An integrated spherical fuzzy AHP multi-criteria method for Covid-19 crisis management in regarding lean six sigma

Ezgi Demir
Department of Management Information Systems, Piri Reis University, Istanbul, Turkey, and

Hakan Turan
Consultancy Services, Sigma Center Consultancy, İzmit, Turkey

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Abstract

Purpose – The Covid-19 pandemic has caused disruptions in many businesses. A difficult process has been experienced for businesses caught unprepared for this situation. The purpose of the study, the difficulties experienced in the business have been mapped in terms of crisis management.

Design/methodology/approach – For this purpose, crisis management strategies have been discussed in terms of lean six sigma (LSS) strategies. Afterward, LSS strategies have been weighted with the spherical fuzzy analytical hierarchy process (AHP) method, which has been recently introduced to the literature (Gündogdu and Kahraman, 2020). While weighting has been done with the spherical fuzzy AHP method, three experts in the field of LSS at the master blackbelt level have been studied.

Findings – The Covid-19 process has caused the usual processes of businesses to change. Businesses do not have enough time to adapt their business processes in the Covid-19 process. To eliminate waste and time in the Covid-19 process, the lean methodology was used. At the same time, quality deficiencies have been tried to be eliminated with the six sigma methodology. Therefore, the six sigma methodology and lean techniques should be considered together. With LSS, the adaptation of this process has been wanted to be accelerated. In this context, the criteria in the Covid-19 process were prioritized and losses were reduced in accordance with the LSS methodology. In this study, the most important criterion during the covid-19 pandemic has been determined as "responding to the changing needs of customers" and the least important criterion has been determined as "communication with stakeholders in enterprises."

Research limitations/implications – This study has been applied the Covid-19 pandemics. So, it has been evaluated related to these specific criteria.

Practical implications – Covid-19 crisis management was examined for the first time within the scope of the LSS methodology. The criteria in the Covid-19 process were determined by six sigma expert master black belts. For the first time, spherical fuzzy AHP, one of the multi-criteria decision methods, has been applied to the Covid-19 process.

Originality/value – This study has been aimed to create a roadmap to apply LSS steps in businesses against a possible second wave of the Covid-19 pandemic. In this context, it is thought that the study will fill the following gaps in the literature: Covid-19 crisis management was examined for the first time within the scope of LSS methodology. The criteria in the Covid-19 process were determined by six sigma expert master black belts. For the first time, spherical fuzzy AHP, one of the multi-criteria decision methods, has been applied to the Covid-19 process.

Keywords Lean six sigma, Crisis management, Covid-19 pandemic, Spherical fuzzy AHP

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1. Introduction

The Coronavirus pandemic is not only a health problem but also is an economic problem. Many studies say that Covid-19 will make a deep decline in the percentage of economic growth by 0.1% in 2020. In general, the next real impact caused by Covid-19 business entities in the private sector in Turkey. For the past five years, the development of business firms in the private sector or public sector in Turkey reached 90% of the total business process. However, in the past six months, the number of business firms decreased in Turkey in regard to trade, food, transport, manufacturing sectors. Then, so, the growth has been still considered slow because some of the factors have been considered not too effective. In fact, at the beginning of 2020 economic situation was not very good. Later in Turkey has been tested with the appearance of the Covid-19 outbreak and the economic growth has been affected so badly. The Covid-19 outbreak began in Wuhan City, Hubei Province, China in December 2019 and was explained as a pandemic by the World Health Organization. More than 620,000 cases of Covid-19 have been declared in more than 190 countries, resulting in more than 28,800 deaths and 137,000 of them recovered. The spread of the Covid-19 virus has an impact on business firms in Turkey. However, because of lean six sigma (LSS) methodologies, business firms can survive the Covid-19 outbreak. One of these methodologies produces consumer goods and services that are close to the needs of the human population. Because it is an important issue to be able to serve consumers and not compromise on quality in this process. Lean techniques aim to minimize waste and time losses in the service sector. At the same time, the six sigma methodology aims to minimize the quality losses that may occur in mass production. Therefore, a large number of production and quality losses that occurred during the Covid-19 crisis period must be taken together. For this reason, it has emerged from the literature and expert opinions that lean and six sigma methodologies should be considered together in this study.

Covid-19 has negative effects on the economy such as decreased consumption and purchasing power of the people, decreased company performance, threats to the banking and financial sectors. In regarding the consumption and purchasing power of the people, this pandemic causes a lot of labor to decrease or even lose income, which affects the level of consumption and purchasing power of the people. Most people are very careful about buying something with respect to their financial expenditures because of the uncertainty of when this pandemic will end. Also, this situation causes a decline in the purchasing power of people for consumer goods and puts pressure on the producers and sellers. As for companies, this pandemic has disrupted the performance of businesses, especially those engaged in the trade, transportation and tourism sectors. Social distancing policy which is then changed to physical distancing and working from home has an impact on decreasing company performance. There are even some businesses that go bankrupt and eventually choose to close their business. In the banking and financial effects, this pandemic raises fears of debit or credit repayment problems which will ultimately affect the sustainability of business performance. In addition, this pandemic causes the threat of fading foreign investment from Turkey which naturally threatens the government's strategic projects. The existence of this pandemic caused a decline in demand performance (consumption and purchasing power of the people) which ultimately impacted the supply side, namely, termination of employment and the threat of non-payment of credit (Syaputra *et al.*, 2020).

LSS methods improved the production process or more generally is to achieve efficiency and optimization of the production process. This is done so that the six standard deviations (Sigma) between the average and the closest detail limit do not exceed the specified limit. The aim of sigma is to decrease variation in expenditure so that it does not cross six standard deviations (Sigma) between the average (mean) and the closest detail limit. The

higher the value of sigma, the less a process experiences variations and the fewer errors will be experienced. LSS implementation implements the process. If it is successful, then LSS will be able to determine that the total production process has been handled at optimal capabilities. Simultaneously, the LSS method is used as a tool in solving production problems so that breakthroughs can be computed in boosted production, decreasing product errors, decreasing costs, decreasing production terms, boosting market share growth, to customer retention.

LSS is the best methodology for developing business processes efficiently and significantly decreasing product errors (Thomas and Barton, 2006). If the product errors decrease, customer satisfaction will increase (Antony *et al.*, 2017, 2005). Six sigma decreases variability in the business process.

Six sigma, reduce variability in business processes (Wessel and Burcher, 2004). Then, LSS has become a business process development strategy that has reached all types of companies, industrial and service enterprises (Antony *et al.*, 2017). LSS has also been seen as a difficult problem-solving strategy (Kumar and Antony, 2008). In some studies that have been implemented LSS and accomplish an increase in performance especially on employee satisfaction, boosting customer satisfaction or solve problems (Kaushik *et al.*, 2012). Thomas *et al.* (2009) conducted an integrated approach to the lean and six sigma model. Its development and implementation have been gathered through studying closely with the company. A. Rymaszewska (2014) conducted an evaluation of the firms' current positions for implementing lean and its challenges. In this way, firms will be more confident in their own capabilities. Furthermore, it has been made a role map for preparing lean implementation and its consistency. Chakraborty *et al.* (2019) conducted differences and similarities in responses from small medium enterprises for two countries. These similarities and differences have been explained regarding quality management practices and also useless techniques and tools. Then, also it has been explained main business performance indicators. Yadav *et al.* (2020) approved 20 performance indicators under different combinations of Information and Communications Technologys, LSS and quality management system. Kumar *et al.* (2009) conducted a survey among the 500 firms with a random sampling technique. It has been found an important difference in the performance of the Six Sigma/Lean companies with ISO certification. Dora *et al.* (2014) conducted lean manufacturing practice deployment in the food industry. It has been defined key barriers faced by good industries to implement lean manufacturing practices. Then, also it has been underlined that limited knowledge is not enough for lean implementation. Ramadas and Satish (2018) also defined 15 different barriers to implement lean manufacturing. Sharma *et al.* (2015) defined two strategic lean criteria as a strategic partnership and cross-functional design and the rest of the criteria have been found a negative effect on performance measures. Achanga *et al.* (2006) defined leadership, management, finance, organizational culture and skills and expertise as the most important criteria for the success of implementing the concept of lean manufacturing.

