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An Optimisation Framework for Improving Supply Chain Performance: Case study of a bespoke service provider

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Abstract

A service supply chain can be described as a system of systems with a highly interactive and complex network of suppliers, service providers, OEMs and customers. Supply chain management could create value for bespoke service providers, customers and stakeholders cooperating through the supply chain. Bespoke service provider companies are responsible for managing their asset based on different service contracts and possibly through the end of the asset lifetime. Providing a through-life service requires tailored strategic dimensions to measure the supply chain performance. The performance can be evaluated with regards to several supply chain elements such as demand management, procurement, logistics, etc. This article takes a different angle to the current supply chain performance frameworks by discussing performance through DMAIC cycle. Considering a through-life service, this paper presents a performance optimization framework to improve the supply chain performance in terms of an asset or component availability and cost of service. Moreover, an exhaustive list of KPIs to evaluate the supply chain performance are identified. A case study of fleet management for a bespoke service provider is considered to test the validity of the framework. The DMAIC technique has demonstrated to be an effective method to improve supply chain strategies and performance.

Keywords: Supply chain management; Through-life service; DMAIC; Optimization; Fleet management; System of systems

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1. Introduction

Supply chain management (SCM) can be described as governing the flow of information, goods, money, capital equipment, manpower, etc. in the interactive network of suppliers, service providers, OEMs, customers and other stakeholders within the supply chain. Managing such a complex network requires understanding of how these individuals interact with each other and ultimately apprehend the impact of their behaviour on one another in making changes and fluctuations on the supply chain decisions and strategies [1]. Considering high-value assets and equipment, the service supply chain can be defined as a system of systems composed of suppliers, bespoke service providers, OEMs and the customers. Bespoke service providers are responsible to maintain, upgrade and manage expensive infrastructure for multiple private or public sector customers. The goal is to provide reliability and availability of such critical assets efficiently. However, the challenge is to find the optimal solution to maximise assets' or components' availability and minimise the service costs in a highly unpredictable environment. Such an uncertainty mainly arises from the complexity inherent in the interactive behaviour of individual stakeholders within the supply chain [2,3]. Identifying and assessing the sources of these uncertainties is crucial and the initial step to tackle the challenge, quantifying and implementing optimisation techniques is vital to find the most efficient solution for the supply chain management. In a service supply chain, providing a through-life service requires tailored service solutions and strategies to measure the supply chain performance. The performance can be evaluated with respect to the supply chain elements such as demand management, procurement, logistics, supply, etc. The importance of considering through-life maintenance, repair and operation (MRO) has been highlighted by Roy et al. [4]. They argued that Through-life Engineering Services (TES) would be able to provide the essential support to achieve the required performance with optimum cost. Despite the existence of a range of frameworks for supply chain management in the literature, there is a lack of comprehensive framework looking at service supply chain for bespoke service providers. To fill this research gap, an optimisation framework for improving supply chain performance using DMAIC cycle (i.e. Define, Measure, Analyse, Improve, and Control) is developed in this paper. This framework is a step-by-step procedure to define areas of possible improvement, aligned with a set of tools and methods to act. Moreover, as part of the framework, an in-depth list of KPIs to evaluate the supply chain performance are identified. This paper is structured as follows: Section 2 discusses the literature as well as the research methodology implemented by the authors to develop the optimisation framework which is presented in Section 3. Section 4 presents the adopted case study to develop the framework for a bespoke service provider supply chain. Section 5 provides the concluding remarks and the future work of this research.

2. Literature Review

2.1. Supply chain management and optimisation

The key characteristics of an efficient supply chain have been defined by Lee, H. [5] as agility, alignment and adaptability. Assuring connectivity, trust, transparency and communication within a service supply chain is challenging [6]. This could have a dramatic effect on supply chain flexibility, sustainability and resilience along with other key characteristics. In this context, flexibility is the measure of control and adaptability of a supply chain against changes in market demand. Agility is the ability to react to such unexpected situations quickly and to maintain efficiency and asset availability and capability. Moreover, sustainability can be defined as preserving the supply chain values over time and to measure the environmental and social impact of the supply chain as well as the economic impacts. Finally, resilience delivers a comprehensive perspective on the supply chain performance, which is described as its capability to maintain the sustainable behaviour when exposed to disruptive events [7].

