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Full Length Research Paper

An investigation and identification of lean supply chain performance measures in the automotive SMEs

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The basic goal of this paper is to identify the underlying lean supply chain performance components and related measures with a special focus on small and medium enterprises in Iran's automotive industry. An initial list of supply chain performance measures was compiled and then modified by six experts in order to extract the appropriate lean supply chain performance measures. Following this, a questionnaire was designed and sent to 580 supply chain practitioners working at small and medium enterprises in Iran's automotive industry in order to score the measures. Principal component analysis was applied to identify and group the lean supply chain performance components and related measures. From the initial list, a total of 28 performance measures were chosen by the experts and considered essential to monitor the leanness of a supply chain. Four underlying components were identified (quality, cost, flexibility, and delivery and reliability) and the 28 related measures were subsequently grouped under these performance components. By identifying and validating a multi-dimensional list of lean supply chain performance components and related measures for small and medium enterprises, the research can be useful for practitioners or academics that are going to evaluate the leanness of a supply chain.

Key words: Iran, lean supply chain, performance measures, small and medium enterprises, automotive industry.

INTRODUCTION

Supply chain management (SCM), nowadays, has become one of the most significant innovations among business managers. It has gained increased attention from scholars, practitioners and managers in the latest two decades (Jin, 2008). Organizations in both the public and private sectors are increasingly aware of the pivotal role that SCM can play in their businesses (Cousins et al., 2006). It has become a strategic priority for organizations which are pioneers in their industry. On the other hand, lean philosophies and related concepts, tools, techniques and practices are rapidly expanding into the different parts of a supply chain because of their great achievements such as lower cost, superior quality, high flexibility and just-in-time (JIT) delivery (Behrouzi and Wong, 2011). By increasing value through waste elimination, lean supply chain (LSC) performance has been emphasized by academics and practitioners in recent years. Monitoring, measuring and improving performance are crucial to the success of a LSC since they contribute to continuously find improvement opportunities, set objectives and determine necessary courses of action. Most of the companies have realized that in order to evolve an efficient and effective supply chain, its performance needs to be assessed (Gunasekaran et al., 2001). This comes from the fact that it is not possible to manage things that cannot be measured. In this regard, identifying and using the right metrics and measures to efficiently and effectively measure LSC performance is a challenge for many practitioners, managers, and researchers (Gunasekaran et al., 2001; Lambert and Pohlen, 2001; Chan and Qi, 2003; Phelps et al., 2003; Neely et al., 2005). This is partially due to the complexity of SCM. Moreover, rapidly changing needs of customers, highly competitive and volatile markets and global trades have led to more attention being given to LSC performance. In addition, supply chain managers attempt to identify and minimize the gaps between planning and execution through

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performance measurement. In this connection, identifying the appropriate metrics and measures plays an important role in the success of a LSC.

When studying LSC performance in a large network of enterprises, it is essential to evaluate the performance measures in a multi-dimensional manner including all parties across the supply chain. It is important to measure what is critical to the customer, for example, delivery time, cost, quality, responsiveness, etc. The priority of customers' need may be different from market to market. For example, quality could be a critical factor for a food market, whereas delivery time is vital for a postal service network. In addition, these priorities may change under certain conditions like economic downturn. The measures need to focus dynamically on the key strategic factors from the customers' point of view. Beamon (1996) presented a number of characteristics that are found in effective performance measurement systems and can also be used in the evaluation of performance measures. These characteristics include:

1) Inclusiveness (measurement of all pertinent aspects).
2)Universality (comparable under various operating conditions).
3)Measurability (data required are measurable).
4)Consistency (measures are consistent with organizational goals).

Maskell (1989) suggested the following seven principal characteristics of performance measures:

1) The measures should be directly related to the firm's manufacturing strategy.
2) Non-financial measures should be adopted.
3) It should be recognized that measures vary between locations (one measure is not suitable for all departments or sites).
4) It should be acknowledged that measures change as circumstances do.
5) The measures should be simple and easy to use.
6) The measures should provide fast feedback.
7)The measures should be designed so that they stimulate continuous improvement rather than simply monitor.

One important issue in performance measurement systems, especially in a LSC, is to minimize the number of measures in order to be effective, easy to use and simple to analyze. Choosing an efficient number of measures is a challenge for many practitioners. Unlike a general perception that more is better, in LSC performance measurement, "less is better"; companies should try to establish a small number of measures which are strongly necessary to monitor the main supply chain processes (that are, plan, source, make and deliver) (Chae, 2009). Keebler et al. (1999) also affirmed that "while there are hundreds of measures, research has shown that less than two dozen measures are critical to evaluating and improving the performance of the logistics process". Maskell and Baggaley (2004) emphasized that in designing a performance measurement system, the goal is to reduce the number of measures to a minimum. Having a balanced set of performance measures is another point on which some authors have emphasized (Kaplan and Norton, 1992; Beamon, 1999; Gunasekaran et al., 2001; Cohen and Roussel, 2005). After an extensive literature review on LSC performance measures, the following questions were raised:

1) What are the important performance measures for a LSC in the automotive SMEs in Iran?
2) How these performance measures can be classified based on their underlying components?
3) To what extent these measures are used by supply chain practitioners in manufacturing SMEs in Iran's automotive industry?

Answering these questions is important for several reasons. First of all, it opens the window to think about LSC performance measurement and motivate managers and practitioners to look at the entire supply chain rather than just their organization. Secondly, it is valuable to identify the right and efficient number of LSC performance measures among many in the literature. Thirdly, the identified underlying performance components and related measures can be considered by practitioners in the automotive industry for measuring the leanness of their supply chain and even for academics as a basis for further investigation. Finally, answering these questions gives a real insight into the utilization status of the LSC performance measures by SMEs in Iran's automotive industry. In this research, principal component analysis (PCA) was applied as the main approach to identify and group the LSC performance components and related measures. The rest of this paper is organized as follows: review of the literature on supply chain, lean concept and supply chain performance measures; step by step explanation of the research methodology; brief introduction of the automotive industry in Iran and some information on SMEs; results and discussion followed by conclusions and limitations of the research.

