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END-TO-END VISIBILITY OF SPARES IN MODERN PUBLIC SECTOR LOGISTICS FIRMS

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Abstract

Spare parts management is an effective method of operational preparedness and ensuring mission-critical systems of public sector logistic organizations. Several decades after giant commitments in centralized inventory management systems, most public sector logistic networks still report inadequate end-to-end visibility, especially at the depot level. The available literature implies that fragmented processes, manual inventory practice, and a lack of proper integration of systems are still a challenge in the realization of real-time visibility in the supply chains. This study aims to review the existing practices of managing spares in logistics depots in the public sector logistic, recognize the major obstacles to end-to-end insight, and discuss the ways the practices can be improved with digital and process-based discussions. The adopted study design was a qualitative case-study research design using semi-structured interviews with six logistics officers serving in two large logistics depots. Thematic analysis was applied in the analysis of data to identify repetitive trends and operating ideas. The results show that, in spite of the fact that centralized inventory systems grant relatively basic access to the information, the presence of excessive manual operations, slow data entry, low system connectivity, and a lack of automated tracking solutions restricts real-time visibility to a considerable degree. This research is relevant to the

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existing literature on supply-chain visibility due to the expansion of empirical studies in the logistics setting and the emphasis on the interplay of technological, organizational, and human aspects. The results can also provide useful advice to logistics managers and policymakers who want to increase operational preparedness by improving the visibility of spare parts.

Keywords: Supply Chain Visibility, Public Sector Logistics, Spare Parts Management, Digital Transformation, Qualitative Case Study

1. Introduction

Public sector logistic organizations function within a complicated and dangerous setting where success largely relies on the accessibility and dependability of machines and frameworks. Logistics systems are important as they help to achieve the correct delivery of spare parts and maintenance resources to the appropriate location at the appropriate time in order to carry out the missions. In this regard, one of the strategic functions is spares-parts management, which directly affects asset preparedness, lifetime expenses, and business continuation (Williams et al., 2020). The probable effect of the inefficiencies of the sole-source logistics spin used on the spare parts is the lengthening of the downtime of the equipment, an increase in operational expenses, and diminishing the separation skills of the mission.

End-to-end visibility can be defined as the capacity to process and monitor the position of inventory, material movement, and information throughout all the supply chain parts in a timely and precise manner (Caridi et al., 2010). Flow of stock may result in stock imbalances, inventory duplication, delays in the maintenance processes, and decision-making. Public sector logistics-related context is especially susceptible to these difficulties as geographically distributed supply chains are subject to security requirements and must quickly adapt to dynamic operational needs (GAO, 2022).

Nevertheless, even after the use of centralized inventory management systems, most of the logistics entities still experience the challenge of

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visibility. Most of the current systems are based on manual data entry, paper-based record-keeping, and the physical count of stock done on a periodical basis, which restricts the real-time situational awareness (Barratt and Barratt, 2011). Previous studies indicate that some of the most prevalent barriers to the attainment of effective supply-chain visibility are fragmented processes and a lack of integration between information systems (Barratt and Oke, 2007; Caridi et al., 2010).

The information systems in logistics departments of the can nominally access the inventory information, yet the delay caused by the lag in information update and the mistakes of humans can decrease the usefulness of such data. Consequently, informal communication and physical checking often become important to the decision-makers to ensure the availability of the stock, which is at a cost of the underperformance of digital systems (Williams et al., 2020). Supply-chain visibility has been significantly identified as a key facilitator of logistics performance and organizational stability. Greater visibility improves coordination of supply-chain actors, minimizes uncertainty, and strengthens proactive decision-making (Barratt and Barratt, 2011). The visibility in commercial supply chains has been linked with enhanced accuracy in the forecast, decreased lead times, and perfect inventory level (Caridi et al., 2010).

