different activities, including concluding contracts with a supplier, analysing stock level/supply availability, materials storage and transshipment, transport processes preparation, deliveries receipt and check or consideration of complaints.

Proper functioning of a supply system has a positive effect on product quality, level of customer logistic service, financial liquidity of a firm, and costs of the whole logistic system. An optimal supply level for goods and services helps an enterprise to achieve competitive advantage over other market participants by optimising its costs (Lysons 2004).

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Over the past years, numerous changes in the area of supply logistics have been observed. This development is caused by diverse factors, with major of them including:

- increase in costs related to material procurement performance;
- occurrence of new organisational conceptions based on a system approach;
- accessibility of new technical resources providing better information processing ability (e.g. information storage and processing);
- acknowlegement of purchasing process as an important source of costs reduction, quality increase, and production process performance improvement/ rationalisation;
- very rapid growth of global competition on the market;
- increase in personnel skill level.

All the presented factors have contributed to the development of global supply chain management methods, relationship orientation in marketing conceptions, establishment and maintenance of partnership with suppliers, and computer systems and information technology progress.

At present, procurement of low-cost raw materials and components, reduced storage and holding costs and improved effectiveness of transport are main objectives to be achieved in an attempt to enhance supply and transport processes performance (Blanchard 2004, Christopher 2000). Thus, the need to increase and maintain a high level of quality of offered products and services has rendered reliable performance of logistic support tasks more difficult. In the opinion of practitioners, having less suppliers reduce the coordination efforts necessary to ensure timely deliveries and enables a high quality level to be maintained accorss the entire product and service offering. As a result, it is less probable that the number of disturbances and errors during the performance of purchasing functions will be significant.

Taking into account the following considerations, the analysis of logistic functions performance is quite difficult, especially because of a lack of reliable information/data which could provide a convenient comparison of logistic system performance levels. Thus, the paper deals with a problem of estimation of some reliability measures of the procurement process for various types of enterprise.

2. Basic measures used in process reliability assessment

The logistic system performance analysis is a multidimensional problem, which has to include the following (Twaróg 2003):

- economic criteria (total logistic costs),
- technological criteria,
- operational criteria (reliability, availability),
- time-related criteria (order cycle time).

Ability to perform a comprehensive performance measurement is fundamental to achieving organisational success. Traditional logistics measurement systems have been designed to capture information regarding five types of performance, generally regarded as essential for accomplishing the systems' logistics activities. These five categories are: asset management, costs, customer service, productivity, and logistics quality. Defined measures from each performance category are generally put in place to monitor and manage a variety of logistic functions, including transport, warehousing, inventory management, order processing, and administration.

In the area of supply subsystem performance measurement, qualitative and quantitative indicators are developed; they characterise the areas of buyer–supplier partnerships. For example, quantitative indicators define the number of types of raw materials ordered, their weight and volume, number of suppliers in the network and number of documents necessary to perform procurement process.

On the other hand, a new awareness of the importance of measures requirements emerges, especially in comparison of enterprises, which vary from one another by, e.g., level of circulation of goods, number of employees and level of frozen capital. Therefore, qualitative indicators have been divided into relative and absolute indicators (Twaróg 2003).

In the group of absolute indicators, the most important are procurement costs and their share in total supply costs, as well as total supplier costs. Moreover, one of the most important factors affecting the purchasing decision processes are costs of complains. Other decision criterion dimensions include the time indicators and measures which support the quality of delivery of raw materials to be estimated (Tab. 1).

Certain groups of indicators were designed to examine the overall logistic performance. In this area, there may be defined a group of indicators measuring the faultlessness of logistic tasks performance (Nowakowski 2006b).

The most important ones, being defined for supply process, are listed below:

- *delivery reliability* – the probability of delivery being executed on time without any order incorrectness (ratio of the number of timely deliveries to the total number of deliveries);
- *quality of delivery* – is connected with ordered products disposal according to e.g. their type or quantity; this includes fault-free delivery, delivery completeness, documentation completeness and accuracy, package providing in line with the customer's needs and regulations (ratio of the number of complains to the total number of requests);
- *delivery flexibility* – ability to adjust to the customer's various needs, it may be defined as a ratio of the number of customers' fulfilled special requests to the total number of special requests;
- *availability of delivery providing* – it may be defined as a ratio of the number of deliveries executed on hand to the total number of requests.

