Time-based responsive logistics for a maintenance service network

A case study of an automated teller manufacturer

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Abstract

Purpose – The purpose of this paper is to identify the main reasons for spare parts logistics failures and address logistics distribution design in order to achieve the desired level of after-sales maintenance service.

Design/methodology/approach – This research is based on an empirical case study on a large corporation providing worldwide with retail banking hardware, software and services. The case study focuses on the automated teller machine (ATM) part of activities, with a focus on the spare parts distribution and after-sales service network in the Eastern Europe.

Findings – The proposed network solution of multiple distribution centers with short-cut distance saving approach will enable the case study company to redesign their spare part logistics architecture in order to achieve short response time. Research findings reveal possible spare parts delivery delays and thus the service-level agreement failures with clients in the case study company.

Research limitations/implications – This research covers a particular supply chain environment and identified research gaps. It discusses a time-based responsive logistics problem and develops a conceptual framework that would help researchers to better understand logistics challenges of installed equipment maintenance and after-sales service.

Originality/value – This case study research shows the "big picture" of spare parts logistics challenges as vital part of installed equipment after-sales and maintenance service network, as well as emphasizes how the unique context of a market like Russian Federation can set-up a distribution network efficiently. Strategies applied to handle such service-level failures, reverse logistics aspects of repairable and non-repairable spare parts to such large ATM after-sales service network based on this longitudinal case offer value for similar scale companies.

Keywords Case study, Distribution network, Maintenance service, Logistics system design, Spare parts logistics

Paper type Case study

1. Introduction

Spare parts logistics is a complex operation and requires a set of strategic decisions such as planning for spare parts demand, inventory policy decisions and setting-up a time-based responsive logistics network of warehouse facilities, all connected to the after-sales service support (Cohen *et al.*, 1999). In line with Cohen *et al.* (1997) the main challenge is to deliver the necessary spare parts for required maintenance service within the committed time.

After-sales service ensures the required maintenance and replacement of spare parts for geographically dispersed clients when they face any problem with their equipment (Duffuaa and Raouf, 2015). Offering a responsive and high-quality support is one of the key instruments for achieving this service (Murthy *et al.*, 2004). A time-responsive and high-availability spare parts logistics network is a critical element for achieving the desired service level (Candas and Kutanoglu, 2007). Despite the vast literature developed over the last 50 years on spare parts logistics in an after-sales service context, there are very few papers dedicated to the empirical case study of installed equipment spare parts logistics

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options and development of optimization solutions in such a particular supply chain. This research focuses on bridging the gap between theory, business practices and specific context by developing a set of practical proposals for response optimization and prevention of logistics failures through a case study approach.

The research context for this study extends up to the East Germany and the entire Russian Federation region; logistics activities there are still suffering from poor logistics service, lack of ability to set-up long-term supply chain strategies, as well as difficulties with distribution channel developments due to significant spatial distances (Johanson, 2004; Lorentz and Ghauri, 2010). In particular, the size of the country and the nature of its economy call for additional research and testing logistics theoretical frameworks in this particular context (Lorentz and Ghauri, 2010; Narasimhan and Mahapatra, 2004).

2. Literature review of spare part logistics

A strategically balanced and well-aligned spare parts logistics network can help enterprises to add value for their customers and build up loyalty (Huiskonen, 2001). Spare part logistics includes market-orientated planning, implementation and execution of supply and distribution, along with information flows between the company and its network partners (Wagner *et al.*, 2012). Spare parts logistics target a demand-driven and minimal cost provision of needed items for maintenance of installed equipment to assure the fulfillment of after-sales contract conditions agreed with the client (Nowicki *et al.*, 2008).

2.1 Challenges in spare part logistics

A spare parts logistics network has to support all the products a company sold in the past, developing a supply chain strategy in order to differentiate them from its competitors, deliver product and service on-time, lower its cost and increase the profit (Wagner *et al.*, 2012). Authors have identified the following challenges, which set pressure for the spare parts logistics flow and can be a reason of logistics failures and supply chain disruptions: the high variety of stock keeping units (SKUs) (Bacchetti *et al.*, 2010), the existence of a sporadic spare parts demand pattern, since the need for repairs is uncertain (Boylan and Syntetos, 2010; Sharma and Kulkarni, 2016), inventory control due to the high-availability required (Ballou, 1981; Christopher, 2011; Kutanoglu, 2008), and the short response time and flexibility needed, as well as a well-designed distribution network in order to avoid logistics failures and ensure the desired service level (Ambrosino and Scutella, 2005; Driessen *et al.*, 2010; Murthy *et al.*, 2004). Liyanage and Kumar (2003) applied the balanced scorecard concept to develop an architecture for effective management of maintenance performance linking results to performance drivers, emphasizing on maintenance value rather than cost.

2.2 Classification of spare parts stock keeping units (SKUs)

Spare parts are exchangeable parts or equipment that can be used to substitute items removed during the maintenance of initial products after they have been sold (Huiskonen, 2001). The overall assortment can be wide and highly varied, with different costs and demand characteristics (Bacchetti *et al.*, 2010). A classification of spare parts SKUs may define the service requirements for different kinds of spare parts and support the assignment of the most appropriate forecasting models and inventory policies (Molenaers *et al.*, 2012). The diverse sets of spare parts SKUs make the classification process challenging, involving different approaches to the ranging of spare parts (Bacchetti *et al.*, 2011).

A widely applied classification model is the ABC-analysis, when SKUs are categorized with regards to a single criterion, such as unit price, demand value or consumption character (Huiskonen, 2001). Syntetos *et al.* (2009) used the ABC-classification to range spare parts based on demand value, with significant benefits for service levels using a demand value approach instead of a demand frequency categorization of SKUs spares. In the early research, Syntetos *et al.* (2009), Ramanathan (2006) and Partovi and Anandarajan (2002) argued that for industrial high-varied spare parts, where the assortment is heterogeneous in character or nature and therefore the ABC-method is not sufficient.

This evidence triggered the need to extend the classical ABC-model to a multi-criteria ABC-model including several criteria as a basis for classification, such as unit price, delivery time, essentiality, weight and volume of the spare part, availability of spares on the market, efficiency of repair, which can be either quantitative or qualitative in nature (Kauremaa and Holmström, 2017). Duchessi *et al.* (1988) introduced a two-dimensional classification pattern, combining inventory holding cost and part criticality as criteria. Morris and Ernst (1988) used a multi-item classification and general grouping technique that can be applied for setting-up a group-based operational control policy for SKUs spare parts. Ramanathan (2006), Zhou and Fan (2007) and Partovi and Anandarajan (2002) suggested the application of an ABC-classification combined with weighted linear optimization models.