Visibility has become all the more important in the logistics situation because the availability of spare parts is directly connected to operational readiness. Enhanced visibility allows planners of the maintenance process to foresee the needs, deploy resources more efficiently, and reduce the downtime of equipment (GAO, 2020). Nevertheless, to become visible goes beyond technological investment, and it also involves standard processes, organizational alignment, and acceptance of information systems by the users (Davis, 1989). Though supply-chain visibility has been given enough concern in scholarly literature, much of the current research is about commercial and

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manufacturing supply chains. Relatively little research exists regarding visibility in logistic settings, where organizational frameworks, security factors, and outdated systems are special issues (Williams et al., 2020). Consequently, the means by which visibility is obtained or inhibited at depots is under-researched.

Visibility is not merely a technological phenomenon but a socio-technical phenomenon that is influenced by human behavior, organizational routines, as well as the design of systems (Skyttner, 2005). Even the advanced information systems might fail to provide any significant benefits of visibility unless properly trained, and the standardization of the processes and the support provided to the organization. The knowledge of these mechanisms is productive toward the development of effective interventions to fit into logistics firms. The literature review shows a gap in empirical studies that analyse end-to-end visibility of the spare parts component of the logistics depots in terms of their operation. The research findings of previous studies confirm the significance of visibility but give limited information on the integration of depot-level operations, level usage of systems, and human factors on how these elements contribute to the effect of visibility (Barratt and Oke, 2007; Caridi et al., 2010).

To bridge this gap, the current study will attempt to:

Analyze the existing spare-parts management in the public sector logistic depots.

Brand name: list the main obstacles and constraints to end-to-end visibility.

Identify potential to enhance visibility by introducing online and process-intensive proposals.

To accomplish such goals, the present study employs a case-study and qualitative approach, which will consist of semi-structured interviews with logistics officers with direct experience with the management of spare parts. Qualitative investigation is especially appropriate to investigate multifaceted

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operational contexts and elicit practitioner approaches toward research that is commonly disregarded in quantitative studies (Caridi et al., 2010).

This research adds to the literature of supply-chain visibility as it expands the scope of empirical investigation into the logistics field and emphasizes that technological systems, organizational processes, and human factors interact. Practically, the results can be used to inform practical suggestions to logistics managers and policymakers who are interested in improving operational preparedness by improving the visibility of the spare parts. The rest of the paper will follow the following format: Section 2 will contain the literature review and theoretical framework, Section 3 will contain the research methodology, Section 4 will contain the findings and revise the results, and finally, Section 6 will contain implications and future research directions.

2. Literature Review and Theoretical Framework

2.1 Supply Chain Visibility

Supply-chain visibility refers to the degree to which the supply-chain participants can have access to timely, cost-effective, and precise inventory status, demand, and material flow information (Caridi et al., 2010). Visibility helps organizations to organize activities and respond to disruption, as well as coordinate decision-making during supply-chain nodes.

Barratt and Oke (2007) suggest that visibility is a precondition of successful supply-chain integration since it helps share information and coordinate the planning process. However, high degrees of visibility need to be accomplished through the integration of both the technological infrastructure, standard processes, and commitment to the organization. In the absence of these aspects, visibility programs can produce minimal returns because the investment is high.

2.2 Observability in Logistics

The logistics systems vary in nature from the commercial supply chain regarding the priorities of the mission, the risk-taking culture, and the

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organisational structures. Whilst commercial supply chains are focused on cost efficacy and response to customers, logistics focuses on readiness, resilience, and reliability (Williams et al., 2020). The differences affect the adoption of visibility technologies and practices.

The research building on the topic of public sector logistics continuously indicates such issues as problems with data accuracy, systems interoperability, and monitoring assets (GAO, 2020; GAO, 2022). Though centralized systems are highly adopted, real-time visibility is still limited, especially at the depot level, by manual processes and legacy infrastructure.

2.3 Theoretical Framework

The proposed study is based on the General Systems Theory and the Technology Acceptance Model (TAM). General Systems Theory perceives organizations as interdependent systems where system performance is impacted in another area when the performance of its components is disrupted or inefficient (Skyttner, 2005). Low visibility at the depot level in logistics is compatible with spreading over the supply network, resulting in delay during maintenance and decreased readiness to operate.

