Review Article GU J Sci 37(2): 875-893 (2024) DOI: 10.35378/gujs.1176313

Gazi University

Journal of Science

http://dergipark.gov.tr/gujs

Lean Six Sigma Studies in Türkiye: A Literature Review

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Highlights

- This paper focuses on lean six sigma studies in Türkiye.
- A literature review was made for both theses and articles.
- Most of the studies cannot be shared internationally because they were written in Turkish.
- Most of the theses have not been converted into articles.

Article Info

Received: 16 Sep 2022
Accepted: 31 Oct 2023

Keywords

Lean Six Sigma
Lean
Six Sigma
DMAIC

Abstract

The literature in the field of Lean Six Sigma (LSS) is developing in Türkiye as well as over the world. However, theses and papers written in Turkish are waiting to be disseminated. This paper aims to investigate LSS in the Turkish context with the purpose of identifying the current state, gaining insight and exploring future directions. This paper implements the systematic literature review methodology to identify and review all relevant studies in Turkish literature. This paper covers the literature on LSS in Türkiye from 2004 to 2021. As a result, a total of 32 theses and 29 papers were investigated in detail. This paper not only focuses on years, sectors, areas etc. of the studies, but also analyses the contents of papers in relation to enterprise size, project prioritization, and quality tools used in DMAIC phases, and improvements after implementation in terms of descriptive and content analysis. The results show that, although there are many LSS implementations in Turkish context, they could not be shared with global academic area due to the national language usage. LSS implementations have an increasing trend in last years and highly focused on manufacturing sector and large companies. The lack of structured way of applying LSS, especially not using project prioritization and selection methodology takes attention. This paper shows the gaps and future directions in Türkiye for researchers and provides a groundwork to develop a roadmap for Turkish organizations.

1. INTRODUCTION

Lean Six Sigma (LSS) is a globally adopted methodology that aims to maintain continuous improvement (CI) in companies. Motorola, General Electric, American Express, Ford Motor Co, and Xerox are some of the companies that used LSS successfully [1]. The methodology combines the perspectives of lean and six sigma to decrease waste and variation concurrently. Implementing LSS methodology can help companies to improve their focus on quality, cost, delivery, customer satisfaction, performance, and to gain a competitive advantage. LSS is beneficial for not only manufacturing companies but also for the service sector. In addition, it is not only used by the private sector, but also by public sector companies [2, 3].

The powerful analytical and statistical tools/techniques used in the context of Define-Measure-Analysis-Improve-Control (DMAIC) methodology are in the key position for the success of LSS. Quality Function Deployment (QFD), Statistical Process Control (SPC), Failure Mode and Effect Analysis (FMEA), Design of Experiments (DOE), Kano Model, and Analysis of Variance (ANOVA) are some of the mostly known tools [4]. There are other tools used in each phase of DMAIC.

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There are some literature reviews on LSS have been carried out. The first critical literature review on LSS was presented by [3]. The paper of [4] differs from the others being a review of LSS in various industrial sectors. On the other hand, there are some countrywide reviews such as Brazil [5] and India [6].

To the best of author's knowledge there is not any review paper related with LSS in Turkish context in the literature. Unfortunately, only one paper [7] was determined about LSS implementation in Türkiye in the review of [8]. The main cause of this scarcity is the language of the studies. Because, both theses and papers were written generally in Turkish, only a small number of theses were converted into papers. This is an undesirable situation, taken into consideration of the academic trend of writing papers based on unpublished thesis results. To address this gap, we aim to conduct a systematic review of LSS studies in the Turkish context. Our goal is to collect not only papers but also theses about LSS in Türkiye and introduce them globally. The main contribution of our paper is to bring together studies that have been written in Turkish but not converted into papers. Hereby, we aim to fill the gap in LSS studies in the Turkish context and to open new avenues for future research. Finally, our paper will allow comparisons with other country contexts to see the place of Türkiye in the world.

This study is organized as follows. Firstly, section 2 covers the research methodology. Section 3 describes results of the review in terms of descriptive and content analysis. Lastly, section 4 highlights the conclusion, limitations and future directions.

2. LITERATURE REVIEW ON LEAN SIX SIGMA

Lean production is a philosophy originated from Toyota Production System (TPS) and focuses on eliminating wastes (*overproduction, waiting, unnecessary transport, over processing, excess raw material, unnecessary movement, and defects*) [9]. On the other hand, six sigma is a CI methodology aims to decrease variability and became popular with Motorola and General Electric implementations [4]. As a complementary CI approach, LSS was implemented in various manufacturing and service sector, since it was appeared [9, 10].