Table I summarizes the different classification models for spare parts logistics.

Even though these multi-criteria classification techniques have positive implications and have been widely used for spare parts maintenance problem as classified in Table I, they also have some disadvantages. For instance, it is difficult to merge qualitative criteria into Artificial Neural Networks models and measurements of categories in the weighted linear optimization models (Braglia *et al.*, 2004). Nagarur *et al.* (2008) suggested a hierarchically structured two- (or three-) dimensional qualitative–quantitative classification model. In comparison to quantitative models, qualitative techniques aim to measure the significance of keeping spare parts, taking into account specific information and factors that affect decision making in spare parts management, such as price, downtime, criticality, storage considerations, time window, etc. (Martinetti *et al.*,2018; Gupta and Mishra, 2016)

2.3 Demand forecasting models in spare parts logistics

The post-sale spare part demand forecasting differs from the forecasting for finished products, mostly because failure of equipment takes place unexpectedly with high degree of uncertainty and that makes the problem so difficult and complicated. Traditionally, two methods are widely applied for demand forecasting in spare part logistics, these are reliability-based and time series based forecasting (Driessen *et al.*, 2010). Reliability-based forecasting of structural uncertainties relate to reliability engineering techniques, such as sensors and changing operating conditions, where forecasts are based on the installed base of the equipment and prognostics (Ebeling, 1997; Heng *et al.*, 2009; Nelson, 1990). Time series based forecasting is based on historical demand data dealing with randomness situation in that, providing high applicability in to spare part logistics making more relevant to ATM maintenance demand forecasting problems.

The past literature covered various techniques of time series based demand forecasting (Silver *et al.*, 1998; Teunter and Duncan, 2009). Croston (1972) suggested to forecast the time between demand occurrences and the size of orders separately, while Willemain *et al.* (2004) adapted a bootstrapping technique where the forecast is made by a replicated sampling from realized demands. Snyder (1993) introduced single exponential smoothing and simple moving averages techniques, which are also often applied in practice for forecasting spare parts demand, and increase the accuracy of planning. Though there has been other forecasting, demand planning and supply planning methods introduced in the recent past, these methods found to be providing little improvement to the situations and customer service in after-sales problems (Jonsson and Holmström, 2016; Phan and Nham, 2015; Hasan *et al.*, 2013).

However, in the modern logistical demand forecasting situations, predictive analytics associated forecasting techniques make pre- and after-sales forecasting more accurate

Table I.
Literature overview of the main contributions in the research of spare parts SKUs classification

Author(s)	Criteria					Approach			
	Spare parts price/value	Spare parts criticality	Supply characteristics	Demand pattern (volume/value)	Demand volatility	Quantitative	Qualitative	Mono-criteria	Multi-criteria
Ahmad and Kamaruddin (2012)			✓		✓			✓	
Al Drugam and Duffuaa (2013)				✓		✓			✓
Boylan *et al.* (2008)					✓	✓			✓
Braglia *et al.* (2004)	✓	✓	✓	✓			✓		✓
Cavalieri *et al.* (2008)	✓		✓				✓		✓
Duchessi *et al.* (1988)	✓	✓				✓			✓
Gajpal *et al.* (1994)		✓					✓	✓	
Gelders and Van Looy (1978)				✓		✓		✓	
Gupta and Mishra (2016)			✓		✓				✓
Huiskonen (2001)	✓	✓					✓		✓
Mahfoud *et al.* (2018)	✓	✓			✓				
Martinetti *et al.* (2018)						✓		✓	
Molenaers *et al.* (2012)		✓	✓			✓	✓		✓
Morris and Ernst (1988)	✓		✓	✓	✓	✓			✓
Nagarur *et al.* (2008)	✓		✓			✓			✓
Partovi and Anandarajan (2002)	✓		✓	✓		✓			✓
Ramanathan (2006)	✓	✓	✓	✓		✓			✓
Syntetos *et al.* (2009)					✓	✓			✓
Sharma and Kulkarni (2016)		✓				✓			
Teunter *et al.* (2010)				✓		✓		✓	
Zhou and Fan (2007)	✓	✓	✓	✓		✓			✓

giving improved results because they were based on non-parametric data mining algorithms (Makridakis *et al.*, 2009; Shmueli and Koppius, 2011; Mishra *et al.*, 2016). In addition, the predictive forecasting techniques, enables to capture complex relationships in the data without making restricting statistical assumptions and thus making the method more flexible as mentioned early in the literature by Friedman and Montgomery (1985) and Collopy *et al.* (1995).

2.4 Time-based logistics flexibility

One of the key elements of business success in the spare parts service market is the application of a time-based logistics flexibility (Christopher, 2011). A short lead-time in spare parts logistics provides a responsiveness to the time-sensitive maintenance, comprising customer loyalty and avoiding downtime penalties (Nowicki *et al.*, 2008). Driessen *et al.* (2010) outlined two kinds of downtime in spare parts service provision, namely, diagnosis and maintenance time, and downtime of systems due to unavailability of spare parts for repair works. Hence, time-based logistics flexibility is important as it affects maintenance delays. The cost of capital assets, inflation growth and a competitive environment drive companies toward shortening the inventory in order to reduce holding costs, while at the same time assuring sufficient spare parts availability (Jafari, 2015). A short response time allows not only to cope with the demand fluctuation and to meet the service contracts requirements, but also helps to reduce costs (Fisher *et al.*, 1994). Time-based flexibility represents the ability of a logistics network to react with minimum time and cost, while performing efficiently (Upton, 1994).

2.5 Spare parts distribution network design

The distribution network design (DND) aims to form the network configuration, involving transportation and inventory decisions, routing decisions, the number of warehousing facilities and its locations where SKUs are temporarily stored on its way to the end customers (Ambrosino and Scutella, 2005). These logistics issues are driven by various contextual factors, namely, the type of product and the demand pattern, have a strong influence on supply chain performance in terms of both logistics operational costs and customer service level (Ballou, 2001). Therefore, DND appears to be one of the key elements of the overall profitability of a company. The globalization of the worldwide economy and the rapid growth of cutting-edge technologies drive toward a shorter product lifecycle, a more volatile customer demand and a need of a time critical after-sales logistics service, consequently, a well-constructed distribution network has become more critical (Melo *et al.*, 2009).

