Influence of the Demand Planning Process on Logistic System Reliability. Case Study

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Authors define the main elements affecting the right logistic system performance level and investigate the possible connections between demand process planning quality and logistic system reliability. Thus, known in the literature definitions of logistic system reliability are characterized. Later, an overview of some recent developments in the analyzed research area is provided. In the next point, authors present the main elements affecting the reliable and available logistic system performance. Finally, the paper is ended by the presentation of the obtained analysis results in comparison with the knowledge about the case companies' present condition.
Keywords: demand planning process, reliability, logistic system.

1. INTRODUCTION

According to the definition developed by the Council of Logistics Management [5], logistics is *that part of supply chain process that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements*. As a result, the components of a typical logistic system are [3]: purchasing, traffic and transportation, warehousing and storage, customer service, demand forecasting, inventory control, material handling, order processing, parts and service support, packing, return goods handling and informational flows. Logistic processes are performed by using resources in the form of: equipment, manpower, facilities, and financial assets [51].

One of the main parameter which defines the performance of a logistic system is its reliability [5]. A literature search identifies numerous logistic reliability-related studies. These studies identified logistic system reliability as:

- the ability to provide all items (including ships, tanks, other means of transport, related spare parts, support equipment) necessary to equip, operate, maintain and support operational activities of technical system, for a specified period of time under stated conditions, without failure [3],
- in a broad sense, encompassing the acquisition, transportation, distribution, inventory management, maintenance, and sustainment policies, practices, and processes that contribute to the availability of system being supported [15],
- in the supply chain sense, probability of a supply chain to completely fulfill the demand of a final product without any loss of supply resulting from failures of suppliers. This, any supplier failure compromises supply chain reliability [6],
- the measure of the ability of a system to operate without placing a demand on the logistic support structure for repair or adjustment [35],
- the supportability – degree of ease to which system design characteristics and planned logistic resources allow for the meeting of system availability and wartime usage requirements [32].

As a result, the focus of this study is twofold. Firstly, authors define elements which affect the right performance of a logistic system. Secondly, the interactions between demand planning process and logistic system reliability are defined.

Following this, the rest of this paper is organized as follows: Section 2 presents the different approaches to logistic system reliability definition. In the Section 3 authors present the main elements affecting the reliable and available logistic system performance. Later, demand planning process and its quality has been investigated. The paper is ended by the presentation of the obtained analysis results in comparison with the knowledge about the case companies' present conditions.

2. LOGISTICS SYSTEM RELIABILITY DEFINITIONS

There is no one unequivocal logistic system reliability definition in the literature [34]. The presented below definitions consider various conditions for systems failure and overall reliability. The first definition develops the reliability model for a logistic system in a commercial sector. The next two consider supply chain reliability and logistic reliability in a defense sector. The last one investigates a technical system support approach.

2.1. BUSINESS-ORIENTED APPROACH

Business-oriented approach determines the correct performance of logistic system in terms of 7R formula implementation [3]: Right product, Right quantity, Right quality, Right place, Right time, Right customer, and Right price. Thus, the reliable performance of the logistic system means delivery: 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 [33].

The possible process reliability indicator methods which can be used to estimate the logistic system reliability, based on the presented 7R formula, are investigated in example [33]. One of these methods is proposed in [11]. This is the "Perfect order fulfillment" method, where indicator OTIF (On-time, In-full, Error-free) is used. The indicator OTIF is calculated from the formula:

$$OTIF = P_{o\text{-}t} P_{i\text{-}f} P_{e\text{-}f} \quad (1)$$

where: $P_{o\text{-}t}$ = probability of on-time delivery; $P_{i\text{-}f}$ = probability of in-full delivery; $P_{e\text{-}f}$ = probability of error-free delivery.

Few examples of this method application can be found in example [35].

Moreover, in the commercial sector the logistic system is investigated as a logistic network, usually with two levels: distribution centres (DC) and stores. In this context, the logistic system reliability is defined in terms of the reliability of the delivery process [50]:

$$R_d = R(T_d < t_0) \quad (2)$$

where: T_d = time of delivery, t_0 = pre-specified time limit.

Delivery time defined as the time to move the products from origin to destination consists two components:

- process time (t_p) at the DC – which includes loading, unloading, packing, sorting time, waiting time per dispatch, and so on,
- travel time (t_v) from DC to stores.

Authors, in their work [50], have also developed the model of the entire system service reliability R_s, when in the logistic network there are many distribution centers with different demands and reliabilities. In this situation reliability R_s might be described as the weighted sum of the service probabilities in all sub regions.

The presented logistic system reliability assessment approach bases on some rules:

- system reliability is defined as a function of demand volume, DC capacities (affecting the process time), and network configuration (affecting the travel distance),
- approach usually used in optimal store locations procedure, or optimal re-routing strategy definition,
- based on traditional deterministic optimization procedures.

2.2. SUPPLY CHAIN RELIABILITY APPROACH

In the literature, there are a lot of studies which underline the importance of supply chain reliability problems [6, 33, 34, 35, 45]. In the presented approach logistic system reliability can be defined in terms of inability to deliver a supply part due to unexpected events. In the context of supply chain reliability, supplier (component) and the supply chain (system) reliability have to be distinguished then.

Supplier reliability refers to the probability that the supplier operates as planned during the planning horizon. The term supply chain reliability is used to express the probability of a supply chain to completely fulfill the demand of a final product without any loss of supply, resulting from failures of suppliers. In this context, supply chain reliability R_s can be calculated as the product of all individual supplier reliabilities in the supply chain [6]:

$$R_s = \prod_{i=1}^{M} r_{vi} \tag{3}$$

where: r_{vi} = reliability of a supplier vi over the strategic supply chain planning horizon, where $i = 1, 2,\dots, M$.