For example, in [11] LSS was implemented in aluminum process, resulting in a 24% improvement in sigma level and 8% improvement in process efficiency. In [12], a study was conducted to reduce waste during the assembly process using LSS techniques such as Kaizen, Value stream mapping, Pareto chart, Single-Minute Exchange of Die (SMED), and 5S. Similarly, [13] used LSS to evaluate a new electrode production for chemical processes.

Due to the increased interest in sustainability and environmental issues, global warming has become an important topic in the production process. In [14], environmental issues were combined with LSS and Green LSS (GLSS) techniques were used to reduce the release of CO_2. Nowadays, Industry 4.0 is another popular topic, and [15] examined studies on GLSS in Industry 4.0. On the other hand, there is a growing interest in the healthcare sector for LSS [16-21]. One of these studies [16] used LSS techniques in a rural hospital, resulting in an acceleration of the process. In [18], 8 critical success factors were identified, with good planning and execution, and the implementation of obvious and sustainable plans being the most important. [19] used LSS techniques in a laboratory hospital and showed an increase in sigma level. Another reducing worthless activities was studied by [21] in healthcare. [20] used LSS techniques, particularly DMAIC and Value Stream Mapping for healthcare operations. [17] examined implementations in hospitals between 2011-2020.

Economic, environmental, and social factors were considered in [22], a review about sustainable LSS. The results show that LSS applications have a constructive impact of 83% on economic charts, 78% on environmental charts, and 70% on social charts. In addition, factors that can be used to measure sustainability have been identified.

On the other hand, there are review articles in different country contexts in the literature. [5] - Brazil, [23] -India, [24] -West of Ireland, and [25]-Austrasia are some of them. Not only literature review methodology [5, 23] was used, but also different research methodologies were used to investigate LSS implementations in these contexts. [23] examined only papers in India. Studies were grouped under five categories, as an author profile, year of publication, type of firms, research methods, and type of industry. According to the results, LSS was more common in medium and small companies, and empirical research has more spread than other research techniques. The other finding shows that the service sector tended to use LSS techniques compared to the manufacturing sector. In [5], papers and theses in Brazil were analyzed and grouped into five concepts, as type of studies (papers or thesis), size of sector, LSS tools, researchers' profile, and critical success factors. In addition, critical success factors were compared with other countries in [23]. The results showed that the implementation of LSS in the manufacturing sector was more common than in the service sector, and the implementation of LSS in the healthcare sector has increased in recent years. Based on the results of these reviews, it can be seen that LSS is improving and there are opportunities for new ventures [5].

Case study [25] and mixed research methodology [24] are examples of different research methodologies. Similarly, the application of LSS in the manufacturing sector is low in West of Ireland [24]. Additionally, it was indicated that LSS implementations in a company, did not spread to the whole company; it was applied in only some departments. The results of [25] were highly important in comparing LSS studies in Australasia with US on three aspects, highlighting differences and similarities. For example, the definition of LSS project is different, but project selection, starting and finishing practices are similar. LSS has reputation in the service sector, but there is no evidence that the service sector or the manufacturing sector is more inclined to use it.

3. RESEARCH METHODOLOGY

This study uses the systematic review methodology used by [26] which is based on the guidelines of [27]. Applying steps starting from the selection of work to analysis, ensures transparency, reliability, and reproducibility.

Figure 1 depicts the flowchart of the review methodology. The review starts with the determination of databases. First of all, to find the papers (English/Turkish) published journals indexed in SCI, SCI-E, SSCI, and ESCI, Web of Science (WoS) database was searched. In addition, the Google Scholar database was used to find other English/Turkish papers in journals published in other indexes. There is a website in Türkiye (https://tez.yok.gov.tr/UlusalTezMerkezi/) which covers all English and Turkish theses prepared in postgraduate programs in Turkish universities.

The paper follows the steps outlined in [26], which include the keywords, first refinement, inclusion and exclusion criteria, and second refinement. These steps are visualized in Figure 1. Database search was performed with the determined keywords. In the first refinement, papers were evaluated to determine their suitability. Suitable papers passed to the second refinement process, while the others were excluded. After determining the related studies in the second refinement step, the descriptive and content analysis were performed. Following sub-sections provide detail information about these steps.

3.1. Keywords

The search was carried out in two languages. "lean six sigma" and "Turkey" keywords were used to find English papers and theses. On the other hand, "yalın altı sigma" and "Türkiye" keywords were used to determine the Turkish paper and theses.