In line with Mangiaracina *et al.* (2015), there are few main decision issues during the strategic planning of DND, such as: storage facility location (distribution centers, warehouses and depots), number of storage facilities, demand allocation to facility, capacity of storage facility and quantity of echelons. Decision issues in DND were discussed by Abrahamsson and Brege (1997) in combination with some other issues, such as inventory level and transport routing design, since they operate as adverbial modifiers to the storage facility location policy. Sourirajan *et al.* (2009) studied safety stock allocation decision issues, in order to ensure a desirable service level. Christopher and Towill (2001) illustrated that distribution systems should be designed based on marketplace characteristics, such as customer density, delivery periodicity and demand pattern. Based on the literature review, the main factors identified as influencing the decision making are: demand level, cycle time, distance between nodes, customer service and marketplace characteristics. Those factors are considered as the base for the theoretical development of this research.

2.6 Theoretical framework and research gaps

Based on the literature review, the following key challenging areas can be a potential reason of logistics failures or supply chain disruptions:

- spare parts SKUs classification;
- spare parts demand forecasting;
- inventory management; and
- utilization of time-based logistics flexibility and DND in the context of high-responsiveness needed in after-sales spare parts logistics.

In the area of SKUs classification, the approaches identified included quantitative or qualitative models, mono or multi-criteria approach, as well as classification criteria (e.g. spare parts price and criticality and demand pattern).

"Although forecasting is far from an exact science, the forecast management process should incorporate input from multiple sources, appropriate mathematical and statistical techniques, decision support capability and trained and motivated individuals" (Bowersox *et al.*, 2010). In the area of demand forecasting, predicting the failure of equipment and thus, to forecast an accurate number of spare parts needed is a challenging task. However, having "Internet of Things," data becoming more accessible and abundant, contributing to the big data environment, many organizations, especially from asset-intensive sectors, such as agriculture, manufacturing, mining, oil and gas, transportation and utilities, are investing in advanced analytics to help them predict the failure of mission-critical equipment or assets (Baaziz and Quoniam, 2014; Lee *et al.*, 2013).

The body of literature describes two main forecasting approaches, the reliability-based method and time series based forecasting based on historical demand data. The inventory management literature in spare parts logistics separates spare parts stock control models from other final product inventories, due to the reparable nature of SKUs and the high service level needed. Two key inventory control approaches in spare parts logistics were identified, three single-echelon models (e.g. deterministic and stochastic models) and multi-echelon models (e.g. batch model, distribution-focused model, simulation-based and queueing-based models, as well as one-for-one replenishment model).

Time-based logistics flexibility in the context of short lead-time and responsiveness of logistics network was highlighted as one of the key elements of business success in after-sales spare parts service logistics. Few main components of flexibility were outlined by Daugherty and Pittman (1995), such as time management (e.g. order processing and distribution time), corporate responsiveness (e.g. service prioritization system and monitoring of service levels), flexibility (e.g. regular shipments and customization of products in distribution centers) and communication/information. These five perspectives mentioned above, can be linked to the after-sales spare parts logistics strategy and help companies to improve the efficiency of spare parts logistics management (Sharma and Kulkarni, 2016). Figure 1 presents a conceptual framework of key challenging areas in a spare parts distribution network that may be a potential reason of logistics failures or supply chain disruptions, following the structure of a cause-and-effect diagram.

3. Case study approach

A case study method is applied in this research to examine this complex area of logistics in-depth, since this method is suitable for investigating and analyzing upon the arising nature of the "how" and "why" questions (Voss *et al.*, 2002) that this research requested. Moreover, this case study aims to observe the spare parts logistics processes in the company in a particular supply chain environment, namely, the Russian Federation market, in order to investigate the reasons of logistics failures. In this research, a single holistic case

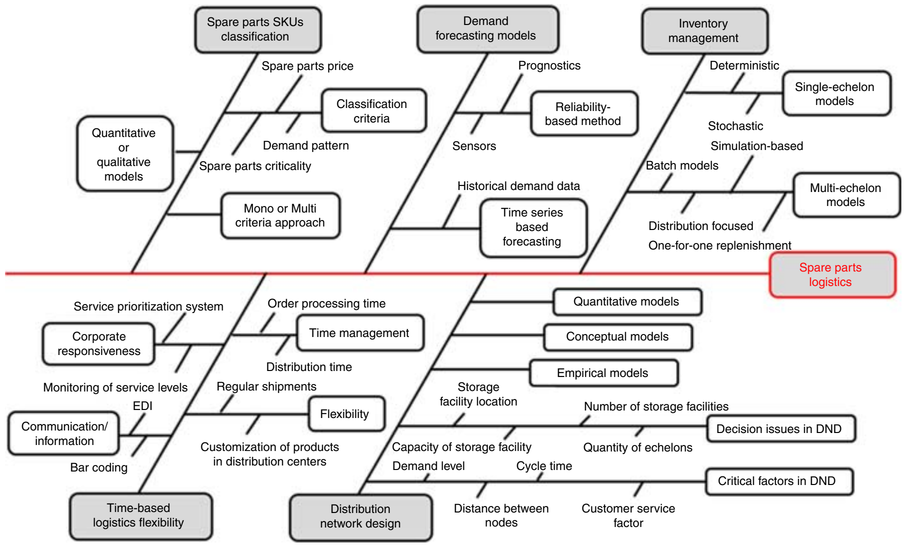

Figure 1. The conceptual framework of spare parts distribution network

study approach was selected for addressing the research objectives, as a proper methodology to understand a phenomenon in a particular environment, which is the spare parts supply chain environment of Russian Federation market (Baxter *et al.*, 2008).

The case study company is a worldwide high technology product manufacturer for the banking and retail sector, while its after-sales spare parts maintenance provision for installed equipment (ATMs) is one of the core business elements of the company. This company was chosen as one of the exemplary representatives of enterprises that deals with after-sales service contracts and organizes spare parts logistics.

This case study investigates the spare parts logistics paradigm in after-sales market, capturing the circumstances and conditions of spare parts logistics management in a particular logistics environment. The case study emphasizes how this unique environment can bring difficulties for enterprises as they adapt to the global market realities (Djankov and Murrell, 2002; Kogut and Zander, 2000; Peng, 2003).

3.1 Data collection

Data were collected via multiple sources in order to enhance data creditability and to elaborate an adequate operational set of measures, avoiding a subjective assessment of information (Meredith, 1998). The multiple approach of data collection appears to be a suitable tool for explanatory investigations. The primary data are received from semi-structured interviews that are the key data collection technique for qualitative research and the most substantial and useful source of evidence for a case study methodology (Blumberg *et al.*, 2008). The questions included in the interviews are given in Table II.

Totally five interviews were conducted; one interview with the senior logistics manager, three interviews with managers of service logistics and one with the logistics analyst regarding the data statistics. The duration of each interview was approximately 4 h in order to reach the understanding of the interviewee, to understand strategic ideas, current difficulties and opinions based on their experience. Being aware of the lengthy duration of this qualitative approach, the researcher contacted the interviewees prior to their meeting, making clear the duration of the interview, and provided with contact information in case the interviewee wanted to withdraw or change the time.

