International Journal of Mathematical, Engineering and Management Sciences
Vol. 5, No. 4, 567-590, 2020
https://doi.org/10.33889/IJMEMS.2020.5.4.047

A New Holistic Conceptual Framework for Leanness Assessment

Cansu Tayaksi
Center for Transportation and Logistics,
Massachusetts Institute of Technology, Cambridge, USA.
E-mail: ctayaksi@mit.edu

Muhittin Sagnak
Department of Information and Document Management,
Izmir Katip Celebi University, Izmir, Turkey.
E-mail: muhittin.sagnak@ikcu.edu.tr

Yigit Kazancoglu
International Logistics Management Department,
Yaşar University, Izmir, Turkey.
Corresponding author: yigit.kazancoglu@yasar.edu.tr

(Received April 4, 2020; Accepted April 12, 2020)

Abstract
Lean principles, aiming at eliminating waste and increasing efficiency at a company, take their roots from the initiatives of Taiichi Ohno. After the implementation of the principles at the Toyota Motor Company for the first time, businesses started to discover the benefits of lean implementation in terms of efficiency increase. As the adaptation of lean into the manufacturing sector is continuing, the necessity of assessing the level of leanness at the firm-level maintains its importance. Taking systems approach as a basis, the lean performance of an organization should be assessed as a whole. Therefore, we propose a holistic leanness assessment framework, which encapsulates various dimensions of the leanness assessment and we identify the importance and causal relationships between the sub-criteria. In order to identify the importance and causal relationships between the sub-criteria, we used fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL). Our findings show that the most influencing factor in the cause group is 'technology and product design' which indicates the companies' necessity to focus on Industry 4.0 during their operations. The results also illustrate that the most influenced factor in the effect group is 'productivity', in which companies can investigate strategic competitive advantages. The design of a holistic framework and the implementation of fuzzy DEMATEL offers a way to identify the importance and the causal relationships between the sub-criteria. With the help of a case study conducted in the plastics industry of Turkey, we offer managerial implications that could help managers to implement the proposed structural leanness assessment framework.

Keywords- Leanness, Lean manufacturing, Leanness assessment, Fuzzy logic, Fuzzy DEMATEL, Performance assessment.

1. Introduction

Lean principles, first implemented at the Toyota Motor Company, were mainly developed by Ohno (1988). The principles used at Toyota and then gained a worldwide reputation due to their success. These principles aim at eliminating waste, thus, increasing efficiency. Lean has many definitions in the literature. According to Schonberger (1987), lean is "the most important productivity-enhancing management innovation since the turn of the century." The lean concept works synergistically and aims to create systematic and high-quality processes. Shah and Ward (2003) specified that lean also fulfills customer demand within the required time. Lean is a management philosophy with the goal of supplying the customers the right product at the right place, at the right time, at the right quality and quantity. The implementation phase of lean includes the integration of waste elimination and the more efficient production of products that meets customers' needs and expectations (Hines and Taylor, 2000).

Lean concept has been continuously developed and adapted in different sectors of industry, despite initial skepticism among both managers and workers (Womack and Jones, 2003). Today, in the competitive conditions of the market, manufacturing firms face great pressure to meet customer expectations about the quality of the product, as well as providing responsiveness to demand, lower cost and a wide range of product variability. By applying lean principles to the manufacturing sector, firms are able to increase efficiency and fully meet customer expectations.

Although there are several studies with the aim to implement lean manufacturing (Emiliani, 2000; Hines and Taylor, 2000), there is still a lack of systematic measurement of the leanness level of a company. The studies in the literature lack a unifying and holistic measure.

This study aims to contribute to the lack of the any systematic measurement in the literature by (1) Presenting a new holistic leanness assessment framework within a three-level structural format as criteria, subcriteria and measures, (2) Revealing different criteria of lean assessment, such as supplier issues, manufacturing activities, marketing, just-in-time, cost & financial management, workforce, management responsibility, and quality management under one framework, (3) Using fuzzy DEMATEL method in order to determine the importance level and causal relationships between the sub-criteria and consequently, proposing managerial implications which may guide managers to implement the proposed structural leanness assessment framework. Figure 1 shows the flow diagram identifying the structure of the paper.

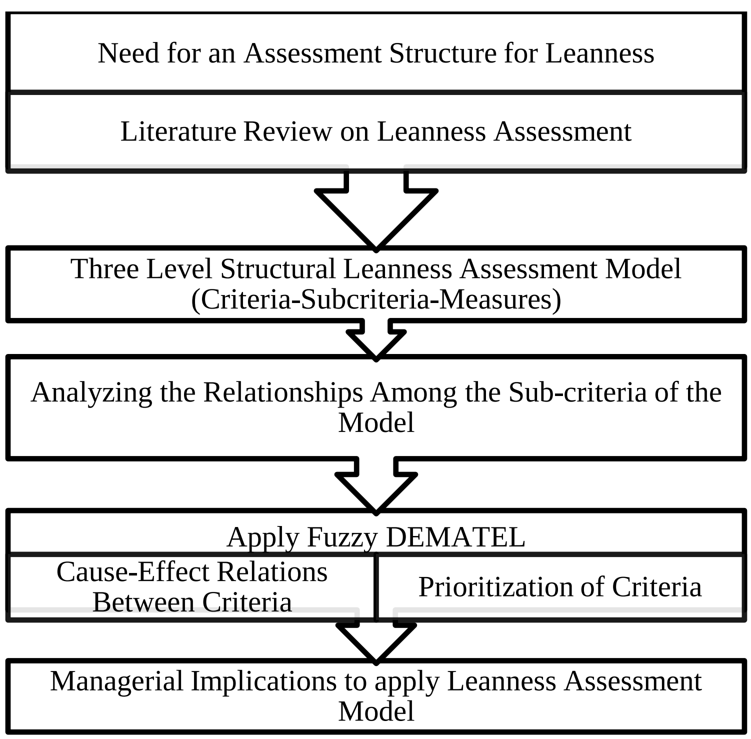

Figure 1. Structure of the paper

The organization of the rest of the paper is as follows: Section 2 presents a literature review about leanness assessment and the need for a holistic framework. Section 3 and 4 deliver the framework and the methodology of the study respectively and Section 5 presents a case study in the plastics industry and managerial implications. Finally, Section 6 presents the conclusions and future research directions.

2. Literature Review

2.1 Leanness Assessment in the Literature

The implementation of leanness by companies implies achieving goals and gaining more efficient output with less input (Bayou and de Korvin, 2008). Therefore, being able to measure lean performance is vital for firms; however, there are few studies that contribute to the approaches for measuring leanness from the point of a holistic framework development (Vinodh and Chintha, 2011).

The overall performance of the current or the new systems should be measured and controlled using various performance measures (Deming, 1986; Imai, 1986). The continuous improvement approach suggests that performance measurement is not only for lean organizations but also for any type of organization. Two key aspects are 'leanness is a process, a journey, not an end state' (Liker, 1998) and 'if you can't measure it, you can't manage it' (Shaw and Costanzo, 1970). Therefore, making assessments throughout the firms is vital to identify deficiencies and potential improvements in the lean concept. Some studies focus on the measurement of the management systems' leanness, pointing to a need for a unifying measure of the effects of these practices (Goodson, 2002; Bayou and de Korvin, 2008; Singh et al., 2010). Bhasin (2008) indicates that the firms should understand how the measures of key performance could help an organization to gain strong outcomes in their area, and in parallel, Saurin et al. (2011) point to the significance of practicing lean assessment in the early stages of lean practices.

Although the existing lean assessment methods in the literature with their own strengths and weaknesses, there is no perfect method for measuring the performance (Devlin et al., 1993). Different practices of lean are combined in assessing manufacturing leanness. The practices measure different aspects, including inventory size, quality defects, Kaizen and asset reduction (Emiliani, 2000), as a result, managers need to unify the measurement process of the effects of applying lean, and, it is important that measurement should integrate these practices into one scalar in a meaningful way (Bayou and de Korvin, 2008). According to Bayou and de Korvin (2008), the manufacturing leanness should entail seven characteristics, which are being dynamic, relative, fuzzy logical, objective, long term, integrating and comprehensive.