3.2. First Refinement

First refinement was made according to the title and abstract of the papers and theses. As a result of this step, 34 theses and 31 papers were refined.

3.3. Inclusion and Exclusion Criteria

Papers and theses that discuss LSS implementations were included in this study. The review papers were also eligible for paper-type publications. The exclusion criteria were determined as studies in which only six sigma implementations were made and despite "lean six sigma" placed in the title or abstract, the implementation is in other concepts.

3.4. Second Refinement

In the second refinement step, all eligible studies were analyzed in detail by reviewing their full-texts. In this step, two theses and one paper were removed according to the exclusion criteria. After the second refinement, 32 theses and 29 papers have remained. Except for 2 PhD theses [28, 29] the other theses were MSc theses. In total, 61 studies were determined to be input for both descriptive analysis and content analysis. To facilitate systematic analysis research questions (RQ) were generated. These twelve questions are listed associated with the analysis types in which they will be answered.

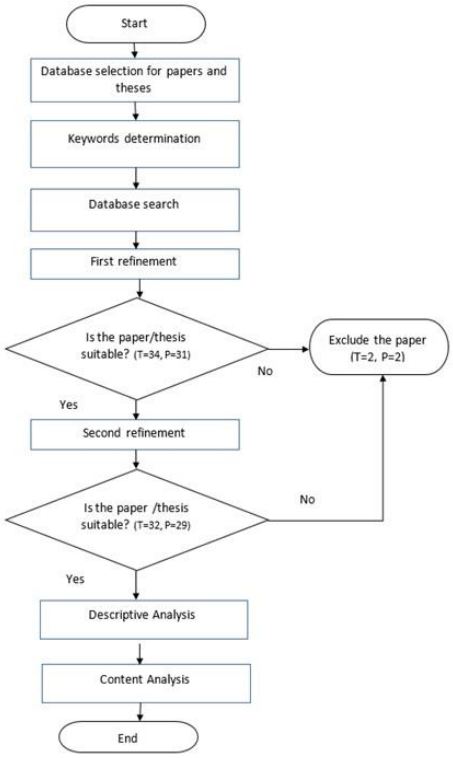

Figure 1. *Review methodology workflow*

Research questions about descriptive analysis

RQ1. What is the chronological status of the studies?
RQ2. How many theses /papers were written in English?
RQ3. In which departments theses were written?
RQ4. What are the author's departments of papers?
RQ5. In which sectors lean six sigma implementations were made?
RQ6. How many papers were written based on the results of unpublished theses?

RQ7. What are the types of studies?
RQ8. In which journals papers were published?

Research questions about content analysis

RQ9. What is the enterprise size of the firms in which lean six sigma implementations were made?
RQ10. What type of project prioritization and selection methods were used?
RQ11. Which one of the quality tools were selected to use in each step of DMAIC?
RQ12. What is the improvement ratio in sigma levels?

4. RESULTS AND DISCUSSION

The results of this review are presented in this section. The first subsection covers the results of descriptive analysis, while the second subsection covers the results of content analysis.

4.1. Descriptive Analysis

Firstly, the number of theses and papers by year were analyzed to answer RQ1. The results are shown in Figure 2. Ozdemir's thesis in 2004 was the first publication in Türkiye, four years after the emergence of LSS in the literature. On the other hand, the first paper was published in 2009 [30] in which a literature review was made on LSS. The popularity of LSS has grown over the years, with the maximum number of papers being published in 2021 (5 papers) and the maximum number of theses being published in 2019 (7 theses). To answer the RQ2, the language of 23 theses was Turkish (72%) whereas 9 theses were written in English. Similarly, the language of 11 papers was English and remaining 19 papers were written in Turkish (63%). This result is important because it highlights the scarcity of sharing the findings globally.

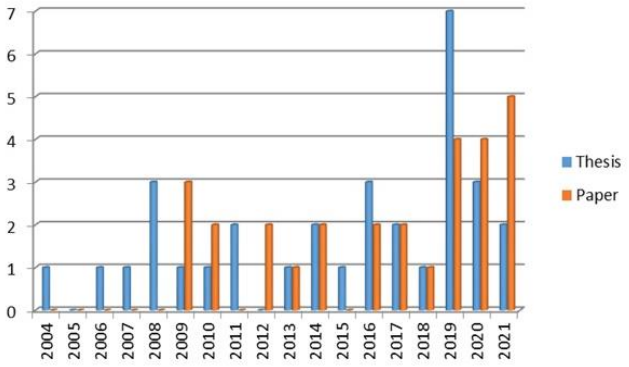

Figure 2. *Number of theses and papers by the year*

After year of publications, the author's profile was analyzed. When LSS theses are analyzed according to the department with Figure 3 to answer RQ3, it is shown that most theses have been done in the field of Industrial Engineering with a rate of 47%. Business Administration is following it with 23%. Total quality management studies are studied with a rate of 9%, while quantitative methods, statistics, chemical engineering, management engineering, wood product industry, and civil engineering are the least working departments with 3%.