LITERATURE REVIEW

Supply chain and performance measurement

The term "supply chain management" (SCM) was originally introduced by consultants in the early 1980s (Oliver and Weber, 1982). During 1980 to 1990, large companies found that it was not sufficient to improve performance only within the organization but the whole supply chain of which they are members needed to be improved. As a result, the competition shifted from the companies to the supply chain as a whole. Hence, SCM became an essential and strategic part of competition in such a hard competitive global economy. Different aspects of supply chain performance have been explained by various authors in the literature. Beamon (1999) focused on three types of measures: Resources (since efficient resource management is critical to profitability), outputs (since without acceptable outputs, customers will turn to other supply chains) and flexibility (since in an uncertain environment, a supply chain must be able to respond to changes). Offering an innovative process-based performance measurement method for SCM, Chan and Qi (2003) emphasized on the main processes and sub-processes in a supply chain. Then, the corresponding performance measures were identified and grouped into the hierarchy of the processes. Cost, quality, reliability, flexibility, efficiency, and productivity were the main components of performance that they measured in connection with the sub-processes. Developed by Kaplan and Norton (1992), the balanced scorecard (BSC) is widely used to select and synthesize the supply chain performance measures from a balanced view. Indeed, it emphasized on balancing four categories, that are, financial, customers, internal processes, and innovations. The BSC includes traditional financial measures representing an organization's past and adds non-financial measures representing the drivers of future performance (Kaplan and Norton, 1992) which are distributed among the four mentioned groups. The critical strength of the BSC is that it measures the performance in all four main areas which are connected to the strategic goals. Relying on five distinct management processes (plan, source, make, deliver and return), supply chain operations reference model (SCOR) was developed to measure and evaluate supply chain performance situations. The initialization of SCOR stemmed from the needs to develop well-defined and independent criteria to measure supply chain performance and the requirement of a common language due to the presence of many partners in the process (Wong and Wong, 2007).

The model involves more than 150 key indicators that measure the performance of supply chain operations. As a process reference model, SCOR has been used to analyze the current state of supply chain processes, quantify the operational performance, and then compare with benchmark data in order to find the gaps. Although the SCOR model has many useful applications, there are some limitations. First of all, it does not include project implementation strategies because it assumes users have the needed project implementation competencies (Husby and Swartwood, 2009). Secondly, it applies benchmarking as a tool to find the performance gaps, but sometimes, access to benchmarking data is not easy, especially in a supply chain network which is complex in nature. Furthermore, the business environments are influenced by many factors such as economic conditions, currency exchange rates, culture, and labor proficiency, which are different in various environments and countries (Behrouzi and Wong, 2011). These differences between supply chain environments can lead to incorrect performance gaps as a result of benchmarking. In addition, finding the "best in class" supply chain as a benchmark is a challenge. In other words, supply chain managers could be unsure about the "best in class" case. By grouping supply chain performance metrics, companies can achieve more benefits. In this regard, Hoffman (2004) suggested a hierarchical grouping of performance measures as top-tier, mid-level and ground-level. The top-tier metrics, such as demand forecast accuracy, are more effective and have impact on other lower levels. The lower level metrics have impact on the lower domain of a supply chain. Considering easy and fast implementation, Chae (2009) recommended two layers, that are, primary and secondary. The primary metrics (for example forecast accuracy) were introduced to show the overall supply chain performance, and should be monitored by the top management and middle management. The secondary metrics were developed as potential indicators to answer why the primary metrics are high or low.

There are several critical points which have been emphasized by different researchers over the last decade:

1) It is critical to establish a strategic alignment between the company's goals and supply chain strategies (Gillyard, 2003; Cohen and Roussel, 2005; Chopra and Meindl, 2007).
2) It is important to minimize the number of measures in order to be effective (Keebler et al., 1999; Maskell and Baggaley, 2004; Chae, 2009).
3) It is essential to have both balanced and comprehensive measures to cover different performance components of a supply chain (Kaplan and Norton, 1992; Ayers, 2001; Brewer and Speh, 2000; Gunasekaran et al., 2001; Lambert and Pohlen, 2001; Cohen and Roussel, 2005).
4) It is necessary to choose both internal and external measures by considering the entire supply chain (Sambasivan et al., 2008; Olugu and Wong, 2011; Olugu et al., 2011).
5) It is necessary to set targets for metrics (Phelps et al., 2003).

Transition from supply chain to lean supply chain

Lean principles, tools and techniques have enabled firms to be more flexible, agile, productive, competitive and profitable. The benefits of lean principles have motivated managers and practitioners to think about expanding the lean philosophies into the whole supply chain. In addition, optimizing only a part of a business environment is not as beneficial as optimizing the whole. Furthermore, it is not possible to become lean without lean suppliers, lean logistics and lean distributors. In order to succeed more effectively, managers have to consider all parts of a supply chain such as suppliers, distributors, manufacturers and customers. Without the cooperation and unity of all key players, the planning and scheduling of components from the manufacturer will continue to impede supply chain performance. As a result, the LSC concept has been created (Manrodt et al., 2008). By focusing on waste elimination, value creation and flexibility enhancement across the supply chain, lean philosophies can be applied to all the supply chain members. In several studies, quality, cost, flexibility, and delivery & reliability have been considered as the most important parts of the value in a supply chain (Johansson et al., 1993; Naylor et al., 1999, Manrodt et al., 2005). To achieve a high degree of these performance components, managers and practitioners must use a combination of lean techniques in the whole supply chain to improve performance, both within and beyond the manufacturing company. There is a very important difference between a supply chain and LSC. The supply chain model, which came first, focuses on activities that get raw materials and sub-assemblies into a manufacturing operation and finally deliver products to the end user smoothly and economically, but the LSC model focuses on values and wastes which may happen all over the supply chain. A LSC is an important enabler for those organizations that struggle to become more productive and competitive. Organizations within a LSC are able to leverage their own lean journey more easily, delivering better customer value by responding more efficiently, quickly, and predictably to customer needs (Srinivasan, 2004). Based on different research and case studies in the lean literature, it could be concluded that there are three approaches for measuring lean performance. The first is measuring the degree of implementation of lean tools and techniques. In other words, this approach tries to answer the question "how much the lean tools and techniques are implemented?" (Both the number and the level of implementation of tools and techniques are considered).

For example, Doolen and Hacker (2005) developed a survey instrument to assess both the number and the level of implementation of a broad range of lean practices in an organization. They identified 29 lean tools and techniques in six areas comprising manufacturing equipment and processes, shop floor management, new product development, supplier management, customer relations, and workforce management. In another research, Jordan and Michel (2001) developed a 36-question survey to assess a company's leanness. The second approach to lean performance evaluation is measuring performance outputs as a result of lean implementation. In this context, cost, quality, delivery and reliability, flexibility, and continuous improvement received the most attention (Kojima and Kaplinsky, 2004; Wan, 2006; Bayou and de Korvin, 2008). The third approach in lean performance evaluation is a mixed mode of the first and second approaches. In other words, in this approach, both lean tools implementation and performance aspects will be considered and aggregated in a unified index. Gurumurthy and Kodali's (2009) study is an example of this type of approach. Through an extensive review of various books and research papers on the concept of lean, they listed down the lean elements (a total of 65 practices) and performance measures (a total of 90 performance measures). After that, a comparison was done to find the differences between the case organization and Toyota in both lean performance context and lean tools implementation. The second aforementioned approach is applied in this paper, and subsequently, a conceptual model has been developed to illustrate the basic model of this study (Figure 1). The connections between measures and performance components are not clear in the first part of the model (the upper-side of Figure 1). Using principal component analysis (PCA), the measures are classified under performance components and are clearly connected to them (the lower-side of Figure 1).