Case study area	Case study questions
Operational process	Please outline your department's business purpose
	Please describe the operations processes of your department
	Please explain the interactions between your department and other departments inside the company
	Please explain procedure of interaction with logistics contractors
Spare parts SKUs classification	How does the company differentiate spare parts?
	What kinds of criteria are used for spare parts categorization?
	Does the company has different service and logistics requirements for the particular group of spare parts? What kind of requirements it is?
Demand forecasting	How does the company manage the demand forecasting for SKUs?
	How does the company decide when and how many units need to be ordered?
Inventory control	How does the company organize inventory management?
	What kind of trade-offs the company has while managing inventory?
Distribution network design and utilization of time-based logistics flexibility	How does the company manage the order processing time and distribution time?
	What kind of system is used for orders processing?
	How does the company monitor the logistics service levels?
	How do you think which elements are important for delivering a good logistics performance in your particular environment?
	Does the company promote a corporate responsiveness?
	Does the company has a service prioritization system for key clients?
Challenges the company faces in spare part logistics	Please describe problems you meet during the after sales service of spare parts
	How these problems affects the operations processes and business overall?
	Does your company have any approaches to handle these issues with spare parts logistics?
	How do you think what is the reasons of these problems?

Table II. Case study questions that are asked during the interview

All the interviews were conducted in a location convenient (and comfortable) for the participants (Bell, 2009).

The interview questions are designed and divided into thematic groups including questions about spare parts SKUs classification, demand forecasting, inventory control, DND and utilization of time-based logistics flexibility, as well as questions about current and future challenges.

In order to ensure triangulation of data and confirm interview statements (Yin, 2009), field visits were conducted to collect secondary data such as internal documents, process files, reports, quantitative statistics data from the ERP system and archive records. This approach enables to rely not on a single source of information; and creates more conclusive and accurate research results with the help of involving data from different sources to cross-check their reliability (Farquhar, 2012). Archive documents, such as customer service-level agreements (SLA), key performance indicators and other information, are gathered after a careful evaluation of the correctness of the records. Field visits were arranged to observe and record the spare parts logistics processes and the responding behavior to the delays and disruptions in the logistics flow.

3.2 Data analysis

According to Yin (2009), the analysis of data is the final and most difficult part in a case study; there are a number of analytical strategies and techniques to facilitate the analysis, such as pattern matching, categorizing, linking data to proposition, explanation construction and time-series study or logic models.

This case study uses the conceptual exploratory approach, in line with Kumar (2014), which seems to be a useful technique for guiding the analysis and pattern matching. The second strategy adopted is the explanation building. According to Yin (2009), developing a case description is a useful tool for explanatory case studies when the collection of evidence can be executed following the descriptive framework, and thereafter the data analysis is easy to be arranged within the developed framework.

The application of these two strategies, such as matching the theoretical proposition and explanation building, are the main methods of data analysis in this research. With regard to the pattern matching technique (Ghauri and Gronhaug, 2010), this research type links the empirical patterns extracted from the case study data with a forecasted pattern established in the theoretical framework. In the case that patterns match, the internal legitimacy of this study will be strengthened. The analytical approach of developing a case explanation aims to elaborate and refine the outcomes of the case analysis (Yin, 2009).

3.3 The company background

Wincor Nixdorf (WN) (2017) is a large corporation within the information technology industry and automated teller machine (ATM) production with €2.427bn in revenue, and €7,772m in profit (Annual Report 2014/15). There are three manufacturing plants, one in Germany, one in China and one in Singapore, two WN global distribution centers in Germany and Singapore, and over 400 branches in different continents. In 2016, through the merger of WN and Diebold Inc., Diebold Nixdorf was formed as an international technology and services company.

Back in 2007, WN expanded its business operations in the Russian Federation establishing WN Russia branch (WN-R). The company observed a big potential for its business, offering after-sales maintenance of their products as part of is overall service portfolio.

3.4 Products and service

WN-R offers ATMs, electronic point-of-sale devices, self-checkout machines, vending systems, lottery systems, as well as after-sales services support for this equipment. The client portfolio of WN-R includes companies such as Metro Cash and Carry, IKEA, OBI, Auchan, HSBC, Barclays and Gazprombank, Sberbank of Russia. WN-R has SLA with bank clients that require the company's field service engineer to fix ATMs within a specified period of time, which is 8 h; failing to conduct maintenance within the defined timeframe, the company faces financial penalties due to downtime costs. The focus of this research is the after-sales service support offered by WN-R and related spare parts service logistics network.

3.5 Operational processes

In order to provide the required level of quality in the after-sales service, the contracts management department decided to set-up a service division within the company to carry out the following functions:

- registration of incoming applications concerning the breakdown of equipment;
- monitoring and controlling of the applications' progress;
- monitoring and controlling of SLA fulfillment;
- development of the regional logistics network;
- cooperation with logistics providers and service partners;
- planning of inventory for Forward Stock Locations (FSL) in all Russian regions;
- repair and restoration of defective spare parts; and
- education and training of field service engineers.

There are six departments within this service division, where partner account managers (PAM) are responsible for the communication with clients, the control of SLA fulfillment and linking information from technical support department and field service engineers. Processing of applications is carried out 24/7.

After a client's incident report, PAM allocates a field service engineer or a service partner to conduct on site diagnostic for the respective ATM and verify which ATM is not functioning properly. The field service engineer or service partner orders the necessary spare part from the nearest FSL via a mobile enterprise digital assistant device. Defective spare parts are normally packed and sent back to the nearest FSL to be used as scrap or for restoration. Figure 2 illustrates the service processes of ATMs repairs.

The service logistics department is responsible for the availability of spare parts to ensure a smooth supply chain flow. Due to the 8 h SLA, the logistics team is not only in charge of planning the demand and inventory, but also has to provide a required level of time-based flexibility to clients in line with contractual obligations.

Figure 3 summarizes the operational processes and illustrates the interaction between field service engineers and service logistics.

