Assessment of Servitization Leagility Using Multi-Grade Fuzzy Approach

Moustafa Elnadi

Lecturer, Business Administration Department
, Faculty of Commerce, Mansoura University, Mansoura, Egypt
elnadimoustafa@gmail.com

Assessment of Servitization Leagility Using Multi-Grade Fuzzy Approach

Abstract

In today's dynamic business environment manufacturing companies face many challenges such as: global competition, market uncertainty, and changing customer's needs. In order to survive manufacturing companies are moving toward new manufacturing paradigms to develop their competitive abilities.

Manufacturing leagility that combines the advantages of both lean and agility in one unit drive the interest of many manufacturing companies as one of the important strategies to be implemented.

This paper presents the first attempt to propose an index to compute servitization leagility in a UK manufacturing company via structured model consisting of leagility enablers, criteria, as well as, attributes using multi-grade fuzzy approach. Fuzzy logic has been applied to deal with linguistic judgments. By using the model, the servitization leagility index was computed for the case company. Then, future opportunities which require special managerial attention toward improving servitization leagility degree were identified as well.

The validation of the case study results confirms the quite easy applicability and feasibility of the proposed model in measuring servitization leagility effectively.

Keywords: Leagility; servitization; assessment; fuzzy logic

1. Introduction

In today's competitive and global market, as well as, changing customers' needs and demand uncertainty, manufacturing companies follow various modern manufacturing initiatives to improve their core competitiveness. Among these improvement initiatives are lean manufacturing, agile manufacturing, leagility and servitization. Such new initiatives allow manufacturing companies to succeed in their severe competitive environment.

After publishing the book "The Machine that changed the world" by (Womack *et al.*, 1990), lean techniques gained the advantage over other traditional manufacturing techniques such as mass production and craft production.

Moreover, lean manufacturing is widely accepted by many manufacturing companies due to its ease of application and its efficient results (Simpson and Power, 2005; Pagliosa *et al.*, 2019). The principles of lean manufacturing are based on the Toyota Production System (TPS) and emphasized doing more with less (Womack and Jones, 1996; Elnadi and Shehab, 2016).

By applying lean principles manufacturing companies can get rid of seven types of wastes, these wastes include: unnecessary transport, waiting, over-production, unnecessary motion, over-processing, unnecessary inventory and defects (Elnadi and Shehab, 2015; Shah and Ward 2007). Lean manufacturing can be viewed as a group of practices used by manufacturing and non-manufacturing companies to organize and control production processes by eliminating non-value-added activities (Womack and Jones, 1996; Schonberger, 2007; Pagliosa *et al.*, 2019; Burch and Smith, 2019).

Womack and Jones (1996) mentioned that lean manufacturing is based on five foundations namely: determining customer value, mapping the value stream, creating production flow, using pull techniques, and finally striving to perfection.

Although many academics and practitioners have been researching lean manufacturing, it is difficult to find a concise definition that everyone agrees on. Regardless of the various definitions of lean manufacturing, the main idea beyond lean practices is determining the value of any process through the continuous detecting and elimination of wastes and non-

value-added activities from the manufacturing process. There are a wide variety of lean tools that can be used, some of these tools include: Value Stream Mapping (VSM), Total Quality Management (TQM), Kaizen, 5s, Just-In-Time (JIT) and Total Productive Maintenance (TPM) (Camacho-Miñano *et al.*, 2013; Elnadi and Shehab, 2015; Sanders at al., 2017; Pagliosa *et al.*, 2019).

On the other hand, the concept of agile manufacturing was propounded in 1991 by a group of scholars at Iaccoca Institute of Lehigh University in the USA. Since then, the concept of agility has received increasing attention among practitioners and academics alike (Yusuf *et al.*, 1999; Bottani, 2009; Vaishnavi *et al.*, 2019).

Agile manufacturing can be defined as the ability of a manufacturing company to operate profitably in a competitive and dynamic market environment with ever-changing and unpredictable customers' demand and requirements while controlling costs and quality (Katayama and Bennett, 1999; Christopher and Towill, 2000; Sherehiy, 2009; Vaishnavi *et al.*, 2019). Therefore, the main idea beyond agility is adaptability and flexibility while responding quickly and effectively to changing markets (Gunasekaran, 1999; Yusuf *et al.*, 1999; Sherehiy *et al.*, 2009).

Sharifi and Zhang (2001) mentioned that agility includes reacting to changes in a correct and timely manner, as well as, taking advantage of changes and use them as opportunities.

There are four main pillars of agility namely: customer and market focus, flexible employees, flexible technology, and strategic planning (Khatri and Dangayach, 2018; Gunasekkaran, 2009).

Manufacturing companies use agile manufacturing to improve their capabilities to face continuous changes. Such changes can occur in markets, in technologies, in business relationships and in all aspects of the enterprise (Kale *et al.*, 2019).

Researchers proposed that neither lean or agile is better nor worth than the other. Both lean and agile can be used together to ensure the advantages of both. The integration of lean and agility led to a hybrid strategy known as leagility (Naylor *et al.* 1999, Vinodh and Prasanna 2011, Vinodh and Aravindraj, 2013).

Leagility enables manufacturing companies to gain the advantages of both lean and agile systems, in order to exploit market opportunities in a cost-efficient manner (Mason-Jones *et al.*, 2000, Prince and Kay, 2003, Potter *et al.*, 2015; Gaudenzi and Christopher, 2016). The main idea beyond leagility is not only to quickly respond to customer needs but also, keeping costs at the minimum level in volatile market.

Lean is an optimal strategy when demand is anticipated and the variety of the product is low, while agile is suitable with less predictable demand and high variety products (Naylor *et al.*, 1999; Christopher and Towill, 2000; Mason-Jones *et al.*, 2000).

In addition to leagility, many manufacturing and non-manufacturing companies have applied servitization as a strategy to achieve growth, profitability, and economic stability (Calabrese *et al.*, 2019). For example, Toyota uses 'Do not buy a forklift', Rolls-Royce applies 'Total Care Package' and 'Power by the Hour'. Also, Xerox implement documentation management business model rather than buying their machines (Wang *et al.*, 2011; Elnadi and Shehab, 2016; Wang *et al.*, 2018).