The current literature regarding the frameworks for supply chain optimisation mainly focus on performance measurement of the characteristics explained earlier. Bourne, M. [8] presented a framework for analysing the implementation of a performance measurement system which can enhance the strategic management process by challenging the assumptions and the strategy itself [8,9]. They categorised the measures into resources, output and flexibility. Similarly, Gunasekaran, et al. [10] developed a framework to measure the performance of a supply chain at strategic, tactical and operational levels. The key metrics are considered in terms of suppliers, delivery performance, customer service and inventory costs. Chan, F. [11] introduced a multi-attribute decision-making technique, an analytic hierarchy process (AHP), to make decisions on a supply chain performance measures based on their priority. The measurements include both quantitative and qualitative indicators in terms of cost, resource utilisation, quality, flexibility, visibility, trust and innovativeness. Bhagwat & Sharma [12] expanded this study to develop a balanced scorecard for supply chain management that evaluates business operations in terms of finance, customer, internal business process, and learning and growth. They concluded that such an approach brings more confidence from all angles of a business system. Different performance measurements which are widely used in supply chain systems have been reviewed by Kurien & Qureshi [13] to build a framework for supply chain management (SCM). They identified strengths and weaknesses of these existing structures from both cost and non-cost perspectives with strategic, tactical or operational focus. With the fast growth of information technology, industries and organisations are moving toward implementing Internet of Things (IoT) infrastructure and digital technologies to address the supply chain challenges. In a more recent study, Wang et al. [14] reviewed the literature on big data business analytics for logistics and SCM. Supply chain analytics (SCA) has been introduced as an effective approach to collect, disseminate, analyse, and use big data-driven information. They have argued that SCA assists companies to measure the logistics and supply chain indicators and enables them to establish a benchmark to determine value-added operations. Li, et al. [15] proposed a stochastic programming model for supply chain planning of MRO spare parts enabling quantification of the uncertain production time capacity. In their study, the MRO activities are based on online production management, offline maintenance management and maintenance bill of material (BOM) management. Adivar, et al. [16] proposed a performance measurement framework, where effectiveness, efficiency, responsiveness, flexibility and sustainability are the main five dimensions to measure accurately. They have tested the framework on an omnichannel retailer supply chain and highlighted that the need for a comprehensive, evidence-based performance management is crucial for providing an empirical analysis for SCM.

2.2. Supply chain optimisation methods

Multi-criteria decision making (MCDM) methods are the most commonly used approaches to analyse the current state in a supply chain and to find the optimal solution for improvement of the future state. Braglia, et al. [17] studied the different attributes for spare part classification and built an inventory policy matrix using the AHP technique. A comparative analysis of AHP and Fuzzy AHP for a multi-criteria inventory classification model has been studied by Kabir & Hasim [18]. They have implemented the proposed models on the inventory of raw materials for switch gear in a power industry sector. The approach brought more flexibility in terms of classification systems. Azadeh et al. [19] studied resilience engineering (RE) in the context of maintenance organisations and developed a methodology using AHP for improved assessment of RE. Moreover, performance shaping factors (PSF) for generic maintenance operators have been designed to collect data from service employees. The results confirmed the close relationship between RE and PSFs. Ferreira, et al. [20] proposed a multi-criteria classification framework for different maintenance spare parts when assigning them different inventory policies. AHP was implemented for the assignation using triangular fuzzy scale.

The core contribution of this paper is to develop an optimisation framework for improving bespoke service supply chain performance using DMAIC cycle. Moreover, this work provides a conceptual model of the supply chain, and the metrics and KPIs which are essential for performance optimisation. The developed framework is a step-by-step procedure to define areas of possible improvement, aligned with a set of tools and methods to act. This paper has considered the existing literature within the area of supply chain optimisation, modelling and world-class fleet management. Moreover, it is prepared based on expert knowledge and industrial experience in from bespoke service provider sectors. The research methodology has been adopted from [21] as presented in Fig. 1.