METHODOLOGY

The methodology was designed to identify and determine the important LSC performance measures of SMEs in the automotive industry in Iran. It consists of the following phases:

Identification and extraction of performance measures

In this stage, the literature was extensively reviewed to identify the performance categories and respective measures that had received more attention in SCM, regardless of industry. Among the vast literature on SCM, a few papers (Beamon, 1998; Chan and Qi, 2003; Gunasekaran et al., 2001; Neely et al., 2005; Saad and Patel, 2006; Gulledge and Chavusholu, 2007; Jeong and Hong, 2007; Bhagwat and Sharma, 2007; Lambert and Pohlen, 2001; Chae, 2009) have more concentration on supply chain performance measures. As a result, an initial list of 148 performance measures was compiled for further analysis (Table 1). In the next stage, six experts (two academics, one senior consultancy manager and three supply chain practitioners who had more than eight years of experience in the automotive industry) were chosen to filter the most important and lean-related measures since the initial list included 148 various measures applied in different industries and was exhaustive for respondents to score. Moreover, as many authors emphasized, in the case of choosing supply chain performance measures, less is better (Keebler et al.,1999; Maskell and Baggaley, 2004; Chae, 2009) and supply chain managers should try to establish a small number of measures which are strongly necessary to monitor. This arises from the complex nature of SCM that there is a tendency to reduce them. While extracting the measures from the initial list, the following points were considered by the experts:

1) Accessibility.
2) Measurability.
3) In line with supply chain strategies and company goals.
4) Important and related to lean components (that are, waste

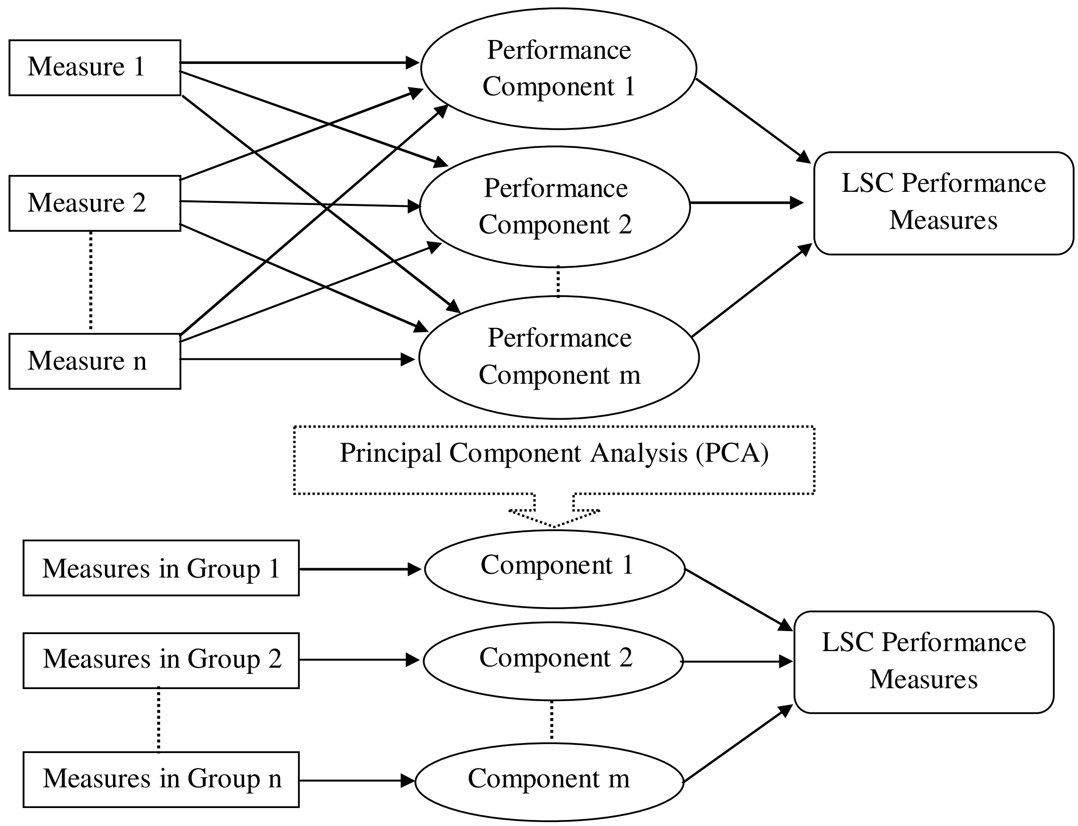

Figure 1. Conceptual model for PCA.

elimination, JIT and flexibility).
5) Balanced between supplier-related, manufacturer-related and customer-related measures.
6) Considering both financial and non-financial measures.

Accordingly, 28 measures received the most attention.

Development of a questionnaire with regard to extracted measures and research objectives

A questionnaire was designed with regard to the 28 measures selected by the experts. The respondents were supply chain managers, chief executive officers, plant managers, and directors working at manufacturing SMEs in Iran's automotive industry. The questionnaire consisted of two parts. The first part surveyed the general information such as total number of employees, work experience, production strategy, etc. Awareness, benefits and barriers to lean supply chain management (LSCM) were also studied in this part. The second part included 28 LSC performance measures, and respondents were asked to rate the importance of each measure according to a five-point scale, ranging from 1 = “not important” to 5 = “extremely important”. Using a two-point scale (0 and 1), they were also asked to determine whether they are using those measures or not. Practically, gathering the actual data of the performance measures would be more appropriate, but this could not be done because most of the SMEs involved were not able to reveal their real data due to the lack of information and confidentiality issues. Hence, theoretically, the opinions of the respondents with respect to their perceived importance on the measures were solicited. After preparing the initial questionnaire, the research objectives were explained to three academics who were specialists in LSCM, and their comments (for example, changing the wordings, adding or removing some sentences and relocating a number of questions) were subsequently considered to refine the questionnaire.

A total number of 580 practitioners from manufacturing SMEs in the automotive industry in Iran were targeted for the main survey. After contacting them via email, phone, or face-to-face interview, a total number of 148 completed questionnaires were collected and among them, only 133 questionnaires were usable, reflecting a response rate of 23%.

Factor analysis and principal component analysis (PCA)

Factor analysis, as Johnson (1998) stated, is used to derive or develop a smaller set of uncorrelated variables (known as the underlying factors or characteristics), with the hope that these latent variables will give a better understanding of the data being analyzed. On the other hand, PCA is simply a variable reduction technique with the aim of identifying the number of latent constructs or factors, and it makes no assumption about the causal model. PCA is used to combine variables into a smaller number of subsets or groups, while factor analysis is utilized when there are certain latent variables or factors that exert causal influence on the observed variables. By using PCA (as a variable reduction procedure), the number of constructs and the underlying factor structure will be identified. In this research, statistical analysis and PCA were conducted to address the basic research questions

Table 1. Partial list of performance measures found in the literature.