Servitization is about providing an integrated products and services package with the sale of use instead of the sale of the product that can fulfill the specific needs of customers (Tukker & Tischner, 2006; Elnadi and Shehab, 2016; Elnadi and Shehab, 2015).

Baines *et al*, (2007) defined servitization as "The innovation of an organization's capabilities and processes to better create mutual value through a shift from selling product to selling product service system". By applying servitization manufacturing companies can achieve higher opeating efficiency, economic stability, profitability and improved strategic position. Similarly, customers will benefit from shifting the risk of owning the product to the supplier of the product. Additionally, customers will enjoy payment schemes instead of paying the total price of the product at once (Mont, 2002; Cook *et al.*, 2006; Tukker and Tischner, 2006; Baines *et al.*, 2007; Maussang *et al.*,2009).

There are three degrees of implementing servitization starting from the traditional way of selling the product with additional services provided to customers (Product-oriented). Motiving to the second degree namely (Use-oriented) that focuses on the sale of use or the availability of the product through activities like leasing or sharing. Finally,

the highest degree of implementing servitization which is (Result-oriented) focusing on selling the functionality or end results instead of the product (Tukker, 2004; Tukker and Tischner, 2006; Baines *et al.*, 2007; Sakao *et al.*, 2009; Yang *et al.*, 2009; Elnadi and Essam, 2016).

This article has the following form. Literature review on leagility evaluation and assessment is discussed in Section 2. Section 3 presents the research methodology used in this study. Section 4 provides an explanation of the model. Computing the servitization leagility index and identifying improvements areas are shown in sections 5 and 6. The results are validated in Section 7. Finally, the conclusion of this study is presented in section 8.

2. Literature review

An exhaustive literature of the extant literature was conducted to identify the various models and techniques used in the assessment of leagility. One of the key articles that influenced the leagile arena introduced by Naylor *et al.*, (1999).

Naylor *et al.*, (1999) compared lean and agile presenting the similarities and differences between the two paradigms. The authors introduced the concept of supply chain leagility by integrating lean and agile using case studies from Hewlett Packard Company and a personal computer manufacturer, considering market demand and lead time reduction, eliminating wastages and making improvements in scheduling.

By using fuzzy logic approach Vinodh and Araindraj (2013) assessed the leagility of an Indian manufacturing supply chain. They developed a leagility model embedded with lean and agile principles. Azevedo *et al.*, (2012) presented Agilean Index to evaluate the agility and leanness of manufacturing companies in the Automobile industry. Delphi technique was used to develop the Agilean index. Moreover, Agarwal *et al.*, (2006) introduced a framework that assess the relation and interdependency between the enablers, criteria, and attributes of both lean and agile across a supply chain leagility model. They developed the model by using the Analytical Network Process (ANP) in the context of fast-moving consumer goods business.

Additionally, Huang and Li (2010) proposed a model of assessing supply chain leagility using data collected from personal computer original equipment manufacturer in Taiwan. By using the proposed model, the case company achieved leagility through reengineering its supply chain.

In the Indian manufacturing industry, Soni and Kodali (2012) evaluated the reliability and validity of lean, agile and leagile supply chain construction. Also, Virmani *et al.*, (2018) identified leagility Key Performance Indicators (KPIs) using Fuzzy TISM approach, as well as, the relationship between these KPIs were determined.

Additionally, Matawale *et al.*, (2016) developed a Fuzzy Overall Performance Index to measure the leagility of a manufacturing company. The structured framework made up of three levels namely: leagile capabilities, attributes, as well as, criterion. Haq and Boddu (2017) identified the most appropriate leagility enablers that can be used by manufacturing companies in order to succeed in implementing leagility. The main enablers and attributes of leagility were identified using Fuzzy logic, in addition to QFD. Likewise, by using Simulated Annealing (SA) Banerjee and Ganjeizadeh (2017) developed an index to assess the degree of leagility. Also, Fadaki *et al.*, (2019) introduced an index med (DFL) Deviation from leagility using the partial least squars (PLS) method.

The assessment of leagility was not exclusive only in the manufacturing industry, but some researchers developed models to evaluate and assess leagility in non-manufacturing sectors. For instance, Rahimnia *et al.*, (2009) examined the extent to which leagility principles can be applied in the service sector like fast Food Restaurant Chains. The study found that the case company gained the advantages of both lean and agile paradigms and serve the customer with short lead times, low costs and high variety. Additionally, Rahimnia and Moghadasian (2010) presented how leagility can be applied in healthcare. They mentioned the critical role of human resources when applying leagility in the healthcare delivery system. In the same way, Mishra *et al.*, (2019) developed an approach for implementing leagility in chronic care. The study found that lean strategy is suitable in some areas such as: (oral medicines, nursing- items and food

supplements) while leagile strategy is suitable for other areas such as: (insulin, assistive technologies, and diabetic footwear).

Although there was extensive work published on leagility and its assessment in the manufacturing and the non-manufacturing sectors, few attempts were made to develop a model or instrument that an be used in assessing servitization leagility. Consequently, the purpose of this paper is to develop a model that can be used in calculating servitization leagility index to determine the degree of leagility implementation in the service offering process. Additionally, validating the mode via a real-life case study.

3. Research Methodology

The servitization leagility assessment model was developed in a consecutive way that includes different steps as presented in Figure 1. In the first step, an extensive literature review was conducted on lean, agile and leagility assessment to develop the initial model that can be used in the assessment process. In the second step, semi-structured interviews were held independently with five academic researchers working in agile, lean and leagility project. Each interview took about 60 minutes. The aim of these interviews was to take the researchers' opinion about the model, its structure and how the servitization leagility index will be calculated. These interviews ended up with the model's second version. In the same manner, in the third step semi-structured interviews also were conducted with industry experts involved in lean and agile projects and working in different manufacturing sectors (transportation, aerospace, trucks and buses, document management) in the UK. Each interview took about one hour to discuss the model, its structure and ability to calculate the level of servitization leagility. These interviews culminated in refining the second version of the model, where some items were added, and others were deleted or modified. Moving to the fourth step, where a suitable company was identified to conduct the case study. According to (Yin, 2017) case study approach is suitable when more in-depth details are required about a set of events over which the investigation has little or no control. The collection of the data from the case company was conducted in the fifth step. Additionally, the servitization leagility index was calculated, as well as, the required improvement areas were determined. Finally, in the last step results were validated.