Table 1. *Measures used in supply system performance assessment (Twaróg 2003)*

	Measures name	Measures formula	Unit
1	Average order cycle time	total delivery time / total number of deliveries	hour
2	Average time of order execution	Time from moment of order entering to moment of order dispatching	day
3	Value of defective raw materials being delivered	Value of defective raw materials + value of defective packages + value of defective supporting materials	PLN
4	Share of uncorrected deliveries of raw materials	Number of defective deliveries of raw materials / total number of deliveries of raw materials	%
5	Share of complained deliveries of raw materials	Number of complained deliveries of raw materials / total number of deliveries of raw materials	%
6	Delay time of deliveries of raw materials	Delay time of deliveries of raw materials + Delay time of deliveries of packages + Delay time of deliveries of supporting materials	day
7	Share of delayed deliveries of raw materials	Number of delayed deliveries of raw materials / total number of deliveries of raw materials	%
8	Share of returned deliveries of raw materials	Number of returned deliveries of raw materials / total number of deliveries of raw materials	%
9	Reliability of deliveries of raw materials	Number of timely deliveries of raw materials/ total number of deliveries of raw materials	%
10	Value share of complained deliveries of raw materials	Value of complained deliveries of raw materials / total value of raw materials	%
11	Delivery flexibility	Number of customers' fulfilled special requests/ total number of customers' special requests	%
12	Average delivery value	Value of accomplished deliveries / number of accomplished deliveries	PLN

When logistic system reliability is defined as its ability to perform supporting task under set conditions for a specified period of time, without any failures (Nowakowski, Werbińska 2007), then the reliability of supply process mainly encompasses:

- *delivery reliability* – defined as the probability of in-full delivery being performed without any delay with respect to the customer's specified time;
- *transport reliability* – the probability of fault-free delivery being performed on time;
- *reliability of logistic support infrastructure* – which includes performance parameters of support personnel and support facilities (support and test equipment and support tools).

In the analysed references (Nowakowski 2006a), each logistics activity (i.e. order documentation accuracy, transport, inventory and product availability, product damage and warehouse processing time) is assessed in different terms. The measures used are adapted to the particular firm's needs and good external measures remain to be developed.

Reliability of logistic system is defined differently from military and business-oriented point of view. According to the glossary published by Defense Systems Management College (OPNAV 2003), logistics reliability recognises the effects of occurrences that place a demand on the logistics support structure without regard to the effect on mission or function.

The defence-related meaning of reliability is similar to that known (Nowakowski 2006) for the technical system definitions of reliability, availability, maintainability, etc.

According to the glossary published by Defense Systems Management College (Nowakowski, Werbińska 2007):

- Logistics reliability is the measure of the ability of an item to operate without placing a demand on the logistics support structure for repair or adjustment. Logistics reliability recognizes the effects of occurrences that place a demand on the logistics support structure without regard to the effect on mission or function.
- Logistics support means the application of a comprehensive, integrated approach to the supply, repair, and maintenance of items necessary for the proper operation of a system in the force.
- Logistics support, supplies, and services refer to any or all of the following – food, billeting, transportation, petroleum, oils, lubricants, clothing, communications services, medical services, ammunition, base operations support (and construction incident to base operations support), storage services, use of facilities, training services, spare parts and components, repair and maintenance services, and port services.
- Logistics supportability is the degree of ease to which system design characteristics and planned logistics resources (including the logistics support (LS) elements) allow for the meeting of system availability and wartime usage requirements.

Under the business-oriented approach (Ballou 2004, Nowakowski 2006b), correct performance of the logistics system may be described by 7R formula:

- right product,
- right quantity,
- right quality,
- right place,
- right time,
- right customer,
- right price.