No.	Performance measure	No.	Performance measure
1	Supplier rejection rate	50	Total supply costs
2	Cash-to-cash cycle time	51	Service costs
3	Delivery to committed date	52	Manufacturing lead time
4	Manufacturing cost	53	Risk costs
5	Supply chain response time	54	Supplier rejection rate
6	On time delivery	⋮	⋮
7	Inventory accuracy		
8	Shipping errors		
9	Labor cost		
10	Raw material cost		
11	Fill rate	118	Setup time/unscheduled downtime/idle time
12	Capacity utilization of containers	119	On time production
13	Distribution cost	120	On-time delivery to customers
14	Delivery reliability	121	Delivery flexibility
15	Forecast accuracy	122	Information processing cost
16	Inventory cost	123	Product development cycle time
17	Warranty cost	124	Utilization of economic order quantity
18	Defect rates	125	Customer response time
19	Customer complaints	126	Commitment to customers
20	Manufacturing cost	127	Information quality
21	Delivery lead time	128	Material quality
22	Customer query time	129	Production quality
23	Back orders	130	On-time shipment
24	Response to urgent demands	131	In-stock availability
25	Supplier lead time	132	Planning cycle time
26	Document accuracy	133	Total inventory days of supply
27	Labor productivity	134	Forecast volatility
28	Supplier fill rate	135	Forecast versus order
29	Defect rates of production	136	Order fill rate
30	Value-added productivity	137	Production plan versus result
31	Time to market	138	Inventory days of raw material supply
32	Total order cycle time	139	Product quality flexibility
33	Cost of goods sold	140	Costs associated with work-in-process inventories
34	Degree of information sharing	141	Costs associated with obsolete inventory
35	Delivery reliability	142	Costs associated with finished goods inventories
36	Customer satisfaction rate	143	Total revenue
⋮	⋮	144	New product flexibility
		145	Response delay
		146	Damages per shipping
		147	Sales volume
		148	Total number of suppliers

stated earlier. The statistical analysis examined the range (minimum and maximum), mean, and standard deviation for each performance measure. PCA was conducted to identify interrelated performance measures, constructs, and a potentially reduced and categorized list of LSC performance measures.

IRAN'S AUTOMOTIVE INDUSTRY AND SMEs

As the 12th largest automaker in the world (in 2010) and the largest in the Middle-East, Iran currently has a crucial role in this large industry. The Iranian automotive industry was first developed in the 1960s by relying on foreign vehicle manufacturers. Today, the industry is dramatically growing and has become one of Iran's key industries, after oil industry. In 2006, Iran was ranked as the 16th biggest automaker of the world, and soon after, in 2009, it experienced a 9.5% growth in production and was ranked fifth in car production growth standing next to China, Taiwan, Romania and India. According to official figures announced in 2010, the value of automotive parts produced in Iran exceeded Iranian $9.6 billion

Table 2. Profile of the respondents and companies (n = 133).

Number of employees	Result (%)
Below 100*	120 (90.2)
100 - 200	8 (6)
201 - 250	3 (2.3)
Not mentioned	2 (1.5)
Work experience of respondents (year)	
Below 5	28 (21)
5 -10	59 (44.4)
More than 10	46 (34.6)
Production strategy	
Make to order	83 (62.4)
Make to stock	37 (27.8)
Assemble to order	13 (9.8)
Engineer to order	0 (0)

Note: The minimum number of ten employees was chosen to exclude the micro firms from the analysis.

and export in this sector was also on the rise. This indicates that the Iranian automotive industry is dramatically growing despite the crushing global economic crisis. In addition, the value of Iran's automotive industry in 2010 was at Iranian $2,000 billion while that for automotive parts manufacturing was at Iranian $1,000 billion (Press TV, 2010). By creating employment opportunities and economic growth through gross domestic product (GDP), SMEs have an important role in the economies of industrial countries. In addition, the performance of large manufacturers is strongly dependent on the performance of SMEs. Similarly, SMEs have a crucial role in the supply chain performance of the automotive industry in Iran, where they serve the roles of parts makers, assemblers, and suppliers. However, LSCM within SMEs in the automotive industry has received less attention. With approximately 2000 parts manufacturers in the automotive industry in Iran, the LSC performance measures of SMEs need to be thoroughly investigated.

In the case of SMEs definition, there is still a partial difference among different researchers, industries, and even government agencies. Aligned with the most recent studies, the number of employees was used in this study as a basis for defining SMEs. Accordingly, a total number of 250 employees or less was adopted to identify SMEs.

The minimum number of ten employees was also chosen to cut off the micro firms from the analysis. This definition has been adopted from the SMEs definition provided by Iran Small Industries and Industrial Parks Organization (ISIPO). It is also consistent with the definition offered by the European Commission.

RESULTS

Profile of respondents

The data were collected from the 133 practitioners who were specialists and familiar with the automotive supply chain. Most of them (79%) had more than 5 years of experience in the automotive industry in Iran. Table 2 shows more details on the profile of the respondents. Awareness, benefits and barriers to LSCM were also studied in the first part of the questionnaire. The respondents were asked to rate their awareness of LSCM according to a five-point scale ranging from 1 = “not familiar” to 5 = “very familiar”, and the results are presented in Figure 2. It shows that most respondents have a pretty good knowledge on LSCM. The benefits of LSCM were also investigated through a question with seven choices. Figure 3 summarizes the answers to this question. Increasing customer satisfaction has the highest score by acquiring a value of 91%, followed by JIT delivery (87%) and superior quality (73%). In order to identify the barriers to LSCM, another question with eight choices was set. These choices were extracted after reviewing the literature and interviewing some practitioners and academics. As Figure 4 shows, unwillingness to change, as a human factor, was the most important issue in this regard. As mentioned by the interviewees, tendency to follow the old ways of managing, working, and operating was the root cause of this barrier. Lack of performance measurement systems was determined as the second important barrier since 36% of the respondents pointed it as a barrier.