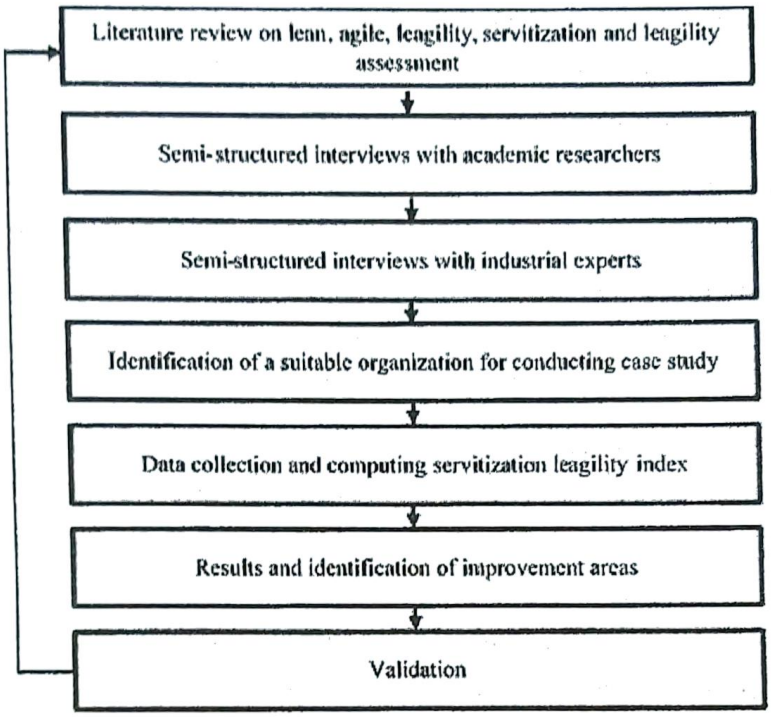

Figure 1. Research Methodology

4. Servitization Leagility Assessment Model

The assessment model comprises three main levels namely: enablers, criteria, and attributes. In the first level there are five basic leagility enablers founded on the literature review:

- Collaborative relationship.
- Management leagility.
- Workforce leagility.
- Process excellence, and finally
- Customer and market sensitivity.

These enablers present the required capabilities and resources that considered crucial for the successful implementation of leagility in the service offering process. In the second level there are 14 leagility criteria that are consider vital to enhance the organization's

capabilities to implement servitization leagility and used as guidelines in assessing the enablers. Finally, there are 53 attributes that present the required characteristics and practices to be performed in order to apply servitization leagility. Moreover, these attributes are used in evaluating criteria.

The servitization leagility index calculation is carried out in successive steps. Each level's assessment depends on the previous level's assessment. The total servitization leagility index equal to the total indices calculated for enablers, and the index of each enabler equal to the total indices calculated for each criterion pertaining to that enabler. In the same way, the index of each criterion is the sum of indices computed for each attribute.

As an example, the management leagility enabler has been explained. The major criteria of management leagility are: nature of management, devolution of authority and organizational structure. The nature of management criteria includes attributes such as: a top management commitment and involvement, transparent information sharing, frequent management employees meeting, participative management style and rapid evaluation and implementation of employees' suggestions. Appendix I presents all the enablers, criteria and attributes used.

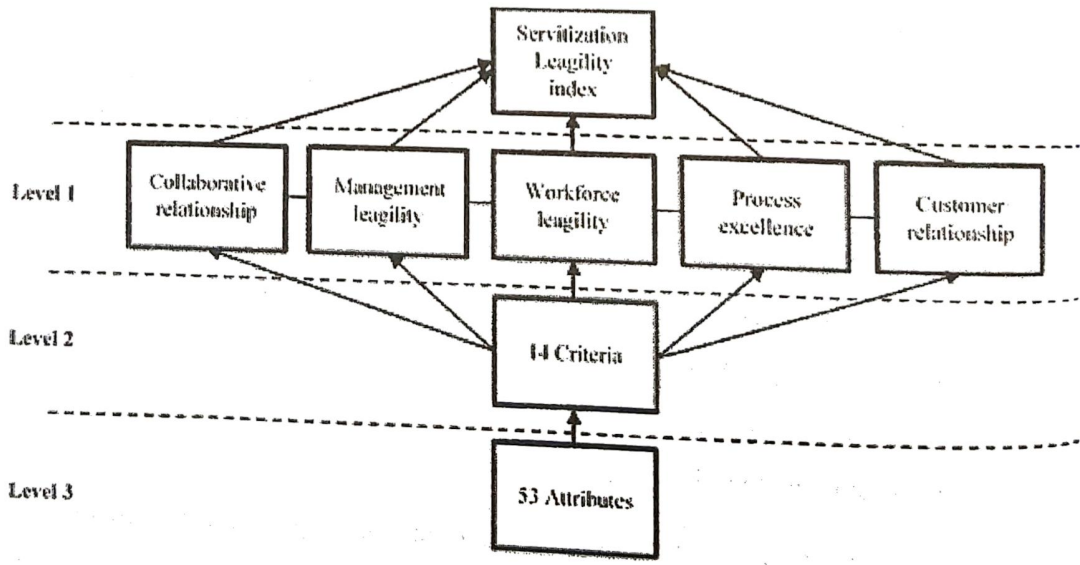

Figure 2. Servitization Leagility Assessment Model

5. Case study Validation

5.1. About the case company

The model has been validated in a UK manufacturing company, this company is specialised in manufacturing commercial heavy vehicles such as, trucks and buses. This company is considered one of the leading international providers of efficient commercial vehicles with European market share of 14.5% in 2018. The name of the company will not be revealed due to confidentiality agreements and will be referred to as ABC company.

ABC company can be considered in the early stage of implementing leagility. The company offers their customers with extensive one-stop shopping services such as: repair and service arrangements, fleet management, customized financing, leasing and insurance, adjustable rental options and different customized services.

5.2. Assessment of ABC Servitization Leagility

This section presents the steps and equations used in the assessment process to calculate ABC Company servitization leagility index. Ten experts participated in the assessment process as presented in Table 1.