2.2 Need for a Holistic Framework

There are many studies in the literature that suggests for a successful lean implementation process, the lean principles have to be applied as a complete business system (Womack and Jones, 1996; Kennedy and Widener, 2008). All functions and processes of a business act as an incorporated and compatible system by using the lean principles as a way to create better value to customers and eliminate waste. A lean enterprise takes the integration of lean practices across all the operations and the other business functions as a basis (Fullerton et al., 2014).

As systems approach suggests, an organization is composed of interdepending and interacting parts and management should look to the organization as a unity or a system made up of sub-systems. For a successful lean implementation process covered in a holistic view, organizations should apply

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the lean principles into all functions of the organization, including accounting, sales and marketing and human resources (Pakdil and Leonard, 2014). As a result, the assessment of leanness in an organization requires an integrated approach that considers all functional developments regarding the implementation of lean. Some qualitative assessments in the literature focus on employee perception (Feld, 2000; Conner, 2001; Goodson, 2002; Soriano-Meier and Forrester, 2002; Doolen and Hacker, 2005; Shah and Ward, 2007; Fullerton and Wempe, 2009; Bhasin, 2011). Other studies have created quantitative assessments using various performance metrics (Bayou and de Korvin, 2008; Behrouzi and Wong, 2011; Wan and Frank Chen, 2008). The managers are very keen on learning how to use the measures for having more control over the lean implementation process. However, all of the models presented for leanness measurement either focus on quantitative measures or qualitative indicators, and none of those studies have concentrated on creating a perspective which combines both the qualitative and quantitative indicators, despite Azadeh et al. (2015) call for a measurement tool for evaluating the efficiency and effectiveness of the implementation of lean throughout an entire organization. Table 1 exhibits a summary of the studies which presented a lean assessment model. These studies usually focus on different aspects of lean management rather than evaluating it as a whole system.

Table 1. Lean assessment dimensions in literature

Researcher, Year	Enabler/ Criteria	Method
Almomani et al. (2014)	The cost of implementation, Time of completion, Benefit, Administrative constraints, Technological capabilities, Risk	AHP
Azadeh et al. (2015)	Manufacturing leanness management, Management responsibility, Employees leanness, Manufacturing leanness strategy, Leanness of technology	Weighted FCM, FDEA, DEMATEL, AHP, DEA
Azevedo et al. (2012)	Supplier Relationships and Long-Term Business Relationships, Total Quality Management, Customer Relationships, Just-in-Time, Pull Flow	The Delphi Technique
Bayou and de Korvin (2008)	Inventory Management, Cost Management	Fuzzy Approach
Behrouzi and Wong (2011)	Waste elimination, JIT	Fuzzy Logic Approach
Bhasin (2012)	Finance, Customer, Process, People, Future	Balance Scorecard
Doolen and Hacker (2005)	Manufacturing Equipment and Processes, Shop-Floor Management, New Product Development, Supplier Relationships, Customer Relationships, Workforce Management	Development of survey instrument, Exploratory study
Hosseini Nasab et al. (2012)	Standardized Work, Work Balancing, Work Levelling, Pull Production, Total Production Maintenance, Zero Defects Quality Control, Single Minute Exchange of Dies (SMED), Continuous Improvement, Visual Management,	AHP, ANN, A3 (Adaptive AHP approach)
Pakdil and Leonard (2014)	Process, Time Effectiveness, Human Resources, Delivery, Inventory, Cost, Customer, Quality	Fuzzy Approach
Shah and Ward (2007)	Supplier Feedback, JIT Delivery, Developing Suppliers, Involved Customers, Pull System, Continuous Flow, Setup Time Reduction, Total Productive/Preventive Maintenance, Statistical Process Control, Employee Involvement	Instrument Development, Exploratory analysis using EFA, Confirmatory analysis using CFA
Singh et al. (2010)	Suppliers Issues, Lean Practices, Investment Priorities, Customers Issues, Various Wastes	Human Judgement Error
Vinodh and Chintha (2011)	Manufacturing management, Manufacturing strategy, Management responsibility, Technology, Workforce	Multigrade Fuzzy Logic Approach
Wan and Chen (2008)	Total time, Total cost, Value	DEA

In this study, we investigated a comprehensive list of measures consisting of both qualitative and quantitative leanness measures, due to the integration of qualitative and quantitative indicators' potential to create more complete and synergistic utilization of data and the lack of this combined

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measurement model in the literature. Also, we aim at providing a new holistic framework for implementing lean, which integrates the different dimensions in an organization, such as supplier issues, manufacturing activities, marketing, just-in-time, cost and financial management, workforce, management responsibility, and quality management. In order to achieve a systematic lean assessment, we propose a framework consists of a three-dimensional hierarchy, which consists of main criteria, sub-criteria, and measures, respectively.

This study is exclusively incorporating all of the eight key areas into one conceptual framework, which includes a three-level structure as criteria, sub-criteria, and measures and performing industry-specific research.

3. Proposed Framework

Many studies focus on the necessity to identify relevant measures for lean assessment and discuss the difficulty of measuring and evaluating lean performance (Hervani et al., 2005). Even though there are numerous studies with the aim of lean assessment, they are focusing mostly on specific departments of the businesses. Observing the need for a holistic assessment framework to assess the level of leanness in a company as a whole, we developed a framework that could help businesses with their assessment activities. As the first step for developing our framework, we investigated literature in detail, combined all the studies under one structure, and added the missing criteria/subcriteria for better measurement. See Figure 2 for our threefold framework.

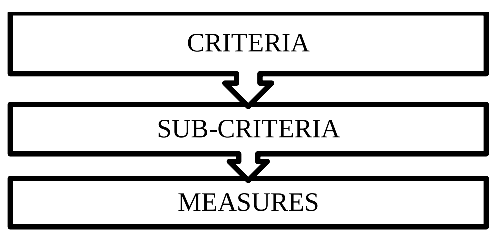

Figure 2. The proposed hierarchy for three-level structure as criteria, sub-criteria, and measures

Our framework contains 8 criteria, which are supplier issues, Manufacturing Activities, Marketing, Just-in-Time, Cost and Financial Management, Workforce, Management Responsibility, and Quality Management. Under this framework, we present 23 sub-criteria and 209 measurements after a comprehensive review of the literature. We assembled the main criteria and sub-criteria of the leanness assessment framework from the related literature regardless these authors have presented a leanness assessment framework or not. Table 2 shows the main criteria and sub-criteria for the proposed lean assessment framework.