3. Supply Chain Optimisation Framework Development

DMAIC is a data-driven outline of an improvement cycle, which can be implemented in business systems, processes and designs for continuous improvement, optimisation and sustainment [22]. The DMAIC cycle is mostly used to implement lean principles and to drive Six Sigma projects. However, it is not exclusive to lean and can be deployed as a framework for other improvement applications. The presented supply chain optimisation framework outlines a step-by-step guideline to improve, optimise and sustain the performance of a supply chain in terms of asset availability and service cost; the framework follows the DMAIC cycle. Performance measurement and improvement has followed a step-by-step approach as outlined in Fig. 2. This framework expands the current DMAIC frameworks by comprising the state-of-the-art supply chain mapping, metrics and optimisation techniques. Step 1. Define, express the problem in a supply chain and as an outcome present the supply chain elements and the interactions between them. Step 2. Measure, identify the essential key performance indicators (KPIs) to assess the current state of the supply chain performance. Step 3. Analyse, perform optimisation based on the decisions to be made to improve the performance. Step 4. Improve, determine potential solutions, tools to implement and test them and ultimately implement the solutions of improvement. Finally, Step 5. Control, generate a complete solution monitoring plan to ensure the target performance is maintained. The five-step process is continued until the improvements stabilisation.

4. Case study: Bespoke service provider supply chain

4.1. Overview of Case Study

To demonstrate the validity of the presented framework, a bespoke service supply chain is considered as a case study. Bespoke service providers are responsible to provide tailored, highly-skilled engineering services which support their customers to improve the performance whilst reduce the costs. To fulfil this, managing the supply chain in an efficient way is crucial. Two workshops with the sponsor company were held, *Step 1*: define the supply chain elements and *Step 2*: identify the necessary KPIs to measure the performance.

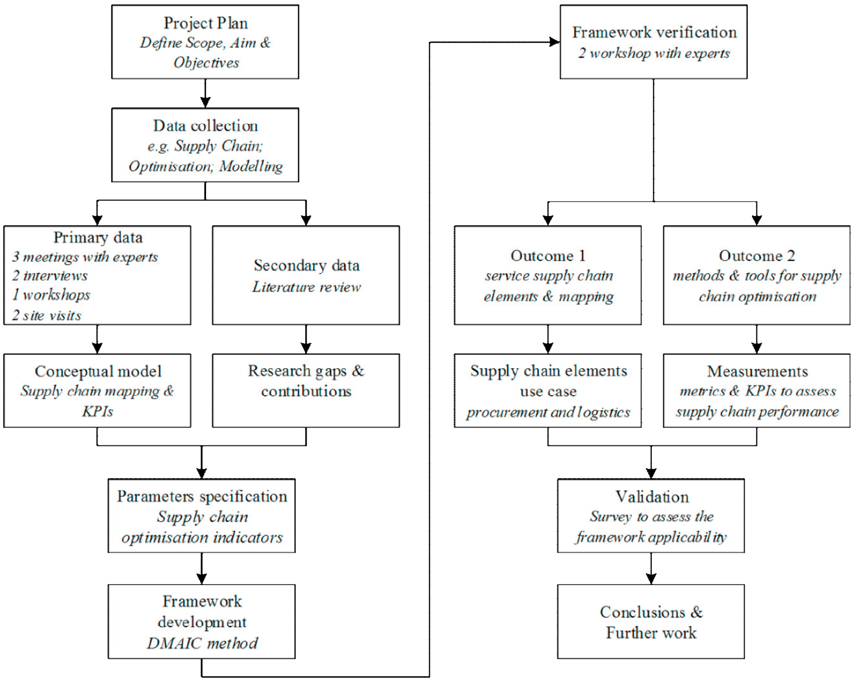

Fig. 1. Research methodology [21]