3.6 Spare parts characteristics

WN-R divides spare parts into three main categories:

(1) repairable spare parts that need to be sent to the repair center or to the GDC;

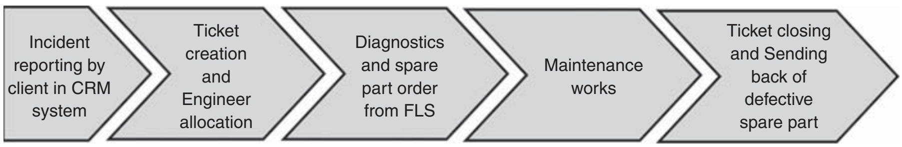

Figure 2.
Field service process of ATMs repairs

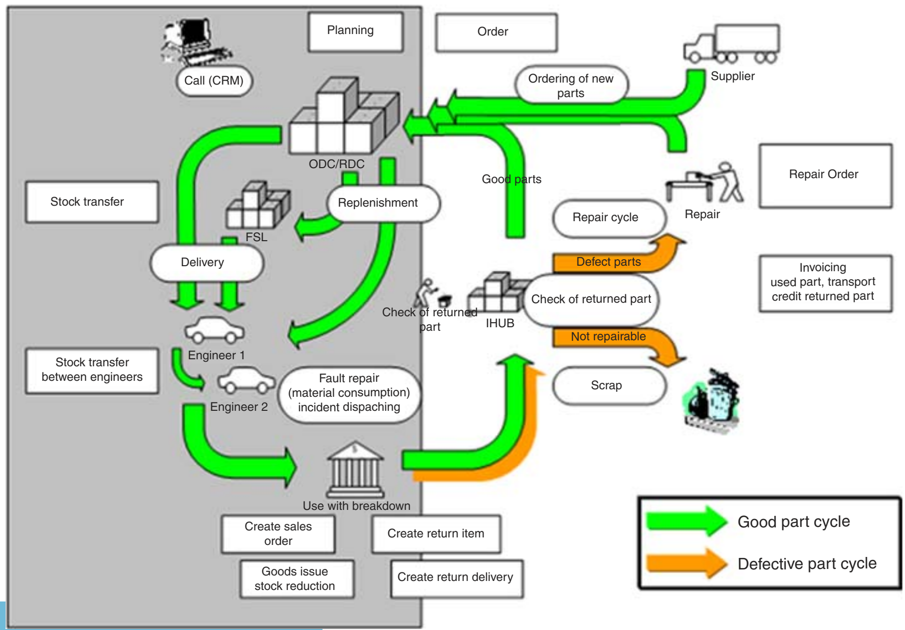

Figure 3.
Standardized field service and service logistics processes

(2) non-repairable spare parts that require to be sent to the utilization center as a scrap; and

(3) consumable spare parts.

Each spare part has its unique article number, which consists of an 11 digits number. There are 22,000 unique articles that are comprised of 4,300 repairable spare parts, 12,400 non-repairable spare parts and 5,300 consumable spare parts. The spare parts price ranges from EURO 0.07 up to Euro 9,100. Considering the wide variety of spare parts, the company had to set-up an on-line system with master data for logistics purposes, comprising detailed technical information, with article gross weight, net weight, classification code and dimensions.

Thus, in line with Bacchetti *et al.* (2010), the mono-criteria model with the reparability characteristic as a criterion is used for categorization of spare part SKUs in this case study. This approach helps WN-R to organize its reverse logistics of defective spare parts back to the GDC or to the repair center automatically, improving significantly the level of efficiency in its operations.

3.7 Spare parts demand forecasting

Spare parts demand is difficult to forecast due to the unpredictable nature of ATMs' failures. Nevertheless, there are certain historical statistics that have been collected over the years of the functioning of the service division. The company has an average pattern of how many of spare parts have been broken for hundreds of ATMs, based on which the service logistics department plans the demand for each FSL in different Russian regions considering the quantity of ATMs installed in that area.

The company applies a time series based demand forecasting based on historical demand data (Teunter and Duncan, 2009). Our analysis shows that the current forecasted FSL targets for each FSL region reflecting the quantity of needed SKUs on place in order to comply with the spare parts availability policy. The regional distribution center (RDC) stock, from where all FSLs are being replenished, is the biggest one accounting for 11,076 SKUs. The biggest FSL stock is located in Moscow city, amounting to 494 SKUs, due to its central location in the business region of Russia. The smallest stock is located in Podolsk and Vladikavkaz, accounting for 28 and 33 SKUs, respectively, because of the small amount of ATMs under service maintenance contracts in these regions.

3.8 Spare parts inventory control

In order to improve the efficiency of after-sales service, to reduce the response time and to provide sufficient spare parts availability, the company, together with its partners, has created a network of regional warehouses, so-called FSL, accounting for 109 FSLs in different settlements across the Russian geography. All spare parts are delivered to the FSLs from the RDC located in Moscow (Figure 5). There are more than 22,500 spare parts SKUs that amount to 10m Euro in total in stock value at the RDC and FSLs at the present time.

The biggest storage facility, 450 square meters, is the Moscow RDC where 11,076 SKUs are kept, waiting to be dispatched to replenish FSLs. Whereas FSLs in Noyabrsk and Orel have only 2 square meters storage facilities, each with 91 and 69 SKUs, respectively.

There are some exceptions for expensive spare parts in order to balance out these two objectives and avoid locking up significant capital resources. For example, the logistics specialist manually analyzes the prices of targeted spare parts, its real demand history in a particular FSL, the express delivery time via courier services from RDC to FSL, and in the case that all parameters are in favor of such a solution, decides to take the risk and does not store the costly spare part in a particular FSL. Since the occurrence probability of such an event is rather low, the potential negative financial impact on the company is also low, and can be compensated in part by express deliveries via third party service providers in the rare case of such an event, as described above.

The stock control and FSLs replenishment processes are managed by the logistics service provider Arvato. Arvato organizes transportation and warehouse facilities on place in different Russian regions, as well as the RDC facility located in Moscow. It is connected with WN-R through an electronic data interchange protocol. In particular, the ERP system SAP is used for all transactions within the company. SAP Arvato and SAP WN-R are interconnected. SAP automatically compares the information about spare parts that were consumed in different FSLs with the information about FSL's target figures and sends an immediate alert to the Arvato RDC regarding the need to dispatch for replenishment of the stock. WN-R utilizes one-for-one (or base-stock) replenishment inventory policy (Graves, 1985).

3.9 Utilization of time-based logistics flexibility

The service logistics division does not only control the spare parts inventory in all FSLs in different settlements, but also controls the procurement of spare parts from the GDC located in Germany. In particular, SAP automatically compares the information about spare parts that were consumed in all FSLs with the information about FSL's target figures and creates a proposal of purchase order based on it. Then, the service logistics specialist submits this purchase order to the GDC once a week. The ordered spare parts arrive in bulk to Moscow in seven days afterwards in order to be stored in the RDC.

The spare parts logistics distribution network of WN-R consists of the RDC and FSLs, as well as pick up and drop off (PUDO) points in settlements where the quantity of ATMs and SKUs targets are small, rendering the set-up of a full FSL facility economically inefficient. In other words, PUDO is the place for picking up of new spare parts or delivering of defective spare parts by field service engineer straight after dispatch from Moscow's RDC without any kind of storage.