Table 1. Experts Participated in the Assessment Process

Experts	Job Title	Years of Experience
1	Chief Financial Officer	22
2	HR Director	26
3	Operation Manager	25
4	CEO	40
5	CRM Manger	23
6	Financial Controller - Operations	15
7	Head of Service	30
8	Head of Parts	29
9	Sales Director	35
10	Director Aftersales	40

ABC Company's servitization leagility index presented by (I) equal to the product of the overall assessment factor (R) and the overall weight (W)

$$I = W \times R$$

ABC Company's Servitization Leagility index will range from 0 to 10 as follow:

(Less than 2)	(2-4)	(4-6)	(6-8)	(8-10)
Extremely not leagile	**Not leagile**	**Generally leagile**	**Leagile**	**Extremely leagile**

The evaluation process started with an introductory session with the ten experts. this session included an explanation of the model, presenting its importance and its structure. Also, an illustration of how the servitization leagility index will be calculated and how the experts will complete the questionnaire were presented. This introductory session lasted for about one hour and it was in the company head office.

Following this introductory session, the experts were asked to complete the questionnaire independently. Each expert took from 30 to 45 minutes to complete the questionnaire. Later, all the collected data were transferred into one Excel sheet to start the calculation of servitization leagility index as presented in the following steps:

- Step (1) Determining each enabler, criterion, and attribute weight (relative importance).
- Step (2) Identifying each criterion index
- Step (3) Calculating each enabler index
- Step (4) Computing the total servitization leagility index for the case company

Step (1) Determining each enabler, criterion, and attribute weight (relative importance)

Because of the small sample size and to avoid the influence of the outliers and extreme values related to using mean, median was used to calculate the weight (relative importance). In Table 2 all the weights (relative importance) for each enabler, criterion and attributes are summarized. Additionally, all the experts' evaluation scores of each attribute are presented.

Step (2) Identifying each criterion index

The calculation of the enterprise wide relationship criterion index is shown follows:

Enterprise wide relationship criterion weights $W_{11} = (0.3, 0.15, 0.15, 0.2, 0.2)$

Enterprise wide relationship assessment scores is given by

$$R_{11} = \begin{bmatrix} 8 & 3 & 6 & 6 & 5 & 4 & 6 & 6 & 4 & 8 \\ 4 & 4 & 5 & 7 & 4 & 4 & 5 & 4 & 3 & 3 \\ 7 & 7 & 5 & 8 & 7 & 7 & 0 & 5 & 4 & 10 \\ 7 & 7 & 4 & 7 & 5 & 7 & 4 & 5 & 4 & 7 \\ 6 & 7 & 7 & 5 & 9 & 8 & 5 & 4 & 9 & 9 \end{bmatrix}$$

Index pertaining to enterprise wide relationship criterion is given by

$$I_{11} = W_{11} \times R_{11}$$

$$I_{11} = (6.65, 5.35, 5.5, 6.45, 5.95, 5.85, 4.35, 4.95, 4.85, 7.55)$$

By following the same steps, all the remaining criteria indices are calculated and presented in Table 3:

Table 2. Weights and Assessment Scores for ABC Company (Refer to Table 1. For Enablers, Criteria and Attributes)

I_i	I_{ij}	I_{ijk}	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	W_{ij}	W_i	W
I_1	I_{11}	I_{111}	8	3	6	6	5	4	6	6	4	8	0.3	0.4	0.1
		I_{112}	4	4	5	7	4	4	5	4	3	3	0.15		
		I_{113}	7	7	5	8	7	7	0	5	4	10	0.15		
		I_{114}	7	7	4	7	5	7	4	5	4	7	0.2		
		I_{115}	6	7	7	5	9	8	5	4	9	9	0.2		
	I_{12}	I_{121}	3	5	5	7	6	5	4	4	4	5	0.1	0.6	
		I_{122}	3	8	2	7	8	5	3	6	2	5	0.05		
		I_{123}	8	6	6	8	6	6	8	7	5	3	0.4		
		I_{124}	3	3	3	6	6	5	3	4	4	7	0.25		
		I_{125}	3	5	2	5	7	4	3	1	2	5	0.1		
		I_{126}	5	8	3	7	9	6	3	0	3	7	0.1		
I_2	I_{21}	I_{211}	3	5	4	8	9	3	7	2	6	7	0.35	0.4	0.2
		I_{212}	6	3	6	7	6	5	4	5	4	8	0.15		
		I_{213}	7	7	5	7	9	9	3	7	4	8	0.2		
		I_{214}	3	5	4	8	9	3	7	4	6	7	0.2		
		I_{215}	2	5	5	5	5	4	4	3	4	5	0.1		
	I_{22}	I_{221}	5	5	4	8	9	6	7	5	6	7	0.35	0.2	
		I_{222}	8	6	4	7	5	6	7	6	4	5	0.65		
	I_{23}	I_{231}	5	4	6	7	7	6	6	4	6	9	0.4	0.4	
		I_{232}	2	5	5	5	5	4	4	3	4	5	0.15		
		I_{233}	6	3	6	7	6	5	4	5	4	8	0.25		
		I_{234}	5	5	5	6	8	2	3	3	6	9	0.2		
I_3	I_{31}	I_{311}	4	7	6	5	6	6	6	3	6	5	0.2	0.4	0.2
		I_{312}	4	6	6	5	7	6	6	5	5	7	0.2		
		I_{313}	1	2	2	3	1	5	0	0	3	2	0.1		
		I_{314}	3	5	6	7	7	5	8	4	2	2	0.2		
		I_{315}	2	3	6	6	7	6	4	2	3	7	0.3		
	I_{32}	I_{321}	4	6	6	7	6	7	2	5	6	7	0.25	0.6	
		I_{322}	4	5	2	5	5	8	2	4	2	4	0.4		
		I_{323}	7	7	5	7	9	9	3	7	4	8	0.35		
I_4	I_{41}	I_{411}	6	3	6	7	8	5	8	5	3	7	0.4	0.2	0.2
		I_{412}	7	4	4	7	7	5	8	4	5	8	0.3		
		I_{413}	3	3	4	6	7	4	3	7	4	9	0.3		
	I_{42}	I_{421}	1	1	2	3	5	2	4	3	1	3	0.4	0.1	
		I_{422}	2	2	4	3	5	3	5	2	1	4	0.25		
		I_{423}	5	5	5	7	7	5	8	4	4	5	0.35		
	I_{43}	I_{431}	2	4	5	7	5	3	7	5	6	8	0.35	0.4	
		I_{432}	2	2	6	6	5	5	3	7	3	5	0.15		
		I_{433}	3	2	2	6	8	3	8	7	5	8	0.2		
		I_{434}	2	7	4	6	5	3	4	3	2	7	0.3		
	I_{44}	I_{441}	7	7	6	5	6	4	8	6	3	6	0.4	0.3	
		I_{442}	3	3	2	4	3	3	1	3	2	5	0.1		
		I_{443}	5	3	4	5	6	3	3	4	3	5	0.1		
		I_{444}	5	4	4	6	4	4	5	5	4	5	0.1		
		I_{445}	4	2	4	3	9	3	2	2	4	7	0.3		
I_5	I_{51}	I_{511}	4	6	5	7	7	4	6	4	5	8	0.6	0.3	0.3
		I_{512}	7	4	5	5	6	4	4	6	3	9	0.4		
	I_{52}	I_{521}	5	2	5	4	6	2	4	5	2	5	0.3	0.3	
		I_{522}	5	6	4	4	7	2	3	3	3	5	0.3		
		I_{523}	3	5	4	4	7	6	3	6	3	5	0.4		
	I_{53}	I_{531}	7	5	6	6	8	6	6	4	4	4	0.55	0.4	
		I_{532}	6	8	5	6	7	3	7	4	4	9	0.25		
		I_{533}	8	7	5	6	7	3	7	6	3	9	0.2		

