International Journal of Lean Six Sigma, Volume 10, Issue 1, 2019, pp. 81-105
DOI:10.1108/IJLSS-03-2018-0027

Assessing the leanness of a supply chain using multi-grade fuzzy logic: a healthcare case study

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Abstract

Purpose – Numerous and diverse organizations have implemented lean principles and practices, which concentrate on improving the efficiency of business processes by reducing cost, waste, consumptions and effort. However, previous assessments have not focused on the leanness of the supply chain in a healthcare setting. This paper introduces a method for assessing the successful implementation of lean principles and tools in a supply chain. Furthermore, this paper validates the method in a healthcare organization.

Design/methodology/approach – This paper starts with an extensive literature review on assessing leanness and using multi-grade fuzzy logic. Then, a conceptual model was developed to measure leanness. The conceptual model was validated by discussing the initial version with select academic experts, especially those who deal with leanness in healthcare organizations. After responding to the experts' valuable comments the healthcare organization that is the focus of this case study was chosen based on two criteria. The first criterion was the organization's ability to participate in the study, and the second was the organization's commitment to implementing lean principles. These criteria were important to ensure the organization had the necessary foundation for implementing change initiatives such as lean process improvements. Next, a multi-grade (multi-attributes) fuzzy logic was used for leanness measurement. A leanness index was calculated, and the results were validated using experts from the case-study organization. Finally, the weaker areas of the organization's processes were identified to point the way for further improvements.

Findings – The assessment indicated that the case-study organization is not lean. The organization's weaker attributes were identified, and improvements have been suggested.

Research limitations – This study focused on a single healthcare organization, which was selected from a limited pool of potential organizations—namely, those organizations which are accredited by both the Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI) and the Joint Commission International (JCI). The scope of future research should be extended to multi-case studies to enhance the findings presented in this paper. This paper's findings can be used to help decision makers at healthcare providers to implement lean thinking in supply chain processes.

Practical implications – This research may be interest to practicing supply chain managers, as it proposes what enablers, factors and attributes should be emphasized in lean implementation. The proposed model can works as assessment tool to identify the gap between the present level of leanness and the desired leanness state so the healthcare organization can identify what can be improved. This model enable decision makers in hospital supply chain to take suitable actions for improving lean implementation level.

Originality/value – This study makes an original contribution to the body of research concerning lean principles; the study developed a conceptual model for leanness assessment that can be applied to the supply chain of healthcare organizations. Indeed, the conceptual model is likely to be useful for assessing leanness outside of the healthcare field, which suggests avenues for future research.

Keywords: lean; lean assessment; leanness; supply chain; fuzzy logic, healthcare

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The final published version (version of record) is available online at DOI:10.1108/IJLSS-03-2018-0027. Please refer to any applicable publisher terms of use.

Introduction

Lean is a widely known approach to quality improvement. It was initially used in the manufacturing and automotive industries, but, lately, the healthcare industry has begun to apply lean principles (Moraros et al., 2016). Many researchers point to the importance of supply chain management (SCM) and its role in preventing medical errors, improving healthcare-provider (hospital) performance, improving quality of care, decreasing waste, producing value-added operations and improving operational efficiencies (Al-Saa'da et al., 2013).

Lean is an approach focused on maximizing value while minimizing waste. The UK National Health Service (NHS) has used a lean approach to achieve its strategic goals with a number of healthcare organizations (Antony et al., 2016). Antony et al. (2017) mentioned that it is necessary to apply continuous improvement approaches, such as lean, to ensure reliability, on-time delivery and quality at reduced overall costs.

However, before implementing any continuous improvement initiatives in a healthcare organization, it is crucial to assess leanness in the supply chain (SC). Given that a healthcare organization's SC represents from 25 percent to 40 percent of its monthly budget, so the organization must improve its SC to ensure quality delivery of material and medications to clients or patients (Machado et al., 2014). That is why this paper seeks to develop a conceptual model to assess healthcare providers' SC leanness. An organization's lean readiness is critical to implementing lean practices. Also, the degree of lean readiness is important for determining to what extent lean implementation will succeed (Achanga et al., 2012).

A lean SC is focused on reducing waste, reducing activities that do not add value, optimizing processes, adding flexibility and searching for simplification. A well-defined lean SC measurement increases the opportunity for success because it enables practitioners to see areas where performance can be improved, thus concentrating practitioners' attention on problem areas. Although lean implementation in a healthcare setting has become increasingly important in the existing body of research (Sobek & Lang, 2010), the question of "how much lean" in a healthcare SC has not been answered. Most of the frameworks for evaluating a lean SC have been restricted to particular non-healthcare sectors (Jasti & Kodali, 2015). Lega, Marsilio & Villa (2012) pointed out there is a lack of research on SC performance in public healthcare institutions. Vries & Huijsman (2011) stated that the supply chain is a crucial and ever-changing issue for healthcare administrators, and it impacts heavily on healthcare management. Lean approaches are effective and efficient quality improvement methodologies in several healthcare organizations(Roberts et al., 2017).Lean assessment

An up-to-date evaluation of leanness assists in determining the contribution of lean practices to improving an organization's operational and financial performance (Narayanamurthy &

Gurumurthy, 2016). According to Vidyadhar et al. (2016), to enable systematic implementation of lean principles, an organization needs to perform a leanness assessment, which measures the extent to which the principles have been put into practice in each process. Cuthbertson & Piotrowicz (2011) said that the supply chain is one of the processes that needs review; SC performance should be evaluated to identify areas requiring further improvement.

Supeekit et al. (2016) employed DEMATEL-modified ANP to calculate weights for different performance aspects in the hospital supply chain. The authors asserted that using weights to measure performance can help healthcare decision makers identify which attributes need further improvement. Previous researchers have used a fuzzy-logic approach to overcome the ambiguity and vagueness associated with a leanness assessment (Vidyadhar et al., 2016). However, researchers have called for studies that examine the aspects of leanness in a healthcare setting (Narayanamurthy & Gurumurthy, 2016). For this reason, this paper attempts to fill this gas by developing a model for assessing leanness in supply chain in healthcare setting. So this model is the first of its kind in leanness assessment. Lean assessment techniques enable a comprehensive audit of the performance of lean principles, and so are able to recognize lean improvements(Omogbai & Salonitis 2016). According to Antony (2011) the concept of lean was evolved from the Toyota Production System (TPS) during the 1950s. In lean the focus is on eliminating waste to result in quicker flow, less variation, greater customer and shorter cycle time to add value (Sinclair et al. 2005). Under senior executives support, the results of the self-assessment can lead organizations to continuously improve their weaknesses(Kim et al., 2010)

The government of Saudi Arabia is making efforts to achieve its vision 2030 and implement continuous improvement initiatives, such as lean. The implementation of lean will lead to many benefits, such as cost reduction and elimination of non-value-added (NVA) activities. Lean assessment needs to be conducted to measure the level of implementation of lean in each process (Vidyadhar et al., 2016).

According to Omogbai & Salonitis (2016), lean attributes are either quantitative or qualitative Table 1.1 shows both types and highlights their strengths and weakness.