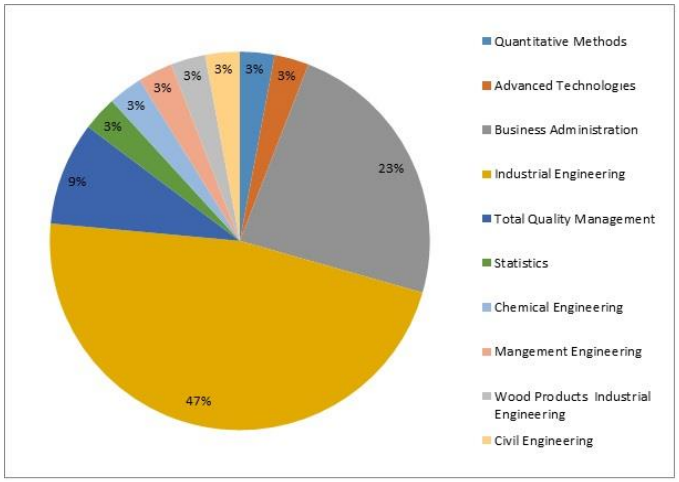

Figure 3. *LSS theses by department*

The distribution of author's departments is shown in Figure 4. Similar to theses, most authors are working in Department of Industrial Engineering (39%). Department of Business Administration (32%). follows Industrial Engineering. Studies in the field of healthcare also attract attention. Technology Faculty, Automotive Technologies, Public Administration, and Agriculture had the same proportion.

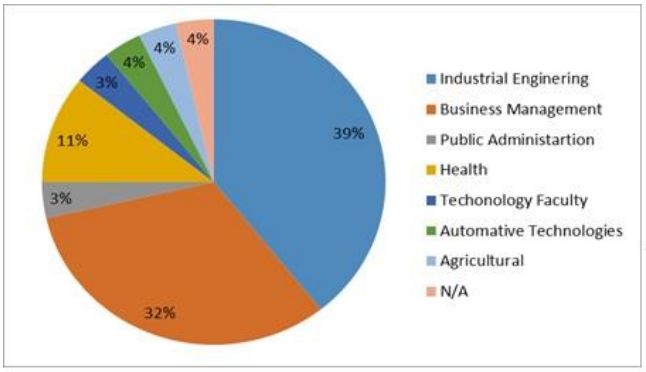

Figure 4. *Papers by author's department*

Theses and papers were analyzed by sector to answer RQ5. Figure 5 depicts the most popular sectors as textile, logistics, and metal industries in theses. Health, foam, and automotive sectors follow these industries. On the other hand, agriculture sector, baked products, furniture, and software were less studied. LSS implementation was less common in other sectors.

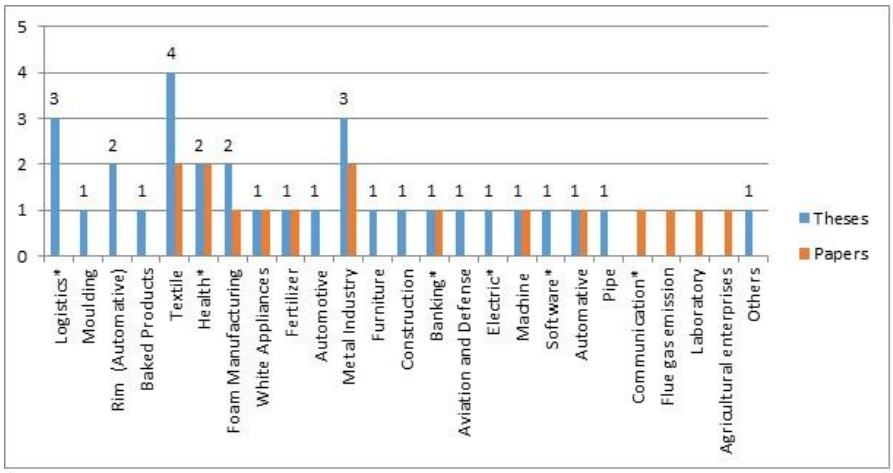

Figure 5. *Theses and papers by sector*

According to Figure 5, the most studied areas in papers are textile (manufacturing sector) and health (service sector). Service sectors are visualized with * after names. White appliances, metal industries, communication, fertilizer, pulley, fuel gas emissions, laboratory, foam manufacturing, automotive, agricultural enterprises, and banking were studied at the same rate.