I_i I_{ij} W_{ij} I_{ijk} W_{ijk} E_i W

Table 3. Indices of the criteria

	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}
I_{11}	6.65	5.35	5.5	6.45	5.95	5.85	4.35	4.95	4.85	7.55
I_{12}	5.2	5.35	4.25	6.95	6.5	5.4	5.1	4.6	4	4.9
I_{21}	4.15	5.1	4.6	7.35	8.15	4.6	5.45	3.95	5.1	7.15
I_{22}	6.95	5.65	4	7.35	6.4	6	7	5.65	4.7	5.7
I_{23}	4.8	4.1	5.65	6.5	6.65	4.65	4.6	3.9	5.2	8.15
I_{31}	2.9	4.7	5.6	5.5	6.2	5.7	5.2	3	3.8	5.1
I_{32}	5.05	5.95	4.05	6.2	6.65	8.1	2.35	5.3	3.7	6.15
I_{41}	5.4	3.3	4.8	6.7	7.4	4.7	6.5	5.3	3.9	7.9
I_{42}	2.65	2.65	3.55	4.4	5.7	3.3	5.65	3.1	2.05	3.95
I_{43}	2.2	4.2	4.25	6.35	5.6	3.3	5.7	5.1	4.15	7.25
I_{44}	5.3	4.4	4.6	4.4	6.4	3.5	4.7	4.2	3.3	6
I_{51}	5.2	5.2	5	6.2	6.6	4	5.2	4.8	4.2	8.4
I_{52}	4.2	4.4	4.3	4	6.7	3.6	3.3	4.8	2.7	5
I_{53}	6.95	6.15	5.55	6	7.55	4.65	6.45	4.4	3.8	6.25

Step (3) Calculating each enabler index

Collaborative relationship enabler index for example, can be computed by:

$$I_1 = W_1 \times R_1$$

Weight belonging to the collaborative relationship enabler is given by:

$$W_1 = (0.4, 0.6)$$

Assessment scores belonging the collaborative relationship enabler is given by:

$$R_1 = \begin{bmatrix} 6.65 & 5.35 & 5.5 & 6.45 & 5.95 & 5.85 & 4.35 & 4.95 & 4.85 & 7.55 \\ 5.2 & 5.35 & 4.25 & 6.95 & 6.5 & 5.4 & 5.1 & 4.6 & 4 & 4.9 \end{bmatrix}$$

The collaborative relationship enabler index is given by:

$$I_1 = W_1 \times R_1$$

$$I_1 = (5.78, 5.35, 4.75, 6.75, 6.28, 5.58, 4.8, 4.74, 4.34, 5.96)$$

Using the same procedures, all the indices for the remaining enablers have been calculated and presented in Table 4.

Table 4. Indices of the enablers

	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}
I_1	5.78	5.35	4.75	6.75	6.28	5.58	4.8	4.74	4.34	5.96
I_2	4.97	4.81	4.9	7.01	7.2	4.9	5.42	4.27	5.06	7.26
I_3	4.19	5.45	4.67	5.92	6.47	7.14	3.49	4.38	3.74	5.73
I_4	3.815	3.925	4.395	5.64	6.21	3.64	5.555	4.67	3.635	6.675
I_5	5.6	5.34	5.01	5.46	7.01	4.14	5.13	4.64	3.59	6.52

Step (4) Computing the total servitization leagility index

ABC Company's servitization leagility index has been computed as:

Enablers' overall weight $W = (0.1, 0.2, 0.2, 0.2, 0.3)$

Enablers overall assessment vector

$$R = \begin{bmatrix} 5.78 & 5.35 & 4.75 & 6.75 & 6.28 & 5.58 & 4.8 & 4.74 & 4.34 & 5.96 \\ 4.97 & 4.81 & 4.9 & 7.01 & 7.2 & 4.9 & 5.42 & 4.27 & 5.06 & 7.26 \\ 4.19 & 5.45 & 4.67 & 5.92 & 6.47 & 7.14 & 3.49 & 4.38 & 3.74 & 5.73 \\ 3.82 & 3.93 & 4.4 & 5.64 & 6.21 & 3.64 & 5.6 & 4.67 & 3.64 & 6.68 \\ 5.6 & 5.34 & 5.01 & 5.46 & 7.01 & 4.14 & 5.13 & 4.64 & 3.59 & 6.52 \end{bmatrix}$$

The servitization leagility index ABC Company has been calculated as:

$$I = W \times R$$

$$I = (4.853, 4.974, 4.771, 6.027, 6.707, 4.936, 4.912, 4.53, 3.998, 6.485)$$

$$I = \frac{1}{10}(4.853 + 4.974 + 4.771 + 6.027 + 6.707 + 4.936 + 4.912 + 4.53 + 3.998 + 6.485)$$

$$I = 5.2193$$

6. Results and Discussion

Based on the data collected from the case company and the empirical evaluation, the current position of ABC Company was found to be generally leagile with an index of 5.2. This index matches the history of the company in its leagility journey where the company is still in the initial stages of implementing leagility.