Content validity

As Nunnally (1978) declared, content validity indicates how well researchers create measurement items to cover the domain of the variable being measured. In this paper, content validity was guaranteed because the performance measures were derived and modified from the literatures which were established by previous

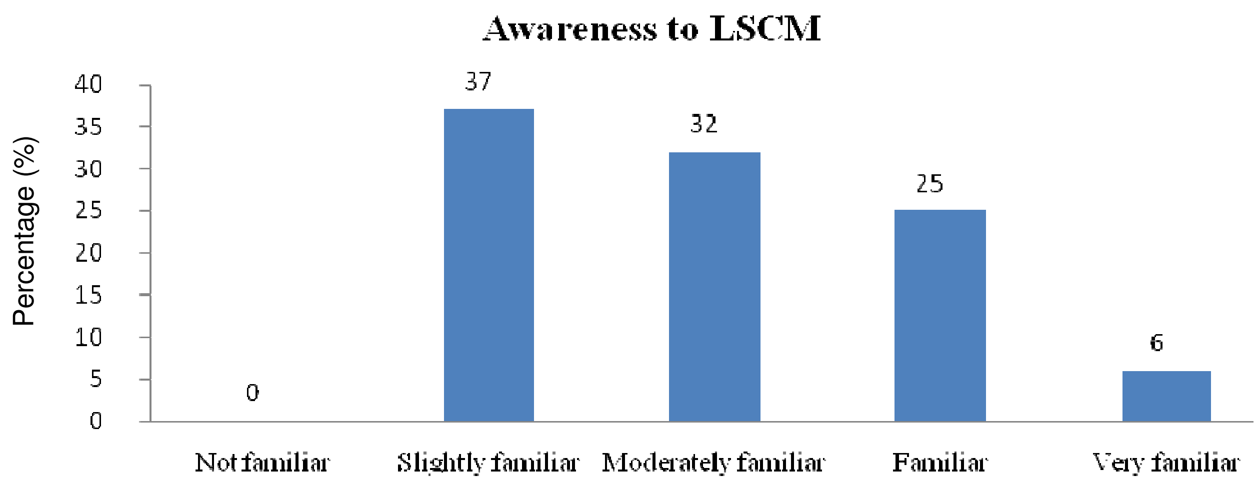

Figure 2. Awareness of respondents to LSCM.

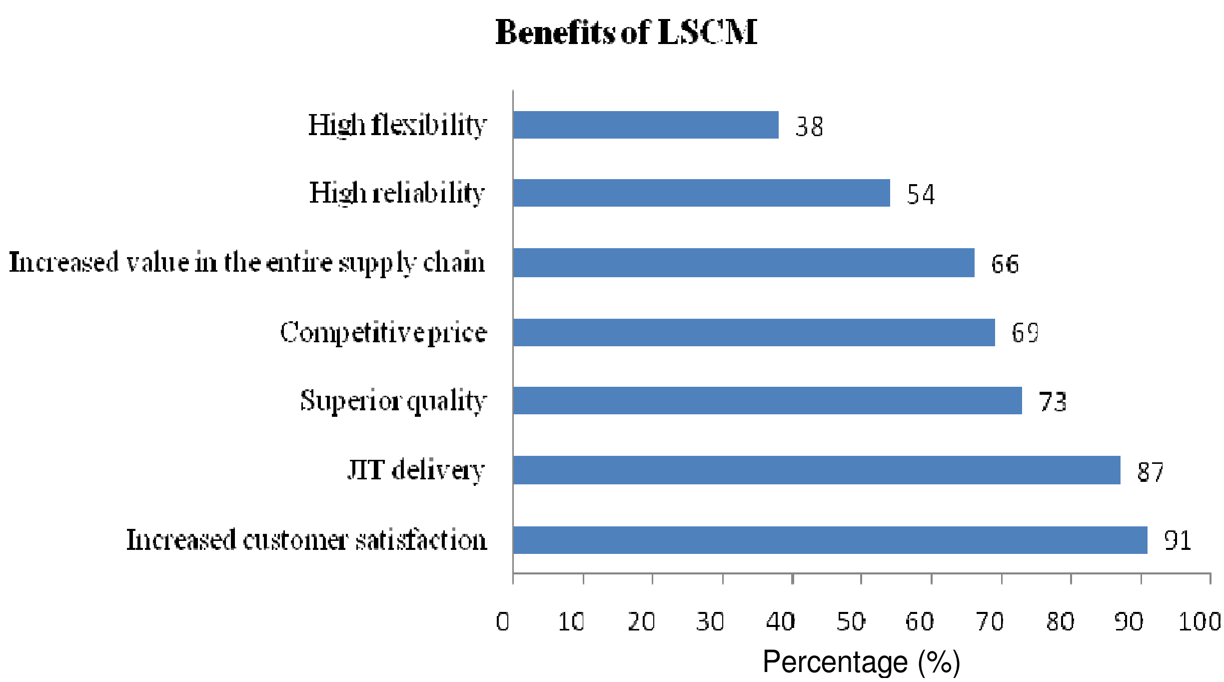

Figure 3. Benefits of LSCM.

researchers, as well as from suggestions of academics and practitioners in the field of automotive supply chain. This procedure is consistent with the requirements to achieve a high content validity.

Descriptive statistics of performance measures

A total number of 28 measures were finally identified to assess LSC performance of SMEs in the automotive industry in Iran (Table 3). The descriptive statistics are also presented in Table 3, which provides insights into the LSC performance measures scored by the respondents. There were five measures (out of 28) that attained mean scores greater than 4.5 (defect rates of production, customer rejection rate, manufacturing cost per unit, on-time production, and on-time delivery to customers) and two that attained mean scores less than 3.0 (supplier product-mix flexibility and manufacturer product-mix flexibility) with the majority of the mean scores being between 3.5 and 4.5. For the two lowest scored measures, it is not surprising that they received a

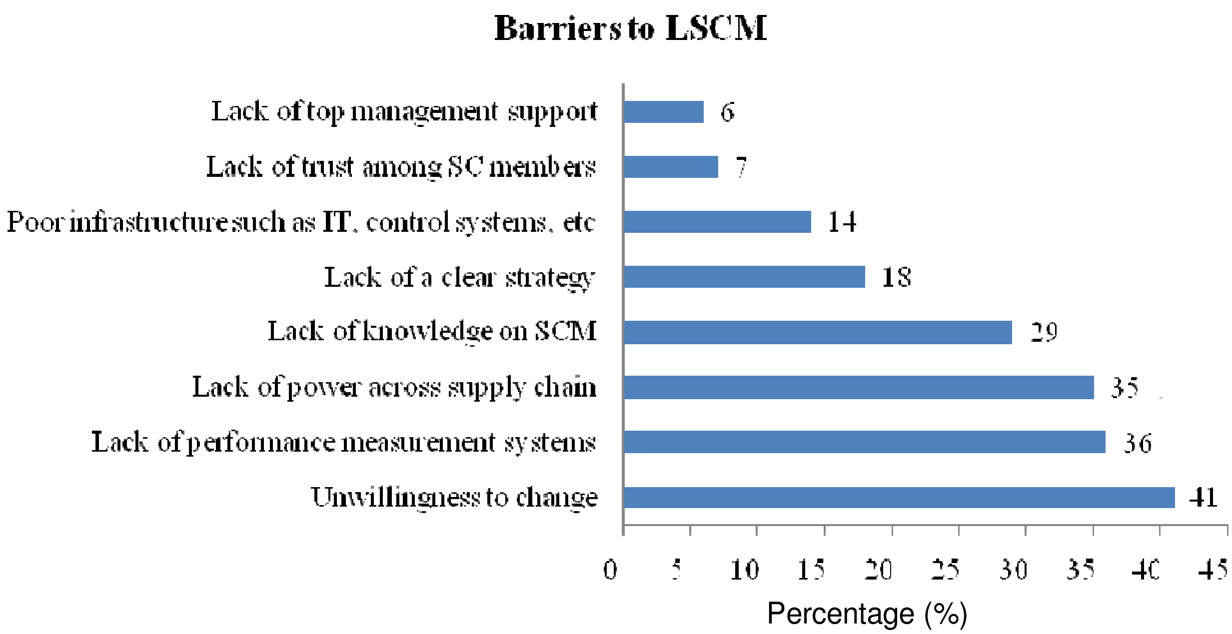

Figure 4. Barriers to LSCM.