Table 1.1 Qualitative and quantitative lean assessment framework

Framework/ model	Qualitative framework	Quantitative framework
Models	Quantitative lean index (Vimal & Vinodh 2012)	Benchmarking (Ray et al. 2006)
	Balanced scorecard (BSC) (Seyedhosseini et al. 2011)	Value stream mapping (Abdulmalek & Rajgopal 2007)
	Lean self-assessment tool (LESAT) (Nightingale & JH. 2002)	Quantitative lean index (Pakdil & Leonard 2014)

Strengths	Lean attributes are easy to develop. Qualitative lean attributes can be generated for most lean practices. The use of linguistic terms (“high” or “low”) to rate performance makes them easy to manage (Omogbai & Salonitis 2016).	Lean performance allows to be mapped and tracked objectively and more regularly. The lean attributes can be statistically analysed. (Omogbai & Salonitis 2016).
Weakness	Self-assessment rating is open to bias. Qualitative lean attributes cannot be analysed statistically. Less informative and precise. Linguistic characterizations less specific than numerical ones (Zadeh 1975).	Data are not always easy to collect. Not all lean practices can be measured with quantitative lean attributes (Omogbai & Salonitis 2016).

Developing a model for assessing lean in a service setting would be a unique contribution to the literature of lean philosophy. Some researchers have previously noted the need for studies to capture healthcare lean assessment aspects (Narayanamurthy & Gurumurthy 2016). To overcome the ambiguity linked to lean assessment, the fuzzy approach has been used (Vidyadhar et al. 2016). Leanness assessment studies in literature have taken many forms. For example leanness index(Wong et al., 2014), fuzzy leanness index(Vinodh & Chintha 2011), assessing lean practices, assessing(Pedersen & Huniche 2011) lean performance measures(Sezen et al., 2012), lean assessment framework(Guimarães & De Carvalho 2014) and lean assessment instrument(Malmbrandt & Åhlström 2013).

Multi-grade fuzzy logic

There are various weighting approaches in the multi-criteria decision making method that use the judgment of experts and stakeholders to weight the effect of alternatives and categories (Myllyviita et al. 2014). Fuzzy logic is based on human logic, and takes advantage of conceptual knowledge with boundaries. Some of the concepts of fuzzy logic include probability distribution, linguistic variables, fuzzy if then, and fuzzy set (Vinodh & Chintha 2011). Fuzzy logic is an effective method to the multi-attribute decision making issue when the given data is presented linguistically or is ambiguous (Klir & Yuan 1995). Velasquez & Hester (2013) note that fuzzy logic itself has proven to be an effective multi-criteria decision making method.

According to Yang and Li (2002), multi-grade fuzzy logic can be used to calculate leanness. There is no ideal methodology, but the fuzzy approach provides a useful way to deal with issues in which attributes of phenomena are vague and imprecise (S Vinodh & Prasanna 2011). Fuzzy multi-attribute is the core of determining the value of the weights for each measure/attribute,

followed by a ranking process to select from among the alternatives that have been given (Deni et al. 2013). One of the main issues in the qualitative research method is ambiguity, which may not be expressed numerically.

The main reason for using a multi-grade fuzzy approach is to avoid any fluctuation in variable values and simple calculations (Ganesh 2016). In addition, fuzzy logic takes the inadequate information into consideration and allows loose, imprecise input. Also, it allows for a few rules to encompass issues with great complexity (Balmat et al. 2011). Moreover, this logic uses experts' judgment to weight the relative importance of each leanness in different enablers. The simplicity of fuzzy logic allows experts to enter the relative importance and weight of leanness straightforwardly. Multi-grade fuzzy logic has been used in different contexts. For example, Suresh & Patri (2017) used fuzzy logic to assess agility in healthcare dispensary, while Vinodh & Prasanna (2011) used the same logic to evaluate agility in the supply chain at a single manufacturing company. Sustainability was assessed by using the same approach (Vinodh 2011). This approach has been used in another sector; Elnadi & Shehab (2016) and Vinodh & Vimal (2012) employed multi-grade fuzzy logic in the manufacturing industry. Leanness has been assessed by the same method (Vinodh & Chintha 2011). Although multi-grade fuzzy logic has been used for lean assessment in different sectors and contexts, leanness has not been used in the supply chain within a healthcare organization.

Lean implementation in supply chain management (LSCM)

LSCM is one way to lower costs and improve the quality and availability of the service/product (Jasti & Kurra 2017). LSCM is defined as "a set of organizations directly linked by upstream and downstream flows of products, services, information and funds that collaboratively work to reduce cost and waste by efficiently pulling what is needed to meet the needs of individual customers" (Vitasek et al. 2005). Supply chain management (SCM) can use the lean approach to reduce costs and improve quality and delivery (Salah et al. 2011). In the supply chain context, performance improvement is becoming a must for those organizations looking for success.

SCM plays a vital role in reducing the final cost of services or products. A huge number of NVA activities are performed throughout the SC process. Lean principles help to eliminate waste activities across the SCM processes, and are tools that endeavour to improve quality and speed, reduce costs, and increase customer satisfaction (Laureani & Antony 2017). In addition, lean tools substantially improve quality (Peter & Lawrence 2002) in the healthcare sector (Gijo et al. 2013). However, there is increasing concern about failures in the implementation of the lean approach in supply chain management. The SCM play a vital role in improving the performance of the supply chain, reducing costs and increasing profitability through effective distribution. The

optimization of an organization's resources is one of the most important roles of the SCM, which deals with raw material and distribution to the customer (Hjaila et al. 2016).

Found & Rich (2007) studied lean supply chain (LSC) frameworks with the survey approach. This study applied empirical research to find out the applicability of the suggested LSC frameworks, but did not include validity and reliability analysis. A number of researchers have developed LSC frameworks to fulfil the requirements of the manufacturing industry (Jayaram et al. 2008). However, no LSC framework has been developed for the supply chain in a healthcare setting.

The Lean methodology has a significant place for reducing and developing the actions which do not have inner process in SC in the organizations. The aim of Lean is defining, analysing, correcting and improving the variables, which impact the quality of supply chain process in order to decrease the failures and to suggest the improvement tools for the processes(Erbiyik & Saru 2015).

It is essential for the success of an organisation and its suppliers that wasteful operations are removed and total SCM costs be minimized by implementing continuous improvement approach such as lean (Dasgupta 2003). According to Kiemele et al. (2007), a quality process such as Lean must be used to eliminate waste across supply chain activities and to design and understand processes that can delete rejected orders due to product damage and build an operating paradigm whereby orders are manufactured, packaged, and transported depending on customer requirements.

Supply chain management and continuous improvement (such as lean) are directly related. Understanding supply chain relationships and dynamics is fundamental driver of business performance (Salah et al., 2010). The significant matter of how to integrate SCM with other operational performance initiatives like lean management is still being developed and investigated (Rong et al. 2011).

Healthcare SCM

Recently, SCM has received considerable attention in the healthcare sector. According to Lee & Schniederjans (2011), the supply chain management in healthcare can be defined as "a set of approaches to efficiently integrate suppliers or vendors, transport, hospital services (including outpatient, emergency, in-patient, laboratory, radiology, stores and purchases, food, laundry and medicines/equipment) to achieve Total Quality Management (TQM) in healthcare services by optimum utilization of resources".