Figure 4 illustrates WN-R spare parts supply chain, where the new spare parts flow goes directly from the GDC located in Germany to the RDC in Moscow. Once customs clearance is accomplished, the ordered spare parts are delivered to the Moscow RDC once a week by truck transportation mode, from where they are forwarded to the FSLs based on target requirements described previously. The field service engineer is responsible for picking up the spare part from the FSL or PUDO location and installing it in the ATM, whereas the

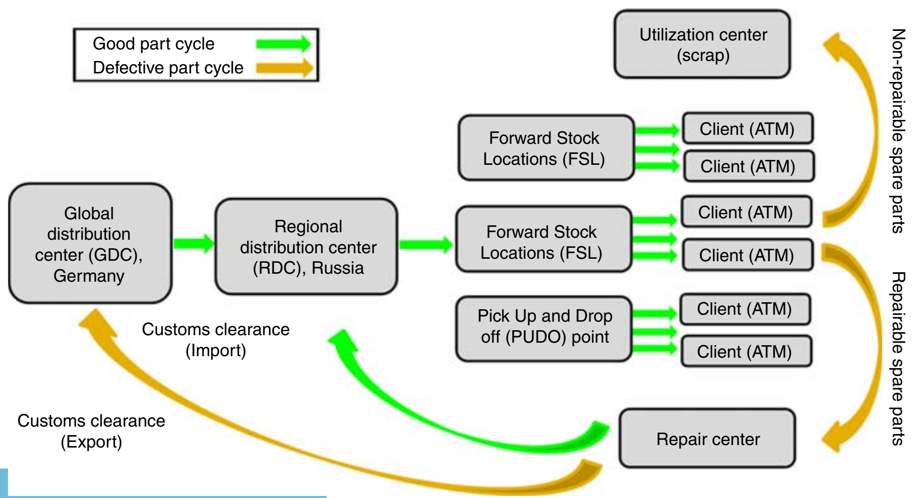

Figure 4.
Wincor Nixdorf Russia supply chain of spare parts

defective part removed from the ATM needs to be sent to the repair center or utilization center as a scrap.

For the most part, the main logistics provider Arvato facilitates all warehouse and delivery operations. Besides that, there is an additional logistics agent, namely, DHL express, which is engaged in case of urgent deliveries, when Arvato is not capable to provide the fast delivery time required.

According to the company's DND, all spare part shipments to FSLs in different Russian settlements are dispatched from Moscow's RDC. In order to control the lead-time, there is a KPI agreement with Arvato concerning the delivery period in days. As data provided by the company, with information regarding the standard and express delivery timeframe from Moscow RDC to different FSLs. Therefore, the core element of time-based logistics flexibility of the company is its SAP system that enables to coordinate all processes in an efficient manner, as well as to organize all standard ordering and shipping processes in an automatic and integrated way. Second, the agreed KPIs with the logistics provider help to control the delivery time of spare parts and performance, as well as help to speed it up in urgent cases, involving another express provider that can ensure faster delivery, even if at an increased level of cost. Finally, the network design with 109 FSLs across all Russian regions and spare parts stock available inside of them ensure a quick response and optimal service level, limiting client downtime and business disruption to a minimum.

3.10 Issues of the existing system

Bank customers need to be able to utilize ATMs to withdraw and deposit money at all times during the day, thus these cash-related processes have to be managed cost-efficiently (Cohen and Agrawal, 2006). The downtime of ATMs does not only cause financial losses, but also impacts on customers' loyalty, which is negatively affected by such events. WN-R, with its sophisticated spare parts logistics, tries to minimize the downtime costs and ensures a quick response that any spare parts arrive at their bank clients as soon as possible. The SLA in percentage that is fixed in the contractual agreement between WN-R and the respective bank client is the main performance indicator. There is an 8 h time slot in which technicians have to conduct repair works, replacing the defect spare part by a new one. If the field service engineer fails to fix the ATM on-time, WN-R faces financial penalties and threatens business development in the event of repeated occurrences with such clients.

Controlling the service performance, the company monitors statistics of SLA failures by clients. Since the level of SLA fulfillment is analyzed and presented weekly on internal service division meetings, the data are recorded on a weekly basis for each client. The case shows statistics regarding the quantity of ATMs under service maintenance, the quantity of incoming incident applications, the quantity of unresolved incidents, the level of SLA fulfillment, as well as the reason of SLA failure.

There are two main reasons of SLA failures, which are first the unavailability of the required spare part in a particular FSL, and second the field service engineer (service partner) incompetence to resolve the problem on site. Figure 5 shows that 60 percent of SLA failures happened due to the human factor of service partner actions and 40 percent happened because of spare part unavailability. Due to the logistics focus of the present research, the scope of this paperwork is limited in investigating the SLA failures due to the unavailability of spare parts only.

According to the interview with the service logistics manager, the company sees the following possible reasons of spare parts unavailability for after-sales service maintenance works, and, as a result, SLA failures: breakage of rare spare parts that are not often used and which were not planned for the FSL target, and therefore were not available on place consequently. Unavailability of spare part due to delays of FSL's replenishment in case of settlements with seven days standard lead-time delivery.

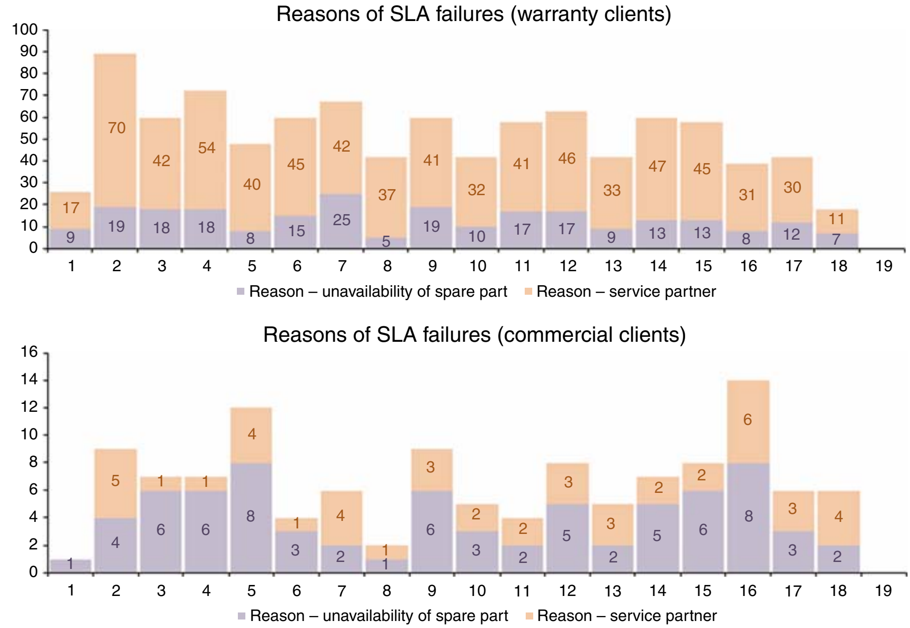

Figure 5.
Statistics data regarding reasons of SLA failures from January to March (weeks 1-19) 2016

4. Research findings

Before the analysis of possible reasons of spare parts delivery delays and, as a result, SLA failures in the case study company, it is important to discuss the research context characterizing the supply chain environment.