The Covid-19 process has suddenly affected businesses. This situation has led to an increase in some demands and a decrease in others in the businesses. At the same time, because it is not a process that businesses and consumers expect, sudden decisions must be made. In this sudden process, businesses cannot be expected to change their normal processes. This process has turned into a crisis management process. More attention should be paid to the waste of resources in the crisis management process. For this reason, the study has been tried to be examined using the LSS methodology. This study has been aimed to implement LSS criteria to the Covid-19 process. Because of the Covid-19 process that businesses come across for the first time and it is very difficult in terms of applying LSS key factors. The Covid-19 process has brought the uncertainty process for businesses. This

situation requires decision-making under uncertainty. The decision-making process under uncertainty requires the examination of many value judgments together. The fuzzy set theory, which is related to the uncertainties in the thinking of people and firms and directed to the rationality of this uncertainty, was first put forward by (Zadeh, 1965). The fuzzy set theory, it is aimed to solve complex systems belonging to the real world, including the human gaze, to develop a more powerful and flexible model, and thus to solve a model by simplifying it. In addition, the fuzzy set theory allows decision-makers to evaluate only existing alternates under given limits (optimize a given system) and develop new alternates (design a new system). The purpose of fuzzy set theory is to bring certainty to concepts that express uncertainty, which is difficult to define or difficult to understand, by assigning a degree of membership to them. The determination approach is achieved by the transformation of the bivalent sets theory to the multivalued sets theory. A fuzzy set is a class of objects whose membership degree is continuous. Such a set is characterized by a membership function, each element of which is specified by membership degrees between 0 and 1.

Many decision-making problems and solutions are too complex to be understood quantitatively. This complexity can be achieved by using uncertain information rather than specific information. Fuzzy set theory likens uncertainty to human questioning in the use of approximate information and making decisions. This situation is specially designed mathematically to show uncertainty and vagueness and is used in many problems to represent uncertain facts. Fuzzy sets provide solving structured problems related to uncertain facts for many problems. The fuzzy set theory tries to classify or group data with boundaries that are not precisely defined. By generalizing a problem with strict definitions, statements have been blurred with certain boundaries. The advantage of augmented exact theory and methods of analysis with fuzzy techniques is that they have the ability to solve real-world problems. This skill can be achieved by using linguistic expressions. For example, it is not entirely clear what linguistic expressions such as low, medium and much can correspond quantitatively. The ability to express this unclear situation can be easily achieved with fuzzy sets.

In this study, the key criteria for managing the Covid-19 process have been explained in accordance with the LSS process. Within the scope of this project, the criteria were determined by three experts, a six sigma master black belt.

Membership functions examine the fuzzy multi-criteria decision-making approach in more dimensions. In this context, extensions of ordinary fuzzy sets such as three-dimensional intuitionistic fuzzy sets (IFS), Pythagorean fuzzy sets (PFS) and neutrosophic sets (NS), which are frequently used in the literature, aim to gather experts' judgments in a more informative and clear way (Gündoğdu and Kahraman, 2019).

Afterward, the criteria were weighted by the spherical fuzzy analytical hierarchy process (AHP) method, which makes binary comparisons between the criteria that have just been added to the literature. Covid-19 process that combines many uncertainties. Spherical fuzzy AHP method is a method that analyzes uncertainties with membership functions and non-membership functions.

Spherical fuzzy sets (SFS) are a new extension of IFS, PFS and NS. SFS consist of the degree of membership, degree of non-membership and degree of hesitancy. The degree of hesitancy ensures that the square sums are equal to or less than one. SFS provide a wider choice for decision-makers in three-dimensional space (Gündoğdu and Kahraman, 2019). For this reason, spherical fuzzy AHP method has been preferred in this study because it rationalizes all uncertainties and analyzes them quantitatively.

In this context, it is thought that the study will fill the following gaps in the literature:

- Covid-19 crisis management was examined for the first time within the scope of the LSS methodology.
- The criteria in the Covid-19 process were determined by six sigma expert master black belts.
- It is not possible to apply in all processes of the businesses at the point of reducing waste in the Covid-19 process. For this reason, the points where losses will be reduced should be prioritized according to the needs of the businesses. Multi-criteria decision-making methodology enables the transformation of qualitative or quantitative statements and examining them as a whole. The process of Covid-19 requires a multi-criteria decision-making methodology as it is necessary to address separate waste in each process, to use resources correctly and to determine the priority decisions of the business. At the same time, as the Covid-19 process is a process that requires rapid decision-making, it is aimed to create a roadmap in the advancing wave processes of the virus with this study. For the first time, spherical fuzzy AHP, one of the multi-criteria decision-making methods, has been applied to the Covid-19 process.

In this study, in the first part, the Covid-19 process and a literature review related to LSS methodology have been given in the introduction. In the second part, it has been explained the relationship and Covid-19 process. In the third part, methodology and spherical fuzzy AHP has been given. Later the application, conclusion and further studies have been also given.

The situation behind SFS is to define a membership function for decision-makers on a global surface. Generalizing the extensions of other fuzzy sets to create a larger domain regardless of parameters. SFS gives more general and effective results in fuzzy logic because it is a synthesis of PFS and NS (Gündoğdu and Kahraman, 2019). It has been preferred the results of SFS in the literature because SFS is more accepted and their validity is confirmed according to the Spearman correlation coefficient.

2. Lean six sigma methodology

Lean approach was first developed as Japanese thinking after the Second World War. In the 1950s, it was introduced as the Toyota production system approach intending lower inventory, workforce, cost after lean manufacturing become famous with his book, the machine that changed the world, written by Womack in the 1990s. The most popular topic for companies is continuous improvement, regardless of the industry (Assarlind *et al.*, 2012). Womack *et al.* (1990) identified lean as a dynamic process of change directed by several policies and best practices purpose continuous improvement. Lean is interested in eliminating non-value activities. Lean aims to dissolve the waste. Wastes are called Muda in Japanese (Womack and Jones, 2003). Similarly, lean production is targeted to remove non-value activities and resolve waste in the productive system as a philosophy. While lean production reduces costs, it never compromises on quality (Walter and Paladini, 2019). Lean manufacturing consists of seven basic wastes. These are transportation, inventory, motion, waiting, over-production, over-processing and defects (Chakravorty and Shah, 2012). In addition, environmental waste and skill waste are also identified (Vinodh *et al.*, 2012).

On the other hand, Duffy and Wong (2013) treat lean production as eight basic wastes.

(1) Transportation points to unnecessary carrying while performing activities.

(2) Inventory consists of all raw materials, semi-finished products (work in process) and finished products.

(3) Motion states the unnecessary movement of staff and equipment while conducting the process.

(4) Waiting entitles the necessary time spent in a phase of the production activities because of slowing or stopping production while before the stage is finished.

(5) Over-processing expresses the practice of additional activities that do not enable value in the way of the customer.

(6) Over-production is to produce more than the client demands.

(7) Defects include rework and scrap.

(8) Skill is the incompetence of staff to implicitly perform their talents.

Six sigma was first performed by Motorola in the 80s and later developed by general electric. Sigma conversion values are as mentioned in Table 1 and Figure 1 below, respectively, it aims at 3.4 faults per million. It is explained with the sigma (σ) symbol which is a statistical tool. Success grades have been measured to this sigma level.

Six Sigma focuses on critical quality characteristics, taking into account the voice of customers. At the same time, six sigma is a process improvement approach to reducing process variability with the help of statistical tools (Walter and Paladini, 2019).

Applying LSS for continuous improvement is a highly applicable method. At the same time, it is extremely effective in attaining desired outcomes for all companies (Muganyi *et al.*, 2019). Laureani and Antony (2012) interpreted the shareholder value maximization technique in terms of companies. Because the combined tool of lean manufacturing and six sigma presents low costs, high quality, fast delivery and customer satisfaction. In this context, LSS should be used to get more effective results. Aldairi *et al.* (2017) claim that lean manufacturing and six sigma complete each other for the project. Albliwi *et al.* (2015)

Defect per million opportunities	Sigma (σ)
690.000	1
308.000	2
66.800	3
6.210	4
320	5
3.4	6

Source: Baas (2007)

Table 1.
Sigma conversion values

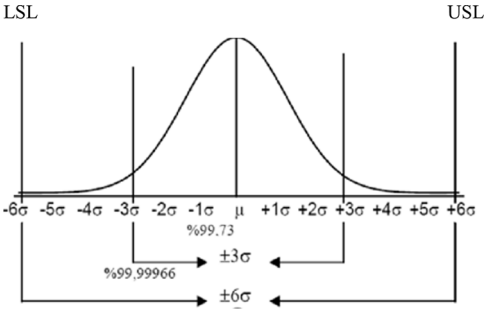

Figure 1.
Six sigma process (Baas, 2007)

investigated the companies applying LSS. It has been revealed that LSS makes an important contribution to manufacturing companies.

Antony and Karaminas (2016) described black belts roles and responsibilities in LSS. Studies conducted in the past have expressed the roles and responsibilities of black belts as follows: team-leader, full-time resource, mentor, help with implementing statistical tools, coach, involved in improvement projects, teacher and trainer.