SCM in healthcare consists of operations and activities that ensure raw materials and services flow seamlessly and continuously to deliver healthcare needs (Lee & Schniederjans 2011). SCM

among healthcare providers encompasses internal and external chains. The internal chain contains, for example, storage, patients, and patient care sections. The external chain contains manufacturers, suppliers, distributors and others (Schneller & Smeltzer 2006).

According to Lee et al., (2011) Healthcare supply chain management activities have three kinds of flows namely: physical product, information and financial. Physical product flow manages the services and products for customers (patients) to meet their needs. Financial and information flow ensures there is effective supply chain performance, and thus improves the performance of the organization (Kowalski 2009).

Pinna et al., (2015) defined supply chain in healthcare, in line with this study, as "upstream and downstream relationship with supplier and customers and to solving problems of functional divisions that occur within and between organizations". Figure 2.1 shows the overall supply chain management process in the healthcare sector from the first step, raw material, up to reaching the end users.

The primary production contains the creation of the medication ingredients while the secondary manufacturing converts ingredients into medical products such as capsules, tablets, etc. Primary and secondary producers may be located in different regional markets.

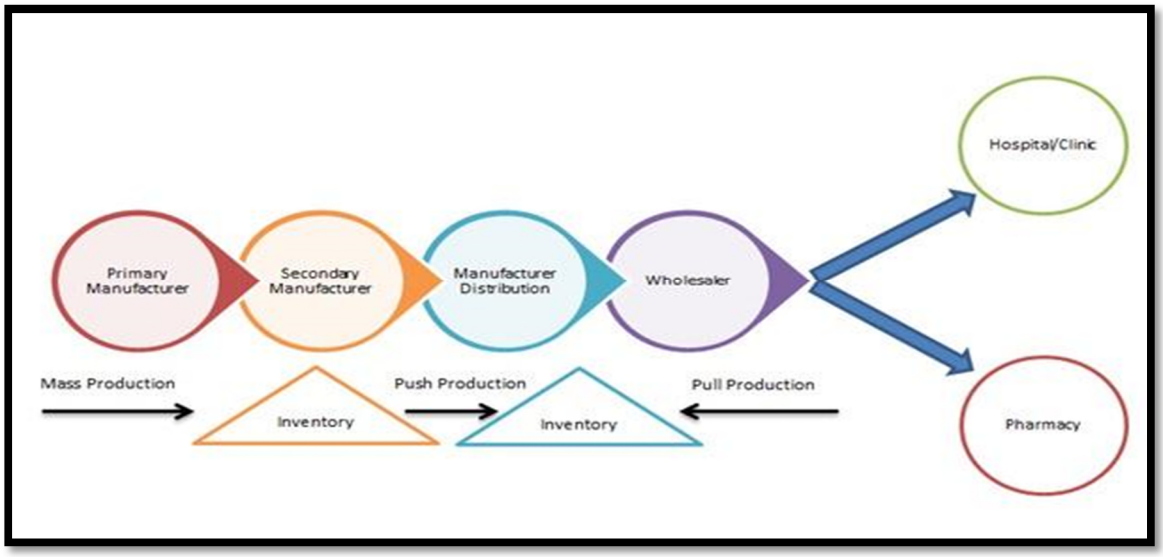


Figure 1: Healthcare Supply Chain Structure (Haszlinna & Potter, 2009).

Over recent the quality of healthcare services has become a globally vital concern, especially with increased worries about the escalation of medical cost, medical errors and patient safety. Implementation of effective supply chain management in the healthcare sector can lead to benefits.

There is a general consensus that SCM brings added value to healthcare organizations, improving competitive advantage and organizational performance (White & Mohdzain 2009; Vries &

Huijsman 2011). Furthermore, saving a considerable amount of money is one of the benefits when supply chain management is applied effectively in the healthcare sector (Oliveira & Pinto 2005; Al-Saa'da et al., 2013).

In addition, many researchers show the importance of SCM in healthcare and its role in preventing medical errors, improving healthcare provider (hospital) performance, decreasing waste, producing value added operations, improving operational efficiencies and helping to improve quality of care (Ford & Scanlon, 2007; Mustaffa & Potter, 2009; Kumar, Ozdamar, & Zhang, 2008; White & Mohdzain, 2009; Al-Saa'da et al., 2013).

In recent year, due to the complexity of supply chain management in healthcare, the integration upstream and downstream has become increasingly significant. Healthcare providers and firms have to do accurate tasks as cost of mistake might be people's life(Kritchanchai, 2012; Turhan & Vayvay, 2009). The health care sectors are usually depicted as a different from other service providers. The healthcare providers have distinguished by sets of specificities that undoubtedly impact the area of SCM(Lega et al. 2013).

Research methodology

This paper begins with an extensive review of the lean assessment and multi-grade fuzzy logic literature by referring to journal database such as Science Direct, Emerald, Taylor and Francis, and Springe. Then, an initial conceptual model (first version) is developed for leanness measurement. This step is followed by conducting semi-structured interviews with academic experts in lean, especially those who deal with healthcare organizations. These academic experts were interviewed during scientific gatherings, such as conferences and symposium. Each interview was conducted independently and ranged from 40 to about 60 min. during the interview, the model was explained clearly and its items. Participants were asked about their opinion in the developed model in order to assess model feasibility and its validity. After responding to the experts' valuable comments, the researchers end up with the second version of the model. The selection of the healthcare organization has been identified based on criteria, including the ability to participate and the keenness to implement lean practices. The second version of the model was revised based on semi-structured interviews with five experts working in supply chain in healthcare sector. The experts number was selected based on the organizational structure (concerned hospital), interviewees' experience (working experience ranged 18 to 25 years) and involved in lean project or participated in continuous improvement initiatives. In addition, five interviewees are acceptable number and was used by many researchers(S Vinodh & Prasanna 2011; Elnadi & Shehab 2016). In some studies, less than five participants are also acceptable. Behrouzi and Wong, (2013) Interviewed three interviewees from supply chain in their study. Each

participant took about 60 minutes discussing the model and its ability to measure hospital supply chain leanness.

Responding to the experts' feedback resulted in revising the second version of the model by removing, adding or changing the name of the model's items. This step followed by identifying suitable hospital for data collection to compute the hospital supply chain leanness index. The healthcare organization was selected from those healthcare organizations are keen to implement lean practices in their supply chain and which are accredited by both the Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI) and the Joint Commission International (JCI). The reasoning behind these criteria was to make sure there was a rigorous foundation on which to implement change initiatives such as lean. Then a multi-grade (multi-attribute) fuzzy logic was used for leanness measurement. The leanness index was calculated, and the results were validated. This step was followed by the identification of weaker areas that might require further improvements. Figure 2 details the research methodology.