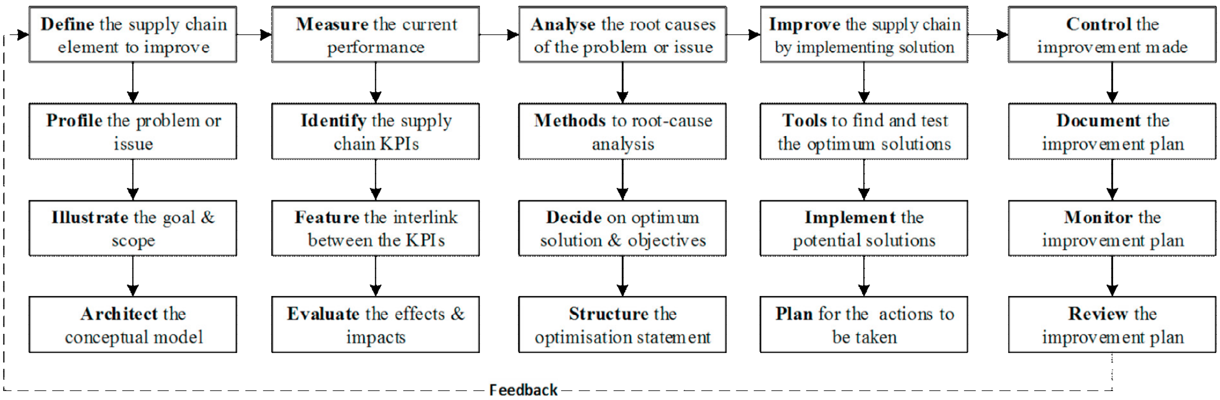

Fig. 2. Optimisation framework for supply chain performance improvement

A generic conceptual model of the studied supply chain was developed in the first workshop, as illustrated in Fig. 3. The mind-map of activities for the bespoke service provider in terms of different elements are included. The service provider's MRO and storage performance depends on the optimal economic solution, short-term hire or lease the asset, fleet contingency, people and staff provisions and infrastructures required for procurement. Moreover, the interactions between the service provided and the customers and suppliers are dependent on the customer requirements, the type of service contract, the frequency and probability of failure for the asset or components, bill of materials (BOM) for a fleet type and obsolescence. Different types of MRO are categorised as planned and unplanned maintenance, condition-based or proactive maintenance and commissions. Furthermore, service contract types are categorised as availability, capability-based contract and utilisation

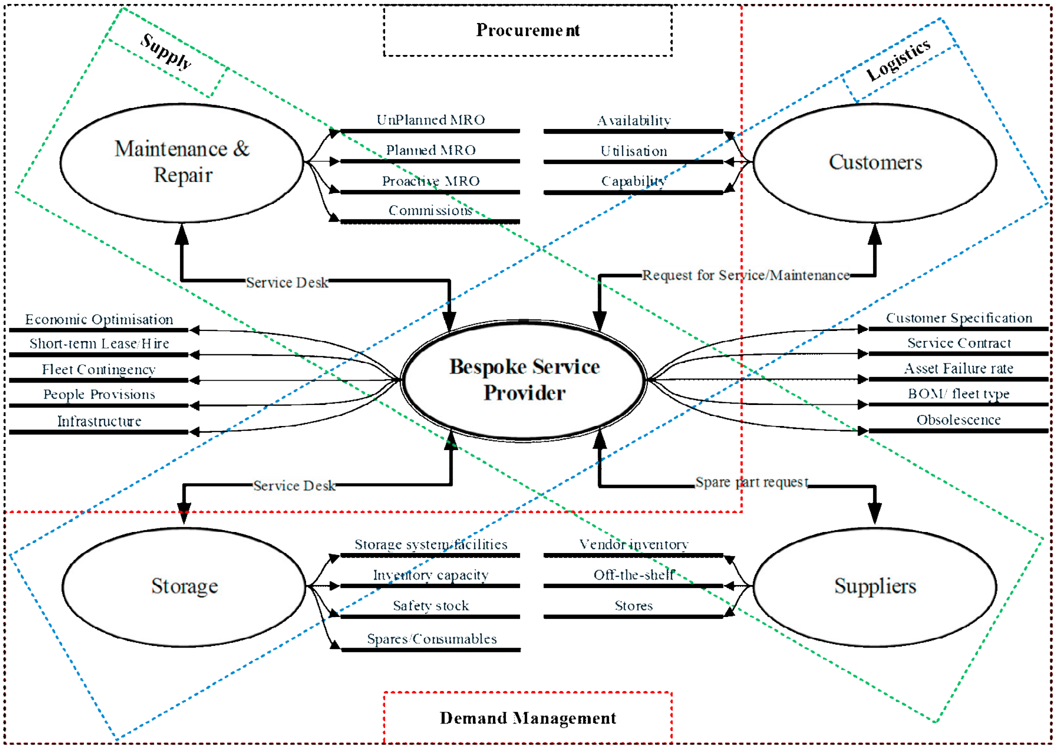

Fig. 3. Conceptual model of the bespoke service supply chain processes mapping (Step 1)