4.1 Geopolitical challenges

Russia and other post-Soviet countries are involved in a group countries with transition economies, shifting from a centralized planning of economic system toward a market-oriented economy, so-called emerging economy (Peng, 2003). In the Communist Soviet time, logistics and supply chains were organized differently compared to market-driven economies, which are governed by volatile, flexible, time-critical and quality-essential features (Bateman, 1998).

Soviet central planning authorities were in charge of the supply chain organization, where all stock of resources and products were government-owned and distributed according to government needs (Aharoni, 1981). As a result, this led to a great number of inventory distortions, including permanent deficit of basic products in the civil economic segments and overstocks in other economic areas, such as in the military sector (Rodnikov, 1994). Since pricing policy was also controlled by the Soviet central planning system, there was no fair trade mechanism of market prices regulation, generating a lack of competition, absence of profit motive and little incentives to address logistics efficiency optimization (Hansen *et al.*, 2008).

With regard to spatial characteristics, Russia is the biggest country in the world comprising 17,075,200 sq. km area with 11 time zones. Thus, the spatial distance element plays a significant role in the context of the Russian supply chain environment.

For example, the distance between Moscow and Ekaterinburg, which approximately is 1,500km, combined together with the low level of development of the logistics infrastructure, do not permit an efficient delivery from the RDC in less than two to three days for standard air delivery.

Beyond Yekaterinburg, which is located on the Ural Mountains dividing the European and Asian parts of Russia, deliveries to Far East cities like Ussuriisk that distant from Moscow more than 6,500km is even more problematic, accounting for seven days of standard air delivery. The insufficient development of commercial activities between the Far East Federal district cities does not allow frequent and economically viable cargo shipments on a daily basis even for commercial cargo freight carriers (Darkow *et al.*, 2015). In Central Russia, namely, in the Urals and Siberian Federal districts, and especially during winter periods, which easily last six months in those regions, and where major areas of population are rather isolated during that time, access to these locations becomes practically impossible by any means of transport, and hinder from proper servicing and logistics activities (Castiglione *et al.*, 2012).

Historically, and linked to the size of the capital city of Russia, Moscow has been the host for most foreign companies and major logistic operators, being very different than other outlying settlements (Bradshaw, 2002). The limited level of delocalization of the Russian economy has made the city grow over time, since average income levels are usually double as in the rest of the country, attracting companies for business opportunities, as well as almost one-quarter of Russia's universities are located in Moscow by accommodating them together.

To sum-up, the Russian supply chain environment is a context where geography and spatial distances play a significant role due to its sheer land mass (Maurseth, 2003). Additionally, the Moscow-driven economy leads to the concentration of business activities and logistics facilities around capital city only, which hinders the development of other Russian regions (Manaenkov, 2000). While there are many other potential variables to consider, these two nuances and the variety of time zones represent the specific supply chain environment, which affects the logistics decision making in terms of lead times, on-time deliveries, DND, demand forecasting and inventory management (Sanders and Premus, 2005).

4.2 Possible negative impact of spare parts logistics

Nevertheless, since the entire statistical data are tracked by the company, considering the SLA fulfillment for each client, and then analyzed manually in detail to find out the reasons of spare parts unavailability, there is no information recorded based on the geographical context of spare parts logistics failures. For more in-depth analysis of evidence, it was decided to look at the SLA fulfillment statistical data and spare parts logistics failures from a different perspective. For this, the quantity of unresolved maintenance incidents with the reason of spare parts unavailability was gathered from the company's SAP system with regards to the social-economic regions where the client and FSL are located for the period from January 2014 to June 2016.

The minimum standard air delivery lead-time guaranteed by the logistics provider from Moscow RDC to the Khabarovsk region is three days, to the Novosibirsk region is two days, to the Republic of Sakha is four days, to the Tyumen region is three days and to the Primorsky Krai is three to six days. According to the logistics manager, this is the minimum delivery time for the optimal cost available on the Russian airfreight forwarding market. The option of choosing another logistics provider can be excluded from the spare parts logistics optimization proposal. Express air delivery mode is available upon request and frequently used by the company in urgent cases for an additional cost, but unfortunately, there are no express delivery options to some distant Russian settlements.

The big amount of spare parts logistics failures in distant Russian regions due to limited availability of air cargo shipments and long delivery times illustrate the contextual nuances of this particular supply chain environment. Another possible reason for logistics failures is a weak spare parts distribution network system with the centralization of the distribution center in the Moscow city, which appears to be not efficient for such a vast land mass.

4.3 Distribution strategies

Figure 6 illustrates the spare parts logistics distribution network of WN-R, which consists of RDC and FSL storage facilities with a two-way flows connection architecture, so-called single terminal hub-and-spoke system (Dobson and Lederer, 1993). In line with the hub-and-spoke approach, deliveries arrived from different originating points are stored at the main terminals (hubs) and sent to their corresponding destination through radial links (spokes).

This traditional system meets a "point-to-point" network, where each FSL (arriving node) is connected by a certain link from the RDC (departure node). Two-way flows facilitate deliveries of new spare parts from RDC to FSL and the dispatch of defective spare parts from FSL back to the RDC. The contextual feature of a transitional economy in this case is the stock centralization in the main logistics distribution center (terminal) in the capital city Moscow. Despite proved facts that centralization of warehouse facilities contributes to logistics cost reduction, whereas concurrently it worsens the service level and lead-time parameters by holding main inventories far from customers (Mangiaracina *et al.*, 2015). Based on the analysis the following recommendations are proposed in order to fulfill the desired level of after-sales SLA.

Recommendation 1: multiple terminal hub-and-spoke system. Compared to the single system, the multiple terminal hub-and-spoke approach, on average, reduces the spatial distance traveled, and thus, lead-time parameters, enabling a quick response within the logistics network (Lumsden *et al.*, 1999).