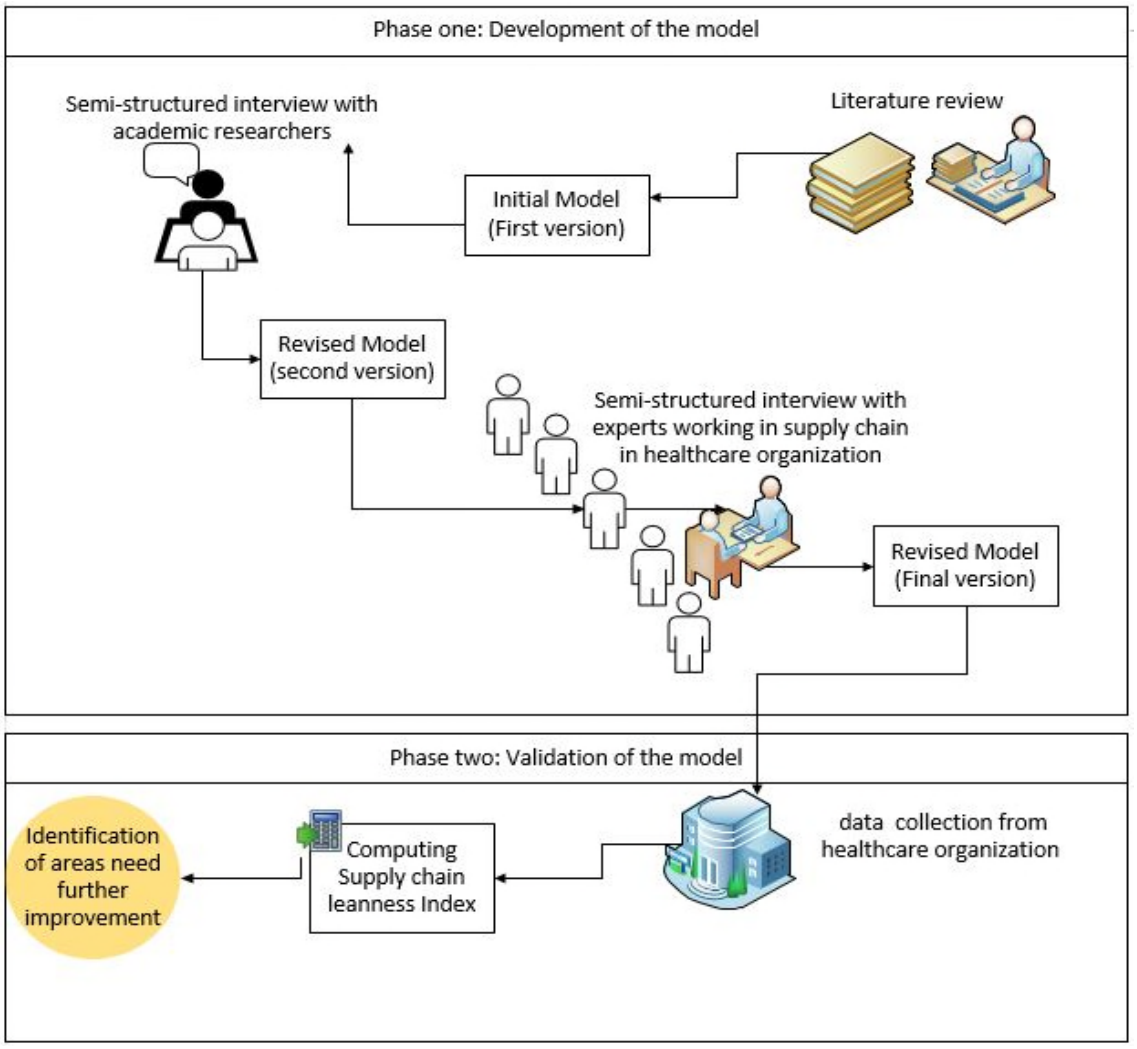


Figure 2 Research Methodology

Development of conceptual model for assessment of leanness in supply chain

The conceptual model and lean assessment tools are developed based on the literature review and the experts' opinions. The aim of the assessment tool is to identify the gap between the present level of leanness and the desired leanness state so the organization can identify what can be improved. Also, the tool identifies both strength and weakness in supply chain practices. In addition, lean assessment is important because it is the most suitable starting point to identify potential improvement areas. The reasoning behind the creation of the model is that it constitutes five main perspectives of lean in the supply chain. The model consists of three levels. The first consists of five leanness enablers, the second consists of ten lean criteria, and the third consists of thirty eight lean attributes. Table 1.2 shows the conceptual model for lean assessment.

Table 1.2 Conceptual Model for lean assessment

Level 1 Lean enabler	Level 2 Lean criteria	Level 3 Lean attributes
1. Medical management responsibility	1.1 Hospital leadership	1.1.1 commitment by medical staff 1.1.2 Patient-oriented focus 1.1.3 Lean approach is driven by top hospital management 1.1.4 Adoption of information technology for hospital SC applications
	1.2 Hospital organizational culture	1.2.1 Culture of problem prevention and waste elimination in hospital 1.2.2 Culture of acceptance of change to enhance patient safety 1.2.3 The clear understanding of lean philosophy by hospital community 1.2.4 Hospital open to new ideas
2. HSC Processes management	2.1 Process improvement	2.1.1 Existence of improvement team including physician, pharmacist or medical equipment engineer with an understanding of improvement tools such 5s 2.1.2 Processes of medical procurement 2.1.3 Information exchange/sharing across the hospital supply chain 2.1.4 Understanding problem solving tools to enhance patient safety 2.1.5 Waste identification and quantification of HSC processes
	2.2 Process streamline	2.2.1 Adoption of value stream mapping 2.2.2 Visual communication 2.2.3 Standardization of process 2.2.4 Jobs are pulled by each supply station from previous supply station 2.2.5 Supply medicine at the pull of the patients
3. Medical human resource	3.1 Employees proficiency	3.1.1 Multi-skilled medical staff 3.1.2 Culture of continuous improvement 3.1.3 Cross-functional collaboration
	3.2 Personnel involvement	3.2.1 Medical staff engagement 3.2.2 Regular meetings with medical staff 3.2.3 Hospital employees' ideas taken seriously
4. Consumer relationship	4.1 Consumer response	4.1.1 A well-defined voice of consumer (physicians/patients) (VOC) 4.1.2 Physician Preference Items (PPIs) 4.1.3 Physician buy-in 4.2.1 Physician/patient feedback on quality, cost, time, and delivery performance
	4.2 Consumer involvement	4.2.2 Physicians/patients participate in continuous improvement initiatives 4.2.3 Close contact with physicians to enable them to engage in continuous improvement projects 4.3.4 Engage physicians in forecasting planning processes
5. Supplier relationship	5.1 Supplier cost	5.1.1 Hospital-supplier integration 5.1.2 Incurred costs due to shortage of medicine 5.1.3 Medical purchasing
	5.2 Supplier delivery	5.2.1 Unpredictable patient demand 5.2.2 Medical supplies arrive on time and in the correct amounts 5.2.3 Minimize delivery lead times of medical supplies 5.2.4 Deliver urgent medicine when needed or in emergency cases

Case study organization (A)

For privacy and confidentiality reasons, the case study will be referred to as Organization (A). Organization (A) is a tertiary care centre in Riyadh, Saudi Arabia, with 1,500 beds. Five experts from the organization participated in the assessment process. The selection of the experts was based on their position, experience, and knowledge of lean, as well as their participation in continuous improvement initiative or projects. Organization (A) is keen to implement lean practices.