requirements. Moreover, storage facilities can be satellite storage facilities and mobile storage systems. The inventory capacity and the level of safety stock are also required to be considered as part of the performance analysis. Acquiring goods and services is possible from different stores, and is dependent on off-the-shelf capacity and vendors' inventory.

Based on the outcomes from the first workshop, the focus of the research work was narrowed down to four elements within the supply chain. The supply chain elements which are selected are demand management (composed of customer, supplies and storage), procurement (composed of customer, supplies, maintenance & repair, storage and provider), supply (composed of supplies, maintenance & repair, and provider), and logistics (composed of customer, storage and provider). Demand management activities include understanding of the current customer demand and forecasting the future market demand to ensure the availability of the asset enquired by the customers. Procurement can be described as the process of acquiring goods and services from third parties within the supply chain. Supply refers to the MRO activities carried out by the bespoke service provider and is strongly influenced by the spare parts management. Logistics manage the storage, transportation and delivery of goods and services to the customer. The essential metrics and KPIs and interlinks between them to assess the supply chain performance were therefore defined in the second workshop as illustrated in Fig. 4. The KPIs are categorised into service (blue color), operational and (green color) economic (yellow color) KPIs. Service KPIs include inventory turnaround, asset availability, DIFOT, first time fix, service fulfilment cycle-time and turnaround time. Operational KPIs include asset utilisation, backorder level, alternative suppliers, forecast accuracy and volatility. Economic KPIs are comprised of resources' costs, cost of third parties, cost of service and inventory cost.

In addition, *Step 3*: the analysis methods for optimisation and *Step 4*: the tools to implement the solutions of improvement were identified and verified as an outcome of the second workshop, as illustrated in Fig. 5. The improvement solutions were identified as accurate demand forecast, selection of adequate suppliers, maximisation of asset availability and finding the optimal safety stock.

The improvement solutions aim to minimise the asset downtime, improve DIFOT, increase asset availability and decrease cost of supply chain. Finally, *Step 5*: was not actually applied for this case study. Nevertheless, in order to complete the cycle, the improvement plan should be validated and documented. Validation should demonstrate that the solutions are reliable.

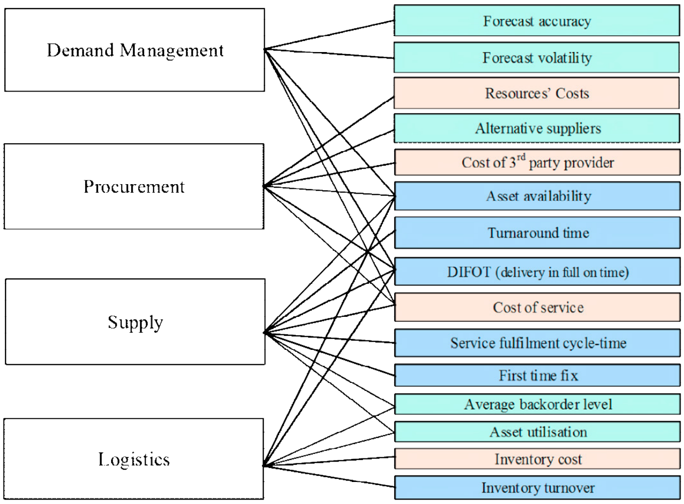

Fig. 4. Case Study: KPIs and their interactions for different supply chain elements (Step 2)