The index calculated for the case company indicates that the company should exert extra effort in many areas as presented in Figure 3 to improve its capabilities to be more successful in the implementation of servitization leagility. The calculated indices for the servitization leagility main enablers were as follows:

- Collaborative relationship (5.433)
- Management leagility (5.58)
- Workforce leagility (5.118)
- Process excellence (4.816)
- Customer and market sensitivity (5.244)

ABC company start point should be improving process excellence with the lowest index of (4.81) and relative importance of (20%). Process excellence can be enhanced via:

- Scheduling activities in a proper way.
- Providing employees with training programmes on time management.
- Using lean tools and techniques to determine all the type of wastes.
- Providing more training programs to employees on problem solving techniques.
- Proposing an action plan for every problem.
- Reducing process variation through the usage of statistical tools and techniques.
- Investing more in IT to improve and enhance the performance of the processes.

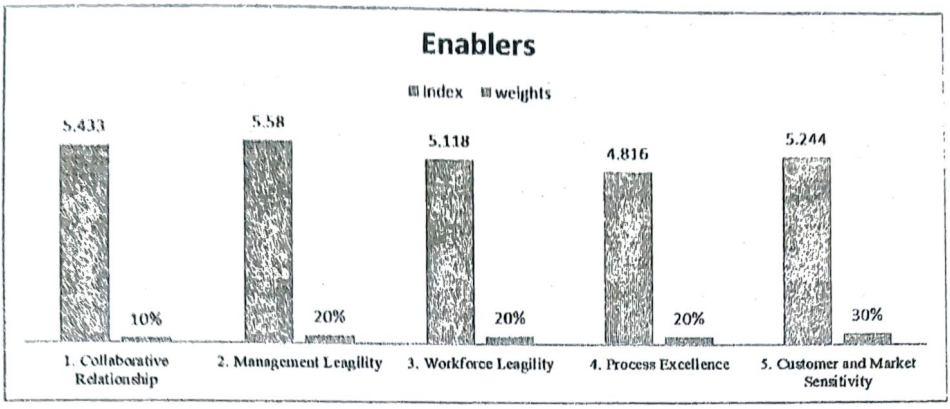

Figure 3. Improvement areas

7. Validation

To prove the applicability and feasibility of the assessment model, two types of validation were carried out. The first one was qualitative validation and the second one was quantitative validation.

7.1. *Qualitative validation*

In a group discussion with the ten experts engaged in the evaluation process, the servitization leagility index as well as areas for further improvements were presented. The experts have been asked if:

- The index represents their views as to what degree leagility had been adopted
- The areas of improvements show the company's present situation.
- There were any missing items or items that should be excluded from the model

The experts argued that the servitization leagility index reflects the current position and situation of the company's activities, moreover there was a consensus between the experts on the proposed improvement areas. Additionally, they declared that the model is inclusive covering all the servitization leagility elements and they did not propose any alterations on the model.

7.2. *Quantitative validation*

At the end of the group discussion, the ten experts were asked to independently fill a validation questionnaire. There were four questions in the validation questionnaire and every expert should choose from a Likert's scale ranging from 0 to 10. By analyzing the answers, it was found that the servitization leagility model is appropriate and can be successfully implemented. All the answers of the experts are presented in Appendix 2.

8. Conclusion

In this paper, literature highlighted that leagility assessment represents an attractive subject for research, most papers focused on developing an assessment model of leagility either on the manufacturing or non-manufacturing sectors with few or no attempts conducted to measure the servitization leagility. Hence, the objective of this paper is to propose a new model that can be used by manufacturing companies to evaluate and assess the degree of servitization leagility implementation by providing a servitization leagility index. In this regard, a combination of both theoretical and empirical methods used to develop the assessment model. Starting from literature review on leagility assessment and ending with calculating the servitization leagility index for a UK manufacturing company. The case company found to be generally leagile and weak areas have been identified as well as improvement areas. The application of the model demonstrated that it is applicable and feasible for assessing the degree of servitization leagility. Therefore, the model has great practical importance with respect to evaluating servitization leagility. Future research can be done across different companies in several sectors and industries to improve the assessment of servitization leagility assessment.

References

AGARWAL, A., SHANKAR, R. and TIWARI, M.K., 2006. Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach. *European Journal of Operational Research,* **173**(1), pp. 211-225.

AZEVEDO, S.G., GOVINDAN, K., CARVALHO, H. and CRUZ-MACHADO, V., 2012. An integrated model to assess the leanness and agility of the automotive industry. *Resources, Conservation and Recycling,* **66**, pp. 85-94.

BAINES, T.S., LIGHTFOOT, H.W., EVANS, S., NEELY, A., GREENOUGH, R., PEPPARD, J., ROY, R., SHEHAB, E., BRAGANZA, A. and TIWARI, A., 2007. State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture,* **221**(10), pp. 1543-1552.

BANERJEE, A. and GANJEIZADEH, F., 2017. Modeling a leagility index for supply chain sustenance. *Procedia Manufacturing,* **11**, pp. 996-1003.

BOTTANI, E., 2009. A fuzzy QFD approach to achieve agility. *International Journal of Production Economics,* **119**(2), pp. 380-391.

CALABRESE, A., LEVIALDI GHIRON, N., TIBURZI, L., BAINES, T. and ZIAEE BIGDELI, A., 2019. The measurement of degree of servitization: literature review and recommendations. *Production Planning & Control,* , pp. 1-18.

CAMACHO-MIÑANO, M., MOYANO-FUENTES, J. and SACRISTAN-DIAZ, M., 2013. What can we learn from the evolution of research on lean management assessment? *International Journal of Production Research,* **51**(4), pp. 1098-1116.

CHAN, F.T. and KUMAR, V., 2009. Performance optimization of a leagility inspired supply chain model: a CFGTSA algorithm-based approach. *International Journal of Production Research,* **47**(3), pp. 777-799.