The problem of supplier reliability evaluation is also investigated e.g. in [26, 47], where authors focus on uncertainty of global logistics systems. In their papers, they provide the model of global logistics system with the use of mixed-integer programming. The developed model is later extended in [23], where authors concern the reliability of all players in a system and use the Fault Tree Analysis to make a deeper analysis of reliability patterns.

Other view on the problem of supply chain reliability is presented in [19], where the supply chain reliability is defined as *the probability that the satisfactory performance of each part towards its own customer in the supply chain, including quality, quantity, delivery time and so one.*

However, many researchers claim that the term supply chain reliability has been defined for the first time by Thomas in 2002 (see e.g. [31]). Author in his work [45], has been investigating the system reliability in terms of *a set of processes for providing the procurement, distribution, storage, and transportation of people, supplies, materials, and equipment*. The supply chain reliability is defined as *the probability of the chain meeting mission requirements to provide the required supplies to the critical transfer points within the system*. The presented by author method provides the means for assessing the effectiveness of a logistic system or any supply chain network comprised of well-defined links and nodes associated with random supply and demand. However, this model does not take into account the randomness of the logistic support processes.

In 2003 Snyder in his work [41] has defined the three main bodies of literature related to supply chain reliability issues. The first group encompasses the network reliability problems. The typical network reliability problem regards to estimation of *probability that a network remains connected in the face of random failures* (e.g. [31]). The second body of literature regards to facility allocation problems and expected covering models (see e.g. [42, 43, 49]). Finally, the last group investigates the approaches for handling disruptions to supply chains. According to the literature, disruptions, that may occur during material and informational flow performance through a supply chain, have a negative impact on operational costs and achieved customer service level. Moreover, they can also lead to supply chain fault because of [8]:

- improper organizational structure implementation,
- employees unreliability,
- information flow unreliability.

2.3. DEFENSE APPROACH

Weapon systems are a typical example of large systems in which the reliability, availability and maintenance analysis is of critical importance. In this kind of the systems the logistic support assessment models includes:

- logistic support during the maintenance processes,
- spare parts and repair facilities needed to support complex systems,

and the reliability is given by the following equation [18]:

$$R_s(t) = P(T_o > t)/P(T_s > T_d) \tag{4}$$

where: T_s = time when the spares are available, T_d = time of delivery, T_o = time when the repair facilities are operable.

In both cases, the importance of reliability analysis is on the proper organization of supply process and designing the right repair channels. This model also takes into account the randomness of the logistic processes. Thus, the reliability of the logistic support systems may be defined as the probability that the logistic resources (e.g. spares, repair facilities) are available when required [18]. Such a problem definition is later investigated and expanded in e.g. [15, 17, 24, 27].

2.4. TECHNICAL SYSTEM SUPPORT APPROACH

Well organized logistic support affects the execution of technical system's operational tasks performance level. When the logistic activity is narrowed down to the supply activity, we can say that the basic elements are focused on providing the necessary supplies and services on the proper time for the right money [51]. In the case of maintaining the operational processes of technical system, the supply stream consists of such elements like maintenance and support personnel, support equipment, spare/repair parts and inventories, maintenance and support facilities, and logistics information [5, 7, 13]. Every logistic support system, operating under an increasingly complex and diverse system environment, may fail what, in consequence, may lead to:

- disruption of supporting task realization,
- inability of system to undertake a new task.

As a result, one can find a lot of studies dealing with the problem of designing reliable and available support systems for repairable items confirm the necessity of this kind problem investigation. Most of the developed models focus only on spare parts availability (see e.g. [7, 13]) and repair facilities availability (see e.g. [39, 44]). Reliability of logistic systems which are designed to support operational system performance usually is pertained to [36]:

- delivery reliability – defined in terms of order delivery process performance without any delays and adequate to customer requirements,
- transportation process reliability – defined as a probability that the transportation process will perform without any disruptions (e.g. load damage),
- reliability of logistic support infrastructure – defined as a probability that all support elements will perform without any failure for a specified period of time in a given operational environment.

The reliability definition of logistic system supporting technical system is developed in [53] *as system ability to undisrupted performance of supporting processes connected with necessary maintenance and logistic resources (e.g. support personnel, spare parts) delivery for a specified period of time, under the specified operational conditions.*

3. FACTORS THAT DETERMINE LOGISTIC SYSTEM RELIABILITY

Taking into account the presented above different approaches to logistic system reliability definition, authors of this study investigate in more depth the supply chain reliability perspective. The reliability definition is taken from [45]. Supply chain may be defined as an integrated process wherein a number of various business entities (like suppliers, manufacturers, distributors, and retailers) work together in an effort to: (1) acquire raw materials, (2) convert these raw materials into specified final products, (3) deliver these final products to retailers and final customers [4]. Such a logistic network is then characterized by a forward flow of materials and a backward flow of information. As a result, the reliability and efficiency of supply chain performance can be affected by many different factors. One can find many models in the literature which are concerned with material procurement, production, transportation, storage or distribution activities. However, lot of them treats each stage of supply chain as a separate system [12]. As a result, many of the supply chain interactions are ignored. This may led to improper identification of elements, which may influence the proper performance of a given chain (Figure 1).