The Technology Acceptance Model describes the effect of perceptions of usefulness and easiness to the user level of information systems adoption (Davis, 1989). The low levels of user acceptance between the varying levels of training and the complexity of a system may decrease the effectiveness of the tools used in the visibility of tools in the logistics depots, despite the availability of technological infrastructure.

2.4 Visibility and Performance Outcomes

Empirical investigation has always shown a positive correlation between supply chain visibility and organizational performance. Improved visibility leads to accuracy in forecasting, shorter lead times, and proactive resource allocation (Barratt and Barratt, 2011). Visibility has been observed in operations to deliver quicker maintenance actions, decrease pieces of

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equipment downtime, and contribute to increased mission capacity (GAO, 2022; Williams et al., 2020).

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3. Research Methodology

3.1 Research Design

In this research, a qualitative case study research design that utilized a national organization in the public sector logistics department of spare parts has been used to explore the end-to-end visibility of spare parts across logistics depots. The reason is that the chosen qualitative approach will consider issues of visibility in public sector logistics as process-oriented and context-specific (and dependent on human and organizational factors that cannot be sufficiently studied with the help of quantitative methods only) (Caridi et al., 2010; Williams et al., 2020).

Case study studies are especially suitable in situations where an in-depth study of different facets of operations is pursued in their real-life situations (Yin, 2018). The qualitative inquiry in a public sector logistic setting that is closed and highly regulated facilitates the researcher to find operational realities, system use practices, and practitioner experiences, which are not frequently provided through a survey setting (Barratt and Oke, 2007).

The case study approach enables us to consider the issue of a holistic vision of the nature of the visibility of the spares in the scope of the logistics depots embedded in the larger framework of a public sector supply chain, including technological infrastructures, procurement processes, and human relations with the information systems.

3.2 Research Context

The study was done in two large logistic depots of one of the large public sector logistic organizations in the country that stores, handles, and reports out spare parts to functional units. These bases play a very essential role in the army's logistic system, as they serve as the service points in case of maintenance and in the provision of equipment to various places of operation. Even though the depots have centralized logistic policies, inventory management and record keeping are done locally daily. The processes

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associated with the management of spare parts are their reception, inspection, storage and classification, issuance, as well as reconciliation. Although centralized inventory management systems are implemented in depots, operational best practices depend on the capacity of infrastructure, work, and expertise of personnel, and are in line with previous research in logistics (GAO, 2020; GAO, 2022).

This working environment gave us the appropriate background to study the issue of visibility, where depots form the point of contact between the physical inventory and the information system.

3.3 Population and Sampling

3.3.1 Target Population

The population of interest included logistics officers and supply-chain individuals who were posted in the sampled public sector logistics depots. These people were in direct contact with the management of spare parts and inventory control, system functioning, and cooperation with the maintenance and procurement departments.

It was only the operational personnel who were restricted from participating so that the data collected could include the first-hand experience of facing the visibility challenges, system limitations, and process inefficiencies. Previous studies note that the views of practitioners are essential in comprehending the areas of visibility gaps within logistics settings (Caridi et al., 2010; Williams et al., 2020).

3.3.2 Sampling Method and Sample Size

The technique of purposive sampling was used to select the participants who were relevant in the field of knowledge and had operational responsibilities. The most common approach to sampling in qualitative logistics studies is purposive sampling, especially in overall and specific settings with limited access to respondents with knowledge (Barratt and Oke, 2007).

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Six logistics officers have been chosen according to their jobs, experience, and participation in the system of spares and inventory management. The sample size was considered sufficient since thematic saturation occurred when no new knowledge was obtained during data analysis, which is conscript to recognised qualitative studies (Yin, 2018).