Today, companies aim to reduce costs, reduce the time to deliver the product to the customer and prevent quality defects to get a competitive advantage (Alhuraish *et al.*, 2017). Lean production and six sigma have accepted the broadest and extended strategies for performing continuous improvement in all fields (Bakar *et al.*, 2015). Lean production and six sigma were integrated in 2000 (George, 2010). Both methods are complementary. Lean production focuses on process optimization and also eliminates waste, while six sigma concentrates to reduce process variation. Therefore, lean production is usually interested in cost, when six sigma is closely related to quality (Walter and Paladini, 2019).

The methods such as value stream mapping (VSM), 5S, total productive maintenance (TPM), has been added to LSS to increase productivity. The improvements conducted have been monitored by defect per unit, overall equipment effectiveness and process capability (Cpk) (Kumar *et al.*, 2006).

LSS is a technique that combines both lean thinking and six sigma in areas such as the manufacturing and service sector by implementing continuous improvement (Albliwi *et al.*, 2014).

LSS reduces cost, quality defects and increases productivity in the serving sector. This situation has been proven by applying it at the university (Wheeler-Webb and Furterer, 2019). Similarly, Vaishnavi and Suresh (2020) stated that LSS accelerates the service and eliminates waste by applying LSS in hospitals. Noori (2015) explained that applying LSS in hospitals decreases waiting time and costs.

On the other hand, some obstacles were observed in the implementation of LSS. These obstacles are senior management deprivation, information, education deprivation and resistance to change (Mustapha *et al.*, 2019).

Swarnakar *et al.* (2020) examined the critical failure factors affecting the sustainable LSS application and investigated the level of relationships among them. Similarly, Ali *et al.* (2020) showed that six sigma positively affects environmental performance and lean manufacturing contributes to operational performance and operating performance.

3. Lean six sigma in Covid-19 for crisis management

The spread of Covid-19 to the world brings along crisis management for companies operating in every field. As (Alharthi and Aziz, 2018) claim, LSS is a tool that can be used to reduce risks in crisis management. A survey has been conducted on this subject and the results have been evaluated with chi-square analysis. Oil firms in Saudi Arabia have been proposed to save their income due to the volatility in prices. It has revealed that it should benefit from qualified immigrants for this.

Simeonova and Nedyalkov (2018) enable the improvement of the reaction procedure in crisis management with LSS. LSS technique has been used to improve quality characteristics based on this procedure. LSS has been used to increase customer reputation by reducing food risks. The crisis team used hazard analysis critical control points and LSS to manage risks. Control points have been determined based on LSS, and thus crisis management was implemented. Crisis action plans have been created according to the define-measure-analyze-improvement-control steps of LSS. It is thought that applying LSS will provide a competitive advantage by defining critical quality points in the company's

vision and behavior. At the same time, it enables to predict the crisis as it is based on statistics. Besides, it provides effective management of resources. Therefore, it also prevents waste.

According to (Egli, 2020), LSS is an important tool in managing crisis management. It can be applied similarly to the crisis situation brought by Covid-19. Alharthi and Aziz (2018) conducted LSS, crises Management and innovation related with a theoretical framework. Egli (2020) conducted six sigma applications for the Covid-19 global outbreak by a case study. Simeonova and Nedyalkov (2018) conducted a crisis management problem by using LSS.

Covid-19 spreads very rapidly. Taking measures quickly is vital for humanity. In this context, any quick action to be taken will play an active role in the management of the epidemic. LSS is an important tool for the management of the epidemic, especially, as it is a quality, speed and cost-oriented approach. On the other hand, although the actions to be taken produce benefits in terms of quality, speed and cost, the priorities of the actions should be determined correctly. Failure to prioritize correctly will lead to unwanted consequences for human life. Although every action to be taken will give good results, it will differ in importance. In this context, actions to be taken based on LSS should be listed according to their importance to managing the epidemic quickly. The spherical fuzzy system, which is one of the most up-to-date methods, has been used for sequencing LSS activities. By determining their priority order with SFS, the relevant LSS activity has been selected. Thus, with the right prioritization, an effective way has been drawn in managing the epidemic.

3.1 5S

5S philosophy developed by Takasa Osada consists of 5S. These are Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize) and Shitsuke (Sustain), respectively (Osada, 1991). Sort is the removal of unnecessary materials from the work area. Set in order are activities to find the necessary materials quickly. Shine are activities carried out in the work area without dust or dirt. Standardize is stated how the first three steps will be done. Sustain shows the responsibilities of the employees with the controls (Ahuja and Khamba, 2008). The 5S method provides a cleaner and safer workplace, lower cost, better equipment reliability, higher quality products and services, better maintenance, more efficient use of workplace space and less labor (Patel and Thakkar, 2014).

3.2 Relationship between covid and crisis management

The Covid-19 disease emerging today has brought many problems. In addition to the threat, it poses to human health, it is seen as one of the biggest obstacles to the survival of companies. Companies survive in proportion to the precautions they try to take during the pandemic period. As Covid-19 is a new disease, there are deficiencies at many points in the activities performed. Therefore, studies on this are extremely lacking. As Covid-19 disease has invaded the whole world for a year, companies need to establish permanent precautions on this disease. In this context, companies have to develop precautions against Covid-19. Although there are still deficiencies in how to develop precautions, hygienic protections are applied by many companies. However, studies on how to integrate this into managerial processes are extremely insufficient. Academic studies in this field are, therefore, quite insufficient. In this study, it was emphasized that the precautions determined for the Covid-19 outbreak should be addressed with the LSS methodology.

A study was conducted to explain what could support innovation in crisis situations such as the Covid-19 outbreak in the short term. For this, a crisis model involving the technological development of two drugs has been proposed. It is focused on how innovation

will be dealt with in managing crises. Local governments may be late to respond to the crisis based on Covid-19. Covid-19 covers two basic dimensions of crisis management as physical/technical and political risks. The findings obtained confirm that crisis management involves more than one issue. It has been demonstrated that it is necessary to work together to cope with the crisis (Shangguan, *et al.*, 2020).

With lean manufacturing tools, it can be used to improve critical processes against the pandemic. Therefore, lean management can also be applied in administrative management against difficulties caused by the pandemic (McGovern, 2020).

For variations between specific causes in Covid-19, the LSS project has been implemented in three different countries (Salentijn *et al.*, 2021).

By applying the LSS method for Covid-19, it has improved the diagnosis prevention and treatment process during the pandemic process. By integrating the idea of operational excellence into the pandemic process, it ensures to be prepared for these events. In particular, Failure Mode & Effects Analysis (FMEA) which is an LSS tool can be used to improve and evaluate the risk of Covid-19 (McDermott *et al.*, 2021).

3.3 Why lean six sigma for Covid-19

According to Antony, with regard to the reduction and management of Covid-19, the LSS method can be used to reduce the variance that occurs in test times. It is also an effective tool to eliminate root causes of variance. Hypothesis tests and regression analysis are used for the accuracy of test results, while VSM can be used to speed up the flow and shorten the time. With the Kano model, the expectations of the customers can be clearly stated. Statistical control can be provided to monitor the results. To increase the reliability of test results, Type 1 error and Type 2 based on hypothesis tests error can be used. Models based on artificial intelligence can be created to predict the results. At least one of these methods can be successful (McDermott *et al.*, 2021).

In the light of problems encountered existing epidemic, its relationship with LSS has been discussed. The criteria for crisis management have been obtained from the literature and the opinions of experts who have worked in the textile industry for many years. First of all, precautions to be addressed against Covid-19 are as follows:

- Tendency to teamwork.
- Accuracy in decision-making.
- Offering solution suggestions for bad situation scenarios.
- Communication with stakeholders.
- Identifying workflows and process owners.
- Compliance of actions with corporate objectives.
- Compliance with employees and feedback.
- Proper technological infrastructure.
- Spreading trend of the virus.
- Analyzing data.
- Employees' competence.
- Customer's changing need.

LSS offers a structure that will make the implementation of these precautions easier. If we examine how to apply these precautions better using the LSS method, item by item:

- *Tendency to teamwork:* With a tendency to teamwork, measures can be taken more quickly in the rapid spread of Covid-19. LSS is based on teamwork. The project leader, that is the belt candidate, is determined at the beginning of the project and the team members who will take part in the project. The manager provides the necessary resource support as the project owner. Therefore, the LSS project involves not a single person but holistic teamwork. Lai and Wong (2020) emphasized the importance of organizational structure in businesses in the Covid-19 process. Branicki (2020) examined the Covid-19 process based on the attitudes and behaviors of individuals.
- *Accuracy in decision-making:* As Covid-19 is not known by anyone, accuracy in decision-making will contribute to this outbreak. It is necessary to know effective techniques to increase the value of accuracy in decision-making. For this, competencies need to be increased. The roles involved in LSS are well versed in knowing and applying many techniques. If we interpret the roles in the light of projects carried out in LSS.