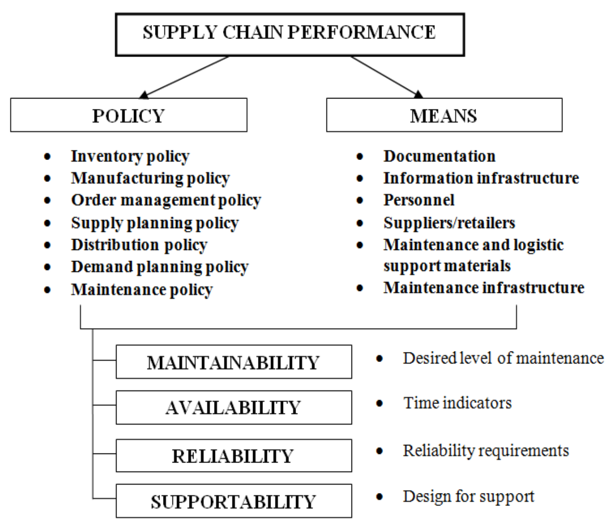

Fig. 1. Reliability, availability, maintainability and supportability in achieving supply chain performance
Source: [5, 36, 53]

Supply chain networks are vulnerable to disruptions and failure at any point in the supply chain may cause the entire network to fail. A key factor in effective supply chain management is the ability to minimize the effects of such undesired events/disruptions occurrence. As a result, understanding what disruptions may occur in a supply chain, how they will affect a supply chain system, and how far reaching these effects will be, would be of considerable benefit [56].

Treating the supply chain disruptions as unexpected events occurrence, we can describe them as having uncertainty in supply chain operations [56]. Uncertainty in the supply chain can be seen from different aspects, such as [48]:

- time (in the sense of duration of activity/process, starting/ending moment of activity realization, frequency of activity/demand occurrence),
- quantity (of supply, demand or physical transfer of goods),
- location/place (where activity starts/ends),
- quality (of service/products),
- cost (fluctuation, occurrence).

For example, Landeghen and Vanmaele in their work [22] profiled sources of uncertainty in the supply chain. They highlighted 13 sources of uncertainty across three supply chain's planning horizons (operational/tactical/strategic) and categorized them as Low, Medium and High.

Taking the presented perspective of supply chain disruptions definition, we can identify the main factors which influence the supply chain reliability (Figure 2). The factors which may affect supply chain reliability are divided into five main groups. The first two regard to supply reliability. At the beginning of supply chain even the most reliable supplier could have a late delivery disrupting the whole production process. Moreover, improper supply process parameters could lead organizations to reschedule the regular production because running out of raw materials.

Problems with manufacturing process are the second source of supply chain unreliability. For example, a new machine could fail to work unexpectedly, even if it has just been purchased. The production process interactions, its stability, manufacturing lead time or changes in production technology are mostly unpredictable and usually hard to measure.

Finally, at the end of supply chain random customer demand is the most challenging problem, as well as the distribution process parameters. An inaccurate forecast of customer demand could lead to overstock or under stock, what could cause the increase of inventory costs of organization performance. Moreover, decisions made during supply chain designing process in the area of distribution process performance also have the influence on chain reliability. The variability of retailers/distribution centers performance, quality of transportation process, quality of demand planning process or information availability and accuracy may significantly disturb chain performance and lead to decrease of achieved customer satisfaction level.

The researchers pay the most attention to demand uncertainty [25]. The errors in forecasting the customers' demand could be e.g. changing customers' preference, irregularity of customer orders in terms of time, quantity and quality. Thus, in this paper authors focus on demand planning process and its quality.

4. DEMAND PLANNING PROCESS

Demand planning is the first step of business planning. As business are moving towards a demand planning becomes the initial step to subsequent business and operations planning process such as purchasing, production, distribution and cash flow planning.

Thus, the performance of a business depends on a large extent upon the quality of the demand plan. The forecasting process is critical for the business success achieving because poor forecast can lead to insufficient or unnecessary high, finished good stocks, unused raw materials, misused production assets, and low margin. The forecasting and demand processes become more critical and difficult because of market evolving, what cause increased pressure on products life cycles, increased global competition and business turmoil. Companies that establish demand planning practice have significant competitive advantages. Every enterprise should make forecast irrelevant to their market sector, size or business activities. Appropriate demand planning process can improve the quality of forecast especially when the increase of number of customers, markets and products can be observed.

The high quality demand planning process is usually understood as:

1. Improved customer service level – a good demand forecast enables better response to actual customer demand with the available goods or services on time;
2. Lower inventory levels and related costs – an accurate demand forecast allows reduced inventory level and thus the costs of maintaining satisfactory service level;
3. Improved purchasing and procurement – a good demand plan leads to better planning of purchasing and procurement, which reduces costs of materials and improves relationship with suppliers;
4. Better use of production assets – an accurate demand plan is the basis of correct production planning, leading to more effective use of internal and external assets.