3.4 Data Collection Methods

3.4.1 Semi-Structured Interviews

Semi-structured interviews were used to gather primary data and offer some type of uniformity as well as flexibility. It is a technique that enables a researcher to investigate pre-determined themes, although it allows the participants to expound on issues they perceive to be important (Caridi et al., 2010).

The interview guide was formulated in terms of the study objectives and the literature related to supply-chain visibility. Questions in the interview:
Current practices of spares-parts management.
Inventory information is readily available and precise.
Inventory systems and digital use.
Inter-departmental coordination and inter-depot.
Problems with visibility due to the operational challenges.
Suggestions on end-to-end visibility.
Interviews were conducted across a span of 20-30 minutes in the workplace of the participants to make sure that it was contextually relevant.
The data will be recorded and transcribed using the methods described below:
Informed consent was signed by the participants, and all interviews were audio-recorded to make it correct and completeness. Field notes were made in order to record the contextual details and observations. Tape recordings were transcribed word-for-word to avoid changing the original language and meaning of the things that were said by the participants, which is a good practice of a rigorous qualitative analysis (Braun and Clarke, 2006).

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3.5 Ethical Considerations

The ethical aspect was highly taken into account because research is sensitive. The objective of the study was explained to the participants, and it was guaranteed that they would be able to participate in the study. Anonymity and confidentiality A 1 were ensured through the removal of identifying information and the generalized description of roles.

No data were gleaned that was classified or operationally sensitive. Only the researcher had access to the data, and all materials were kept safe. Such procedures are acceptable regarding research entry in defense and civil bodies (GAO, 2020).

3.6 Data Analysis Technique

The thematic analysis was used to analyze the data based on the six-step model that was suggested by Braun and Clarke (2006). Thematic analysis has been extensively used in research regarding supply-chain and logistics because of its flexibility and methodical key to determining patterns in the qualitative data (Caridi et al., 2010).

The process of the analysis was as follows:

- Interviews. The interview transcripts were familiarized.
- Generation of initial codes
- Possible themes identification.
- Themes Review and revision.
- Themes definition and naming.
- Themes on theory and research goals were interpreted.

The systematic coding and organization of qualitative data were supported with the help of qualitative data analysis software to increase the transparency and analytical rigor.

4. Results

4.1 Overview of Emergent Themes

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Dependent analytical interventions led to the development of six significant themes that were recurrently detailed in every interview. These themes represent common experiences and understanding among logistics officers in terms of perceiving the visibility of the spare parts in the logistics depots, which are in line with the previous qualitative findings in the research on the defense supply chain (Williams et al., 2020).

The themes identified are:

- Current practices in the management of spare parts.
- Availability/dependability of inventory data.
- Digital tool and system interrelatedness.
- Operation difficulties that influence visibility.
- Obstacles to end-to-end visibility.
- Causes of reason why the future could be better.

4.2 Current Practices in Managing Spare-Parts

Respondents added that management of spare parts involves an intermediate solution, where digital inventory management is used, but on a large scale with a lot of manual work. Racking systems are also used to physically arrange inventory and put it into categories through a specific established classification technique, say, ABC or 123 analysis.

Inventory transactions are recorded by using centralized systems, although physical verification of the stock is common practice. This use of manual processes is similar to those of previous research that suggested that logistics depots frequently rely on manual processes to mitigate the weaknesses of a system (GAO, 2022; Williams et al., 2020).

4.3 Accessibility and Reliability of Inventory Information

The answer to this question was in the affirmative, with all the respondents stating that inventory data is available on centralized systems, whereby officers can monitor the amount of stock and the position of items.

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Respondents, however, pointed out that even though accessibility is available, reliability may not be guaranteed.

Late entry of data, system unavailability, and hand-increment often create a mismatch in the recorded and actual stock level. A similar report existed in the case of defense logistics auditing, pointing to the accuracy of data as a frequent problem in the supply chain (GAO, 2020; GAO, 2022).