  Yellow belts receive information training on LSS. They know what purpose LSS is applied for. They play the role of team members in projects. Green belts focus on daily quality improvement projects. Training of green belts takes 10–12 days. They have information about statistics. They take part in projects part-time. Black belts work full time. Training of black belts takes 20–24 days. They are representatives of change assigned to critical projects. At the point of statistics, they know more techniques than the green belt. Master black belts guide and train green and black belts. It supports them where they get stuck. Saroj and Pal (2020) investigated the analysis of the Covid-19 process and the decision-making methodology. Branicki (2020) examined the decision-making processes of individuals in the Covid-19 process. Ardito *et al.* (2021) examined the decision-making processes of the business during the Covid-19 process.

- *Offering solution suggestions for bad situation scenarios:* offering solution suggestions for bad situation scenarios will allow focusing on the solution of this complex problem. Many different methods can be used in LSS to develop solutions for worst-case scenarios. Process FMEA method can be applied to address risks. The poka-yoke method can be used to prevent errors that may occur and become standard. At the same time, problems that may occur with brainstorming, fishbone diagram, 5-cause analysis and tree diagram can be examined by teamwork. Saroj and Pal (2020) conducted a situation analysis against possible bad scenarios in the Covid-19 process. Ardito *et al.* (2021) conducted a bad scenario analysis during the Covid-19 process. Krausz *et al.* (2020) mentioned technological emergency measures against bad scenarios in the Covid-19 process.
- *Communication with stakeholders:* communication with stakeholders will reduce the loss of time in the pandemic and prevent mistakes that may arise from a lack of coordination. Communication with the suppliers can also be achieved by putting forward the process flow studies effectively. On-site quality and supplier development ideas in the lean philosophy also support this development. At the same time, supplier input process output and customer (SIPOC) analysis is performed in LSS. This structure consisting of SIPOC is created from the process flow. It allows seeing clearly the components of the current process to be improved. SIPOC is examined visually with VSM. Ardito *et al.* (2021) mentioned the impact of communication with stakeholders of the business on decisions made during the Covid-19 process.

- *Identifying workflows and process owners:* identifying workflows and process owners will speed up information access during the outbreak. As mentioned above, when determining the workflow and process owners, LSS includes the process drawing in the definition phase of the problem. It also uses techniques such as VSM and 5S to accelerate the flow of materials and information. Lai and Wong (2020) mentioned the importance of speeding up workflows in the Covid-19 process. Saroj and Pal (2020) defined the roles of individuals in the Covid-19 process. Ardito *et al.* (2021) examined the processes of businesses during the Covid-19 process.
- *Compliance of actions with corporate objectives:* Compliance of actions with corporate objectives will ensure the coordinated management of the outbreak. An evaluation is made in terms of operational excellence in ensuring the compliance of actions with corporate objectives. Therefore, a part of operational excellence is also constituting LSS. Saroj and Pal (2020) have defined the goals of each step in the Covid-19 process. Ardito *et al.* (2021) examined the goals and priorities of businesses in the Covid-19 process.
- *Compliance with employees and feedback:* Compliance with employees and feedback will ensure that even the slightest information about the outbreak is not missed. Thus, a solution will be produced for this epidemic, the solution of which is not yet known. Compliance with employees and feedback: One of the basic points of lean production includes respect for employees. They provide a structure focused on continuous improvement at the point of their employees' thought. According to lean manufacturing, the one who knows a job best is the one who does it. Therefore, the people who will do kaizen consist of employees inside rather than senior management. At the same time, studies are carried out by creating quality circles. Suggestion systems, which are an important element of lean manufacturing, are also extremely necessary in terms of feedback. Gemba's philosophy also requires being in the field to solve the problem. 5S also includes active participation and feedback of employees. Similarly, other lean techniques also include employee compliance and feedback. Lai and Wong (2020) mentioned the importance of business employees' attitudes and behaviors in the Covid-19 process. Branicki (2020) examined the reactions of individuals in the Covid-19 process. Ardito *et al.* (2021) emphasized the correct use of employees and resources in the Covid-19 process.
- *Proper technological infrastructure:* Proper technological infrastructure will present correct analysis with correct data about Covid-19. Having the appropriate technological infrastructure ensures proper data production. This enables statistical analysis such as regression analysis, hypothesis testing, statistical process control (SPC), Cpk, measurement systems analysis (MSA) and design of experiment (DoE) used in LSS. Saroj and Pal (2020) made a social media-based technological analysis of the Covid-19 process. Ardito *et al.* (2021) emphasized the importance of technological infrastructure competence of businesses in the Covid-19 process. Krausz *et al.* (2020) discussed the initiative process to invest more in technological developments in the process of controlling the virus.
- *Spreading trend of the virus:* Spreading trend of the virus is important in determining the areas to be quarantined and shaping the measures. The spreading trend of the virus is revealed by estimation methods. For this, trend/prediction analysis and regression analysis used in LSS can be used. At the same time, the scope of the project created when starting LSS is determined and the supplier and

customer network is determined with the SIPOC diagram. Shangguan *et al.* (2020) mentioned the spread of the Covid-19 process in China. Krausz *et al.* (2020) discussed the application development process at the point of tracking the spread of the virus with electronic applications.

- *Analyzing data:* Analyzing data is essential to manage the pandemic. In particular, it constitutes a vital foundation for such an unknown epidemic simple six sigma techniques such as Cpk, design of experiments, Regression analysis, hypothesis testing, MSA and SPC mentioned above are used. Lai and Wong (2020) ensured the correct management of business data in the Covid-19 process. Saroj and Pal (2020) analyzed social media data during the Covid-19 process. Branicki (2020) analyzed the behavioral data of individuals in the Covid-19 process. Krausz *et al.* (2020) mentioned the importance of data and data security in application and process development by analyzing data on individuals in the Covid-19 process.
- *Employees' competence:* Employees' competence is necessary for both analysis and saving the lives of patients. Then, also it is extremely important in terms of LSS. To apply the techniques mentioned in LSS, it is also necessary to have a certain competence. Therefore, a person who knows LSS will be able to manage the process more effectively in the Covid-19 environment. Branicki (2020) emphasized the sociological and psychological competence of individuals in his study. Ardito *et al.* (2021) emphasized the importance of employees' ability to use technological tools in the Covid-19 process. Krausz *et al.* (2020) mentioned the ability of individuals to use technological applications in Covid-19 crisis management.
- *Customer's changing need:* Customer's changing need allows to manage the situations that occur when the virus is mutated in the epidemic. Addressing the changing needs of customers is extremely important in the covid process. In this context, lean manufacturing that puts the customer in focus and six sigma that initially shaped the project according to the voice of the customer (VoC) will also be useful in responding to these requirements. Quality function deployment, canoe model and VoC used in LSS will guide these studies. Saroj and Pal (2020) investigated the changing requests of people in the Covid-19 process, as each individual is a customer. Branicki (2020) examined the changing attitudes and behaviors of individuals in his study. Each individual is also a customer on a sectoral basis. Krausz *et al.* (2020) mentioned the changing needs of individuals for Covid-19 crisis management.

In crisis management, it is necessary to make a correct elimination to minimize costs and not compromise on quality. LSS methodology is based on the approach of eliminating non-value activities. Which activities should be eliminated first in this elimination is the main research point. At this elimination point, many years of experience, knowledge and decision-making process are required. There are no certain conditions in this decision-making process. Crisis management process also requires decision-making under uncertainty and fuzzy decision-making methodology as conditions could not be expressed in numerical values. For this reason, the elimination of non-value activities in the crisis management process was examined with the LSS methodology and the spherical fuzzy AHP, which is an extended fuzzy decision-making methodology. There is no academic study conducted for the criteria used in this study. After demonstrating that these criteria are also important in terms of LSS, the importance of these criteria has been examined. Effective work is extremely important during the pandemic period. Therefore, before applying the criteria, it will be

advantageous for companies to know the importance of these criteria and to take action accordingly. As Covid-19 has just appeared in the world, even the number of publications on this subject is very low. Therefore, 12 activities determined on this subject are based on the opinions of experts.