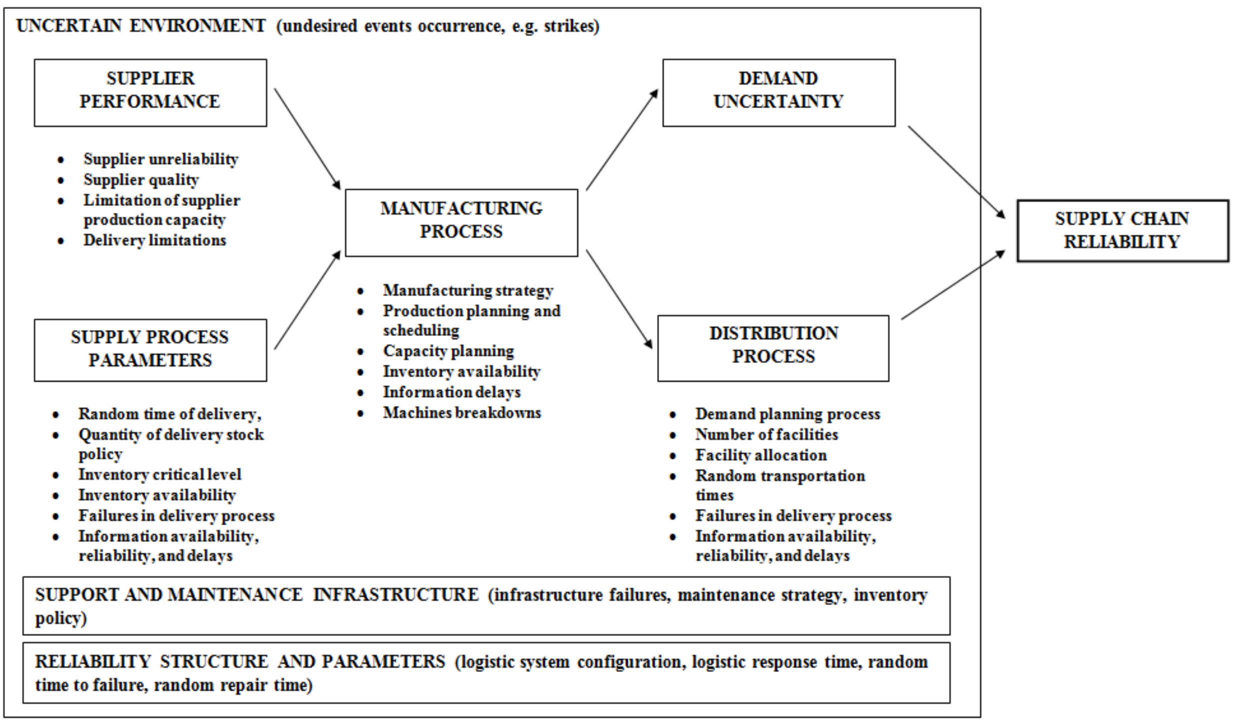

Fig. 2. Main factors which influence supply chain reliability

Demand planning process depends on the model of collecting information from the market. It is important to look beyond the enterprise to create correct demand planning process. Two main models can be descried - information sharing and non-information sharing models [9].

The initiator of the first model is the plan determined on the basis of historical data – most sales forecast. Manufacturer does not collect the information about retailer's orders and its sales data. This model is shown in the Figure 3.

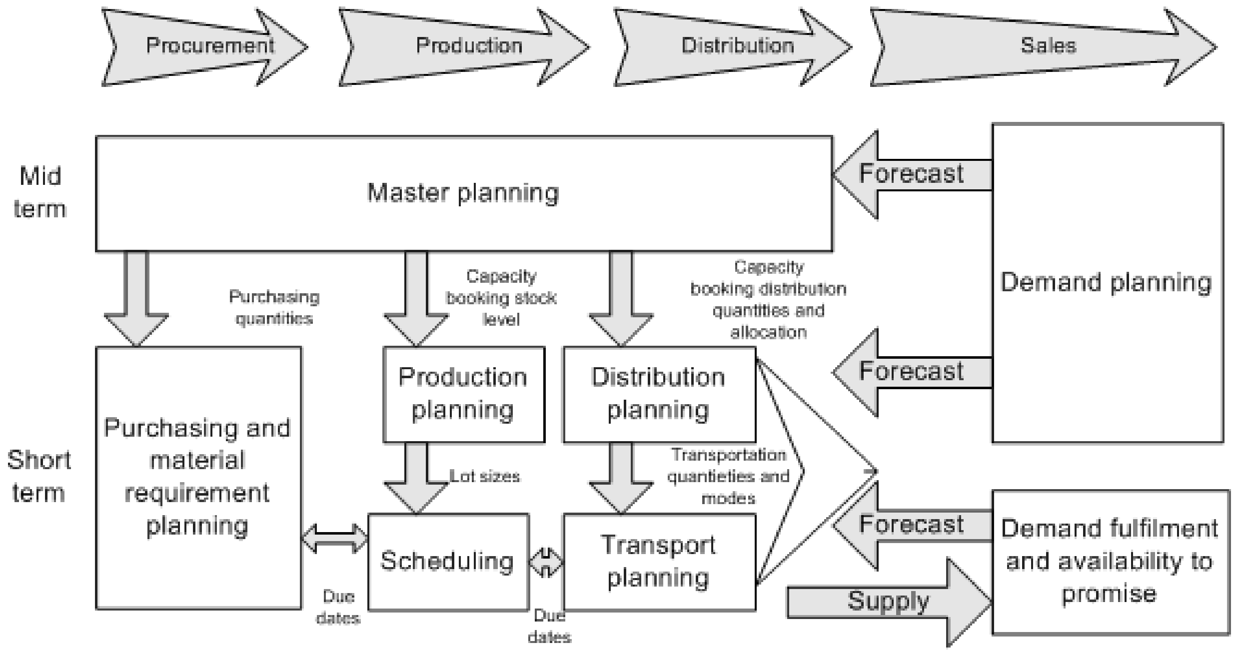

Fig. 3. Mid and short term planning process in manufacturing companies

Source: [37]

The demand planning process starts when appropriate numbers of historical data are gathered. However, not only this information should be taken into consideration. The demand planning process ought to consist of marketing and sales input, statistical analysis, business plan and strategy and product/brand management [14], as it is shown in the Figure 4.