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4.4 Digital Tool and System Stationary

The depot operations are supported by the centralized inventory management system as the main digital tool. The system offers the most basic inter-depot visibility, whereby the officers can determine stock availability within the different locations. Nonetheless, not one of the depots uses RFID identification technologies and the item level barcoding. This has led to the inventory being recorded in the past and not on a real-time basis. It is postulated by previous studies that the lack of such technologies can be a major limitation to visibility and reliance on manual verification (Ngai et al., 2008; Ben-Daya et al., 2019).

4.5 Visibility Killing Operational Challenges

All the respondents consistently pointed out various operational issues that erode visibility, and these are:

- Problems faced with network connectivity.
- Late or incomplete data entry.
- High dependency on hard copy paperwork.
- Limited user training.
- Absence of inbuilt communication tools.

All these issues decrease the performance of the existing systems, which is similar to the results of commercial and logistics studies (Barratt and Barratt, 2011; Williams et al., 2020).

4.6 Barriers to End-to-End Visibility

There was a unanimous indication that manual processes were the key factor to the attainment of true end-to- end visibility. Manual processing increases the chances of errors, misplacement, and slow updating, especially of small but important parts of the spare parts.

In the absence of automated tracking, inventory records are usually behind the physical stock conditions, which restricts proactive planning. This observation is consistent with the Systems Theory, where inefficiencies in a

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single subsystem have the ability to spread to other subsystems in the whole logistical system (Skyttner, 2005).

4.7 Future Improvement and Technological Opportunities

Every respondent indicated that they had strong support for digital transformation initiatives. Some of the improvements recommended were:

- Adopting RFID and bar-coding technology.
- Real-time inventory updates.
- Increased system integration.
- Far-reaching training programs.

The abovementioned suggestions align with the previous literature that notes the importance of digital technologies in terms of improving the visibility of supply chains and their resilience (Ben-Daya et al., 2019; Queiroz et al., 2021).

5. Discussion

This study was conducted to analyze end-to-end visibility of logistics depot spare parts and to find out the main challenges and opportunities for improvement. The results are valuable in terms of the current methods used to establish visibility, the problem areas, and the reasons as to why the current systems are unable to provide real-time situational awareness. These results are below and analyzed in reference to the literature and the theory.

5.1 Visibility in Logistics Firms

The results show that visibility of spares in the examined public sector logistic depots is part-wise, but not end-to-end. Even with an installed centralized inventory management system, the visibility is limited due to the high attitude to lead the process with manual work and delayed data input. This finding aligns with previous literature that points to the fact that visibility is not only a factor of information system existence but also the efficiency with which it is incorporated in operational processes (Barratt and Oke, 2007; Caridi et al., 2010).

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In line with the research by Williams et al. (2020), even the public sector logistic depots usually use physical verification as a way of replacing system errors. This dependency negatively affects real-time decision making and operational risk, as specifically in situations involving replacement works, accessibility of spare parts at the right time is of the essence.

5.2 The use of technology in improving Visibility

Lack of automated identification technologies like RFID and item-level barcoding became one of the critical obstacles to end-to-end visibility. The inventory flows are updated in hindsight, and not captured in real-time, hence leading to information lag. However, it is not the first study to reveal that RFID and IoT-type technologies are highly effective in terms of precision and visibility of the inventory through automation of data capture and minimizing human mistakes (Ngai et al., 2008; Ben-Daya et al., 2019).

The results indicate that the existing digital infrastructure only provides informational visibility and not operational visibility. Such a difference is vital, since real-time and continuous monitoring of the chain of activities throughout the supply chain is a prerequisite of the true end-to-end visibility (Caridi et al., 2010). Public sector logistic systems are reactive and not proactive without automation.

5.3 Organizational and Human Factor

In addition to technological constraints, the paper has pinpointed organizational and human influences in determining the results of visibility. Poor training, infrequent use of different systems, as well as the reliance on informal communication avenues makes centralized systems less effective. These results are aligned with those of the Technology Acceptance Model, which highlights that perceptions of usefulness and ease of use have an effect on system adoption and use (Davis, 1989).