4. Methodology

The concept of SFS enables an extended option area for decision experts to define membership degrees the squared sum of the spherical parameters has been at (Gündoğdu and Kahraman, 2019). The next definition of SFS has been presented:

Definition 1. Single valued SFS $\tilde{B}_s$ of the universe of discourse X is given by (Gündoğdu and Kahraman, 2019). Equations (1)–(6) are explained as the basic elements of the SFS:

$$\tilde{B}_s = \{\langle \mu, \left(\mu_{\tilde{B}_s}(x), \nu_{\tilde{B}_s}(x), \pi_{\tilde{B}_s}(x) \vee x \in X\rangle \tag{1}$$

where:

$$\begin{aligned} &\mu_{\tilde{B}_s}(x) : \mathrm{X} \to [0,1],\ \nu_{\tilde{B}_s}(x) : X \to [0,1],\ \pi_{\tilde{B}_s}(x) : X \to [0,1] \text{ and} \\ &0 \le \mu^2_{\tilde{B}_s}(\mathrm{x}) + \nu^2_{\tilde{B}_s}(\mathrm{x}) + \pi^2_{\tilde{B}_s}(\mathrm{x}) \le 1, x \in \mathrm{X} \end{aligned} \tag{2}$$

For each x, the numbers $\mu_{\tilde{B}_s}(x)$, $\nu_{\tilde{B}_s}(x)$ and $\pi_{\tilde{B}_s}(x)$ are the degree of membership, non-membership and hesitancy of x to $\tilde{B}_s$, respectively. $R^{(X)}_{\tilde{B}_s} = \left(1 - \mu_{\tilde{B}_s}(x)^2 - \nu_{\tilde{B}_s}(x)^2 - \pi_{\tilde{B}_s}(x)^2\right)^{\frac{1}{2}}$ is called a refusal degree. Refusal degree means the opposite of the values corresponding to μ, ν and π values on spherical surfaces.

Definition 2. Main operators of single-valued SFS;

$$1.\ \tilde{B}_s \oplus \tilde{C}_s = \left\{ \left(\mu^2_{\tilde{B}_s} + \mu^2_{\tilde{C}_s} - \mu^2_{\tilde{B}_s}\mu^2_{\tilde{C}_s}\right)^{1/2}, \nu_{\tilde{B}_s}\nu_{\tilde{C}_s}, \left(\left(1 - \mu^2_{\tilde{C}_s}\right)\pi^2_{\tilde{B}_s}(x) + \left(1 - \mu^2_{\tilde{B}_s}\right)\pi^2_{\tilde{C}_s}(x) - \pi^2_{\tilde{B}_s}(x)\pi^2_{\tilde{C}_s}(x)\right)^{1/2} \right\} \tag{3}$$

$$2.\ \tilde{B}_s \otimes \tilde{C}_s = \left\{ \mu_{\tilde{B}_s}\mu_{\tilde{C}_s}\left(\nu^2_{\tilde{B}_s} + \nu^2_{\tilde{C}_s} - \nu^2_{\tilde{B}_s}\nu^2_{\tilde{C}_s}\right)^{1/2}, \left(\left(1 - \nu^2_{\tilde{C}_s}\right)\pi^2_{\tilde{B}_s} + \left(1 - \nu^2_{\tilde{B}_s}\right)\pi^2_{\tilde{C}_s} - \pi^2_{\tilde{B}_s}\pi^2_{\tilde{C}_s}\right)^{1/2} \right\} \tag{4}$$

$$3.\ \lambda.\tilde{B}_s = \left\{ \left(1 - \left(1 - \mu^2_{\tilde{B}_s}\right)^{\lambda}\right)^{1/2}, \nu^{\lambda}_{\tilde{B}_s}, \left(\left(1 - \mu^2_{\tilde{B}_s}\right)^{\lambda} - \left(1 - \mu^2_{\tilde{B}_s} - \pi^2_{\tilde{B}_s}\right)^{\lambda}\right)^{1/2} \textit{for } \lambda > 0 \right\} \tag{5}$$

$$4.\ \tilde{B}_s{}^{\lambda} = \left\{ \mu^{\lambda}_{\tilde{B}_s}, \left(1 - \left(1 - \nu^2_{\tilde{B}_s}\right)^{\lambda}\right)^{1/2}, \left(\left(1 - \nu^2_{\tilde{B}_s}\right)^{\lambda} - \left(1 - \nu^2_{\tilde{B}_s} - \pi^2_{\tilde{B}_s}\right)^{\lambda}\right)^{1/2} \right\} \text{for } \lambda > 0 \tag{6}$$

Definition 3. Single-valued spherical weighted arithmetic mean (SWAM) in regarding of, W= $(w_1, w_2, \ldots, w_n)$; $w_i \in [0,1]$; $\sum_{i=1}^{n} w_i = 1$, SWAM has been explained as;

$$SWAM_w\left(B_{s1,\ldots,}\tilde{B}_{sn} = w_1B_{s1} + w_2B_{s2} + \ldots.. + w_nB_{sn}\right.$$

$$\left\{\left[1-\prod_{i=1}^{n}\left(1-\mu_{\tilde{B}_{si}}^{2}\right)^{w_i}\right]^{1/2}, \prod_{i=1}^{n}\nu_{\tilde{B}_s i}^{w_i}, \left[\prod_{i=1}^{n}\left(1-\mu_{\tilde{B}_{si}}^{2}\right)^{w_i} - \prod_{i=1}^{n}\left(1-\mu_{\tilde{B}_{si}}^{2}-\pi_{\hat{B}_s}^{2}\right)^{w_i}\right]^{1/2}\right\} \tag{7}$$

Definition 4. Single-valued spherical weighted geometric mean (SWGM) in regarding of, W= $(w_1, w_2, \ldots, w_n)$; $w_i \in [0,1]$; $\sum_{i=1}^{n} w_i = 1$, SWGM has been explained as:

$$SWGM_W = \tilde{B}_{s_1}^{w_1} + \tilde{B}_{s_2}^{w_2} + \ldots.. + \tilde{B}_{s_n}^{w_n}$$

$$= \left\{\prod_{i=1}^{n}\nu_{\tilde{A}_s i}^{w_i}, \left[1-\prod_{i=1}^{n}\left(1-\nu_{\tilde{B}_{si}}^{2}\right)^{w_i}\right]^{1/2}, \left[\prod_{i=1}^{n}\left(1-\nu_{\tilde{B}_{si}}^{2}\right)^{w_i} - \prod_{i=1}^{n}\left(1-\nu_{\tilde{B}_{si}}^{2}-\pi_{\hat{B}_s}^{2}\right)^{w_i}\right]^{1/2}\right\} \tag{8}$$

Definition 5. An interval-valued SFS $\tilde{B}_s$ of the universe of discourse U has been explained as in equation (9).

$$\tilde{B}_s = \left\{\langle u, \left(\left[\mu_{\tilde{B}_s}^{L}(u), \mu_{\tilde{B}_s}^{U}(u)\right], \left[\nu_{\tilde{B}_s}^{L}(u), \nu_{\tilde{B}_s}^{U}(u)\right], \left[\pi_{\tilde{B}_s}^{L}(u), \pi_{\tilde{B}_s}^{U}(u)\right]\right) | u \in U\right\} \tag{9}$$

where $0 \le \mu_{\tilde{B}_s}^{L}(u) \le \mu_{\tilde{B}_s}^{U}(u) \le 1$, $0 \le \nu_{\tilde{B}_s}^{L}(u) \le \nu_{\tilde{B}_s}^{U}(u) < 1$ and $0 \le \left(\mu_{\tilde{B}_s}^{U}(u)\right)^2 + \left(\nu_{\tilde{B}_s}^{U}(u)\right)^2 + \left(\pi_{\tilde{B}_s}^{U}(u)\right)^2 \le 1$. For each u ∈ U, $\mu_{\tilde{B}_s}^{U}(u)$, $\nu_{\tilde{B}_s}^{U}(u)$ and $\pi_{\tilde{B}_s}^{U}(u)$ are the top degrees of membership, non-membership and hesitancy of u to $\tilde{B}_s$, respectively. For an interval-valued SFS $\tilde{B}_s$, the pair $\langle\left[\mu_{\tilde{B}_s}^{L}(u)\mu_{\tilde{B}_s}^{U}(u)\right], \left[\nu_{\tilde{B}_s}^{L}(u) \le \nu_{\tilde{B}_s}^{U}(u)\right], \left[\pi_{\tilde{B}_s}^{L}(u)\pi_{\tilde{B}_s}^{U}(u)\right]\rangle$ has been called an interval-valued spherical fuzzy number. To make it easier, the pair $\left\langle\left[\mu_{\tilde{B}_s}^{L}(u), \mu_{\tilde{B}_s}^{U}(u)\right], \left[\nu_{\tilde{B}_s}^{L}(u), \nu_{\tilde{B}_s}^{U}(u)\right], \left[\pi_{\tilde{B}_s}^{L}(u), \pi_{\tilde{B}_s}^{U}(u)\right]\right\rangle$ has been indicated by $\tilde{\alpha} = \langle[a, b], [c, d], [e, f]\rangle$ where [a,b] ⊂ [0,1], [c,d] ⊂ [0,1], [e,f] ⊂ [0,1] and $b^2 + e^2 + f^2 \le 1$.