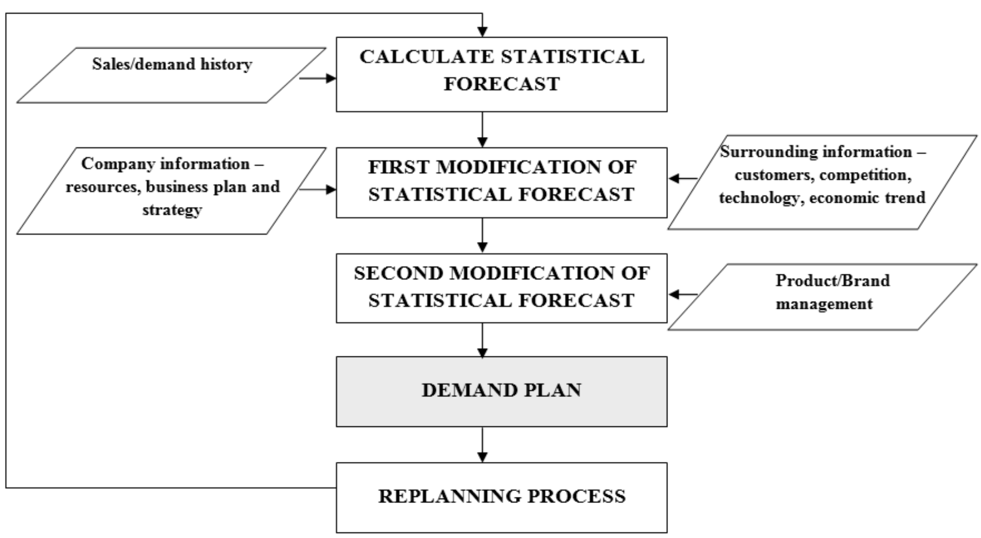

Fig. 4. Demand planning process

Demand planning process starts with demand forecasting, which is a key process for maintaining efficiency throughout supply chain [14]. When demand forecasting is considered as a process, the company has clear cut goals and predefined priorities towards it [28]. However, some problems appear to arise with demand forecasting. These problems correspond to making a forecast, which is based on pure historical data that could cause errors. It also causes a repetition of mistakes due to processing without understanding true customer demand [38]. This is the reason why demand forecasting should change or evaluate into demand planning based on multiple inputs. The correlation between planning and forecasting is shown in the Figure 5.

The forecast is modified using information from the company (resources, production capacity etc.) and environment (customers, competition, technology, economic trend etc.). In the second step, it is compared with business plan and strategy: if margin and profit is achieved, business plan is accomplished. The third step puts the product/brand management on the received plan. The final plan should take into consideration assumptions like: promotional and event planning, new product development, product launch and exit plans, product life cycle, product pricing plans, brand and category plans and competitors' product tactics.

Favorable situation for the company is connected with planning in the area of interaction with others. Sharing information allows determining the forecast based on the procurement and no historical data. The mid and short term collaboration planning process in manufacturing companies is shown in the Figure 6.

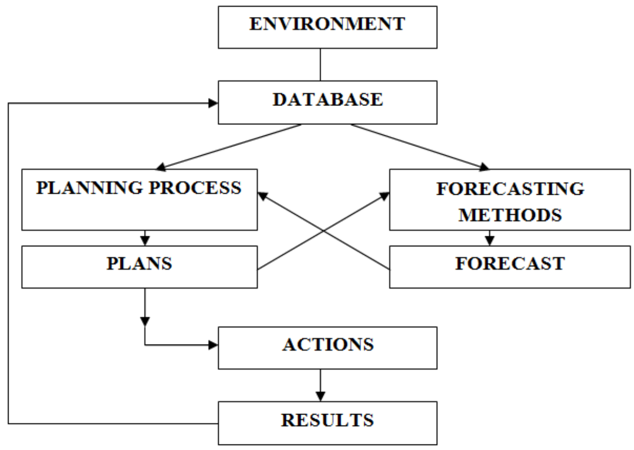

Fig. 5. Correlation framework for planning and forecasting

Source: [1]

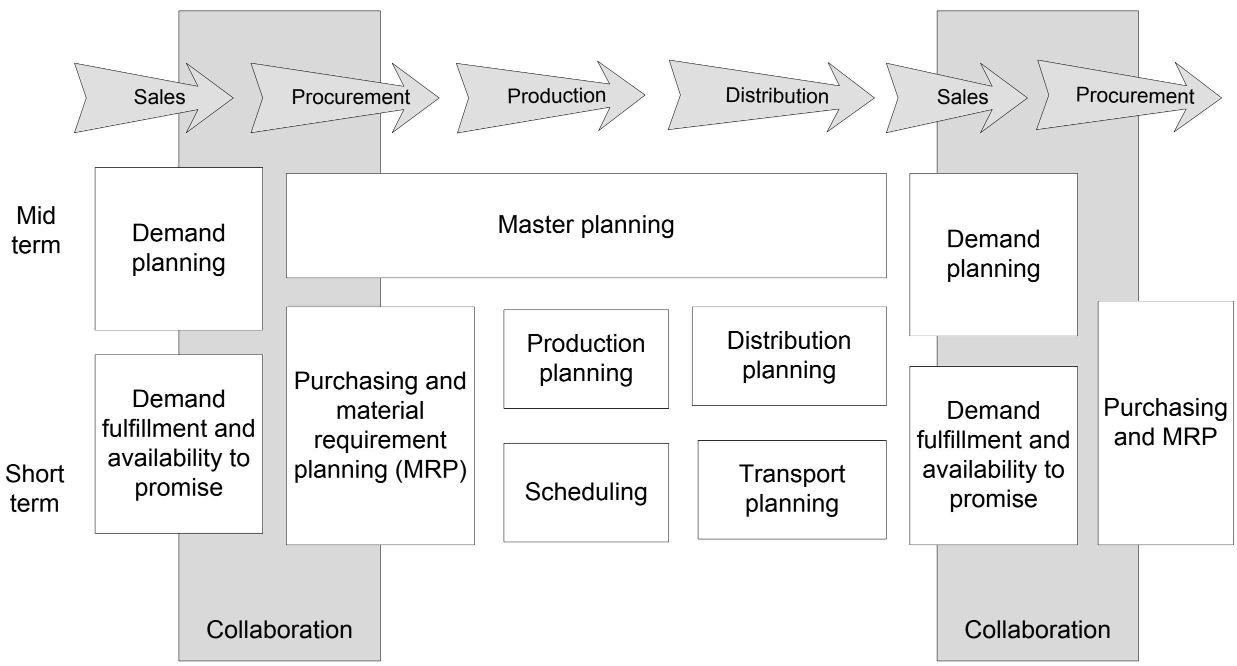

Fig. 6. Mid and short term collaboration planning process in manufacturing companies