Table 3. Selected measures with their mean, range and SD.

No.	Measure	Mean score	Range	S.D	Percentage of use
1	Supplier rejection rate	4.49	2 - 5	0.74	71
2	Percentage of standardized processes	4.06	2 - 5	0.64	74
3	Labor value added productivity	4.15	2 - 5	0.77	68
4	Customer delivery lead time	4.22	1 - 5	0.86	65
5	Percentage of total value-added time	4.20	2 - 5	0.77	56
6	Setup, unscheduled, and idle time	4.28	3 - 5	0.62	63
7	Average freight cost per unit	3.54	1 - 5	0.75	38
8	On-time delivery to customers	4.53	2 - 5	0.58	74
9	Customer complaints	4.41	3 - 5	0.58	87
10	Customer rejection rate	4.51	2 - 5	0.60	86
11	Total inventory	3.64	2 - 5	0.76	74
12	Supplier delivery flexibility	3.71	1 - 5	0.88	9
13	Manufacturer delivery flexibility	3.15	1 - 5	0.91	16
14	Defect rate of raw materials	4.05	1 - 5	0.73	89
15	Percentage of reworks	4.41	2 - 5	0.78	61
16	Manufacturing cost per unit	4.55	3 - 5	0.54	89
17	Supplier volume flexibility	3.71	1 - 5	0.86	13
18	Supplier product-mix flexibility	2.92	1 - 5	0.84	7
19	On-time delivery by suppliers	4.17	1 - 5	0.80	77
20	Warranty costs	3.36	1 - 5	0.85	30
21	Defect rates of production	4.77	3 - 5	0.45	92
22	Cost of energy	3.41	1 - 5	0.76	79
23	Perfect order fulfillment by suppliers	4.11	2 - 5	0.67	68
24	Supplier delivery lead time	4.17	1 - 5	0.71	53
25	On-time production	4.57	3 - 5	0.57	68
26	Perfect order fulfillment to customers	4.28	3 - 5	0.57	74
27	Manufacturer volume flexibility	3.62	1 - 5	1.01	22
28	Manufacturer product-mix flexibility	2.80	1 - 5	0.98	11

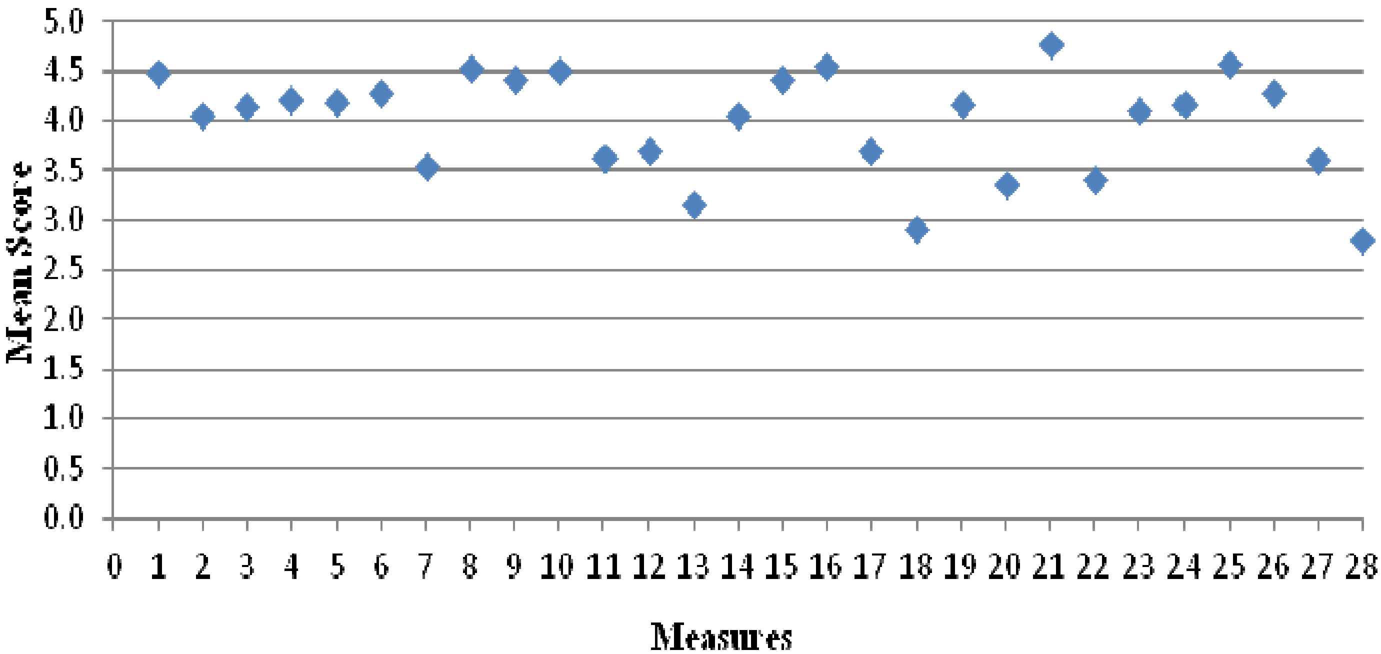

Figure 5: Mean scores for the 28 LSC performance measures

Table 4. Principal component analysis (PCA).