Papers were examined whether they were based on an unpublished thesis or not to answer the RQ6. Results show that only 8 (27%) papers were based on an unpublished thesis and only 3 of them were LSS implementation papers. Similarly, only 3 (10%) of them were written in English.

According to the results, LSS implementations in theses were mostly made in the manufacturing sector. Only [31-33, 29, 34] implemented LSS in the services sector, such as health, logistics, banking, and software. In this context, 6 papers were implemented in service sector [35- 40]. The fields covered in these papers are health, communication, laboratory, and banking in this area.

To answer Q7, when theses were analyzed, [3] (9%) of them were review, and [29] (91%) of them were LSS implementation in different sectors such as a good and services sector. Besides, the studies of [36, 41] were presented in conferences.

The journals indexed in WoS are listed in Table 1 to answer RQ8 as follows. "Sigma Journal of Engineering and Natural Sciences" and "Journal of the Faculty of Engineering and Architecture of Gazi University" are the only journals in which more than one paper was published.

Table 1. *Journal names by frequencies and indexes*

Name of Journal	**Frequencies**	**Type of journal**
Sigma Journal of Engineering and Natural Sciences	2	WoS
Journal of the Faculty of Engineering and Architecture of Gazi University	2	WoS
International Journal of Lean Six Sigma	1	WoS
Asia-Pacific Journal of Business Administration	1	WoS
Total Quality Management & Business Excellence	1	WoS
International Journal of Mathematical Engineering and Management Sciences	1	WoS
Quality Quantity	1	WoS
Journal of Cleaner Production	1	WoS
Journal of Clinical Laboratory Analysis	1	WoS
Journal of Social Sciences of Mus Alpaslan University	1	TR Index
Journal of Health Academics	1	TR Index
Journal of Accounting and Finance	1	TR Index
Afyon Kocatepe University, Journal of the faculty of economics and sciences	1	TR Index
Electronic Journal of Social Sciences	1	TR Index
Journal of Business Studies	1	TR Index
AJIT-e: Online Academic Journal of Information Technology	1	TR Index
Journal of Quality and Accreditation in Health	1	TR Index
Electronic Journal of Social Sciences	1	TR Index
Electronic Journal of Vehicle Technologies (EJVT)	1	TR Index
KSU Journal National Science	1	TR Index
Journal of Muğla University Institute of Social Sciences	1	TR Index
Journal of Life Economics	1	TR Index
Press Academia	1	TR Index
International Journal of Multidisciplinary Thought	1	TR Index

Suleyman Demirel University The Journal of Faculty of Economics and Administrative Sciences	1	TR Index

4.2. Content Analysis

According to [42], content analysis is defined as "*a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use"* and it gives chance to the researchers to describe and quantify specific phenomena [26]. In this section it is aimed to answer RQ7-10 respectively.

Enterprise sizes

To answer the RQ9 in content analysis, enterprise sizes of companies were investigated. According to OECD reports the threshold value is 250 people to determine the size of the enterprise. They are classified as "large" enterprises if they employ more than 250 people. On the other hand, if the employee number is lower than 250, they are called small and medium-sized enterprises (SMEs). In detail, SMEs are also subdivided as micro enterprises (fewer than 10 employees), small enterprises (10 to 49 employees), and medium-sized enterprises (50 to 249 employees).

There is information related to enterprise size in nearly half of the theses (n=18). In these theses, generally the company name is generally kept confidentially. The size of the enterprise was inferred from the number of employees. The results indicate that 61.11% (n=11) of these companies [43, 32, 44, 45, 33, 46-51] were large companies, while the remaining companies (n=7) were all medium-sized enterprises [52-58] with employee numbers ranging from 80 [57] to 220 [52] employees.

The papers contain limited information about enterprise size. In only 20% (n=6) papers, the enterprise size was reported. [7, 59, 60, 39, 36] reported that the size of the companies was big. Only among them, [61] reported the employee number as 120 which corresponds to medium size.

As a result, there was not any implementation reported in small and micro sized SMEs.