CHRISTOPHER, M. and TOWILL, D.R., 2000. Supply chain migration from lean and functional to agile and customised. *Supply Chain Management: An International Journal,* **5**(4), pp. 206-213.

COOK, M.B., BHAMRA, T.A. and LEMON, M., 2006. The transfer and application of Product Service Systems: from academia to UK manufacturing firms. *Journal of Cleaner Production,* **14**(17), pp. 1455-1465.

ELNADI, M. and SHEHAB, E., 2016. A multiple-case assessment of product-service system leanness in UK manufacturing companies. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture,* **230**(3), pp. 574-586.

ELNADI, M. and SHEHAB, E., 2015. Main enablers and factors for successful implementation of lean in product-service systems. *International Journal of Agile Systems and Management,* **8**(3-4), pp. 332-354.

GAUDENZI, B. and CHRISTOPHER, M., 2016. Achieving supply chain 'Leagility' through a project management orientation. *International Journal of Logistics Research and Applications,* **19**(1), pp. 3-18.

GHOBAKHLOO, M., FATHI, M., FONTES, DALILA BENEDITA MACHADO MARTINS and TAN CHING, N., 2018. Modeling lean manufacturing success. *Journal of Modelling in Management,* **13**(4), pp. 908-931.

GUNASEKARAN, A., 1999. Agile manufacturing: a framework for research and development. *International Journal of Production Economics,* **62**(1-2), pp. 87-105.

HAQ, A.N. and BODDU, V., 2017. Analysis of enablers for the implementation of leagile supply chain management using an integrated fuzzy QFD approach. *Journal of Intelligent Manufacturing,* **28**(1), pp. 1-12.

HUANG, Y. and LI, S., 2010. How to achieve leagility: A case study of a personal computer original equipment manufacturer in Taiwan. *Journal of Manufacturing Systems,* **29**(2-3), pp. 63-70.

KALE, E., AKNAR, A. and BAŞAR, Ö, 2019. Absorptive capacity and firm performance: The mediating role of strategic agility. *International Journal of Hospitality Management,* **78**, pp. 276-283.

KATAYAMA, H. and BENNETT, D., 1999. Agility, adaptability and leanness: a comparison of concepts and a study of practice. *International Journal of Production Economics,* **60**, pp. 43-51.

KHATRI, A., GARG, D. and DANGAYACH, G.S., 2018. Modelling of Prime Agile Enablers: People, Virtual Integration and Information Technology. *Procedia Manufacturing,* **20**, pp. 464-469.

MATAWALE, C.R., DATTA, S. and MAHAPATRA, S.S., 2016. A fuzzy embedded leagility assessment module in supply chain. *Benchmarking: An International Journal,* **23**(7), pp. 1937-1982.

MAUSSANG, N., ZWOLINSKI, P. and BRISSAUD, D., 2009. Product-service system design methodology: from the PSS architecture design to the products specifications. *Journal of Engineering Design,* **20**(4), pp. 349-366.

MISHRA, V., SAMUEL, C. and SHARMA, S.K., 2019. Lean, agile and leagile healthcare management–A case of chronic care. *International Journal of Healthcare Management,* **12**(4), pp. 314-321.

MONT, O.K., 2002. Clarifying the concept of product–service system. *Journal of Cleaner Production,* **10**(3), pp. 237-245.

NARASIMHAN, R., SWINK, M. and KIM, S.W., 2006. Disentangling leanness and agility: an empirical investigation. *Journal of Operations Management,* **24**(5), pp. 440-457.

NAYLOR, J.B., NAIM, M.M. and BERRY, D., 1999. Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain. *International Journal of Production Economics,* **62**(1-2), pp. 107-118.

PAGLIOSA, M., TORTORELLA, G. and FERREIRA, J.C.E., 2019. Industry 4.0 and Lean Manufacturing. *Journal of Manufacturing Technology Management,* .

POTTER, A., TOWILL, D.R. and CHRISTOPHER, M., 2015. Evolution of the migratory supply chain model. *Supply Chain Management: An International Journal,* **20**(6), pp. 603-612.

PRINCE, J. and KAY, J.M., 2003. Combining lean and agile characteristics: creation of virtual groups by enhanced production flow analysis. *International Journal of Production Economics,* **85**(3), pp. 305-318.

RAHIMNIA, F. and MOGHADASIAN, M., 2010. Supply chain leagility in professional services: how to apply decoupling point concept in healthcare delivery system. *Supply Chain Management: An International Journal,* **15**(1), pp. 80-91.

RAHIMNIA, F., MOGHADASIAN, M. and CASTKA, P., 2009. Benchmarking leagility in mass services: The case of a fast food restaurant chains in Iran. *Benchmarking: An International Journal,* **16**(6), pp. 799-816.

SAKAO, T., ÖLUNDH SANDSTRÖM, G. and MATZEN, D., 2009. Framing research for service orientation of manufacturers through PSS approaches. *Journal of Manufacturing Technology Management,* **20**(5), pp. 754-778.

SANDERS, A., SUBRAMANIAN, K.R., REDLICH, T. and WULFSBERG, J.P., 2017. Industry 4.0 and lean management–synergy or contradiction? *IFIP International Conference on Advances in Production Management Systems* 2017, Springer, pp. 341-349.

SCHONBERGER, R.J., 2007. Japanese production management: An evolution—With mixed success. *Journal of Operations Management,* **25**(2), pp. 403-419.

SERRANO, I., OCHOA, C. and CASTRO, R.D., 2008. Evaluation of value stream mapping in manufacturing system redesign. *International Journal of Production Research,* **46**(16), pp. 4409-4430.

SHAH, R. and WARD, P.T., 2007. Defining and developing measures of lean production. *Journal of Operations Management,* **25**(4), pp. 785-805.

SHAH, R. and WARD, P.T., 2003. Lean manufacturing: context, practice bundles, and performance. *Journal of Operations Management,* **21**(2), pp. 129-149.

SHARIFI, H. and ZHANG, Z., 2001. Agile manufacturing in practice-Application of a methodology. *International Journal of Operations & Production Management,* **21**(5/6), pp. 772-794.

SHEREHIY, B., KARWOWSKI, W. and LAYER, J.K., 2007. A review of enterprise agility: Concepts, frameworks, and attributes. *International Journal of Industrial Ergonomics*. **37**(5), pp. 445-460.