Similarly, in the SCOR model (SCOR 2006), performance attributes require estimation of seventh parameters. And the perfect performance of the supply chain means the delivery (Tab. 2):

- of the correct product,
- to the correct place,
- at the correct time,
- in the correct condition and packing,
- in the correct quantity,
- with the correct documentation,
- to the correct customer.

Table 2. *SCOR model performance attributes (SCOR 2006)*

Performance attribute	Performance attribute definition	Level 1 indicators
Supply chain delivery reliability	The performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct condition and packing, in the correct quantity, with the correct documentation, to the correct customer	Delivery performance Fill rates Perfect order fulfilment
Supply chain responsiveness	The velocity at which a supply chain provides products to the customer	Order fulfilment lead time
Supply chain flexibility	The agility of a supply chain in responding to market changes to gain or maintain competitive advantage	Supply chain response time Production flexibility
Supply chain costs	The costs associated with operating the supply chain	Cost of goods sold Total supply chain management costs Value-added Productivity Warranty/returns processing costs
Supply chain asset management efficiency	The efficiency of an organisation in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital	Cash-to-cash cycle time Inventory days of supply Assets turns

The reliability of delivering goods has become more important for Just-in-Time transport systems (Nowakowski 2006a). Delivering products to stores (customers or customer's customer), according to schedule is now very important for meeting replenish requirements and preventing stock out (or overstocking). It means that reliability of the delivery process is regarded as the most important of the logistics processes with respect to potential losses.

Thus, two types of reliability are taken into consideration:

– delivery without any damage of goods,
– delivery without any delay with respect to specified time at customer.

To include the importance of time factors in logistics operations, the service reliability for logistics networks is defined as follows (Nowakowski 2006b):

$$R_d = P\left(T_d < t_0\right) \tag{1}$$

where:

T_d – time of delivery,
t_0 – pre-specified time limit.

A more complex method of the system reliability assessment is proposed in (Christopher 2000). This is "perfect order fulfilment" method, where the indicator OTIF (On-time, In-full, Error-free) is used. Perfect delivery means that goods are delivered without any delay (on-time), all ordered elements are present (in-full) and no element is omitted during the logistic process (error-free).

The OTIF indicator is computed as follows:

$$\mathrm{OTIF} = P_{o-t} P_{i-f} P_{e-f} \tag{2}$$

where:

P_{o-t} – probability of timely delivery,
P_{i-f} – probability of in-full delivery,
P_{e-f} – probability of error-free delivery.

In the OTIF method, the criteria for estimation of the main factors are as follows (Kapera 2007):

– Delivery is considered performed on time, when its estimated shipment arrival date does not exceed the defined time-limit ($P_{o-t} = 1.0$). Otherwise, the criterion is computed as the relation of the delivery delay days to the time of the most recent delivery realisation (number of days including holidays and work-free days).
– Delivery is considered complete, if the delivered number of products correspond to ordered amounts ($P_{i-f} = 1.0$). Otherwise, the partial indicator is evaluated with use of the ratio of the number of parts absent in the delivery to the total number of ordered parts.
– Quality of delivered parts – is considered satisfied, if delivery is performed without any quality defects/failures ($P_{e-f} = 1.0$). When any quality failure is observed, the level of indicator P_{e-f} drops to 0.98, and decreases proportionally to the ratio of the number of faulty parts to the total number of parts in the delivery.

SCOR model performance attributes (Tab. 2) require seven parameters to be estimated.

Thus, to estimate the process reliability indicator, it is necessary to find the partial indicators for each possible error (failure):

$$P_{cpr} = \frac{N_{cpr}}{N}; P_{cpl} = \frac{N_{cpl}}{N}; P_{ccu} = \frac{N_{ccu}}{N}; P_{cti} = \frac{N_{cti}}{N};$$
$$P_{cql} = \frac{N_{cql}}{N}; P_{cqt} = \frac{N_{cqt}}{N}; P_{cdo} = \frac{N_{cdo}}{N} \tag{3}$$

where:

P_* – probability of correct action,
N_* – number of correct actions,
N – number of deliveries,
cpr – correct product,
cpl – correct place,
ccu – correct customer,
cti – correct time interval of delivery,
cgl – correct quality of product,
cqt – correct quantity of product,
cdo – correct documentation.