Definition 6. Suppose that $\tilde{\alpha} = \langle[a, b], [c, d], [e, f]\rangle$, $\tilde{\alpha}_1 = \langle[a_1, b_1], [c_1, d_1], [e_1, f_1]\rangle$ and $\tilde{\alpha}_2 = \langle[a_2, b_2], [c_2, d_2], [e_2, f_2]\rangle$ be and interval valued SFS then;

$$\tilde{\alpha}_1 \cup \tilde{\alpha}_2 = \left\{\left[\max\{a_1, a_2\}, \max\{b_1, b_2\}\right], \left[\min\{c_1, c_2\}, \min\{d_1, d_2\}\right], \left[\min\{e_1, e_2\}, \min\{f_1, f_2\}\right]\right\} \tag{10}$$

$$\tilde{\alpha}_1 \cap \tilde{\alpha}_2 = \left\{\left[\min\{a_1, a_2\}, \min\{b_1, b_2\}\right], \left[\max\{c_1, c_2\}, \max\{d_1, d_2\}\right], \left[\min\{e_1, e_2\}, \min\{f_1, f_2\}\right]\right\} \tag{11}$$

$$\tilde{\alpha}_1 \oplus \tilde{\alpha}_2 = \left\{ \left[\left((a_1)^2 + (a_2)^2 - (a_1)^2.(a_2)^2 \right)^{1/2}, \left((b_1)^2 + (b_2)^2 - (b_1)^2.(b_2)^2 \right)^{1/2}, [c_1c_2, d_1d_2], \right. \right.$$
$$\left[\left[\left(\left(1 - (a_2)^2 \right)(e_1)^2 + \left(1 - (a_1)^2 \right)(e_2)^2 - (e_1)^2(e_2)^2 \right)^{1/2} \right], \right.$$
$$\left. \left. \left[\left(\left(1 - (b_2)^2 \right)(f_1)^2 + \left(1 - (b_1)^2 \right)(f_2)^2 - (f_1)^2(f_2)^2 \right)^{1/2} \right] \right] \right\} \tag{12}$$

$$\tilde{\alpha}_1 \otimes \tilde{\alpha}_2 = \left\{ \left[a_1a_2, b_1b_2, \ , \left((d_1)^2 + (d_2)^2 - (d_1)^2.(d_2)^2 \right)^{1/2} \right], \right.$$
$$\left[\left[\left(\left(1 - (c_2)^2 \right)(e_1)^2 + \left(1 - (c_1)^2 \right)(e_2)^2 - (e_1)^2(e_2)^2 \right)^{1/2} \right], \right.$$
$$\left. \left. \left[\left(\left(1 - (d_2)^2 \right)(f_1)^2 + \left(1 - (d_1)^2 \right)(f_2)^2 - (f_1)^2(f_2)^2 \right)^{1/2} \right] \right] \right\} \tag{13}$$

$$\lambda \ . \ \tilde{\alpha} = \left\{ \left[\left(1 - (1 - a^2)^{\lambda} \right)^{1/2}, \left(1 - (1 - b^2)^{\lambda} \right)^{1/2} \right], \ [c^{\lambda}, d^{\lambda}], \right.$$
$$\left. \left[\left((1 - a^2)^{\lambda} - (1 - a^2 - e^2)^{\lambda} \right)^{1/2}, \left((1 - b^2)^{\lambda} - (1 - b^2 - f^2)^{\lambda} \right)^{1/2} \right] \right\} \lambda > 0 \tag{14}$$

$$\tilde{\alpha}^{\lambda} = \left\{ [a^{\lambda}, b^{\lambda}], \left[\left(1 - (1 - c^2)^{\lambda} \right)^{1/2}, \left(1 - (1 - d^2)^{\lambda} \right)^{1/2} \right], \right.$$
$$\left[\left((1 - c^2)^{\lambda} - (1 - c^2 - e^2)^{\lambda 1/2}, \right] \right\} \lambda > 0 \tag{15}$$

Definition 7. Assume that $\lambda, \lambda_1, \lambda_2 \geq 0$, after that:

1. $$\tilde{\alpha}_1 \ \oplus \ \tilde{\alpha}_2 = \tilde{\alpha}_2 \oplus \tilde{\alpha}_1 \tag{16}$$
2. $$\tilde{\alpha}_1 \otimes \tilde{\alpha}_2 = \tilde{\alpha}_2 \otimes \tilde{\alpha}_1 \tag{17}$$
3. $$\lambda (\tilde{\alpha}_1 \oplus \tilde{\alpha}_2) = \ \lambda . \tilde{\alpha}_1 \oplus \ \lambda . \tilde{\alpha}_2 \tag{18}$$
4. $$(\tilde{\alpha}_1 \otimes \tilde{\alpha}_2)^{\lambda} = \tilde{\alpha}_1{}^{\lambda} \otimes \tilde{\alpha}_2{}^{\lambda} \tag{19}$$
5. $$\lambda_1 . \tilde{\alpha} \oplus \lambda_2 . \tilde{\alpha} = (\lambda_1 + \lambda_2).\tilde{\alpha} \tag{20}$$

$$6. \quad \tilde{\alpha}^{\lambda_1} \otimes \tilde{\alpha}^{\lambda_2} = \tilde{\alpha}^{\lambda_1+\lambda_2} \tag{21}$$

Definition 8. Assume that $\tilde{\alpha} = \{[a_j, b_j], [c_j, d_j], [e_j f_j]\}$ has been gathered from interval-valued spherical weighted arithmetic mean (IVSWAM) in regarding of, $w_j = (w_1, w_2, \ldots, w_n)$; $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$, so IVSWAM has been defined as;

$$IVSWAM_w(\tilde{\alpha}_1, \tilde{\alpha}_2, \ldots, \tilde{\alpha}_n) = w_1.\tilde{\alpha}_1 \oplus w_2.\tilde{\alpha}_2 \oplus \ldots \oplus w_n.\tilde{\alpha}_n = \tag{22}$$

Definition 9. Assume that $\tilde{\alpha}_j = \langle [a_j, b_j], [c_j, d_j], [e_j f_j] \rangle$ has been gathered from IVSWGM in regarding of, $w_j = (w_1, w_2, \ldots, w_n)$; $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$, so IVSWGM has been defined as;

$$IVSWGM_w(\tilde{\alpha}_1, \tilde{\alpha}_2, \ldots, \tilde{\alpha}_n) = \tilde{\alpha}_1^{w_1} \otimes \tilde{\alpha}_2^{w_2} \otimes \ldots \otimes \tilde{\alpha}_n^{w_n} = \tag{23}$$

4.1 Spherical fuzzy AHP

In this study, the main and sub-criteria weights have been determined by spherical fuzzy AHP using spherical fuzzy numbers. The stages of the proposed integrated methodology have been detailed in the next stages.

Stage 1. Determine criteria with respect to literature and alternates by project decision-makers for this problem.

Stage 2. Gathered information from decision-makers to build pairwise comparison matrices. The decision-makers define their assessments using linguistic terms given in (Gündoğdu and Kahraman, 2020).

Stage 3. Organize spherical fuzzy pairwise comparison matrices using the linguistic terms among all the criteria for two hierarchical levels of criteria.

$$A = \begin{bmatrix} 1 & \tilde{a}_{12} \ldots\ldots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \ldots\ldots & \tilde{a}_{2n} \\ \vdots & & \\ \tilde{a}_{n1} & \tilde{a}_{n2} \ldots\ldots & 1 \\ \vdots & \vdots & \end{bmatrix} \tag{24}$$

Suppose that $\tilde{a}_{ij}$ is the pairwise comparison i and j.

Stage 4. Compute score indices (SI) of each member of matrice using pairwise comparison using equations (25) and (26) for having importance (AMI, VHI, HI, SHI, EI, SLI, LI, VLI and ALI).

$$SI = \sqrt{100\left[\left(\mu_{\tilde{a}_{ij}}^2 - \pi_{\tilde{a}_{ij}}^2\right)^2 - \left(\nu_{\tilde{a}_{ij}}^2 - \pi_{\tilde{a}_{ij}}^2\right)^2\right]_\vee} \tag{25}$$

$$\frac{1}{SI} = \frac{1}{\sqrt{100\left[\left(\mu_{\tilde{a}_{ij}}^2 - \pi_{\tilde{a}_{ij}}^2\right)^2 - \left(\nu_{\tilde{a}_{ij}}^2 - \pi_{\tilde{a}_{ij}}^2\right)^2\right]_\vee}} \tag{26}$$

Stage 5. Examine the consistency of the being built pairwise comparison matrices using score indices. Use score indices computed in Stage 4 to determine the consistency ratio (CR) of a matrix as asserted by (Saaty, 1977). Consistency index (CI) of the matrix has been computed by equation (27):

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \tag{27}$$

CR has been computed by equation (28):

$$\mathrm{CR} = \frac{CI}{RI} \tag{28}$$

λ max is the maximum or principal eigenvalue of the decision matrix of pairwise comparison. Random index depends on matrix order (n) and has been computed and the CR has been computed as less than 0.1, the relevant matrix will have been accepted as consistent. In this way, the weight calculation stage has been begun.