The enablers and factors were grouped according to the European Foundation for Quality Management (EFQM) model, which can be employed in healthcare settings. Implementing EFQM in hospitals leads to improved organisation performance over time, and helps detect areas requiring further improvement (van Schoten et al. 2016). EFQM can be used in a certain subsector in healthcare settings, in this case, the hospital supply chain. Also, any factors related to healthcare policy and strategy have been classified under the leadership factor, since the strong relationship between strategy and leadership is responsible for drafting, forming and executing the hospital's strategy. These tasks are discussed and validated by the experts' judgment.

Assessment of leanness using multi-grade fuzzy logic

The calculation of the SC leanness index goes through several steps (mentioned in appendix A). The LSC index of an organization (A) is denoted by ***I***. The formula for the leanness index is given by the equation no (1):

$$\boldsymbol{I = W \times R} \text{ ---------- } \textbf{(1)}$$

Where:

W: Overall weight

R: Overall assessment factor

The assessment has been divided into five grades, since lean supply chain factors involve fuzzy determination.

$\boldsymbol{I = \{10, 8, 6, 4, 2\}}$

Where:

8.01 – 10	The supply chain implements lean practices in its processes and shares them internally and externally along the complete value chain
6.01 – 8	The supply chain implements lean practices in all its processes and measures the results to implement improvement actions
4.01 – 6	The supply chain implements lean practices in all its processes and achieves a basic level of implementation
2.01 – 4	The supply chain is aware of the lean practices and is keen to implement them
0.00 – 2	The supply chain does not implement lean practices in any supply chain processes

Results and discussion on the case study

The assessment of leanness in healthcare sector gains vital significance. The hospital supply chain index provides decision makers a real insight into the level of leanness. This index identifies the gap between the current situation and the future desire and this will enable supply chain mangers in identifying areas need further improvements. Although, there were several methods to measure the leanness, this paper develops an unique model that can be used as diagnostic tool in measuring the level of leanness of supply chain in healthcare organization the findings of this study assure that there is urgent need to improve level of lean in healthcare organisation especially in developing countries such as Saudi Arabia. The improvement of level of lean implantation can be improved by improving lean enablers, factors and attributes. The first lean enabler is medical management responsibility. Poor leadership and a lack of continuous support and commitment from top management are considered challenges faced during lean implementation. Therefore, senior executive managers must always take responsibility for the implementation of lean initiatives (Abuhejleh et al. 2016). According to Al-Borie & Abdulla (2013), a majority of development initiatives are directed top-down and not bottom-up. This can be improved by changing leadership style to a bottom-up leadership approach. Such an approach will encourage employees to strongly participate in lean projects. Leaders should refer to personnel and look to them as associates. Leading by example is another way to improve leadership style.

Management commitment (MC). MC can be improved by the introduction of quality policies and by conducting management reviews. Linking lean implementation with organization vision and strategic goals is considered critical point in success of lean implementation. Also, increased supportive commitment toward lean projects from top management is one of the main pillar to success lean initiatives. The second organizational area which needs further improvement is patient-orientation. Nabelsi & Gagnon (2017) note that hospitals must become patient-oriented in order to achieve hospital mission and patient needs. The authors mention that "SCM can only be successful if it is truly patient-oriented". Patient-oriented care processes require a supportive supply chain adhering to strong principles of fully-integrated and seamless inventory-sourcing processes. SC and inventory automation are necessary for lean patient-oriented processes. (Nabelsi & Gagnon 2017). This organizational area can be improved by clearly identifying patients' needs and linking these needs with the hospital strategic goals.

Organizational culture (OC). Since the patient's safety is the ultimate goal for any healthcare provider, hospital leaders should enhance the culture of patient safety Dobrzykowski et al. (2014) note that OC plays a vital role in patient safety. Lillrank et al. (2011) mention, in healthcare settings, how the organizational culture leads to decreasing medical mistakes. Also, a study conducted on a large number of American hospitals shows the relationship between organizational culture and the reduction of medical errors. In this research, OC refers to "need and belief about ongoing improvement" (Noori

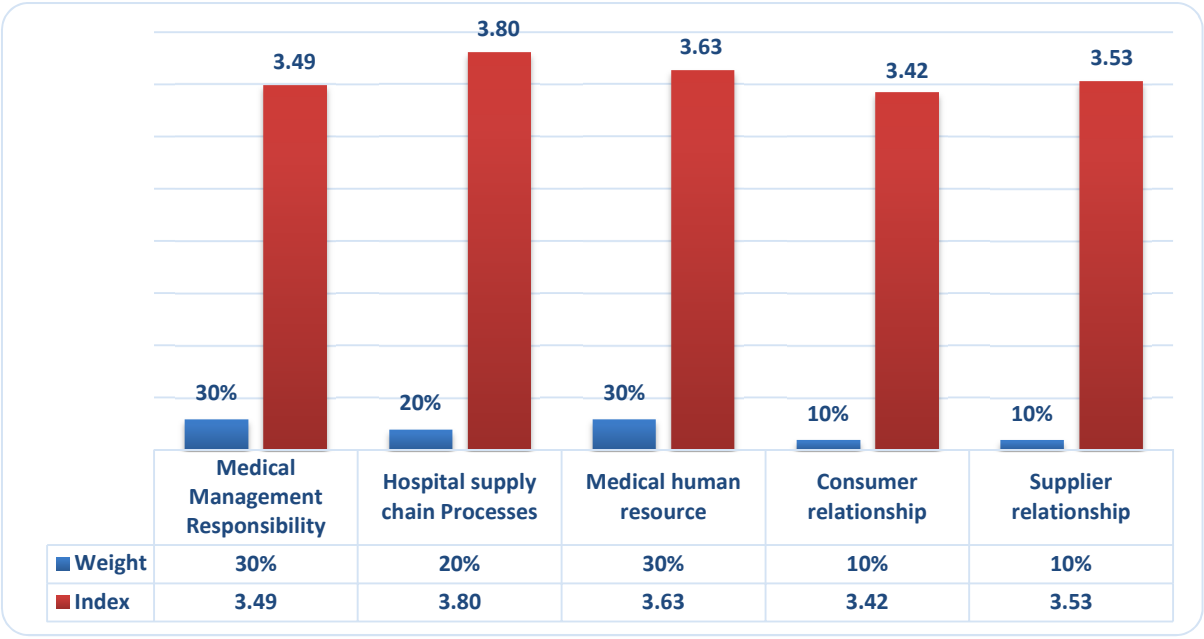
2015). This area can be improved, starting with top management. Patient safety starts with a transformational leadership, which in turn leads to the formation of a culture of safety, the adoption of patient safety plans, and the development of patient safety outcomes (Dobrzykowski et al. 2014). The significance of OC in the supply chain is undeniable (Braunscheidel et al. 2010). There are two main reasons for focusing on OC. First, OC plays a significant role in SCM (Dowty & Wallace 2010; Braunscheidel et al. 2010; Cao et al. 2015). Second, OC is more intractable than other factors, such as information or technology (Fawcett et al. 2008; Cao et al. 2015). According to Schilke & Cook (2014), OC shapes the attitude of staff with respect to risk-taking, teamwork and information sharing. Appropriate organizational culture also improves trust and inter-firm associations.