Components	Total variance explained								
	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Percentage of variance	Cumulative (%)	Total	Percentage of Variance	Cumulative (%)	Total	Percentage of Variance	Cumulative (%)
1	5.979	21.353	21.353	5.979	21.353	21.353	3.875	13.839	13.839
2	3.286	11.737	33.090	3.286	11.737	33.090	3.520	12.572	26.411
3	2.368	8.456	41.546	2.368	8.456	41.546	3.133	11.188	37.599
4	1.915	6.838	48.383	1.915	6.838	48.383	3.019	10.784	48.383
⋮	⋮	⋮	⋮						
27	0.179	0.638	99.489						
28	0.143	0.511	100.000						

Notes: KMO measure of sampling adequacy = 0.780; Bartlett's test of sphericity = 1406; $p < 0.000$.

not have authority to produce a high variety of products for large car makers as their main customers. Figure 5 shows a graph of the mean scores for the 28 measures, obtained by taking the average of 133 responses. It illustrates the dispersion of the mean scores from 2.8 to 4.77. The respondents were also asked if they are using the 28 performance measures and the results are shown in the last column of Table 3. The most often used measures were defect rates of production (92%), defect rate of raw materials (89%) and manufacturing cost per unit (89%).

Principal component analysis (PCA)

The data collected were suitable for PCA because the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was more than 0.5 and the p-value for Bartlett's test of sphericity was less than 0.05 (Table 4). Following this, PCA with varimax rotation was employed to group the variables and to examine the dimensionality of the performance measures in each category. The set of performance measures was used to determine the number of underlying factors based on their significance

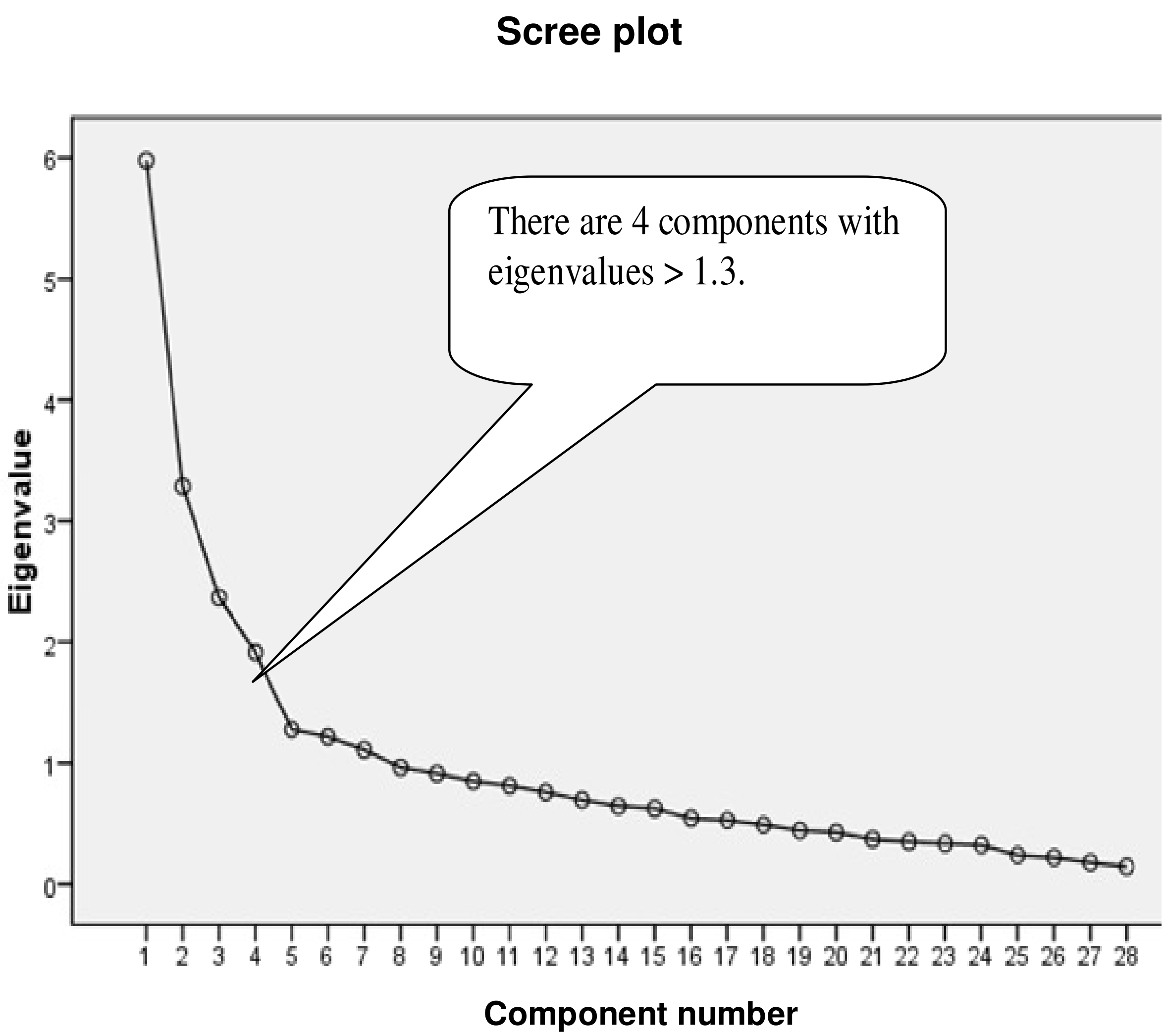

Figure 6. Scree plot of principal components.

in explaining the variance in the data set. Accordingly, four performance categories were identified, and the results of PCA are included in Tables 4 and 5. With respect to Table 4, the first principal component has an eigenvalue of 5.98 that explained 21.35% of the variance observed in the data. It followed through the fourth principal component which has an eigenvalue of 1.92 and explained 6.84% of the variance in the data set. Beyond the fourth principal component, the eigenvalues were less than 1.3 and explained less than 4.5% of the variance in the data. Cumulatively, 48.38% of the variance observed in the data was explained by the four extracted principal components. As a graphical tool, Scree plot was also applied to find out how many factors could be extracted. Indeed, Scree plot was provided to examine the variance explained by each subsequent eigenvalue developed from PCA (Figure 6). Using this plot along with the results of PCA, and looking at the eigenvalues greater than 1.3 helped to determine the appropriate number of underlying factors which best described the data observed in this analysis. Kaiser (1960) suggested a stopping criterion that uses an eigenvalue greater than one.

In this study, a more stringent stopping criterion was set by requiring each factor to have an eigenvalue higher than 1.3 since the Kaiser criterion is a less conservative method for retaining factors. After examining the eigenvalues greater than 1.3, four principal components were found (Figure 6), and later were named as quality, cost, flexibility, and delivery and reliability.

DISCUSSION

Resulting from the rotated component matrix (Table 5),the 28 performance measures were assigned to the four principal components based on the significant correlation coefficients greater than 0.5 and the results are presented in Table 6. The four significant factors identified and their related performance measures are discussed more in the following sub-sections.