The lack of confidence in the accuracy of the system reduces the inclination of the users to use the digital data to make these decisions, and this

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supports manual workarounds. Such a cycle makes the visibility weak and the desired advantages of digitalization ineffective in public-sector logistics situations (GAO, 2020; Williams et al., 2020).

5.4 Visibility Gaps through a Systems Perspective

The depot level visibility gaps, according to a General Systems Theory perspective, have propagated throughout the whole logistic network. Lack of efficiency in inventory listing and the flow of information is diffused in maintenance planning, procurement decision making, and operational preparedness (Skyttner, 2005).

As illustrated by the findings, the issue of depot-level visibility is not a singular aspect of the problem but a systematic problem that has an impact on the performance of the overall defense supply chain. This goes to suggest that the improvement in visibility should be a holistic approach that should not just focus on technology, processes, and organizational structures (Barratt and Barratt, 2011).

5.5 Restatement of Existing Literature

The findings of the current research are aligned with empirical studies of supply-chain visibility undertaken in the past. Caridi et al. (2010) focus on the fact that to be visible, information needs to be available, accurate, and timely. On the same note, Barratt and Barratt (2011) note that organisations should not invest in such visibility initiatives when they concentrate on technology only, without working on standardizing processes and involving the user.

In the environment, GAO reports appear to highlight the issue of data accuracy and asset visibility as a challenge that remained unresolved despite significant investments into logistics information systems (GAO, 2020; GAO, 2022). The current study supports the findings with depot-level data on the practical limitation of visibility by manual processes and system constraints.

6. Conclusion

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This research paper has studied the concept of end-to-end visibility of spares within logistic depots of one of the national institutions through a qualitative case-study methodology. The results have shown that a centralized inventory system offers fundamental access to information, but the end-to-end visibility is not achieved because of manual inventory operations, slow recording of data, a lack of system integration, and a lack of automated tracking systems.

The research shows that logistics visibility issues are not technical but are socio-technical in essence. Good visibility means that there is coordination of technology, company procedures, and human abilities. Investing in digital systems will not be able to reach full potential without solving these interconnected factors. My study helps to better comprehend the operational realities of depot levels and is an important research in the field of understanding the issue of visibility in logistics and the strategic significance of the end-to-end visibility as an element of operational readiness maintenance.

7. Implications

7.1 Managerial Implications

Simplification of the automated identification technology, i.e., RFID and barcoding, should be the main concern of logistics managers so that manual processing can be minimized and data accuracy. Inventory standardization and data entry on time are critical in improving transparency. Also, the elaborate training modules must be implemented to enhance the uptake and efficient usage of the systems.

7.2 Policy Implications

Defense organizations to which spare parts visibility is a strategic capability and not a support requirement should implement it at the policy level. The investments ought to be geared towards system integration, infrastructure upgrades, and depot-department interoperability. The policymakers are also

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supposed to set data governance principles to enhance inventory accuracy and accountability.

7.3 Theoretical Implications

The paper is a continuation of the existing body of knowledge on supply-chain visibility because it uses mainstream theories in the logistics scenario. The study uses a combination of the General Systems Theory and the Technology Acceptance Model to show the interplay between the influences of technology, organization, and human factors on the result of visibility. This helps towards a more holistic interpretation of the concept of visibility in high-reliability organizations.

8. Limitations and Future Research

The research has a number of shortcomings, even though it has made contributions. Firstly, the sample size and design of the study are too small to be generalized. Second, the study is narrow in that it targets logistics depots in one environment, which could limit its application to other settings in the defense.

Further studies might utilize the quantitative analysis techniques in order to explore the effects of the visibility improvement on such performance variables as maintenance turnaround time and inventory expenses. Comparative analysis of various organizations or longitudinal integration analysis of the impact of digital transformation programs would also contribute further knowledge to the idea of visibility in defense supply chains.

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