Table 2. Main criteria and sub-criteria for leanness assessment framework

SUPPLIER ISSUES	
Supplier Relationship Management	Biazzo and Panizzolo (2000); Shah and Ward (2003); Liker (2004); Bhasin and Burcher (2006); Pettersen (2009); Jabbour et al. (2013); Pakdil and Leonard (2014)
Procurement Management	*Our Contribution*
MANUFACTURING ACTIVITIES	
Product Design	González-Benito (2005); González-Benito and González-Benito (2005); Jabbour et al. (2013)
Layout Design	*Our Contribution*
Production Planning	Vinodh and Chintha (2011); Azadeh et al. (2015)
Inventory Management	Bayou and de Korvin (2008); Searcy (2009); Goodson (2002); Taj (2005); Pettersen (2009)
Production Process	Pakdil and Leonard (2014); Liker (2004)
Productivity	Vinodh and Chintha (2011); Azadeh et al. (2015); Allen et al. (2001); Searcy (2009)
Technology	Vinodh and Chintha (2011); Azadeh et al. (2015)
MARKETING	
Customer Relationship Management	Azevedo et al. (2012)
Customer Satisfaction	Chan et al. (2003); Bhasin (2012)
Sales management	*Our Contribution*
JUST-IN-TIME	
Adaptation of JIT Philosophy	Liker (2004); Pakdil and Leonard (2014)
JIT Implementation	Shah and Ward (2007)
COST AND FINANCIAL MANAGEMENT	
Cost Management	Hayes and Wheelwright (1984); Allen et al. (2001); Doolen and Hacker (2005); González-Benito (2005); González-Benito and González-Benito (2005); Bayou and de Korvin (2008); Wan and Frank Chen (2008); Searcy (2009); Vinodh and Chintha (2011); Behrouzi and Wong (2011); Jabbour et al. (2013); Azadeh et al. (2015)
Financial Management	Almomani et al. (2014); Sharma and Bhagwat (2007)
WORKFORCE	
Employee Involvement	Vinodh and Chintha (2011); Azadeh et al. (2015); Pakdil and Leonard (2014); Liker (2004); Fullerton and Wempe (2009); Goodson (2002); Doolen and Hacker (2005); Shah and Ward (2007); Taj (2005); Pettersen (2009)
Employee Cross-functioning	Biazzo and Panizzolo (2000); Jabbour et al. (2013); Shah and Ward (2003); Bhasin and Burcher (2006); Soriano-Meier and Forrester (2002); Pettersen (2009)
Employee Benefits	Almomani et al. (2014)
MANAGEMENT RESPONSIBILITY	
Organizational Structure and Management	Vinodh and Chintha (2011); Azadeh et al. (2015)
Applying lean practices in management	*Our Contribution*
QUALITY MANAGEMENT	
Value Management	Wan and Frank Chen (2008)
Total Quality Management	Doolen and Hacker (2005); Shah and Ward (2007)

3.1 Supplier Issues

Implementing lean principles in all processes between a buyer and supplier is crucial because when suppliers practice lean processes, they reduce their inventory level and lower the stock out costs. Therefore, the suppliers which adopt lean processes in their internal processes will be more coherent with the buyer's logistics requirements (Wu, 2003).

Table 3. Sub-criteria and measures for the supplier issues main criterion

SUPPLIER ISSUES	
Supplier Relationship Management	**Procurement Management**
Having communication and making suggestions to suppliers	Attempt to reduce the average number of supplier of the most important parts/ materials
Involve suppliers in new product development	Supplier Related Procedures are written or documented in the IT applications at the company
Supplier performance evaluation	Evaluation and decrease in the total supply cost
Maintaining quality of products sent by suppliers	Establishing a network with the partners who exercise zero inventory system.
Keeping long term partnerships with the most important suppliers	Eliminate distant suppliers from manufacturer location
The extent of the contract with the foremost suppliers	Reducing time to supply products
Percentage of parts delivered JIT by the suppliers	Using supplier selection methods
Helping supplier development & increasing their performance level (technological assistance, financial assistance, training in quality issues)	Predicting the Bullwhip Effect in demand
Lean production tools usage rate by suppliers	
Document transmission percentage through EDI (Electronic Data Interchange) with suppliers	

Supplier issues dimension has two sub-dimensions, supplier relationship management, and procurement management. Procurement management is not mentioned in literature as a dimension, sub-dimension or measure; however, some measures in the literature did not fit under the supplier relationship management sub-dimension, so they were collected under a new sub-dimension, called procurement management due to their relevance on the procurement management subject. Table 3 represents the sub-criteria and the measures for the supplier issues main criterion.

3.2 Manufacturing Activities

According to Bayou and de Korvin (2008), implementation of leanness strategy into the manufacturing activities is a way to obtain a better output with less input, regarding organizational goals. In their statement, output refers to the quality and quantity of the products for sale, and the ideal customer service level and the input refer to the quantity and the cost of the physical resources used. Narasimhan et al. (2006) also highlighted that waste minimization for the efficient use of an organization's resources is a vital aspect of leanness due to the main aim of lean manufacturing is reducing waste and non-value added activities.

This dimension includes manufacturing related issues as product design, layout design, production planning, inventory management, production process, productivity, and technology. Table 4 represents the sub-criteria and measures for manufacturing activities.

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Table 4. Sub-criteria and measures for the manufacturing activities main criterion

MANUFACTURING ACTIVITIES						
Product Design	**Layout Design**	**Production Planning**	**Inventory Management**	**Production Process**	**Productivity**	**Technology**
• Usage of DFMA principles (DFMA)	• Having a cellular manufacturing layout	• work leveling (Heijunka - Distributing work evenly)	• Reducing WIP material inventory	• Control of TAKT Time	• Productivity increase with the increase in the personnel welfare	• Designing and developing firms own technological tools
• Products designed for easy serviceability	• Percentage of products produced with the cellular manufacturing method	• work balancing (balancing the work in the work cells)	• Reducing raw material inventory	• The decrease in the production time (throughput time)	• Non-value-adding costs removal	• Making IT Investments
• Rotation of jobs between the departments of design and manufacturing	• Having a focused factory system for production	• Production Smoothing/ Production Levelling	• Reducing finished goods inventory	• Cycle time reduction	• Implementation of totality concepts in the way of achieving productivity	• Having an IT-based communication system
• Product data management (PDM) system usage	• Arranging manufacturing activities around similar product families	• Making use of the MRPII (Manufacturing Resource Planning) systems	• Decreasing inventory turnover ratio	• Using automated tools in the production enhancement process	• Labor productivity	• The machine suitability for special operations
• New Product Development Lead Time	• Calculating the utilization of manufacturing cells	• Using ERP (Enterprise Resource Planning) systems		• Creating a continuous process flow	• Capital utilization percent in creating value	• Develop dedicated technologies for specific product use/ new technology development
• Decrease of entry time to market of the new products	• Visual management through visual factories	• Performing short-range plans		• Flexibility in the system/ ability to react rapidly to any changes (FMS)		• Use only reliable, thoroughly tested technology
• Anticipating future changes	• Keeping work areas clean, tidy and organized (5S)	• Capacity improvement that the enterprise is able to produce.		• Improvement in the machine flexibility		• Vertical information systems (control of raw materials, production, and distribution of your products)
• Flexible product design	• Space productivity	• Having flexible set-ups		• Using process focus strategy		
• Concurrent engineering practices	• Usage of visual information system (Andon)	• Production scheduling performance		• Utilizing equipment in the most effective way (OEE)		
• Matrix organizational structure application while designing a product				• Trying to change the machine set-ups to be less than 10 minutes (SMED)		
• Redesigning of a product after its market entry				• Reducing lost time at bottlenecks (Bottleneck Analysis)		
• The productivity of the employees as product design/man-hour						
• Designing products according to user demands (QFD)						

3.3 Marketing

Womack and Jones (1996) emphasized that true lean system applications involve the application of all the principles along the value stream, not just in certain defined parts. However, few studies in the literature explore the integration of lean principles in the marketing function. As Piercy and Morgan (1997) stated, great improvements could result from lean thinking in every business function, and in particular, for marketing. The lean thinking concept should be understood by marketing scholars and executives, who should be proactive in using lean thinking to improve the performance of the marketing function.

As mentioned earlier, the lean implementation should be conducted through all functions of an organization according to the systems approach. Therefore, assessment of the lean implementation should include the marketing function as well. Adding the marketing dimension in our conceptual framework we present three sub-dimensions: customer relationship management, customer satisfaction, and sales management. Table 5 represents the sub-criteria and the measures for the marketing main criterion.

Table 5. Sub-criteria and measures for the marketing main criterion

MARKETING		
Customer Relationship Management	Customer Satisfaction	Sales Management
Transparent data sharing with customers	Customer retention rate	Improvement in the market share by product group
Employee empowerment for solving the problems of the customers	Increase in customer satisfaction index	% sales from new products
Prevalence of the continuous improvement culture (regarding customer response)	Products exceeding the customers' expectations	Increase in sales volume
Customers involvement in product design	The decrease in the customer complaint	New market development
Transparent data sharing with customers	Improvement of the service quality level (customer-defined)	
	On-time delivery to the customer	
	Responsiveness (customer-defined)	
	After-sale services and satisfaction rate	
	Increase in the percentage of the resale	
	The decrease in the return rates	
	Service centers well equipped with spare parts	

3.4 Just-in-Time

Just-in-Time is a management practice that supports the idea of having the necessary amount of material available where it is needed when it is needed. The main aim is reducing work-in-process inventory and unnecessary delays on flow time (Demeter and Matyusz, 2011; Furlan et al., 2011). Huson and Nanda (1995) argue that in an integration system, lean production should be considered as a multi-dimensional method, including various management practices, and Just-in-Time is described as one of the key principles (Gurumurthy and Kodali, 2009; Demeter and Matyusz, 2011).