Hospital SC processes management. Process improvement can be attained by creating a department, such as Business Process Streamlining Department (BPSD), that is responsible for continuous process improvements. This department should be linked directly to the Chief Executive Officer (CEO) or the executive general manager for supply. A form steering lean committee (improvement team), which might include physicians, pharmacists or medical equipment engineers working closely with SC decision makers, is necessary to improve SC processes.

The improvements can be accomplished through medical procurement processes. Ordering the right medical devices for daily processes puts pressure on hospitals to look for opportunities to deliver a high quality of patient care, and to improve supply chain operational efficiencies (Al-Karaghouli et al. 2013). For example**,** in the United Kingdom, the National Health Service (NHS) aims to achieve £1.2 billion in efficiency savings via improved procurement (Al-Karaghouli et al. 2013). The NHS (2011) notes that 30% of a hospital's budget is spent on procurement, so any tangible improvement in the medical purchasing process will lead to considerable cost savings.

Redesigning supply chain processes by implementing Business Process Re-engineering (BPR) will improve workflow, reduce cost, and improve quality. For example, an organization might link procurement department directly with the CEO in the organizational structure (normally under supply chain department). Also, redesigning the OC to reduce the number of decision-making levels will contribute significantly to accelerating the purchasing process. Figure 1.1 shows weights and indices for all main lean enablers after calculation (calculation steps illustrated in appendix A).

Figure 1.1 Weights and indices for main lean enablers



Information exchange in hospital supply chains is defined as "accurate and timely information interchange among those involved in the associated processes"(Mandal, 2017). The timely sharing of relevant information along the SC can dramatically reduce the "bullwhip effect" (Wei & Wang 2010). The coordination between all hospital supply chain departments and medical departments should be done in the proper way to avoid unexpected medicines demand. According to Blome et al. (2014), information exchange is the basis for effective coordination that forms the core of efficient hospital supply chain management. Also, prompt information exchange plays a vital role in meeting patients' needs. Blome et al. (2014) remark that an information exchange relationship between healthcare providers is necessary to achieve desirable patient outcomes. These actions may improve information exchange throughout the hospital supply chain (HSC) if implemented properly.

Patient safety is another important factor in HSC**.** Measuring a hospital's SC performance is required to accomplish the performance aim of patient safety (Supeekit et al. 2016). HSC not only delivers medical items and services to patients, but also plays an important role in patient safety. Patient safety is the ultimate aim and main concentration of healthcare (Dobrzykowski et al. 2014). Improving HSC performance can enhance patient safety by avoiding medical errors (Kenagy et. al., 2007).

Process streamlining (PS). PS in HSC can be improved by adopting value stream mapping and visualizing communication. The implementation of lean methodology in healthcare, and using value stream mapping (VSM), can deliver value for customers (in this case, patients) by eliminating waste and providing value-added services at a reasonable cost. This will help organizations save, and make them sustainable in this sector (Salam & Khan 2016). Also, VSM has been used as a lean SC tool to reduce lead time and cost, and to enhance quality (Wee & Wu 2009).

In the healthcare supply chain, the breakdown of effective communication between the different departments/parties within the procurement process has led to dysfunctional SC (Al-Karaghouli et al.

2013). The lack of communication within the healthcare sector is one of the main challenges for lean implementation (Grove et al., 2010). Communication can be improved by exchanging information between the different departments/parties involved to improve the purchase of the correct medical devices needed for daily operations, to minimize the cost of distribution, and to reduce time of delivery, while meeting doctors' and surgeons' needs (Al-Karaghouli et al. 2013).

Medical human resource. Medical and non-medical staff related to the supply chain are considered important factors when adopting any new change initiatives. In other words, without the effective participation and support of staff, lean practices in the hospital supply chain is useless. Womack et al. (1990) assured the importance role of employees in adding value to the organization. Training hospital supply chain employees is essential to implementing the lean initiative. Human resources in hospitals can be improved by concentrating on training supply chain employees, while adopting job rotating systems to increase the ability of the employees to perform more than one role can help employees overcome issues related to quality (Womack & Jones 1996).. Also, empowering HSC staff to take suitable actions and minimizing centralization will improve decision making at the lowest level of supply chain employees. Empowerment of HSC increases motivation and productivity.

The fourth lean enabler that begs improvement is the consumer relationship. Because patients often rely on the advice of physicians, patients and physicians are considered to be consumers. Medical staff in other hospital departments, such as physicians or pharmacists, play vital roles in making sure the hospital supply chain is lean. Disagreement between physicians, in terms of a certain type of medicine, slows supply chain processes and increases delivery lead time. Physician Preference Items (PPIs) constitute 40% of total medical supply spending for a hospital (Toba et al. 2008) and this can be improved by physicians' buy-in. This is a main area for SC savings, especially with respect to the use of high-cost clinical items and changes in purchases (Toba et al., 2008). Physicians' involvement in continuous improvement is integral to implementing lean successfully within the supply chain. Toba et al. (2008) identified on the role of consumers as value co-creators in hospital supply chains. Also, Consumer relationships can be improved by increasing physician involvement and engagement.

Supplier relationship. Hospital-supplier integration plays an important role in improving hospital supply chain performance (Chen et al. 2013). Additionally, hospital-supplier collaboration has an impact on hospital supply chain performance (Mandal 2017). Enhancing and creating long-term relationships with key suppliers contributes significantly to reducing fluctuation in demand and minimizing medicine shortage. Medical purchases are the key purchases for any healthcare provider, as medical supplies can often constitute more than 40% of a hospital's operating cost. This cost can be improved through SC practices (Nabelsi & Gagnon 2017). Alliance with other healthcare providers is one of the most important factors in reducing the total cost of medical supplies. Group purchasing organizations (GPOs) have provided significant cost saving opportunities for healthcare providers by taking advantage of economies of scale and purchasing from select suppliers/venders for many hospitals at once. GPOs can reduce hospital supply chain costs up to 15%. Hospital supply chain costs

decreased for providers using GPOs, but group purchasing also helped to optimize the supply chain (Jacqueline & Belliveau 2017).

Kwon et al. (2016) indicated that GPOs manage more than 70% of healthcare expenditures. One of the main reasons GPOs are advantageous is that they have a global network of suppliers, which gives healthcare organizations the leverage to access more suppliers. Also cooperation between healthcare organizations plays a vital role in reducing the overall costs of healthcare providers (Nabelsi & Gagnon 2017). Recent developments demonstrate the extent to which SC is gaining the attention of hospital leaders. In the United State of America (USA) and Canada, hospital reforms are prompting a number of departments (such as materials management) to outsource a part of what were once their traditional activities. Most departments turn to a GPO to find main suppliers and negotiate contracts; others use the stockless approach, calling on medical supply distributors to deliver medical products directly to nursing stations (Landry & Beaulieu 2013). The responsiveness of suppliers is a sensitive point for hospitals, as any delay of medical supplies constitutes a possible threat to patients' lives. Lead-times of medical supplies and unpredictable patient demand are key points that should be dealt with seriously.