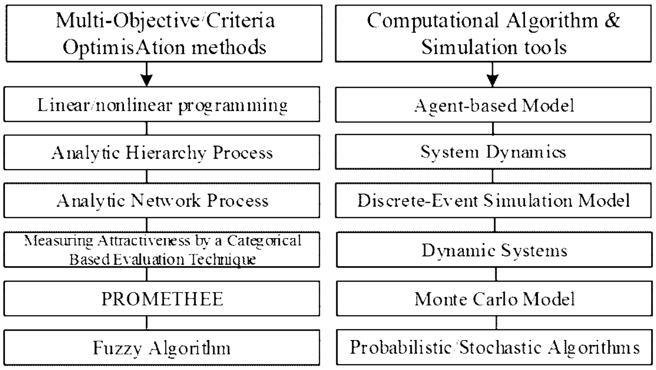

Fig. 5. Case study: List of identified tools and analysis methods (Step 3, 4)

Moreover, it is crucial to create a monitoring plan, which clarifies how the improvement plan or solutions will be monitored, who will be notified if there is a problem and what mitigation strategy is appropriate. Variations are then required to be properly documented and disseminated to all levels of the organisation to create awareness of changes as well as foster an environment of continuous growth and acceptance of change within the company.

4.2. Framework Validation

The applicability of the presented framework has been tested by the sponsor using a qualitative survey instrument. The questions focuses on the level of understanding, applicability and implementation of the framework and the supply chain mapping within the studied company. Four level of qualitative scale of measurement i.e. excellent, good, satisfactory and fair, are considered to classify the data. The data collected from the survey were analysed and the results are presented in Fig. 6. The results show that the framework is highly applicable and can increase the awareness and the knowledge of the supply chain KPIs, their inter-links and optimisation methods and tools. However, implementation and control of the performance improvement plan are required to be more detailed with in-depth expected benefits for the Company.

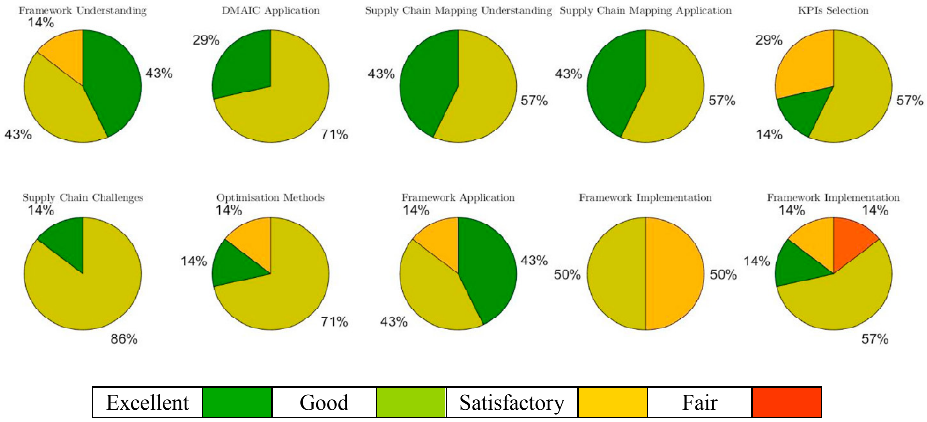

Fig. 6. Validation outcomes for applicability of the developed optimisation framework

6. Concluding remarks

An optimisation framework for improving service supply chain performance is presented using DMAIC cycle. A case study from a bespoke service provider was used to test the applicability of the framework. The conceptual model of the supply chain, including the metrics which are essential for performance optimisation are presented. Moreover, a list of required KPIs for different supply chain elements and their interconnections are identified and presented. The supply chain KPIs are categorised into service, operational and economic. This study contributed to the current research by developing a performance optimisation framework for service supply chain using DMAIC cycle. The proposed framework highlighted the importance of understanding supply chain elements, their interactions, and the associated KPIs in order to optimise the performance. Moreover, the outcomes from the framework validity survey demonstrated that the developed framework is highly applicable to service supply chains and can support the service providers to improve their service and MRO activities' performance. The application of the framework raises the awareness about state-of-the-art supply chain mapping, performance dimensions and measurements and optimisation techniques and tools. The DMAIC cycle has been demonstrated to be an effective approach to improve supply chain strategies and performance. Further work will focus on deployment and control of improvement plan, qualitative demonstration and alanysis of the supply chain performance and the application of digital technologies and IoT [23] to improve supply chain visibility and security.

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