In our framework, we divided the Just-in-time dimension into two sub-dimensions. Adaptation of JIT philosophy, the former, concerns adopting the management practices of JIT throughout an organization; JIT implementation, the latter, is the implementation process of JIT after the internalizing phase. Table 6 represents the sub-criteria and the measures for the just-in-time main criterion.

Table 6. Sub-criteria and measures for the just-in-time main criterion

JUST IN TIME	
Adaptation of JIT Philosophy	**JIT Implementation**
Having the essential amount of material available where it is needed when it is needed	The decrease in unnecessary delays in flow-time
Production in small lot sizes	The decrease in the late delivery rates from suppliers/ JIT Delivery
Executing a pull production system	Delivering the materials just-in-time in a manufacturing environment with the help of KANBAN
Percentage of the pull system usage in a year - degree of pull	Process sequence and flow optimization in shop floor
Flexibility in the adjustment of the number of workers according to demand fluctuation	JIT product delivery
Having company-wide commitment	Increase in the right products delivery in yearly base
	Increase in the right quantity delivery in yearly base
	Increase in the on-time delivery in yearly base
	EDI (Electronic Data Interchange) usage rate between customers, sales and production planning departments
	Continuous flow

3.5 Cost and Financial Management

Comm and Mathaisel (2000) described leanness as a management philosophy aimed at reducing cost and cycle time throughout the entire value chain while continuing to develop product performance. Hopp and Spearman (2004) stated that the core of lean production is waste reduction, which will lead to cost-reducing. Emiliani (2000) pointed out, that the customer and stockholder pressure on senior management of a firm for the improvement in the financial position creates awareness about the leanness level of the firm.

For reaching a comprehensive assessment of the leanness level of the firm, we combined cost management and financial management in order to establish a new dimension. Table 7 represents the sub-criteria and the measures for the cost management and financial management main criterion.

Table 7. Sub-criteria and measures for the cost & financial management main criterion

COST & FINANCIAL MANAGEMENT	
Cost Management	**Financial Management**
Having a costing system with the aim of identifying value-adding and non-value adding activities	Increase in Earnings per share
The decrease in Warranty Costs	Increase in Current ratio - [current assets - current liabilities]
The decrease in service cost	Increase in rate of return on capital employed
Amount of investment on lean tools	Increase in Profit
The decrease in manufacturing cost	Increase in Capital efficiency
The decrease in inventory cost	Increase in the Return on Investment
The decrease in COPQ (Cost Of Poor Quality)	Cash flow increase
The decrease in raw material Cost	Market share increase
The decrease in labor cost	Profits/employee increase
Reducing transportation cost through strategic supplier selection	
Operating cost for lean tool implementation	
Kaizen method of product pricing (cont. cost improvement)	
The decrease in scrap rate	
The decrease in the logistics cost	

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3.6 Workforce

Worker involvement and expansion of their responsibilities and giving them autonomy is vital for continuous quality improvement programs. In implementing lean, beneficial processes include employee recruitment and selection, educating and training, evaluating and rewarding their contributions to the process and increasing their empowerment and responsibility.

The workforce dimension consists of the three sub-dimensions which related to the employee-related processes. They are employee involvement, employee cross-functioning, and employee benefits. Table 8 represents the sub-criteria and the measures for the workforce main criterion.

Table 8. Sub-criteria and measures for the workforce main criterion

WORKFORCE		
Employee Involvement	**Employee Cross-Functioning**	**Employee Benefits**
Standardized Work for employees	Multi-skilled personnel/ personnel flexibility	Healthier workforce, decrease in illness
Employee's willingness to adapt changes	Multifunctional workers rate	Healthier workforce, decrease in injury due to accidents
workforce ability to be flexible, to adapt and to use new technologies	Implementation of a job rotation system	Safety improvement
Employee empowerment	Pilot training program for the appreciation of lean practices	Labor Turnover (for measuring health and safety per employee)
Teamwork for effective implementation of lean practices	Cross-training of employees	Absenteeism (for measuring health and safety per employee)
Worker's ability to identify defective parts and power to stop the line	Workforce development	Employee Morale
Job rotation rate	Quality of professional/technical development	Performance assessment and its projection on salaries
Employee Commitment	Quality of leadership development	
Retention of top employees	Employee perception surveys	
Expansion of autonomy and responsibility	The employee's ability to conduct the assigned tasks	
Kaizen circles	Hiring expert employees	
Worker training rate		
Number of suggestions in a year which made by employees		
The implementation rate of the suggestions made by employees		

3.7 Management Responsibility

A radical rethinking over how the management of a firm uses the lean principles and methods is essential for reaching optimal performance level throughout an enterprise. While an organization is at the adaption stage, they focus more on the 'process-centered approach', such as the elimination of waste and reduction of cost. As the stage on to the adaptation phase, the focus should be more on the human-centered approach through empowerment and management of the human resources in the work design (Wong et al., 2014).

Management responsibility dimension consists of two sub-dimensions: Organizational Culture and Management, and Applying lean practices in management. Table 9 represents the sub-criteria and the measures for the management responsibility main criterion.

Table 9. Sub-criteria and measures for the management responsibility main criterion

MANAGEMENT RESPONSIBILITY	
Organizational Structure and Management	**Applying Lean Practices in Management**
Smooth information flow	Application of waste elimination (Muda)
Interchange-ability of personnel	Continuous improvement (Kaizen)
Integrated Functions	A pilot study for new production or business processes
Team management for decision making by consensus	Time Management
Becoming a learning organization (Hansei)	Using an organized framework that can be used for strategic management purposes. (Hoshin Kanri)
Clear managerial goals	Constant evaluation of management practices (PDCA)
Involved management/ Leadership for lean implementation	Selecting operationalizable, measurable, amenable to evaluation, and time-bounded targets (SMART)
Transparency in information sharing	Visits from management to workplace and observing the practices followed (Gemba)
Management's attention towards investment in FMS concepts	Finding the root causes of the problems
Management commitment or adopting lean	
Depth and quality of strategic planning	
Creating competitive benchmarks	
Go and see the problem (Genchi Genbutsu)	

3.8 Quality Management

Brown et al. (2001) indicate that lean manufacturing enables manufacturing with less input, at a lower cost with less development time, and higher quality levels. Producing with a higher quality level brings the usage of the Total Quality Management process, which, according to Demeter and Matyusz (2011) aims at continuous improvement and sustaining the quality of the product and processes. The actions of TQM include the usage of Six Sigma, quality circles, statistical process control, equipment problem solving and poka-yoke. Wan and Frank Chen (2008) also point that there are various tools and techniques developed to solve specific problems in order to eliminate non-value-added activities, and that process will help becoming lean.

The last dimension is comprised of the sub-dimensions of total quality management and value management. Table 10 represents the sub-criteria and the measures for the quality management main criterion.