Source: [30]

This model can be characterized as continuous planning process. The customers are the initiators of the process and sales collaboration is crucial. Co-operating companies share information on demand patterns, lead times, process and product configuration. If the collaborations are managed appropriately then the downstream supply chain will not lose its capability to promise lead times to customers and at the same time minimize the total costs of the supply chains [21]. Thus, each of the two shaded blocks in Figure 6 represents both sales and procurement collaboration to create a common and mutual agreed-upon plan [10]. Furthermore, sales and procurement collaboration should also be supported by using, for instance, vendor managed inventory (VMI) by sharing demand and inventory information amongst enterprises or factories such that it creates demand collaboration, inventory collaboration, capacity collaboration, and transport collaboration, as shown in the Figure 6 [20].

In this model the demand planning process starts when customer's orders are collected. The statistical forecast is replaced by procurements. However, other sources of information are also needed to calculate accurate demand plan (Figure 7).

Fig. 7. Sources of information for demand planning process

Source: [54]

The enhancement of the demand plan quality depends on the model of business planning used in companies. There are two main ways to increase forecast quality:

- increase forecast accuracy – for the first model presented in Figure 3,
- efficient information flow [16] - for the second model presented in Figure 6.

The data quality of the forecast becomes worse when the demand is estimated multiple-step-ahead and without external data. It is more reliable to use today's facts to forecast demand of tomorrow rather than those of the next year [9]. It is more reliable to use clients' procurements rather than historical demand (usually sales data).

5. CASE STUDIES

In this part of the article two cases will be considered. The examples presented below illustrate leading manufacturing companies from the appliance industry. One of the producers cooperates in no-sharing information model, the second one in the opposite model. If the company operates without the possibility of obtaining information from the market the demand planning has to be based on historical data. In this case, a proper selection of forecasting models becomes important. However, if the company operates in an integrated environment and it is possible to use the procurement forecasting models, the problem of forecasting models selection does not play an important role. For both the cases, at the forefront are an information flow system and its performance reliability.

5.1. MANUFACTURER COOPERATES IN THE NO-SHARING INFORMATION MODEL

In no-sharing information model the quality of forecast can be defined by many different parameters such as customer service level, inventory level, costs of materials, effective use of internal and external assets, forecasting accuracy, etc. In analyzed company three indicators are compared:

1. Forecasting error MAPE [29]:

$$MAPE = \frac{1}{n}\sum_{t-1}^{n}\left|\frac{O_t - F_t}{O_t}\right| \cdot 100\% \qquad (5)$$

where:
MAPE = Mean absolute percentage error [%],
O_t = Order quantity at time t [pcs],
F_t = Forecast quantity at time t [pcs]

2. Average inventory level [55]:

$$I_l = \frac{1}{n}\sum_{t=1}^{n} I_t \qquad (6)$$

where: I_l = Inventory level [pcs]; I_t = Inventory level at time t [pcs]

3. Rate of completed orders which could be called as an level of customers service [55]:

$$O_c = \frac{1}{n}\sum_{t=1}^{n}\left(1 - \frac{O_t - S_t}{O_t}\right) 100\% \qquad (7)$$

where: O_c = Rate of completed orders [%], O_t = Order quantity at time *t* [pcs], S_t = Sales quantity at time *t* [pcs]

In the first company, the forecast is calculated as an average sales level using data from previous year. Almost in every appliance sector, demand fluctuations can be observed due to seasonality, however they were not taken into consideration. Such planning performance results in quite large demand forecast errors achieving, reaching even 40%.

For the case company, the forecast error *MAPE* equals 14.95%, rate of completed orders - 90%, and average inventory level - 19 621 pieces. Obtained results indicate that customers are satisfied in 90%. Detailed information is shown in the Figure 8.

The main problem is connected with choosing the incorrect forecast model during the demand planning process. Coefficient of variation computed for sales data equals 17%. This value is too high to use naïve forecasting methods.

In the next step, there has been determined demand forecast using adaptive models which are adequate for the given data. This allowed to obtain the following results: the forecast error *MAPE* – 5.,83%, rate of completed orders - 97% (Figure 9) and average inventory level - 14 194 pieces. As a result, for the presented case company, in the demand planning process one of the key elements has been improved – chosen methods of forecasting. This company was able to raise the customer service level by 7% while reducing inventory level of 28%.