Project prioritization and selection method

There is scarce information in terms of project prioritization and selection to answer the RQ10. The only thesis using Multi-Criteria Decision Making (MCDM) techniques for project prioritization and selection were [45], [31], and [62]. This corresponds to 4.92% (n=3) of studies. Analytical Process (AHP) was the only MCDM method used in these studies, which is consistent with the literature review on six sigma project prioritization and selection methods [63]. There were also factor scoring methods used by [28] and Risk Priority Factor (RPF) by [43] for project prioritization and selection.

In addition, [50] conducted a Pareto analysis to identify the daily encountered problems (80%) and then investigated white and yellow belt improvements. The product that was highly affected after nine months according to critical output characteristics was chosen in this analysis

Quality tools

There were some quality tools used in each phase of DMAIC methodology. Before starting the define phase of DMAIC, [63, 47, 51, 56, 57, 64, 65, 59, 40] constituted project charter. The only study in which education was provided for employees before the implementation is reported is the thesis of [57]. These activities can be considered as initial step.

Define Phase Tools

The first phase of DMAIC is the "Define" phase which aims to answer "What is the problem?" and "What is the project objective?". The following tools can be used in this phase: project charter, problem definition, flow chart, Supplier-Input-Process-Output-Customer (SIPOC) chart, and current state value stream map

(VSM) [66]. Table 2 depicts the quality tools reported in the Define Phase of DMAIC in terms of theses and papers. According to the results, Supplier–Input–Process–Output–Customer (SIPOC) was the most preferred tool. Critical to Quality (CTQ) Tree Diagram followed SIPOC. On the other hand, the only study in which risk analysis was made is the thesis of [62]. Other tools used in the "Define" phase of DMAIC include focus group, voice of the customers, Kano model, fish-bone diagram, and stakeholder analysis.

Table 2. *Quality tools reported in define phase of DMAIC*

Tools	**Thesis**	**Frequencies**	**Papers**	**Frequencies**
SIPOC	[34, 52, 63, 67, 68, 45, 49, 31, 33, 47, 51, 56, 69]	14	[64, 59, 70]	3
Process Map	[52, 68, 71, 58]	4	[52, 72, 37]	3
Value Stream Map	[49,46,43]	3	[61]	1
Focus Group	[57, 34]	2	[61]	1
Voice of the Customer (VoC)	[68, 71, 31, 57, 67],	5		
Kano Model	[57, 34, 48]	3		
Fish-Bone Diagram (Cause- and effect)(Ishikawa)	[32, 51, 73]	3		
Cause and Effect Matrix			[40]	1
Stakeholder Analysis	[51]	1	[40]	1
Risk analysis	[62]	1		
Critical to Quality (CTQ) Tree Diagram	[68, 33, 34, 47, 51, 56, 67]	7	[65, 74, 70, 37, 59]	5

Measurement Phase Tools

The "Measurement" phase in DMAIC methodology follows the "Define" phase. This phase aims to answer the questions "What is the current state of the process?" and "Which data should be collected?". In this context, waste categorization, process capability analysis, and activity categorization are some of the tools can be useful [66]. Quality tools reported in this phase are placed in Table 3. The results indicate that the diversity of tools in theses was higher than papers. Capability analysis, pareto charts, and control charts were top three tools in this phase.

Table 3. *Quality tools reported in measurement phase of DMAIC*

Tools	**Thesis**	**Frequencies**	**Papers**	**Frequencies**
Gage-Run Chart	[68, 45]	3	[65]	1
Control Chart	[45, 31, 43]	3	[35, 52, 72, 75]	3
Process observation	[34]	1		
Value Stream Map	[31, 57, 76]	3	[70]	1
SIPOC	[71, 47]	2		
Time value map	[62]	1		

Tools	Thesis	Frequencies	Papers	Frequencies
Time series analysis	[62]	1		
Capability Analysis	[57, 77, 50, 48, 62, 51, 58]	7	[61, 40]	2
Pareto charts	[31, 43, 49, 54, 71, 46, 45]	7	[70]	1
Time series plots (run charts)	[51]	1		
Histogram	[77]	1		
Binary odds test	[58]	1		
Lost time analysis			[61]	1

Analysis Phase Tools

The third phase of DMAIC is the "Analyze" phase. Defect Analysis, cause and effect diagram, and pareto analysis are some of the tools to answer "What are the root causes of the problem?" in this stage [66]. Brainstorming based Fish-Bone Diagram came forward among thirteen tools reported in Table 4. 5 Why, scatter plots, regression and correlation analysis, ANOVA, VSM were the other tools used in papers. Moreover, FMEA, control charts, process capability analysis, and Pareto analysis/charts are the tools used in theses.