Table 10. Sub-criteria and measures for the quality management main criterion

QUALITY MANAGEMENT	
Value Management	**Total Quality Management**
Value identification through value stream mapping	Quality rating and certification
Non-value-adding cost decrease	Quality of new product development and project management processes
Non-value-adding time decrease	Build a culture to stop right away to fix the problems
Seven deadly wastes identification	Total productive maintenance
Percentage of waste Elimination	Having organization-wide efforts to deliver high-quality products
	Usage of TQM tools
	Training the supplier personnel in related quality issues
	Zero Defects Quality Control
	Improvement of the Cp and Cpk values of the processes
	Usage of statistical process control (SPC)
	Reduce in effects of critical products/components
	Making surveys to ensure the quality status
	Forming quality circles
	Poka-yoke / Mistake-Proofing for production
	Reducing defects with the usage of autonomation (Jidoka)

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https://doi.org/10.33889/IJMEMS.2020.5.4.047

4. Methodology

We used the Decision Making Trial and Evaluation Laboratory (DEMATEL) method to assess the cause-effect relationships between the relevant criteria, and allow an analysis of a structured model. DEMATEL method initiated first at the Battelle Memorial Institute (Gabus and Fontela, 1972; Gabus and Fontela, 1973). The method consists of matrices and digraphs in order to categorize the relevant factors as cause factor, or effect factor, and identify the dependencies between the factors. The pairwise comparisons between the relevant criteria are used to represent the mathematical relationships (Wu and Lee, 2007).

There is a set of factors $C = \{C_1, C_2, \dots, C_n\}$, in the DEMATEL method. The pairwise comparisons between the relevant criteria are used to represent the mathematical relationships. Due to the subjectivity and vagueness, in pairwise comparisons, the linguistic terms are used to show the degree of effect of each criterion over others. Table 11 shows these linguistic terms described in positive triangular fuzzy numbers (l_{ij}, m_{ij}, r_{ij}).

Table 11. Fuzzy linguistic scale

Linguistic terms	Triangular fuzzy numbers
Very high influence (VH)	(0.75,1.0,1.0)
High influence (H)	(0.5,0.75,1.0)
Low influence (L)	(0.25,0.5,0.75)
Very low influence (VL)	(0,0.25,0.5)
No influence (No)	(0,0,0.25)

The linguistic terms are transferred into fuzzy numbers. Then, the average of pairwise comparisons are defuzzified into crisp values by Converting Fuzzy Data into Crisp Scores (CFCS), which was proposed by Opricovic and Tzeng (2003).

After the defuzzification process, we followed the following step-by-step application:

Step 1: The average of pairwise comparisons constitute nxn direct relation matrix, Z. Z_{ij} represents the degree of the influence of i^{th} factor to j^{th} factor, i.e. $Z = [Z_{ij}]_{n\times n}$.

Step 2: Using formulas (1) and (2), we found the normalized direct relation matrix, X, i.e., $X = [X_{ij}]_{n\times n}$, and $0 \leq x_{ij} \leq 1$.

$$X = s \cdot Z \tag{1}$$

$$s = \frac{1}{max_{1\leq i\leq n}\sum_{j=1}^{n} z_{ij}}, \quad i,j = 1,2,\dots,n \tag{2}$$

Step 3: Using formula (3), we calculated total relation matrix, T. "I" symbolizes here the identity matrix.

$$T = X(I - X)^{-1} \tag{3}$$

Step 4: Using formulas (4)-(6), we found the sum of values in rows and columns of the total relation matrix, T, and symbolized by D, and R, respectively.

$$T = t_{ij}, \quad i, j = 1,2, \dots, n \tag{4}$$

$$D = \sum_{j=1}^{n} t_{ij} \tag{5}$$

$$R = \sum_{i=1}^{n} t_{ij} \tag{6}$$

Step 5: We drew the cause-effect diagram by graphing the dataset. (D+R), and (D-R) values show the values in the horizontal axis, and in the vertical axis, respectively. (*D*+*R*) is called "Prominence", which refers to the level of importance, and (*D*-*R*) is called "Relation", which categorizes the factors as cause factor, or effect factor, respectively. If the value of (*D*-*R*) is positive, the factor is named as cause factor, and if negative, as effect factor (Wu and Lee, 2007).

5. Case Study and Managerial Implications

After the development of our framework, we conducted an application in 18 companies in the plastics industry in Izmir, Turkey. We selected the plastic industry due to its importance for the Turkish economy. According to the data of Turkish Statistical Institute (TUIK), the plastic industry in Turkey generates 4.8% of the Turkish manufacturing industry in economic terms and mobilizes a labor force rate of 4.2% within the manufacturing industry labor force. The plastic industry is the 11th biggest industry in Turkey representing nearly 5 billion euros of turnover. Also, the share of plastic industry among the whole manufacturing industry is increasing every year. The export rate of the plastic industry is 4.6% of Turkish manufacturing industry, and it is also developing (Karaca, 2011).

34 experts carried out pairwise comparisons from these 18 companies, including the general managers, the plant managers, and the production managers. We sent the survey questions, in other words, the matrix for getting the judgments of the experts, by e-mail to the 126 representatives of the plastic industry, and 34 of them replied. We limited the scope of the study to the plastics sector in order to prevent the potential ambiguity that may arise when the analysis is conducted in multiple sectors.

Hervani et al. (2005) pointed out the fact that since the application and the scales are specific to the organizations, there is no generally applicable tool or approach for generalizing the results. Consistent with this, the proposed framework including 8 criteria, 23 sub-criteria, and 209 measurements may be generalized and used in different applications. However, each application is specific to the company, which means, the results may be different when applied in another company.

Table 12 shows the direct relation matrix; Z. We found direct relation matrix by using the formulas (7)-(14) (See Table 13 for the normalized direct relation matrix, X). Following, we calculated normalized direct relation matrix by the formulas (1) and (2). (See Table 14 for the total relation matrix, T). Lastly, we found the total relation matrix by the formula (3) and we calculated D and R values by using the formulas (4)-(6). According to the results, a cause-effect diagram occurs as seen in Figure 3.

Using formulas (4)-(6), row totals (D), and column totals (R) of Total Relation Matrix were found, respectively. The dataset is graphed in order to generate a cause-effect diagram. Horizontal axis shows *(D+R)* values, which refer to the importance level. The vertical axis represents *(D-R)* values, which classifies each criterion as either cause or effect group. If the value of (*D*-*R*) is positive, then the factor is referred to as cause factor, and if negative, as effect factor (Wu and Lee, 2007).