SIMPSON, D.F. and POWER, D.J., 2005. Use the supply relationship to develop lean and green suppliers. *Supply chain management: An international Journal*, **10**(1), pp. 60-68.

SONI, G. and KODALI, R., 2012. Evaluating reliability and validity of lean, agile and leagile supply chain constructs in Indian manufacturing industry. *Production Planning & Control*, **23**(10-11), pp. 864-884.

TUKKER, A., 2004. Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. *Business strategy and the environment*, **13**(4), pp. 246-260.

TUKKER, A. and TISCHNER, U., 2006. Product-services as a research field: past, present and future. Reflections from a decade of research. *Journal of Cleaner Production*, **14**(17), pp. 1552-1556.

VAISHNAVI, V., SURESH, M. and DUTTA, P., 2019. Modelling the readiness factors for agility in healthcare organization: an TISM approach. *Benchmarking: An International Journal*, pp. 45-50.

VINODH, S. and ARAVINDRAJ, S., 2013. Evaluation of leagility in supply chains using fuzzy logic approach. *International Journal of Production Research*, **51**(4), pp. 1186-1195.

VINODH, S. and PRASANNA, M., 2011. Evaluation of agility in supply chains using multi-grade fuzzy approach. *International Journal of Production Research*, **49**(17), pp. 5263-5276.

WANG, W., LAI, K. and SHOU, Y., 2018. The impact of servitization on firm performance: a meta-analysis. *International Journal of Operations & Production Management*, **38**(7), pp. 1562-1588.

WOMACK, J.P. and JONES, D.T., 1996. Beyond Toyota: how to root out waste and pursue perfection. *Harvard business review*, **74**(5), pp. 140-158.

WOMACK, J., JONES, D. and ROOS, D., 1990. The machine that changed the world. New York: Rawson. *Mc.Millan*.

YANG, X., MOORE, P., PU, J. and WONG, C., 2009. A practical methodology for realizing product service systems for consumer products. *Computers & Industrial Engineering*, **56**(1), pp. 224-235.

YIN, R.K., 2017. *Case study research and applications: Design and methods*. Sage publications.

YUSUF, Y.Y., SARHADI, M. and GUNASEKARAN, A., 1999. Agile manufacturing: The drivers, concepts and attributes. *International Journal of Production Economics*, **62**(1-2), pp. 33-43.

Appendix 1. Servitization Leagility Assessment Model

Enabler (I_x)	*Criteria* (I_{ij})	*Attributes* (I_{ijk})
1. Collaborative-Relationship	1.1. Enterprise wide relationship management	1.1.1. Concurrent relationship of supply chain activities
		1.1.2. Focus on core competencies
		1.1.3. Team based on goal setting
		1.1.4. Active data sharing with partners
		1.1.5. Interlinking of departments
	1.2. Supplier relationship management	1.2.1. Trust and competency of the suppliers
		1.2.2. Supplier involvement in product and service development
		1.2.3. Deliveries arrive on time and in the right quality and amount every time
		1.2.4. Supplier selection is not based only on cost, but on a set of value-adds
		1.2.5. Key suppliers are located close
		1.2.6. Information transparency
2. Management Leagility	2.1. Nature of management	2.1.1. Top management commitment and involvement
		2.1.2. Transparent information sharing
		2.1.3. Frequent management employees meeting
		2.1.4. Participative management style
		2.1.5. Rapid evaluation and implementation of employees suggestions
	2.2. Devolution of authority	2.2.1. Clear definition of personnel responsibility and authority
		2.2.2. Education and training to create self-managed teams
	2.3. Organizational structure	2.3.1. Flattened organisational structure
		2.3.2. Smooth information flow
		2.3.3. Team management for decision making
		2.3.4. Interchange ability of personnel
3. Employees Leagility	3.1. Employees status	3.1.1. Flexible workforce to accept the adoption of new technologies
		3.1.2. Multi-skilled personnel
		3.1.3. Implementation of job rotation system
		3.1.4. Education and cross-training imparted to all the existing and new employees
		3.1.5. Innovation embedded culture
	3.2. Employee involvement	3.2.1. Strong employee spirit and cooperation
		3.2.2. Employee empowerment
		3.2.3. Promoting creative thinking

Enabler (I_i)	*Criteria* (I_{ij})	*Attributes* (I_{ijk})
4. Process excellence	4.1. Inventory management	4.1.1. Zero-inventory system
		4.1.2. Pull production system
		4.1.3. Streamlining of processes
	4.2. Time management	4.2.1. Proper scheduling of activities
		4.2.2. Training programme on time management concepts
		4.2.3. IT-based communication system
	4.3. Quality Status	4.3.1. Application of lean principles for waste elimination
		4.3.2. Employees are exposed to problem solving tools and techniques
		4.3.3. Each problem has a well-defined action plan
		4.3.4. Use of statistical techniques to reduce process variance
	4.4. Knowledge and Information Technology	4.4.1. Enterprise Resource Planning (ERP)
		4.4.2. World Wide Web
		4.4.3. IT application to eliminate paper work
		4.4.4. Adoption of multimedia technology
		4.4.5. Supply Chain wide information access
5. Customer and Market Sensitivity	5.1. Customer involvement	5.1.1. Close contact with customers
		5.1.2. Customers give feedback on quality, cost and delivery performance
	5.2. Customer response adoption	5.2.1. Usage of a well-defined VOC
		5.2.2. Customer touch points have been identified
		5.2.3. Empowerment of employees to resolve customers problems
	5.3. Service quality & reliability	5.3.1. Service consistently exceed customers' expectations
		5.3.2. Service is available when desired
		5.3.3. Scheduling of customer service

Appendix 2. Responses of experts

Question	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	Average
1. To what extent do you believe that the model used in the evaluation is practically feasible in your company?	8	7	8	8	9	9	9	7	8	9	8.2
2. To what extent do you believe that the model used in the evaluation is understandable?	8	8	7	9	9	8	9	8	7	9	8.2
3. To what extent do you believe that the servitization leagility index represents the reality of your company?	8	8	8	9	8	9	9	9	8	9	8.5
4. To what extent do you believe that the model is comprehensive and cover lean perspectives?	8	8	7	10	9	9	8	8	9	10	8.6