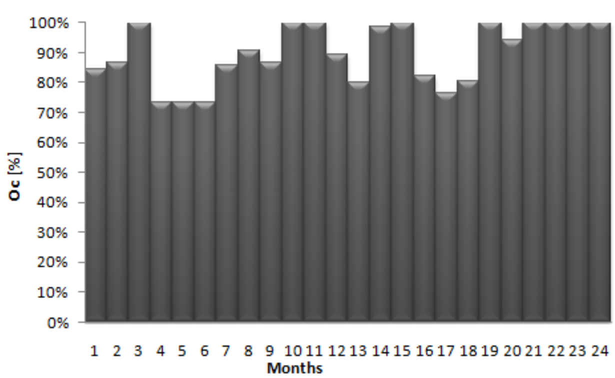

Fig. 8. Rate of completed orders when forecast model has not been chosen properly

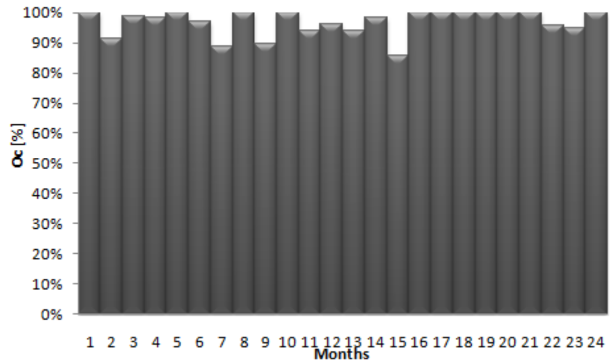

Fig. 9. Rate of completed orders when forecast model has been chosen properly

5.2. MANUFACTURER COOPERATES IN THE SHARING INFORMATION MODEL

In the case of companies operating in the sharing information model, system reliability measurement becomes more complicated. Generally, the primary object of measurement is the correct process and quality of information that provides an adequate customer service level through the service on time. The quality of the forecast could be defined as the correct process of information flow, because the forecast for the manufacturer is customer's procurement. For the sharing information model the forecast process quality can be measured e.g. by:

1. Time of the whole process [2]:

$$P_t = \frac{1}{n}\sum_{t=1}^{n} A_t \tag{8}$$

where: P_t = Time process [hours]; A_t = Execution time activity at time *t* [hours]

2. On time customers' service [55]:

$$C_s = \frac{1}{n}\sum_{t=1}^{n}\left(\frac{P_t - Pd_t}{P_t}\right) 100\% \tag{9}$$

where: C_s = Customers' service performed on time [%], P_t = All procurements at time *t* [pcs], Pd_t = Procurements delayed at time *t* [pcs]

A demand planning process being implemented in manufacturer of home appliances industry is shown in the Figure 10. The execution time is measured to give authors a possibility of making the improvement of this process. In this case the problem is connected with the communication process. During the process performance two main disadvantages could be observed: the clients' approvals are involved twice and the customers are informed by two distinct departments. Customers must confirm the orders in accordance with the production capacity, and then orders are determined from the capacities of the suppliers. The clients are informed by two distinct departments: the customer service and the planning department. The process lasts 67 hours, what gives about 8.5 working days.

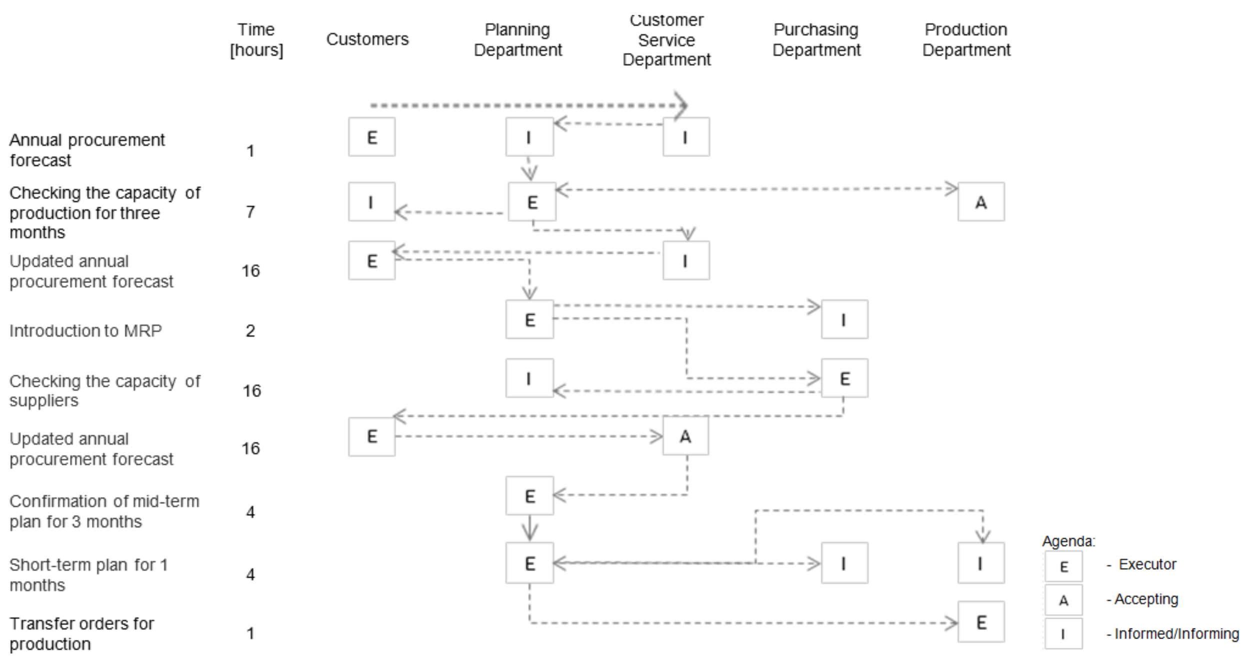

Fig. 10. Demand planning process being performed in the analyzed case company

If the process sequence is changed and the responsibility for customers contacts is moved to the customer service department, a quality level of the process – the efficiency of information flow, should improve. The proposed changes are shown in the Figure 11. The change of the process helps to reduce the time involved in demand planning process by 24%. Now, mid and short term planning takes place within 51 hours, which gives about 6.5 working days and shorten the process by 2 days.