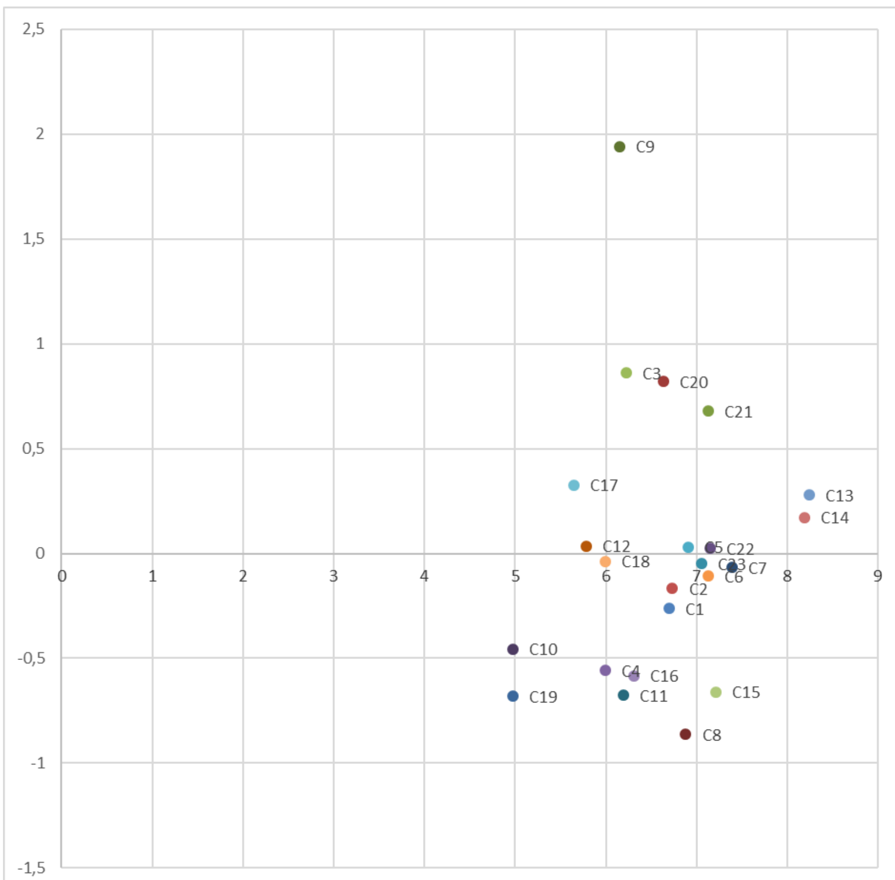

Figure 3. The cause - effect diagram

Table 12. Direct relation matrix, Z

C23	C22	C21	C20	C19	C18	C17	C16	C15	C14	C13	C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1	**Z**
0.79	0.44	0.50	0.21	0.03	0.21	0.21	0.68	0.62	0.91	0.79	0.85	0.85	0.68	0.56	0.44	0.44	0.91	0.79	0.27	0.79	0.85	0.03	C1
0.44	0.44	0.50	0.68	0.03	0.21	0.38	0.73	0.68	0.85	0.91	0.44	0.62	0.79	0.68	0.44	0.50	0.91	0.85	0.27	0.62	0.03	0.79	C2
0.85	0.85	0.44	0.15	0.03	0.21	0.21	0.50	0.62	0.50	0.44	0.62	0.85	0.03	0.85	0.27	0.44	0.44	0.62	0.03	0.03	0.27	0.62	C3
0.79	0.44	0.50	0.27	0.38	0.62	0.38	0.56	0.38	0.73	0.73	0.33	0.27	0.15	0.85	0.38	0.85	0.85	0.79	0.03	0.85	0.50	0.56	C4
0.73	0.44	0.68	0.27	0.27	0.56	0.56	0.38	0.50	0.85	0.85	0.56	0.38	0.03	0.73	0.38	0.68	0.68	0.03	0.73	0.91	0.79	0.79	C5
0.73	0.79	0.91	0.50	0.03	0.03	0.03	0.27	0.73	0.91	0.91	0.73	0.27	0.15	0.79	0.79	0.79	0.03	0.85	0.62	0.73	0.79	0.85	C6
0.91	0.79	0.62	0.50	0.38	0.73	0.62	0.38	0.62	0.85	0.85	0.56	0.79	0.03	0.79	0.44	0.03	0.38	0.85	0.85	0.91	0.68	0.38	C7
0.85	0.79	0.73	0.27	0.62	0.79	0.56	0.15	0.62	0.85	0.79	0.27	0.50	0.15	0.85	0.03	0.91	0.73	0.85	0.85	0.68	0.73	0.85	C8
0.73	0.38	0.56	0.85	0.03	0.03	0.03	0.62	0.73	0.62	0.62	0.38	0.03	0.03	0.03	0.15	0.27	0.21	0.21	0.27	0.27	0.15	0.38	C9
0.38	0.21	0.03	0.85	0.03	0.27	0.33	0.27	0.33	0.68	0.62	0.73	0.73	0.03	0.56	0.44	0.21	0.73	0.44	0.15	0.50	0.79	0.79	C10
0.91	0.73	0.56	0.73	0.38	0.44	0.44	0.33	0.44	0.62	0.62	0.79	0.03	0.91	0.56	0.38	0.33	0.68	0.62	0.09	0.79	0.79	0.79	C11
0.09	0.38	0.68	0.68	0.03	0.03	0.33	0.62	0.33	0.56	0.62	0.03	0.85	0.85	0.79	0.44	0.21	0.73	0.44	0.09	0.56	0.73	0.73	C12
0.73	0.68	0.79	0.85	0.56	0.79	0.68	0.56	0.85	0.79	0.03	0.56	0.38	0.56	0.62	0.56	0.79	0.79	0.73	0.73	0.56	0.62	0.73	C13
0.73	0.73	0.79	0.79	0.44	0.79	0.73	0.62	0.73	0.03	0.91	0.38	0.27	0.21	0.79	0.68	0.91	0.79	0.79	0.62	0.62	0.79	0.85	C14
0.91	0.73	0.73	0.85	0.85	0.62	0.73	0.85	0.03	0.79	0.73	0.44	0.50	0.44	0.73	0.79	0.85	0.56	0.56	0.38	0.79	0.44	0.50	C15
0.44	0.73	0.73	0.85	0.85	0.21	0.21	0.03	0.79	0.62	0.56	0.85	0.73	0.38	0.73	0.62	0.62	0.68	0.44	0.27	0.44	0.73	0.38	C16
0.15	0.73	0.85	0.79	0.79	0.85	0.03	0.15	0.15	0.56	0.85	0.27	0.21	0.33	0.73	0.21	0.73	0.15	0.38	0.50	0.15	0.33	0.15	C17
0.21	0.56	0.79	0.79	0.68	0.03	0.85	0.38	0.44	0.79	0.79	0.33	0.33	0.21	0.79	0.62	0.68	0.38	0.33	0.62	0.68	0.03	0.09	C18
0.03	0.73	0.73	0.79	0.03	0.62	0.62	0.56	0.50	0.73	0.79	0.33	0.33	0.21	0.56	0.62	0.62	0.33	0.33	0.56	0.38	0.03	0.09	C19
0.03	0.73	0.85	0.09	0.38	0.73	0.79	0.56	0.50	0.56	0.62	0.73	0.56	0.68	0.38	0.56	0.56	0.33	0.33	0.38	0.33	0.15	0.09	C20
0.50	0.21	0.09	0.79	0.38	0.73	0.79	0.56	0.44	0.56	0.56	0.50	0.38	0.50	0.50	0.62	0.73	0.73	0.56	0.50	0.62	0.56	0.33	C21
0.79	0.03	0.73	0.73	0.27	0.73	0.79	0.44	0.50	0.73	0.79	0.21	0.38	0.56	0.68	0.73	0.73	0.62	0.56	0.62	0.50	0.73	0.44	C22
0.09	0.85	0.73	0.73	0.50	0.73	0.73	0.38	0.50	0.73	0.73	0.03	0.21	0.56	0.73	0.62	0.73	0.56	0.56	0.50	0.62	0.73	0.73	C23

International Journal of Mathematical, Engineering and Management Sciences
Vol. 5, No. 4, 567-590, 2020
https://doi.org/10.33889/IJMEMS.2020.5.4.047