Table 5. Rotated component matrix[a]

Variables (Measures)	Components 1	2	3	4	Variables (Measures)	Components 1	2	3	4
V_1	0.732	0.067	-0.047	0.266	V_{15}	0.615	0.092	0.043	0.004
V_2	0.637	0.120	0.195	0.166	V_{16}	0.078	0.850	-0.010	-0.030
V_3	0.184	0.613	0.105	0.089	V_{17}	0.012	0.032	0.569	-0.010
V_4	0.077	0.103	0.395	0.505	V_{18}	0.001	0.222	0.695	0.147
V_5	-0.010	0.548	0.054	0.043	V_{19}	-0.024	0.288	0.042	0.588
V_6	0.069	0.137	0.141	0.721	V_{20}	0.372	0.673	-0.016	0.030
V_7	0.116	0.782	-0.036	0.157	V_{21}	0.758	0.031	0.013	0.183
V_8	0.008	-0.054	0.147	0.558	V_{22}	0.055	0.559	-0.022	0.251
V_9	0.640	0.366	0.111	-0.115	V_{23}	0.018	0.104	0.158	0.587
V_{10}	0.827	0.214	0.131	0.044	V_{24}	0.107	0.199	0.126	0.757
V_{11}	0.074	0.508	0.192	0.126	V_{25}	0.145	-0.063	-0.056	0.511
V_{12}	-0.075	-0.063	0.655	0.099	V_{26}	0.146	0.227	0.327	0.513
V_{13}	0.104	0.020	0.717	0.089	V_{27}	0.045	0.041	0.624	0.085
V_{14}	0.777	0.002	-0.167	-0.041	V_{28}	0.034	-0.020	0.701	0.118

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. [a] Rotation converged in 5 iterations.

Table 6. Significant factors and related measures

	Component 1 (Quality) Cronbach's α = 0.84	Factor Loads		Component 2 (Cost) Cronbach's α = 0.79	Factor Loads
V_1	Supplier rejection rate	0.732	V_3	Labor value added productivity	0.613
V_2	Percentage of standardized processes	0.637	V_5	Percentage of total value-added time	0.548
V_9	Customer complaints	0.640	V_7	Average freight cost per unit	0.782
V_{10}	Customer rejection rate	0.827	V_{11}	Total inventory	0.508
V_{14}	Defect rate of raw materials	0.777	V_{16}	Manufacturing cost per unit	0.850
V_{15}	Percentage of reworks	0.615	V_{20}	Warranty costs	0.673
V_{21}	Defect rates of production	0.758	V_{22}	Cost of energy	0.559
	Component 3 (Flexibility) Cronbach's α = 0.76	**Factor Loads**		**Component 4 (Delivery & Reliability) Cronbach's α = 0.75**	**Factor Loads**
V_{12}	Supplier delivery flexibility	0.655	V_4	Customer delivery lead time	0.505
V_{13}	Manufacturer delivery flexibility	0.717	V_6	Setup, unscheduled, and idle time	0.721
V_{17}	Supplier volume flexibility	0.569	V_8	On-time delivery to customers	0.558
V_{18}	Supplier product-mix flexibility	0.695	V_{19}	On-time delivery by suppliers	0.588
V_{27}	Manufacturer volume flexibility	0.624	V_{23}	Perfect order fulfillment by suppliers	0.587
V_{28}	Manufacturer product-mix flexibility	0.701	V_{24}	Supplier delivery lead time	0.757
			V_{25}	On-time production	0.511
			V_{26}	Perfect order fulfillment to customers	0.513

Component one – quality

In total, seven variables were identified under the first component since all of them received a factor loading greater than 0.5 in connection with it. Among them, customer rejection rate received the highest factor loading (0.827) and strongly belonged to the first component. The next relevant variable was defect rate of raw materials with a strong factor loading of 0.777. Other variables related to this component were defect rates of production (0.758), supplier rejection rate (0.732), customer complaints (0.640), percentage of standardized processes (0.637) and percentage of reworks (0.615). By explaining 13.839% of the variance observed in the data, the first component was found to be the most significant. Due to the nature of the subsidiary variables, it was named quality. The reliability of this component was also strongly approved by obtaining a high Cronbach's alpha of 0.84 (Table 6). A scale is reliable if the alpha value is 0.7 or higher (Nunnally, 1978).

Component two – cost

With seven variables related to cost, the second component was detected and named as cost. Manufacturing cost per unit was assigned to this component with the highest factor loading (0.850). Other variables related to this factor were average freight cost per unit (0.782), warranty costs (0.673), labor value added productivity (0.613), cost of energy (0.559), percentage of total value-added time (0.548), and total inventory (0.508). This component explained 12.572% of the variance observed in the data. Since the Cronbach's alpha for this component was 0.79, it was accepted as being reliable for this research.

Component three – flexibility

Having a Cronbach's alpha equal to 0.76, the third component was also reliable and consisted of six performance variables with a maximum factor loading of 0.717, belonging to manufacturer delivery flexibility. Other variables were manufacturer product-mix flexibility (0.701), supplier product-mix flexibility (0.695), supplier delivery flexibility (0.655), manufacturer volume flexibility (0.624) and supplier volume flexibility (0.569).

This component explained 11.188% of the variance observed in the data. The third component was verified as flexibility since all the subsidiary variables were a kind of flexibility.

Component four – delivery and reliability

The Cronbach's alpha for this component was equal to 0.75 which justified the reliability of this component. In total, eight variables were identified under this component which were supplier delivery lead time (0.757), setup, unscheduled and idle time (0.721), on-time delivery by suppliers (0.588), perfect order fulfillment by suppliers (0.587), on-time delivery to customers (0.558), perfect order fulfillment to customers (0.513), on-time production (0.511) and customer delivery lead time (0.505). The best name recognized for this component was delivery and reliability.

CONCLUSION AND LIMITATIONS

This paper has presented an empirical methodology to identify the underlying LSC performance components and their respective measures with a special focus on manufacturing SMEs in the automotive industry of Iran. Data were collected from a sample of 133 practitioners working at manufacturing SMEs in Iran's automotive industry. Following the first research question, the literature was extensively reviewed, and interviews with experts, academics, practitioners and consultants were conducted. After filtering by experts, a list of 28 measures that represents the important items in relation to LSC performance of SMEs in Iran's automotive industry was identified. The second question was answered through the PCA method. As a result and in line with the literature, four underlying components were identified including quality, cost, flexibility, and delivery and reliability. Based on the eigenvalues generated from PCA, the 28 measures were grouped under the four underlying performance components. The third question was answered through the survey and the results are collected in Table 3. Studying only manufacturing SMEs in the automotive industry of Iran can be a limitation of this study. Hence, generalization of the results to other industries or even other countries may be a challenge, and needs to be further investigated. However, the identified performance components and related measures can be considered as a reference for future research. They can be considered by academics and practitioners as an input for a LSC performance measurement system.

While LSC performance measures are studied in this paper, more assessments seem to be necessary since this new topic is still under development. It will be useful to study lean performance measures in other supply chains and draw a comparison with this paper. Furthermore, the methodology employed in this study can be expanded to identify the most critical performance measures in a LSC.

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