To combat the impact of these inventory management challenges, pharmacy departments located within hospitals carry safety stock. However, building up safety stock inventory levels may result in shortages of medical supplies due to their short shelf-life (Kitsiou et al. 2007; Bhakoo et al. 2012; Krichanchai and MacCarthy 2016; Chung & Kwon 2016). Medical shortages put patient health at risk, and possible medication errors, non-treatment and under-treatment can result from attempts to substitute missing medicines. Medicine and equipment shortages have been increasing in recent years (Hedman, 2016). Shortages of medicines and technologies can be avoided by improving coordination between countries, while an end-to-end approach across the healthcare system is needed to mitigate the impact on patients and public health. Global healthcare leaders will be required to improve access to needed medicines in healthcare systems and will need to develop an approach to market shaping in collaboration with global partners. In addition, work will need to be done among global industry representatives and professional associations to develop good standards practices in managing shortages. Moreover, information technology systems that facilitate the collection of information need additional support. Using GS1 as an example for standardized bar coding is acknowledged as significant and feasible (Hedman, 2016).

Approval results/ Validation

After calculating the supply chain leanness index and high-lighting weaker areas for further improvement for the healthcare organization, five experts were asked to provide their professional opinion on the status of leanness in the supply chain. Table 1.3 outlines those experts' responses.

Table 1.3 Experts Opinion

Question	experts					Average rating in Likert's scale of range 0-10
	E_1	E_2	E_3	E_4	E_5	
To what extent the index computed presents the reality?	9	8	7	8	9	8.2
To what extent the improvement areas reflect the current position of supply chain in organization (A) in terms lean?	8	7	9	8	8	8.0
To what extent using multi-grade fuzzy approach is practically feasible and adoptable in supply chain in organization (A)?	9	8	8	8	9	8.4

Conclusion

The assessment of leanness in healthcare organizations is gaining vital significance. An innovative model has been developed for assessing the lean level at supply chains in healthcare organizations. The model has been validated via five knowledgeable and experienced employees. The supply chain leanness was calculated for the healthcare organization based on the weight (relative importance) and score assessment by experienced staff from a Saudi healthcare organization. Then, further improvements have been were suggested for implementing lean practices in the supply chain. The supply chain index identifies the gap between the current situation and the desired state, assisting which helps in understanding and determining attributes for further improvements.

Although the developed model has been validated in a single healthcare organization, the interviews indicated that similar results should be expected in the sector in Saud Arabia. The results of this study confirm previous studies that mentioned lean practices is still in early stage in Saudi Arabia. There is an opportunity for future researchers to investigate lean practices in other Saudi industries and in other Middle East countries as well.

The present study have some limitations, which can formulate the future agenda for further research. As mentioned already, the model has been validated for only one case (single healthcare organization). Thus, in future, more case studies should be investigated. Moreover, the research was conducted for public healthcare organization managed by Saudi Ministry of Health (MOH). Other healthcare organizations operated by different healthcare systems (such as hospitals working under the ministry of defence and hospitals working under the ministry of interior) should be examined to investigate the impact of healthcare system on the level of lean implementation. In addition, the study was constrained to public healthcare organization in Saudi Arabia. Therefore, findings of this study should be validated in other developing countries to ensure that the developed model works consistency in a different context. Therefore, the developed model can be used in the healthcare organization in different

developing countries. Finally, the study was conducted on an organization that has been already accredited by both the Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI) and the Joint Commission International (JCI). Examining the relationship between achieving accreditation by quality institutional bodies and the level of lean implementation in healthcare organizations can be one more research question worth answering.

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Appendix A

How to calculate lean index by using multi-grade fuzzy logic

There are four steps should be followed to assess leanness in supply chain:

1. Computing the weight (relative importance) for
   I. Enablers
   II. Criterions
   III. Attributes
2. Computing the index for each criterion.
3. Computing the indices for each enabler.
4. Computing supply chain leanness (SCL) for an organization.

The five experts from the organization have been identified to participate in the assessment process based on their ability to participate and their experience. The aim of the assessment tool has been explained clearly to all experts. Every expert was kindly asked to answer the Microsoft Excel assessment tool independently.

Calculating the Weight for each Enabler

Due to the small sample size, mean has not been used instead the median was used in computing the weight in order to avoid the impact of the outliers and sensitivity to extreme points related to mean. Before calculate the median, put all the numbers in order from the smallest to largest. The **median formula** is $\{(n + 1) \div 2\}$, where "n" is the number of items in the set.

By computing the median for each enabler, the weight (relative importance) of each enabler was calculated. For instance, the weights given by the experts for medical management responsibility leanness enabler was: 30%, 20%, 20%, 30% and 30%. By using the median, the weight (relative importance) for medical management responsibility leanness was 30%. By adopting the same procedures, the weight (relative importance) for the rest enablers was calculated.

Calculating the Weight for each Criteria

The second step in the assessment is computing the weight (relative importance) for each criterion by calculating the median also. For instance, the weights given by experts for hospital

leadership criterion were: 55%, 65%, 70%, 70% and 65% as illustrated in Figure. Therefore, the weight of the hospital leadership criterion was computed to be 65% using median.

Calculating the Weight for each Attribute

By using the same procedures, the third step in the assessment is computing the weight (relative importance) for each attribute by calculating the median also. Finally, the experts provided assessment scores for each attribute.

Primary assessment calculation

The computation pertaining to 'hospital leadership' criterion is illustrated as follows:
Weights pertaining to the hospital leadership criterion W_{11} = (0.3, 0.2, 0.3, 0.1, and 0.1) and the assessment scores for the same criterion is given by the following matrix:

$$\mathbf{R_{11}} = \begin{vmatrix} 4 & 3 & 4 & 3 & 3 \\ 3 & 5 & 4 & 4 & 5 \\ 3 & 3 & 3 & 4 & 3 \\ 4 & 2 & 4 & 3 & 4 \end{vmatrix}$$

$$\boldsymbol{I_{11}} = (0.3, 0.2, 0.3, 0.1, 0.1) \times \begin{vmatrix} 4 & 3 & 4 & 3 & 3 \\ 3 & 5 & 4 & 4 & 5 \\ 3 & 3 & 3 & 4 & 3 \\ 4 & 2 & 4 & 3 & 4 \end{vmatrix}$$

$$= (3.50, 3.20, 3.70, 3.50, 3.60)$$

Using the same principle, the following indices relating to the reset lean criteria have been calculated as illustrated in Table 1.4

Table 1.4 Indices of the Criteria

Symbol	E_1	E_2	E_3	E_4	E_5	$E_{Average}$
I_{11}	3.50	3.20	3.70	3.50	3.60	3.48
I_{12}	3.80	4.20	3.40	3.20	3.20	3.65
I_{21}	3.35	3.65	3.35	3.65	3.35	3.50
I_{22}	3.55	4.00	3.75	3.75	3.75	3.76
I_{31}	3.35	3.65	3.35	3.65	3.35	3.50
I_{32}	3.45	4.25	3.85	3.00	3.70	3.64
I_{41}	4.30	3.00	3.40	3.80	4.30	3.63
I_{42}	3.55	3.05	3.85	3.95	4.00	3.60
I_{51}	3.30	3.50	3.70	3.60	3.70	3.53

I_{52}	4.00	4.00	4.10	3.60	3.30	3.93

Table 1.5 shows assessment and weights provided by experts to enablers, criteria, and attributes.