And the simplest reliability indicator of the logistics system (delivery process) may be estimated as:

$$R_d = P_{cpr} P_{cpl} P_{ccu} P_{cti} P_{cql} P_{cqt} P_{cdo} \tag{4}$$

It is assumed that the random events analysed (faults, failures) are statistically independent and the significance of the events are equal. Thus, the other possible solution is to add weighed partial indices:

$$R_d = w_{cpr} P_{cpr} + w_{cpi} P_{cpl} + w_{ccu} P_{ccu} + w_{cti} P_{cti} +$$
$$w_{cgl} P_{cql} + w_{cqt} P_{cqt} + w_{cdo} P_{cdo} \tag{5}$$

where w_* – weight of the partial index P_*.

Presented measures can be used in supply process performance assessment. However, despite their simplicity, the possibility of computing them for small and medium-sized enterprises is very limited. Very few companies collect and publish data concerning errors that occur during the logistic process. Therefore, making decisions is connected with the necessity of using employees'the more or less subjective opinions.

3. Example of supply process reliability assessment

The analysed company (Kapera 2007) is classified as a small or medium-sized enterprise (SME). Development of an SME is strictly connected with a set of internal and external limitations, e.g. in the enterprise's environment. Thus, material flow

analysis in a typical SME was supposed to support its effectiveness evaluation and identification of causes of the problems met.

Since the launch of its operation, the company under analysis has been employing 11 people: the owner of the company, a driver, supply department employee, two designers, and six equipment assemblers.

The company offers:

- design and implementation of industrial processes control systems using hydraulic or pneumatic drives,
- elements and subassemblies packing and purchasing,
- diagnosing, regenerating and repairing of elements and subassemblies,
- modernisation of drives and control systems,
- technical consultancy,
- distribution of Parker Hannifin elements.

Thus the company offers products incorporating hydraulic, pneumatic and industrial automatic subassemblies of renowned brands. Those products are mostly operated at research institutes, production companies and maintenance systems. Thus, the main functions of those elements include control of manufacturing processes performance, as well as testing and inspections of semi-finished and final products. Moreover, all machines and devices are sold with at least 24-month-warranty (since the start of the product operation) and full after-sale maintenance.

The company does not manufacture elements/subassemblies of the machines or devices by itself. All the components used are purchased or manufacturing thereof is outsourced to the company's cooperating subcontractors. As a result, the company does not have any machines which are necessary to manufacture subassemblies of the products offered (like e.g. turning lathes, grinding machines or milling machines). It is also worth noting that, whenever necessary, the company may employ contract employees, who would support the performance of machine assembly process.

The main types of products and services offered by the company include (Fig. 1):

- machines and devices,
- repairs,
- diagnostics,
- project design,
- modernisation processes,
- assembly processes,
- the company's own shop (distribution of Parker Hannifin elements).

In 2005, the company spent over PLN 490 thousand for purchases of operational and supporting materials. About 99.6% of total costs incurred, were spent on operational materials, and about 0.4% of total costs were connected with supplying of supporting materials. Moreover, supporting materials represent 3.75% of the entire product range.

The company operates one van and employs one driver. Moreover, transport is partially performed by external transport companies. However, the distribution of transport tasks between external carriers and the company's own van is performed on a case-by-case basis.