Stage 6. Compute the spherical fuzzy AHP weights with respect to each criterion using a spherical weighted arithmetical mean operator given in equation (29).

$$SWAM(\tilde{a}_1 \tilde{a}_2, \ldots, \tilde{a}_n) = \tilde{S}\left(\sqrt{1 - \prod_{i=1}^{n}\left(1 - \mu_{\tilde{a}_i}^2\right)^w}\right), \prod_{i=1}^{n} \nu_{\tilde{a}_i}^w, \sqrt{\prod_{i=1}^{n}\left(1 - \mu_{\tilde{a}_i}^2\right)^\lambda - \prod_{i=1}^{n}\left(1 - \mu_{\tilde{a}_i}^2 - \pi_{\tilde{a}_i}^2\right)^w} \tag{29}$$

n has been defined as the number of criteria and also $w = \frac{1}{n}$.

Stage 7. Defuzzify spherical fuzzy numbers to indicate the importance levels of the criteria, using equation (30).

$$\tilde{S}_{WM} = \sqrt{100\left[\left(3.\mu_{\tilde{WM}} - \pi_{\frac{\tilde{WM}}{2}}\right)^2 - \left(\nu_{\frac{\tilde{WM}}{2}} - \pi_{\tilde{WM}}\right)^2\right]} \tag{30}$$

Stage 8. Normalize the defuzzied criteria weights using equation (31).

$$W_j = \frac{S\left(\tilde{WM}_j\right)}{\sum_{i=1}^{n} S\left(\tilde{WM}i_j\right)} \tag{31}$$

5. Application

SFS handle decision-makers' value judgments as membership function, non-membership function and hesitancy value. SFS give better results than other fuzzy sets because they deal with problems in three dimensions. In this study, 12 criteria were determined with the help of the literature and decision-makers for the management of the Covid-19 pandemic within the scope of the LSS methodology. This study is dealt with in a textile production factory. The textile production company also receives consultancy services on lean production. The general directorate of the textile production factory is located in Istanbul in Turkey. The production place is in the Çorlu district of Tekirdağ province in Turkey. The business has

been serving in the field of textiles since 1990. In this way, the business, despite the economic and social crisis that occurred in Turkey, has continued its production without economic loss. Within the scope of the measures taken in the Covid-19 process, the textile industry was highly affected by the process due to the closure of shopping centers, the closure of businesses selling clothing and individuals online shopping. The business has been receiving consultancy support on lean manufacturing since 2000. Therefore, a business can continue the production process without economic loss in the 2002 crisis in Turkey. During the suddenly developing Covid-19 crisis, the business has already received lean production consultancy support, so this process has been easily turned into a project and started to manage the process. As this project takes place in the manufacturing company and the production affects all operational processes (Swarnakar *et al.*, 2020; Ali *et al.*, 2020), it has been aimed to be realized without sacrificing quality and to remove waste in production. Within the scope of the project aimed at this target, this situation should only be carried out in accordance with the LSS methodology. This project was managed by three decision-makers who were previously involved in the unexpected crisis processes of the business. As one of the decision-makers, he has more than 30 years of experience in managerial and operational involvement in many expert projects as a "Project Manager." This person is also a master black belt and has a certificate in project management. As the business is a production firm, the other decision-maker is an industrial engineer who has worked in all processes, as the establishment of the business and is currently a 15-year production manager who has worked on various projects in the production and is a master blackbelt. The other decision-maker provides consultancy to the business from outside on lean production. The third decision-maker is a master blackbelt, an industrial engineer with 20 years of experience in the field, who has been doing lean production consultancy. On lean manufacturing, as stated in the study (Mustapha *et al.*, 2019), it is very important to receive external consultancy in terms of training, up-to-date content control and employee collaboration. Before the project meeting, the foresight was made by the lean manufacturing consultant based on the current literature review and past experiences on crisis management in accordance with the LSS methodology. Covid-19 measures started to be taken on March 11, 2020. In this context, the first meeting was held in the first week of April and the project was started. The project group examined the existing criteria, removed some criteria and added some new criteria. In the second meeting held on the 2nd week of April 2020 the calculation process started by entering the criteria by the project group. A consensus has been reached that the study should be examined in accordance with the fuzzy decision-making methodology during the crisis, as the net results were not known and could not be reflected in sales and income flow. In recent years, spherical fuzzy decision-making methodology, which is an advanced synthesis of other fuzzy decision-making methods, has been preferred because it has gained general acceptance and it has been generalized with statistical methods. In this context, the linguistic terms and values of the criteria according to the spherical fuzzy analytical hierarchy method have been defined in Table 2. The linguistic values of the existing three decision-makers at the point of defining the superiority of the criteria compared to each other have been stated in Table 3. These interviews were held in 2-h meetings every week. After the interviews, studies were continued and the process was followed up in the e-mails. The literature, experience-oriented and uniquely determined criteria in accordance with the needs of the textile production company, the calculations were completed in the 4-week calendar process and the results were interpreted. According to the results obtained in the study, it was ensured that the business processes were leaned in accordance with the LSS structure. As the first wave process of the Covid-19 pandemic has been successfully managed, it has been aimed to be a roadmap for other

Linguistic meanings	Linguistic terms	μ	V	π
Absolutely more importance	AMI	0.9	0.1	0
Very high importance	VHI	0.8	0.2	0.1
High importance	HI	0.7	0.3	0.2
Slightly more importance	SMI	0.6	0.4	0.3
Equally importance	EI	0.5	0.4	0.4
Slightly low importance	SLI	0.4	0.6	0.3
Low importance	LI	0.3	0.7	0.2
Very low importance	VLI	0.2	0.8	0.1
Absolutely low importance	ALI	0.1	0.9	0

Source: Kahraman and Gundogdu (2019)

Table 2.
Linguistic terms and values

DM1	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	1	EI	EI	EI	AMI	EI	HI	EI	HI	SLI	EI	SLI
C2		1	EI	EI	SLI	SLI	EI	EI	SMI	SLI	EI	SLI
C3			1	EI	AMI	SLI	SMI	SLI	HI	SLI	SMI	LI
C4				1	LI	SLI	SLI	LI	EI	SLI	SLI	LI
C5					1	SLI	SMI	LI	SMI	SLI	SMI	LI
C6						1	SMI	EI	SMI	SLI	SMI	SLI
C7							1	SLI	SMI	SLI	EI	SLI
C8								1	SMI	SLI	SMI	SLI
C9									1	VLI	SLI	SLI
C10										1	SMI	SLI
C11											1	ALI
C12												1
DM2	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	1	SMI	SMI	HI	SMI	EI	HI	EI	HI	SLI	EI	SLI
C2		1	EI	EI	SLI	SLI	EI	EI	SMI	SLI	EI	LI
C3			1	HI	EI	SLI	SMI	SLI	HI	SLI	SMI	VLI
C4				1	LI	LI	SLI	LI	EI	VLI	SLI	VLI
C5					1	SLI	SMI	LI	SMI	SLI	SMI	VLI
C6						1	SMI	EI	SMI	SLI	SMI	SLI
C7							1	SLI	SMI	SLI	EI	VLI
C8								1	SMI	SLI	SMI	SLI
C9									1	LI	SLI	SLI
C10										1	VHI	SLI
C11											1	VLI
C12												1
DM3	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	1	HI	SMI	VHI	SMI	EI	HI	EI	HI	SLI	EI	LI
C2		1	EI	SMI	SLI	LI	EI	EI	SMI	ALI	EI	ALI
C3			1	VHI	EI	SLI	SMI	SLI	HI	VLI	SMI	VLI
C4				1	LI	ALI	SLI	ALI	EI	ALI	SLI	ALI
C5					1	SLI	SMI	LI	SMI	SLI	SMI	VLI
C6						1	AMI	EI	SMI	SLI	SMI	SLI
C7							1	SLI	SMI	VLI	EI	VLI
C8								1		SLI	SMI	SLI
C9									1	ALI	SLI	ALI
C10										1	AMI	SLI
C11											1	ALI
C12												1

Table 3.
The paired comparisons for decision-makers

businesses by sharing it in the literature against the second or third wave risk through this study. Spherical fuzzy AHP has been applied for parsing and binary comparisons for various levels of the hierarchy. The aim is to set priority criteria to rank.