Table 4. *Quality tools reported in analysis phase of DMAIC*

Tools	Thesis	Frequencies	Papers	Frequencies
Brainstorming and Fish-Bone Diagram (Cause-and effect)	[31, 43, 69, 52, 67, 46, 71, 45, 49]	9	[52, 72, 70, 74]	4
5 Why	[47, 51]	2		
Scatter plots	[57, 58]	2	[28]	1
Regression Analysis	[51]	1		
Correlation Analysis	[34, 62]	2		
Simulation	[31, 58]	2		
Value Stream Map	[50]	1		
Taguchi	[62]	2	[40]	1
ANOVA	[46, 47, 57, 69]	4		
FMEA			[61, 59]	1
Control Charts			[61]	1

Tools	Thesis	Frequencies	Papers	Frequencies
Process Capability Analysis			[65]	1
Pareto Analysis/charts	[52, 71, 49]	3	[72, 70, 40]	3

Improvement Phase Tools

The "Improvement" phase of DMAIC aims to answer the question "What are the potential solutions that can be implemented?" [66]. As stated in Table 5 there are several tools used to improve the actual state. In spite of there was not a dominant tool, studies that used "Kaizen" and "Root Cause Analysis" are higher than the others (Table 5).

Table 5. *Quality tools reported in improvement phase of DMAIC*

Tools	Thesis	Frequencies	Papers	Frequencies
FMEA	[56]	1	[37]	1
Implementation Difficulty Matrix	[57, 58]	2	[61]	1
5S	[34, 45, 49]	3		
Kaizen	[45, 77, 62]	3	[36]	1
DOE (Design of Experiments	[34, 58]	2		
Pareto analysis	[46]	1	[59]	1
Kanban	[67, 49]	2	[40]	1
Single Minute Exchange of Die (SMED)	[48]	1		
FMEA	[57, 58]	2		
Mathematical modelling	[57]	1		
Standardized work	[58]	1		
t-test			[61, 65]	2
PICK chart			[40]	1
Root Cause Analysis	[57, 76, 51]	3	[61, 59]	2

Control Phase Tools

The last phase of DMAIC has the lowest variability in terms of tools. Control charts and sustainability plans can be used to determine the KPIs and follow them [66]. One of the reasons for the scarcity of information about the control phase is that it is not as widely studied as the other phases. Table 6 shows that ANOVA was the most commonly used tool in this phase, followed by I-MR charts.

Table 6. *Quality tools reported in control phase of DMAIC*

Tools	Thesis	Papers
Pareto analysis	[46]	
TPM	[47]	
ANOVA	[44]	[40]

RACI Matrix		[78]
I-MR Chart		[74, 70]

Improvement Ratio in Six Sigma Levels

Last but not least, research question (RQ12) is related with the outputs of the LSS implementations. The scarcity of information is similar in improvement ratios across six sigma levels. Only in 15.2% (n=5) theses the improvement ratios were stated with before and after sigma level. Table 7 depicts these improvements results.

Table 7. *Improvement ratio in sigma levels*

Thesis	Sigma Level (Before)	Sigma Level (After)	Improvement Ratio (%)
[45]	2.2	2.7	22.73
[46]	3.40	3.9	14.71
[49]	3.20	4.1	28.13
[28]	2.64	2.91	10.23
[57]	3.4	4	17.65

Despite the lack of information about the improvement ratios, in some of the theses and papers some improvements were reported.

On the theses side, the reported improvements can be listed as:

- Increase in yield and decrease in setup time [62]
- Purchasing process was reduced by %55 [71]
- 33.6% increase in average monthly production [56]
- Production speed has been increased by 20% [57]
- Productivity rate increased to 84% [58]
- The Process Cycle Efficiency has increased from 31% to 42% and length of stay decreased from 16.05 to 12 minutes for less acute patients (level 4 and 5) need diagnosis [34]
- Increasing productivity of logistics processes and reducing of logistics costs ratio from 26% to 13% [48]
- 16% decrease in the amount of traffic fines, 18% decrease in the number of accidents, 42% decrease in the number of complaints, and 12% improvement in the fuel rate [32]
- Waiting time in different operations decreased between 7% and 26% [45]
- Inventory cost was decreased [67]
- Due to the lack of training is a reason for failure, education before DMAIC implementation needs to be emphasized.

Similarly, the scarcity of information is also valid in papers. As an example, [72] reported an increase in efficiency (4.4%) and general equipment effectiveness (32.4%). They also reported a decrease in production flow time (75.13%), process time (32.5%), set-up time (12.6%), and error rate per unit (41.2%). Customer satisfaction rate increased from 62.54% to 66.37% in the paper of [65]. Other improvements include a decrease in pollution [78], turnaround time [39], energy consumption [61], and cost [59].