Table 1.5 Weights and Assessment Scores

I_i	I_{ij}	I_{ijk}	E_1	E_2	E_3	E_4	E_5	W_{ij}	W_i	W
I_1	I_{11}	I_{111}	4	3	4	3	3	0.30	0.65	0.3
		I_{112}	3	5	4	4	5	0.20		
		I_{113}	3	3	3	4	3	0.30		
		I_{114}	4	2	4	3	4	0.20		
	I_{12}	I_{121}	4	3	4	3	3	0.20	0.35	
		I_{122}	4	4	3	3	4	0.40		
		I_{123}	3	5	3	4	2	0.20		
		I_{124}	4	5	4	3	3	0.20		
I_2	I_{21}	I_{211}	3	3	5	3	3	0.25	0.5	0.2
		I_{212}	5	5	3	4	6	0.20		
		I_{213}	6	5	5	4	5	0.15		
		I_{214}	2	4	4	2	2	0.20		
		I_{215}	4	5	3	3	3	0.20		
	I_{22}	I_{221}	2	4	3	3	4	0.30	0.5	
		I_{222}	5	6	4	5	4	0.15		
		I_{223}	4	3	5	4	5	0.20		
		I_{224}	4	4	3	4	3	0.25		
		I_{225}	4	3	5	3	2	0.10		
I_3	I_{31}	I_{311}	3	4	3	2	3	0.35	0.5	0.2
		I_{312}	4	3	4	5	4	0.35		
		I_{313}	3	4	3	4	3	0.30		
	I_{32}	I_{321}	4	4	5	3	4	0.45	0.5	
		I_{322}	3	5	4	3	4	0.25		
		I_{323}	3	4	2	3	3	0.30		
I_4	I_{41}	I_{411}	4	3	4	5	4	0.40	0.3	0.2
		I_{412}	5	3	3	4	5	0.30		
		I_{413}	4	3	3	2	4	0.30		
	I_{42}	I_{421}	4	3	4	4	4	0.30	0.7	
		I_{422}	4	4	5	3	5	0.25		
		I_{423}	3	3	4	4	3	0.25		
		I_{424}	3	2	2	5	4	0.20		

I_5	I_{51}	I_{511}	3	4	4	3	4	0.30	0.6	0.1
		I_{512}	4	5	3	5	3	0.30		
		I_{513}	3	2	4	3	4	0.40		
	I_{52}	I_{521}	5	4	3	3	3	0.20	0.4	
		I_{522}	4	5	5	4	4	0.30		
		I_{523}	3	4	4	3	3	0.20		
		I_{524}	4	3	4	4	3	0.30		

Secondary assessment calculation

The index relating to criterion can be calculated by using the following formula:

$$I_i = W_i \times R_i \text{ ---------- (2)}$$

For instance, the calculation pertained to leadership criterion for supply chain in organization (A) is illustrated as follows:

Weights pertaining to the management responsibility leanness enabler $W_1 = (0.65, 0.35)$ and the assessment scores for the same criterion is given by the following matrix:

$$R_1 = \begin{vmatrix} 3.50 & 3.20 & 3.70 & 3.50 & 3.60 \\ 3.80 & 4.20 & 3.40 & 3.20 & 3.20 \end{vmatrix}$$

$$I_1 = (0.65, 0.35) \times \begin{vmatrix} 3.50 & 3.20 & 3.70 & 3.50 & 3.60 \\ 3.80 & 4.20 & 3.40 & 3.20 & 3.20 \end{vmatrix}$$

= (3.61 3.55 3.60 3.40 3.46)

Using the same principle, the following indices relating to the reset lean enablers have been calculated as illustrated in Table 1.6

Table 1.6 Indices of the Enablers

Symbol	E_1	E_2	E_3	E_4	E_5	Average
I_1	3.61	3.55	3.60	3.40	3.46	3.52
I_2	3.45	3.83	3.55	3.70	3.55	3.62
I_3	3.40	3.95	3.60	3.33	3.53	3.56
I_4	3.42	4.07	3.70	3.20	3.60	3.60
I_5	3.58	3.70	3.86	3.60	3.54	3.66

Secondary assessment calculation

The overall value of leanness index in supply chain for supply chain in organization (A) was calculated using the following formula:

$$\boldsymbol{I} = \mathbf{W} \times \mathbf{R} \text{---------- (3)}$$

Overall weight $\mathbf{W} = (0.3, 0.2, 0.3, 0.1, 0.1)$

Overall assessment vector $\mathbf{R} =$

$$\begin{vmatrix} 3.61 & 3.55 & 3.60 & 3.40 & 3.46 \\ 3.45 & 3.83 & 3.55 & 3.70 & 3.55 \\ 3.40 & 3.95 & 3.60 & 3.33 & 3.53 \\ 3.42 & 4.07 & 3.70 & 3.20 & 3.60 \\ 3.58 & 3.70 & 3.86 & 3.60 & 3.54 \end{vmatrix}$$

Leanness index in supply chain for organization (A) $= \mathbf{W} \times \mathbf{R} \text{---------- (4)}$

$$\boldsymbol{I} = (0.3, 0.2, 0.3, 0.1, 0.1) \times \begin{vmatrix} 3.61 & 3.55 & 3.60 & 3.40 & 3.46 \\ 3.45 & 3.83 & 3.55 & 3.70 & 3.55 \\ 3.40 & 3.95 & 3.60 & 3.33 & 3.53 \\ 3.42 & 4.07 & 3.70 & 3.20 & 3.60 \\ 3.58 & 3.70 & 3.86 & 3.60 & 3.54 \end{vmatrix}$$

$$\boldsymbol{I} = \mathbf{3.49 \ , 3.80 \ , 3.63 \ , 3.42 \ , 3.53}$$

$$\boldsymbol{I} = \frac{1}{5} (3.49+3.80+3.63+3.42+3.53)$$

$\boldsymbol{I}_{\text{Aver.}} = \mathbf{3.58 \in (2.01\text{- }4).}$

Leanness index in supply chain for organization (A) is 3.58 and $3.58 \in (2.01\text{- }4)$. The overall outcome indicates that supply chain in organization is not lean.



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2018-07-20
Emerald
https://doi.org/10.1108/IJLSS-03-2018-0027
Abdulaziz Marzouq Almutairi, Konstantinos Salonitis and Ahmed Al-Ashaab. Assessing the leanness of a supply chain using multi-grade fuzzy logic: a health-care case study. International Journal of Lean Six Sigma, Volume 10, Issue 1, 2019, pp. 81-105

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