Taking into account supply the chain context of Russia, namely, vast spatial distances, it can be proposed to set-up a multiple hub-and-spoke DND (Figure 7). Two main RDCs, one in the capital city, Moscow, and another one in Novosibirsk, could facilitate time-based logistics

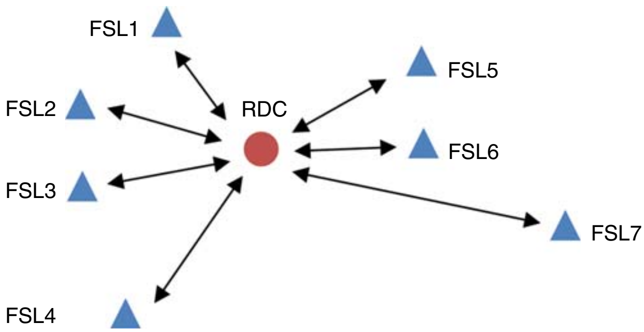

Figure 6.
Single hub-and-spoke network configuration of Wincor Nixdorf Russia's spare parts logistics

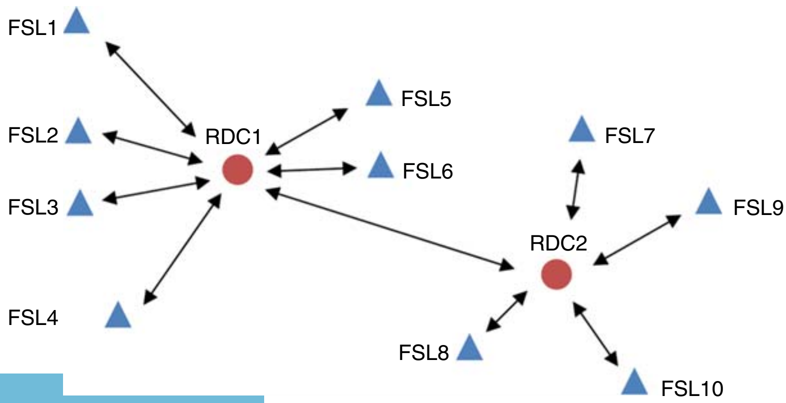

Figure 7.
Multiple terminal hub-and-spoke network proposal for the Wincor Nixdorf Russia's spare parts distribution network

flexibility by splitting up spare parts distribution activities in terms of geographical location, that could potentially improve the overall logistics response and reduce lead-time for deliveries, especially to the Siberian and Far East regions, where, according to statistics, is the biggest amount of logistics failures.

Novosibirsk was chosen for the second RDC, as it is the third largest city in Russia following Moscow and Saint-Petersburg, the main administrative region and business-center of the Siberian Federal District (The Mayor's Office of Novosibirsk, 2016), as well as geographically located nearly in the middle of Russia, providing an advantageous position of RDC facility nearby FSLs in the Siberian and Far East regions (Figure 7). Transportation facilities of Novosibirsk city, such as a big international Tolmachevo airport and two small local airports, as well as an important railroad junction of the Trans-Siberian Railway as a potential alternative of spare parts transportation for taking into consideration (The Mayor's Office of Novosibirsk, 2016), could cope with the potential after-sales spare parts business flow.

To clarify, the suggested improvement is not aimed to reduce the lead-time to 8 h or less as agreed in SLAs with clients. The objective is to ensure fast FSLs replenishment with the safety stock, especially in those regions where standard air deliveries take four to seven days, which was pointed out by managers of the company as one of the main reason of logistics failures.

Recommendation 2: distance savings approach. Another optimization scenario that can be proposed is the connection of two different nodes of DND by means of a short-cut (distance saving), not passing though the main hub (Lumsden *et al.*, 1999). In other words, this approach can be used in urgent cases or/and if the express delivery option is not available for the particular settlement by delivering spare parts from FSL1 to FSL2 without the RDC being involved by means of short-cuts, while for the remaining FSLs delivery and FSL1 replenishment are performed through the RDC (Figure 8).

In line with Jeng the effective implementation of a short-cut system depends on the relative spatial position of each node with respect to the main hub, since it is rational to serve particular points directly without the hub being involved. Thus, in WN-R the short-cut approach for an urgent case scenario can be set-up after an investigation of reasonable connections in terms of transportation cost and lead-time compared to deliveries from the RDC by quoting from different logistics providers. If the delivery cost and lead-time parameters are optimal to give some logistics flexibility contributing to fast spare parts provision, the matrix of possible short-cuts could help logistics coordinators to organize deliveries in a faster way than with the RDC being involved.

5. Conclusion

This research work considered an after-sales spare parts logistics problem in a specific supply chain environment with unpredictable demand pattern and time-critical service required.

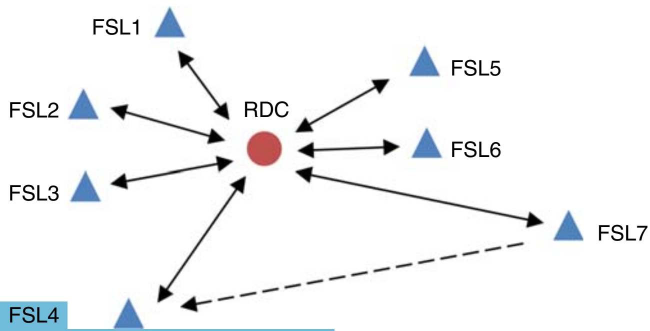

Figure 8.
Short-cut approach proposal for the Wincor Nixdorf Russia's spare parts distribution network

The high technology product manufacturer located in Russia was engaged for an empirical single case study in order to test the theoretical framework, to disclose nuances of logistics organization within a transition economy context, to find out the reasons of spare parts logistics failures in the case study company and to develop heuristics solutions.

Analysis reveals that several most common problematic areas within spare parts logistics that could potentially cause failures and set pressure for the spare parts flow in the after-sales service market were revealed. Having done a thorough analysis of the case study, the research proposes two possible scenarios for the redesigning of the distribution network of WN-R in order to improve the response time for its spare parts provision system and, as a result, to reach the fulfillment of a desired service level. Namely, it proposes to set-up a multiple terminal hub-and-spoke system with multiple distribution centers for the sake of quick FSL replenishment in the most problematic Siberian and Far East regions, from the logistics point of view, as well as to apply a short-cut approach in urgent cases or/and if the express delivery option is not available for the particular settlement.

Spare parts logistics presented in this research would help both, WN-R and other after-sales spare parts companies, operating in transition economies, to organize their spare parts supply chain wisely, ensuring a better service level. Findings of the research could also help managers to analyze their main bottlenecks within after-sales spare parts logistics and thus to optimizing the efficiency of its spare parts provision.

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