5. CONCLUSION

LSS is a crucial CI methodology that synergistically addresses both wastes and variations. There are numerous LSS implementations on the academic side both in theses and papers in Türkiye. However, due to the language of studies (Turkish), the results of a huge part of these studies cannot be shared internationally. Furthermore, the conversion rate of theses to papers is very low.

The main contribution of this research is to collect all studies, both papers and theses, about LSS in Türkiye and introduce them globally. The originality of this work is being the first review about LSS conducted in the Turkish context. In this context, we conducted a systematic literature review based on WoS, Google Scholar and the national database for theses from 2004 to 2021. Both theses and papers were analyzed in terms of publication years, author's profile, sectors, type of research, etc. We suggest valuable insights based on a systematic literature review for both academic researchers and practitioners. The main findings of the paper listed as follows in terms of research questions:

- The first thesis was published in 2004 only after four years after the world like in Brazil. There is an increasing trend in LSS studies in the last few years. 2019 was the year that maximum number of work have been published similar to India.
- From the perspective of departments of the authors of the theses, Industrial Engineering and Business Administration departments are at the forefront.
- LSS was mostly studied in the Department of Industrial Engineering, and Department of Business Administration is in the second position. LSS was less studied in other departments.
- LSS studies have been applied in many fields, such as logistics, health, and the metal industries. Textile is the first rank across manufacturing sectors. These sectors are different in contexts such as automobile and its components in India and in Brazil.
- While 23 theses were written in Turkish, only 9 of them were written in English. Similarly, the language of only 11 papers is English, whereas 19 papers were written in Turkish.
- Writing papers based on unpublished thesis results is an academic trend. However, unfortunately, only 8 papers were written based on the results of the unpublished theses about LSS.
- Results showed that type of studies was generally implementation, and several studies are review papers. This is an important information to show practical contributions beyond theoretical ones.
- Papers were published in ten different Web of science Journals, and others were published in Turkish Journals. There is not a dominant journal and there are only two journals in which more than two papers were published.
- According to the company size analysis, LSS implementations were generally made in large companies. The literature showed the same situation occurred in India and West Ireland. The implementation cost is probably the first barrier for LSS implementations in small and medium size companies.
- There is a gap detected in project prioritization and selection methods. The only MCDM method used for this aim is AHP.
- There were a variety of tools used in each phase of DMAIC. Supplier–Input–Process–Output–Customer (SIPOC) is placed at the top across ranking tools in Turkish publications different from the Brazilian context in which control charts are the first.
- There was a lack of sigma improvement level in publication results. The improvement ratio changes were reported between 10.23% and 28.13%.

This paper is based on the literature review based on Web of Science, Google Scholar and Council of Higher Education Thesis Center which is a special database for theses written in Turkish universities (https://tez.yok.gov.tr/UlusalTezMerkezi/) in Turkish context. Limited databases, only one research method and only one country context are the limitations of the paper.

Gaps and future directions

In this section, possible future research areas are explored to inspire researchers in LSS. These directions are listed below:

- Specific generalizations could be made using case studies.
- Projects can be prepared to reveal LSS implementations and results in Turkish companies which are not a subject to academic publications. Project results can be shared with academic area with reports or articles generated from this project.
- Roadmaps can be useful for especially small and medium size companies in Türkiye to expand LSS implementations.
- MCDM methods other than AHP can be used such as CODAS [79] and KEMIRA-M [80] which have been used for project prioritization and selection in six sigma projects before.
- The effect of enterprise size can be explored. In addition, LSS applications can be made in micro and small-sized companies (SMEs). In addition, studies can be made in different size SMEs and they can be compared according to challenges and success/failure factors.
- There is a lack of information about LSS implementation results especially in sigma level improvements. Improvements ratios need to be declared after LSS applications.
- LSS implementation in the service sector is limited to hospitals and banks. LSS implementations can be made in other service sectors.
- A standard framework can be developed for LSS implementations [3].
- The results of the quality tools are consistent with the results of [81] Uluskan (2019) and there are some highly used tools such as Pareto, brainstorming, process flow maps, SIPOC, control charts, etc. In the future studies the need for more sophisticated statistical methods [5] is still valid.
- It is determined that the Critical Success Factors (CSFs) are not reported. The relationship between the LSS tools and critical success factors can be analyzed [5].
- LSS methodology can be combined with agile as LSS-agile [29] in the next studies.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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