Table 13. Normalized direct relation matrix, X

X	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
C1	0.00	0.05	0.05	0.02	0.05	0.06	0.03	0.03	0.03	0.04	0.05	0.05	0.05	0.06	0.04	0.04	0.01	0.01	0.00	0.01	0.03	0.03	0.05
C2	0.05	0.00	0.04	0.02	0.05	0.06	0.03	0.03	0.04	0.05	0.04	0.03	0.06	0.05	0.04	0.05	0.02	0.01	0.00	0.04	0.03	0.03	0.03
C3	0.04	0.02	0.00	0.00	0.04	0.03	0.03	0.02	0.05	0.00	0.05	0.04	0.03	0.03	0.04	0.03	0.01	0.01	0.00	0.01	0.03	0.05	0.05
C4	0.03	0.03	0.05	0.00	0.05	0.05	0.05	0.02	0.05	0.01	0.02	0.02	0.05	0.05	0.02	0.03	0.02	0.04	0.02	0.02	0.03	0.03	0.05
C5	0.05	0.05	0.06	0.05	0.00	0.04	0.04	0.02	0.05	0.00	0.02	0.03	0.05	0.05	0.03	0.02	0.03	0.03	0.02	0.02	0.04	0.03	0.05
C6	0.05	0.05	0.05	0.04	0.05	0.00	0.05	0.05	0.05	0.01	0.02	0.05	0.06	0.06	0.05	0.02	0.00	0.00	0.00	0.03	0.06	0.05	0.05
C7	0.02	0.04	0.06	0.05	0.05	0.02	0.00	0.03	0.05	0.00	0.05	0.03	0.05	0.05	0.04	0.02	0.04	0.05	0.02	0.03	0.04	0.05	0.06
C8	0.05	0.05	0.04	0.05	0.05	0.05	0.06	0.00	0.05	0.01	0.03	0.02	0.05	0.05	0.04	0.01	0.03	0.05	0.04	0.02	0.05	0.05	0.05
C9	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.02	0.04	0.04	0.05	0.04	0.00	0.00	0.00	0.05	0.03	0.02	0.05
C10	0.05	0.05	0.03	0.01	0.03	0.05	0.01	0.03	0.03	0.00	0.05	0.05	0.04	0.04	0.02	0.02	0.02	0.02	0.00	0.05	0.00	0.01	0.02
C11	0.05	0.05	0.05	0.01	0.04	0.04	0.02	0.02	0.03	0.06	0.00	0.05	0.04	0.04	0.03	0.02	0.03	0.03	0.02	0.05	0.03	0.05	0.06
C12	0.05	0.05	0.03	0.01	0.03	0.05	0.01	0.03	0.05	0.05	0.05	0.00	0.04	0.03	0.02	0.04	0.02	0.00	0.00	0.04	0.04	0.02	0.01
C13	0.05	0.04	0.03	0.05	0.05	0.05	0.05	0.03	0.04	0.03	0.02	0.03	0.00	0.05	0.05	0.03	0.04	0.05	0.03	0.05	0.05	0.04	0.05
C14	0.05	0.05	0.04	0.04	0.05	0.05	0.06	0.04	0.05	0.01	0.02	0.02	0.06	0.00	0.05	0.04	0.05	0.05	0.03	0.05	0.05	0.05	0.05
C15	0.03	0.03	0.05	0.02	0.03	0.03	0.05	0.05	0.05	0.03	0.03	0.03	0.05	0.05	0.00	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.06
C16	0.02	0.05	0.03	0.02	0.03	0.04	0.04	0.04	0.05	0.02	0.05	0.05	0.03	0.04	0.05	0.00	0.01	0.01	0.05	0.05	0.05	0.05	0.03
C17	0.01	0.02	0.01	0.03	0.02	0.01	0.05	0.01	0.05	0.02	0.01	0.02	0.05	0.03	0.01	0.01	0.00	0.05	0.05	0.05	0.05	0.05	0.01
C18	0.01	0.00	0.04	0.04	0.02	0.02	0.04	0.04	0.05	0.01	0.02	0.02	0.05	0.05	0.03	0.02	0.05	0.00	0.04	0.05	0.05	0.03	0.01
C19	0.01	0.00	0.02	0.03	0.02	0.02	0.04	0.04	0.03	0.01	0.02	0.02	0.05	0.05	0.03	0.03	0.04	0.04	0.00	0.05	0.05	0.05	0.00
C20	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.04	0.03	0.05	0.04	0.03	0.03	0.03	0.05	0.05	0.02	0.01	0.05	0.05	0.00
C21	0.02	0.03	0.04	0.03	0.03	0.05	0.05	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.02	0.05	0.01	0.01	0.03
C22	0.03	0.05	0.03	0.04	0.03	0.04	0.05	0.05	0.04	0.03	0.02	0.01	0.05	0.05	0.03	0.03	0.05	0.05	0.02	0.05	0.05	0.00	0.05
C23	0.05	0.05	0.04	0.03	0.03	0.03	0.05	0.04	0.05	0.03	0.01	0.00	0.05	0.05	0.03	0.02	0.05	0.05	0.03	0.05	0.05	0.05	0.01

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https://doi.org/10.33889/IJMEMS.2020.5.4.047

Table 14. Total relation matrix, T

T	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
C1	0.12	0.17	0.17	0.11	0.17	0.18	0.16	0.13	0.18	0.12	0.15	0.16	0.20	0.20	0.15	0.14	0.12	0.12	0.08	0.15	0.17	0.15	0.17
C2	0.16	0.12	0.16	0.11	0.17	0.18	0.16	0.13	0.18	0.13	0.14	0.13	0.20	0.20	0.16	0.15	0.13	0.12	0.08	0.17	0.17	0.15	0.15
C3	0.13	0.11	0.10	0.08	0.13	0.12	0.13	0.10	0.16	0.07	0.13	0.12	0.14	0.14	0.13	0.11	0.09	0.09	0.06	0.11	0.13	0.15	0.15
C4	0.14	0.14	0.17	0.09	0.16	0.17	0.17	0.12	0.19	0.08	0.11	0.12	0.19	0.18	0.13	0.13	0.12	0.14	0.09	0.14	0.16	0.15	0.17
C5	0.16	0.16	0.18	0.14	0.13	0.16	0.17	0.13	0.19	0.08	0.12	0.14	0.20	0.20	0.15	0.13	0.14	0.14	0.09	0.15	0.18	0.15	0.17
C6	0.17	0.17	0.18	0.14	0.18	0.13	0.18	0.16	0.20	0.09	0.12	0.15	0.21	0.21	0.17	0.12	0.11	0.11	0.08	0.17	0.20	0.18	0.18
C7	0.15	0.16	0.19	0.15	0.18	0.16	0.14	0.14	0.20	0.09	0.15	0.14	0.21	0.21	0.16	0.13	0.15	0.16	0.11	0.17	0.19	0.18	0.19
C8	0.18	0.17	0.18	0.16	0.19	0.18	0.20	0.12	0.21	0.10	0.14	0.13	0.22	0.22	0.17	0.12	0.15	0.17	0.12	0.16	0.20	0.19	0.19
C9	0.09	0.08	0.09	0.07	0.09	0.09	0.10	0.08	0.09	0.05	0.06	0.09	0.13	0.13	0.12	0.10	0.07	0.07	0.05	0.13	0.12	0.10	0.12
C10	0.14	0.14	0.13	0.08	0.12	0.14	0.11	0.11	0.15	0.07	0.12	0.13	0.16	0.16	0.11	0.10	0.10	0.10	0.06	0.15	0.11	0.11	0.12
C11	0.16	0.16	0.17	0.10	0.16	0.16	0.15	0.13	0.17	0.14	0.10	0.15	0.19	0.18	0.14	0.12	0.13	0.13	0.10	0.17	0.17	0.17	0.18
C12	0.14	0.14	0.14	0.08	0.13	0.15	0.12	0.11	0.16	0.12	0.13	0.09	0.16	0.16	0.12	0.12	0.10	0.09	0.06	0.15	0.15	0.13	0.11
C13	0.17	0.17	0.18	0.16	0.18	0.19	0.20	0.16	0.20	0.12	0.13	0.15	0.18	0.22	0.18	0.15	0.16	0.17	0.12	0.20	0.21	0.19	0.19
C14	0.18	0.18	0.18	0.15	0.19	0.19	0.21	0.16	0.21	0.10	0.13	0.14	0.23	0.17	0.18	0.15	0.17	0.17	0.12	0.20	0.21	0.19	0.19
C15	0.16	0.16	0.19	0.13	0.17	0.17	0.20	0.17	0.21	0.12	0.14	0.14	0.21	0.21	0.13	0.17	0.17	0.16	0.14	0.20	0.20	0.19	0.19
C16	0.14	0.16	0.15	0.11	0.15	0.16	0.17	0.14	0.19	0.10	0.14	0.15	0.18	0.18	0.16	0.10	0.12	0.12	0.13	0.18	0.18	0.17	0.15
C17	0.09	0.11	0.10	0.11	0.12	0.10	0.14	0.09	0.15	0.08	0.09	0.09	0.17	0.15	0.10	0.09	0.09	0.13	0.11	0.15	0.16	0.14	0.10
C18	0.10	0.10	0.15	0.12	0.13	0.13	0.15	0.13	0.17	0.08	0.10	0.11	0.18	0.17	0.13	0.11	0.14	0.10	0.11	0.16	0.17	0.15	0.12
C19	0.10	0.10	0.12	0.11	0.12	0.12	0.14	0.12	0.15	0.08	0.10	0.10	0.17	0.16	0.12	0.12	0.13	0.13	0.07	0.16	0.16	0.15	0.10
C20	0.10	0.11	0.12	0.10	0.12	0.12	0.14	0.12	0.14	0.11	0.12	0.13	0.16	0.16	0.13	0.12	0.14	0.13	0.09	0.12	0.17	0.15	0.11
C21	0.13	0.14	0.15	0.12	0.15	0.16	0.16	0.14	0.16	0.10	0.11	0.13	0.17	0.17	0.13	0.13	0.15	0.14	0.09	0.17	0.13	0.13	0.14
C22	0.14	0.16	0.16	0.14	0.16	0.16	0.18	0.15	0.19	0.11	0.12	0.12	0.20	0.20	0.15	0.13	0.16	0.15	0.10	0.18	0.19	0.13	0.18
C23	0.16	0.16	0.17	0.13	0.16	0.16	0.18	0.15	0.19	0.11	0.11	0.11	0.20	0.20	0.15	0.13	0.15	0.15	0.11	0.18	0.19	0.18	0.13