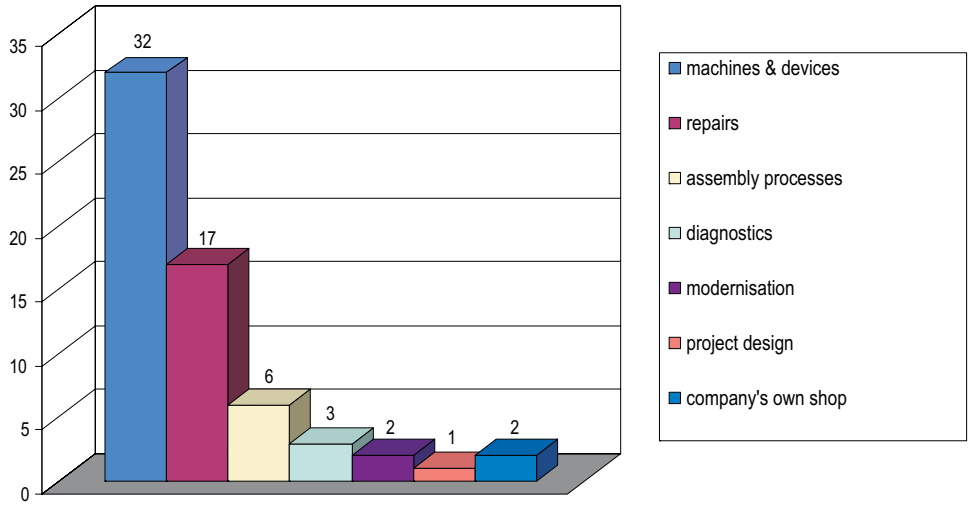

Fig. 1. *Quantitative structure of products and services being by the chosen company*

The analysis of material flow performed at the company has been carried out based on data sourced from company's internal documents (mainly invoices) and the author's observations made during the execution of operational processes (Tab. 3).

Table 3. *Measures used in supply system performance assessment for the enterprise under analysis*

Number of orders being accepted	All-in	75
	Machines and devices	37
	Repairs and modernisations	26
	Transaction at the company's shop	2
	Other	10
Number of suppliers	All-in	94
	Fundamental materials	82
	Supporting materials	12
Number of subcontractors	7	
Number of employees working at the supply department	1	

The author's observations enable kinds of problems which may occur in the course of the company's operations to be identified. The identified failures/errors mostly include:

- incorrect address of supply delivery,
- unavailability of supporting materials in a system,
- lack of transport documents.

Errors/failures of the first type can be deemed typical for companies of the type analysed. The address of the company's headquarter is usually the same as the company owner's address of residence. However, the maintenance workshop and office are located in the centre of Wrocław. As a result, it may happen that ordered spare elements are sent to the company's owner residence and not to the maintenance workshop. Such events disrupt the operation of the supply department, production department and assembly line. Moreover, every instance of incorrect supply results in the company incurring additional transport process performance costs.

All errors/failures connected with incorrect addresses of supply are attributable to the suppliers' or subcontractors' negligence. However, these negative events can be easily eliminated by the implementation of graphical changes in the ordering documents. More precisely, highlighting the delivery address field may prevent dispatch of supplies at incorrect address.

Errors/failures of the second type result from the cooperation with external subcontractors, which manufacture all the elements necessary to execute orders placed by the company's customers.

The effectiveness of material flow performance in the chosen company strictly depends on:

- operational materials availability,
- supporting materials availability,
- time of orders execution by suppliers and subcontractors,
- delivery timeliness,
- quality of components purchased or manufactured by external companies.

The company can fulfil its customers' orders exclusively with use of the both types of materials, operational and supporting elements. Moreover, the company's employees are especially focused on the availability of operational materials. Therefore, it may sometimes happen that a customer's request cannot be fulfilled because of the lack of supporting elements (e.g. screws, screw caps, tab screws or washers). Such a problem occurs, because no process has been implemented for monitoring of stock of spare parts in this respect.

Errors/failures of the third type are problems with purchased elements, whose further use depends on the additional mechanical performance. The company cooperates with subcontractors. The problem may arise when an element is delivered to a subcontractor by an external transport company and then forwarded by the company's own transport (or *vice versa*). In such a situation it may happen that the number or characteristics of delivered elements are incorrect.

This problem is a consequence of an improper organisation of information flow. At the time of forwarding materials from the subcontractor, an employee does not know the right number and expected parameters of the elements ordered.

4. Summary

The presented example of supply system reliability assessment analysis shows the possibilities of implementation of simple and cheap reactions to prevent failure occurrence. The activities performed enable purchasing process reliability to increase significantly without use of the described activity methods. Moreover, a lack of procedures may be observed which could address SME performance. This renders necessary further development in the areas of logistic support processes identification methods and their performance measurement.

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