6. CONCLUSIONS

The demand planning process and demand forecasts play an important role in many supply chain decisions. For example, inventory management decisions, production planning and scheduling decisions are made on the basis of developed demand plans. As a result, the reliable performance of supply chains cannot be obtained without making of high quality forecasts.

As it can be seen from the case studies, the model of collecting information from the market plays an important role in the demand planning process. The main differences are: the forecast calculations and system reliability. The possible quality measures, that are possible to be used when forecasting the customer demand, are given in the Figure 12.

Moreover, logistic performance measurement systems are dedicated to concrete supply chains. As a result, one can use many different measures to analyze the level of demand planning process quality and supply chain reliability. Thus, the proper choice of performance measures depends on e.g. operational data being gathered in a system, used integrated systems or personnel skills. To sum up, the paper is to be the starting point of consideration about the role of demand planning process in supply chain reliability achieving and maintaining. In the next step, authors could focus their research affords on the investigation of supply chain unreliability factors (unwanted events) extended classifications e.g. in terms of time resource having, or informational flow likelihood perspective.

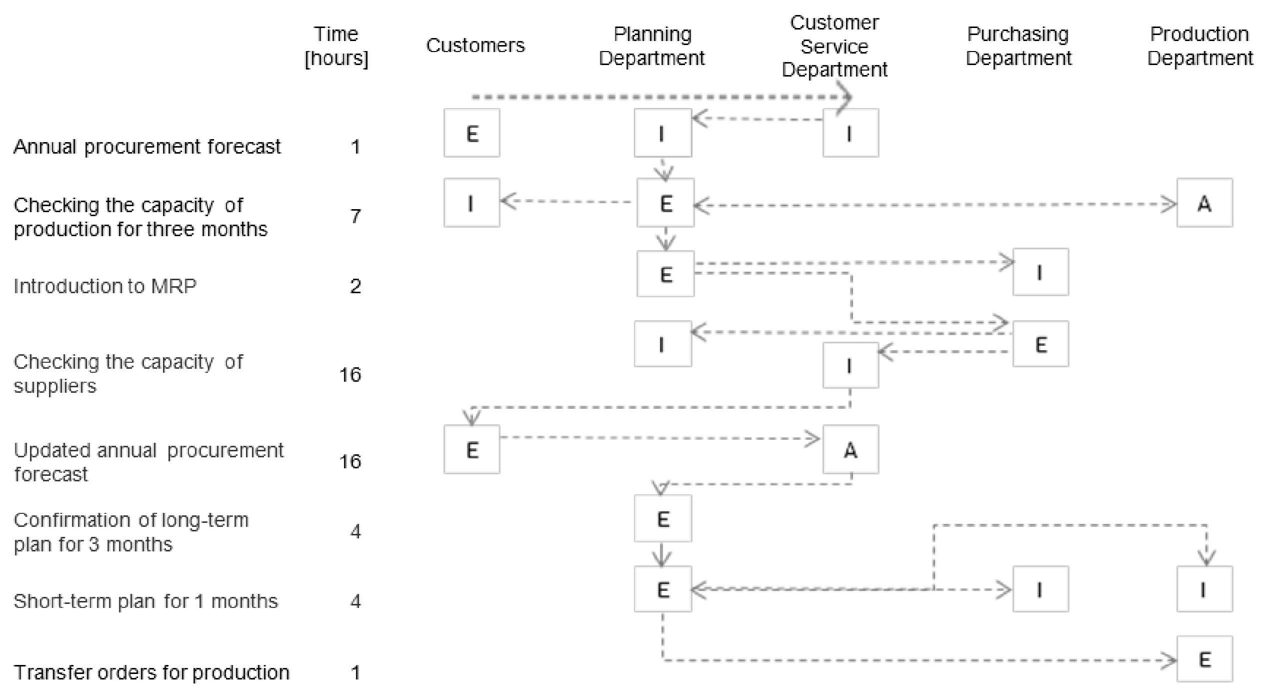

Fig. 11. Revised demand planning process for the analyzed case company (Agenda like in Fig. 10)

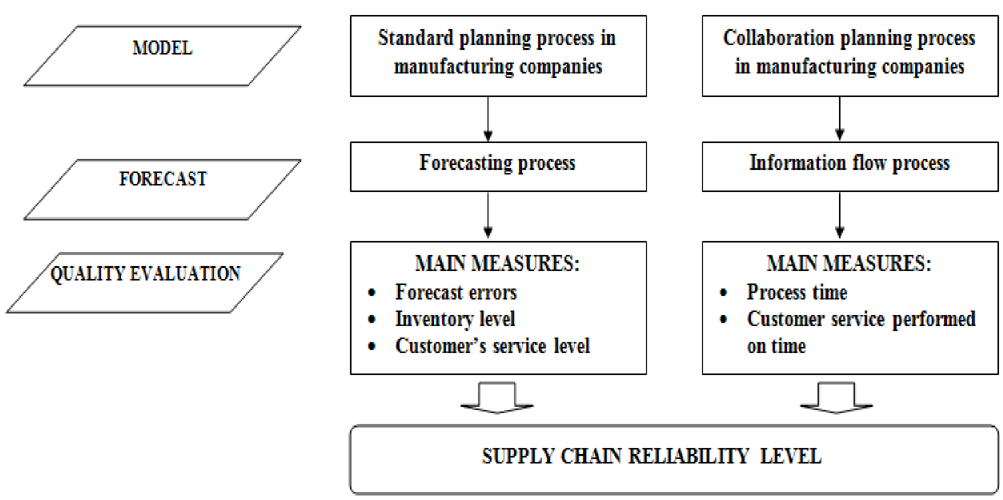

Fig. 12. Quality in the demand planning process

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