According to the results of the fuzzy DEMATEL causal diagram (see Figure 3), we state the following:

1) The Cause Group consists of Technology (C9), Product Design (C3), Organizational Structure and Management (C20), Applying Lean Practices in Management (C21), Employee Involvement (C17), Adaptation in JIT Philosophy (C13), JIT Implementation (C14), Sales Management (C12), Production Planning (C5), and Value Management (C22).

2) The Effect Group consists of Employee Cross-Functioning (C18), Total Quality Management (C23), Production Process (C7), Inventory Management (C6), Supplier Relationship Management (C1), Procurement Management (C2), Customer Relationship Management (C10), Layout Design (C4), Financial Management (C16), Cost Management (C15), Customer Satisfaction (C11), Employee Benefits (C19), and Productivity (C8).

Cause factors refer to the influencing factors. It is critical to monitor cause factors in order to attain high performance from effect factors, which can be referred to as influenced factors (Fontela and Gabus, 1976). Within this context, an adaptation of JIT Philosophy (C13) is the most important factor, because it has the most significant relationship among all factors (it has the highest D+R value). The second and third were JIT Implementation (C14), and Production Process (C7) respectively. Technology (C9) is the most influencing factor, located at the top of the Cause Group, and Productivity (C8) is the most influenced factor, located at the bottom of the Effect Group.

Technology and product design are at the top of the cause group; therefore, the company should focus on the R & D activities, concentrating on the Industry 4.0 from the technology aspect, and concurrent engineering on the product design aspect. As a result, the opportunities in Industry 4.0 may contribute to productivity, which is at the top of the effect group.

The third and fifth influencing factors of Cause Group are organizational structure and employee involvement. Hence, we suggest for management to choose a matrix organization structure. This may increase employee involvement with its interdisciplinary structure and may even contribute to the JIT implementation which was the second most important factor in the results.

The Lean practices in management and the JIT philosophy were the fourth and sixth influencing factors in the results of the study in which the importance of senior management arises. Therefore, the companies may benefit from the establishment of a lean council to allocate the required resources and take decisions in this strategic issue. This will eventually make a contribution to the first and second most important factors of the study, adaptation in JIT philosophy, and JIT implementation, respectively.

The first influenced factor in the Effect Group is productivity; therefore, the company should consider it as a strategic competitive advantage, and focus on the production process which was the third most important factor in our study. Therefore, the first implication is that the design phase should be based on the modularity of the products whereas the second implication is to implement cellular manufacturing to increase the productivity of the production process and the third implication is aforementioned focusing on Industry 4.0.

The second and third influenced factors of the Effect Group are, employee benefits and customer satisfaction, respectively. By using Total Quality Management principles, the management should institutionalize the internal and external customer concepts. In order to do this, related training and educational programs can be organized and conducted to contribute lean practices in management, employee involvement; and therefore, adaptation in JIT philosophy, and JIT implementation.

The technology factor may affect productivity. As technology supports the efficient use of resources it is crucial to improve productivity. Another aspect is the third most important factor which is the production process. The technology shows itself especially through automation in the production process which reveals that the plastics industry should transform Industry 4.0 as soon as possible. Therefore, investing in technology in the production process based on industry 4.0 will bring productivity.

The technology factor may affect customer satisfaction. The technology factor may support customer satisfaction in two ways, firstly, the improved product features and secondly, increased product and quantity variety may contribute to customer satisfaction. In order to pursue the positive effect of technology on customer satisfaction, additional features should be added through product design, which is the next cause-effect. As the next step flexibility should be improved. Especially with JIT implementation which is the second important factor, pull system may contribute to faster order fulfillment and flexibility with satisfying relatively small lot sizes.

Another outcome of the model may be that the effect of product design on productivity. As the design of the product is made simpler and suitable for modularization the productivity will be positively affected. In this way, possible problems and obstacles that may arise against productivity can be observed and even prevented. Especially concurrent engineering can be applied to facilitate the interdisciplinary teamwork within the systems approach.

There may be another effect caused by design for customer satisfaction. Generally, the design is an important issue to increase customer satisfaction with improved and enriched product features and functions. However, in the plastics industry, value-added products play an important role in the competition. Therefore, innovation is an important aspect of this case. In design and innovation activities 3D printers should be hired for faster prototyping and analyzing the product. In addition, Quality Function Deployment (QFD) can be applied, the voice of the customer can be heard and reflected the product within the capabilities of the company. Meanwhile, the second most important factor of the model, JIT implementation, is going to increase customer satisfaction by providing flexibility and shorter lead times as mentioned above.

Organizational structure and management may be revealed as a factor affecting employee benefits. The organizational structure is important for an employee for job satisfaction. One way to increase job satisfaction is related to job enrichment. Therefore, a matrix organization is suggested for these companies to facilitate interdisciplinary teamwork and job enrichment, as just we can see in concurrent engineering and in interdisciplinary design teams. The most important factor appears to be Adaptation to JIT where the matrix organization structure is strongly suggested in the transformation phase.

6. Conclusion

The concept of lean is founded on the principle that customer needs are to be provided at the right time, at the right place and at the right quantity. When a company adopts the lean management philosophy, it means that the aim of the company is to eliminate waste throughout the company in the process of meeting customers' demands. Currently, manufacturing processes are facing a shift towards lean manufacturing practices due to the lower costs, shorter processing time and more efficient processes. With this kind of transition, there is a need for companies to assess their level of leanness throughout the company. The usage of the assessment will provide the management with information to reveal both their strong and weak aspects.

This study employs a holistic approach, by integrating different dimensions of lean to create a framework which contains 8 criteria: supplier issues, manufacturing activities, marketing, just-in-time, cost and financial management, workforce, management responsibility, and quality management. We also present 23 sub-criteria and 209 measurements for the use in the evaluation of the leanness of a firm.

The main three contributions of this study are, 1) to reveal the different dimensions of lean assessment, such as supplier issues, manufacturing activities, marketing, just-in-time, cost & financial management, workforce, management responsibility, and quality management; 2) to present a new holistic leanness assessment framework within a three-level structural format as criteria, subcriteria and measures; and 3) to use fuzzy DEMATEL method in order to determine the importance level and causal relationships between the sub-criteria and consequently, to propose managerial implications which may guide managers to implement the proposed structural leanness assessment framework. Figure 1 shows the flow diagram identifying the structure of the paper. Finally, we conclude with an application of the framework in the plastics industry.

The limitation of this research is that, as with all Multi-Criteria Decision-Making (MCDM) applications, the research includes subjective judgments. The proposed leanness assessment framework may be generalized, however; the result of the implementation of the framework is industry-specific.

Further research could focus on finding the criteria weights, respective measurement weights, and an overall performance score of the company. In addition, different methods may be employed to assess the level of leanness.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

Acknowledgements

Authors express their sincere thanks to the 18 companies operating in the plastics industry in Izmir, Turkey for pairwise comparisons.

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