In spherical fuzzy AHP methodology, linguistic terms and triangular values have been defined in Table 2.

Spherical fuzzy AHP, a newly developed method, has been applied for weighting the criteria. The weight of the 12 criteria has been determined using spherical fuzzy AHP. Thus, the criteria created for this newly emerging situation have been handled with a new technique. The paired comparisons for decision-makers according to the criteria in the order above are given in Table 3.

Criteria weights in Table 4 were obtained using equation formulas between 24 and 31. Results are given in Table 4. The SWAM and the spherical weighted geometric mean were both made. As values are close to each other, SWAM results have been given. When we examined the criterion weights, it was revealed that the 12th criterion was the most important criterion. Therefore, the changing needs of customers are important during the pandemic period. This criterion was followed by the 10th criterion in terms of importance. It can be said that the data of this new period are in need of analysis. It cannot be stated that the importance of this criterion is an independent result from the 12th criterion.

6. Comparison

The study is also covered with crisp value sets evaluations in Table 5. The relative status of the criteria is also compared. In this study, the values using SFS were also performed with NS and the results were compared. The results are consistent, as the SFS have been developed as an extension of NS and PFS. The sensitivity analysis of the results was also examined with the Spearman correlation test and a 90% consistency rate was found. This situation is shown in Table 6.

7. Sensitivity analysis

Kahraman *et al.* (2018) extended Buckley's fuzzy AHP using interval NS. Neutrosophic AHP has been proposed in their paper and applied to the performance comparison of law firms successfully. In this study, our proposed methodology was compared with neutrosophic AHP for the Covid process. Table 7 presents the neutrosophic linguistic scale, which we use for comparison purposes. In the proposed scale, with spherical fuzzy AHP, it has been modified "absolutely more importance" degrees to ease of geometric operations.

Table 4.
Criteria weights

Criteria	Weights
C1	0.09279
C2	0.06823
C3	0.082325
C4	0.052343
C5	0.079076
C6	0.096782
C7	0.066933
C8	0.095572
C9	0.059758
C10	0.115011
C11	0.068836
C12	0.122346

Criteria relations	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	1	1	1	9	3	1	5	1	5	0.33	1	0.33
C2	1	1	1	3	0.33	0.33	1	1	3	0.33	1	0.33
C3	1	1	1	9	1	0.33	3	0.33	5	0.33	3	0.2
C4	0.11	0.33	0.11	1	0.2	0.33	0.33	0.2	1	0.33	0.33	0.2
C5	0.33	3	1	5	1	0.33	3	0.2	3	0.33	3	0.2
C6	1	3	3	3	3	1	3	1	3	0.33	3	0.33
C7	0.2	1	0.33	3	0.33	0.33	1	0.33	3	0.33	1	0.33
C8	1	1	3	5	5	1	3	1	3	0.33	3	0.33
C9	0.33	0.33	0.2	1	0.33	0.33	0.33	0.33	1	0.14	0.33	0.33
C10	3	3	3	3	3	3	3	3	7	1	3	0.33
C11	1	1	0.33	3	0.33	0.33	1	0.33	3	0.33	1	0.11
C12	3	3	5	5	5	3	3	3	3	3	9	1

Table 5. Crisp value sets evaluation

Criteria	Spherical fuzzy AHP weights	Neutrosophic AHP weights	Crisp value weights
C1	0.09279	0.08992	0.095532172
C2	0.06823	0.06678	0.054101612
C3	0.082325	0.08654	0.075315614
C4	0.052343	0.05641	0.021070972
C5	0.079076	0.07802	0.06818306
C6	0.096782	0.09546	0.098640232
C7	0.066933	0.06714	0.041302376
C8	0.095572	0.09362	0.100441443
C9	0.059758	0.05893	0.02485333
C10	0.115011	0.106417	0.156504236
C11	0.068836	0.06684	0.041860608
C12	0.122346	0.11987	0.222194345

Table 6. Comparison of criterion weights in neutrosophic, spherical fuzzy AHP and crisp value sets

It has been checked the consistency of pairwise comparison matrices by using equation (32):

$$\mathrm{dv} = 0.6 + 0.4\mathrm{T} - 0.2\mathrm{I} - 0.4\mathrm{F} \tag{32}$$

where dv is the deneutrosophicated value. As there is a consensus in the decision-makers group, an aggregation operation is not required for this study's problem.

For the next step, the geometric mean for criteria and subcriteria will be calculated based on equations (33), (34) and (35).

$$\begin{aligned} T_1 &= [1xT_{12}x \ldots .xT_{1n}]^{1/n} \\ &\ldots . \\ T_n &= [1xT_{n2}x \ldots .xT_{nn}]^{1/n} \end{aligned} \tag{33}$$

Table 7.
Neutrosophic AHP linguistic scale

Linguistic meanings	Linguistic terms	T	I	F
Absolutely more importance	AMI	1	0.07	0.015
Very high importance	VHI	0.9	0.2	0.1
High importance	HI	0.8	0.3	0.2
Slightly more importance	SMI	0.7	0.4	0.3
Equally importance	EI	1	1	1
Slightly low importance	SLI	0.02	0.226	0.623
Low importance	LI	0.016	0.145	0.679
Very low importance	VLI	0.013	0.100	0.711
Absolutely low importance	ALI	0.009	0.005	0.765

Source: Kahraman *et al.* (2018)

$$I_{1m} = [1xI_{12m}x \ldots .xI_{1nm}]^{1/n}$$
$$\ldots . \tag{34}$$
$$I_{nm} = [I_{n1m}xI_{n2m}x \ldots .x1]^{1/n}$$

$$F_{1m} = [1xF_{12u}x \ldots .xF_{1nu}]^{1/n}$$
$$\ldots . \tag{35}$$
$$F_{nm} = [F_{n1m}xF_{n2m}x \ldots .x1]^{1/n}$$

The result of these equations for the criteria is given in Table 8.

We obtained neutrosophic weights of criteria and subcriteria by dividing T, I, F values with the sum of the geometric means in the row for lower, medium and upper parameters. And then, we defuzzified and normalized the neutrosophic weights of criteria with the performance scores of the criteria and calculated the overall performance score to aggregate them in Table 9.

8. Conclusion and further studies

In this study, Covid-19 crisis management was analyzed according to the LSS approach-based criteria via novel spherical fuzzy AHP methodology. The importance of LSS for crisis

Table 8.
Geometric means of the criteria

Criteria	Geometric mean T	I	F
C1	0.78	0.50	0.45
C2	0.13	0.20	0.12
C3	0.24	0.34	0.23
C4	0.05	0.36	0.21
C5	0.08	0.47	0.35
C6	0.10	058	0.25
C7	0.56	0.51	0.14
C8	0.32	0.64	0.07
C9	0.47	0.54	0.16
C10	0.21	0.12	0.146
C11	0.15	0.11	0.42
C12	0.11	0.05	0.23

Criteria	Overall performance Score	Ranking
C1	0.082	3
C2	0.067	7
C3	0.078	4
C4	0.050	10
C5	0.076	5
C6	0.097	1
C7	0.065	8
C8	0.089	2
C9	0.061	9
C10	0.10	11
C11	0.072	6
C12	0.09	12

Table 9. Overall performance of the criteria

management has been demonstrated in Covid-19. For this aspect, 12 criteria were determined in Covid-19 process. It has been stated that these criteria are directly related to LSS. Therefore, it was emphasized that it can produce highly effective solutions with LSS tools in crisis management that may occur due to the epidemic. Based on this point, it was decided to list the criteria to use the resources effectively during the epidemic. Accordingly, it was decided to determine the importance weights of the criteria to apply the LSS technique in the solution. Afterward, fuzzy spherical AHP, which is the most recent method, has been applied to determine the weights of these criteria in terms of importance. While this decision-making process, the opinion of three decision-makers have been consulted during the evaluation. These decision-makers are 3 master black belts who have experience of over 20 years. Accordingly, "customer's changing need" has been seen to be the most important criterion. Following this criterion, it turned out to be an "analyzing data," "compliance of actions with corporate objectives," "proper technological infrastructure," "tendency to teamwork," "offering solution suggestions for bad situation scenarios," "identifying workflows and process owners," "employees' competence," "cccuracy in decision-making," "compliance with employees and feedback," "spreading trend of the virus" and "communication with stakeholders," respectively. In addition, the results were compared with neutrosophic fuzzy sets. The consistency of the results was found to be 90% with the Spearman Correlation Coefficient. This is an acceptable rate. At the same time, the CR of 0.09 was obtained with the crisp value values. This result corresponds to Saaty's CI (Saaty, 1977). Then, also the sensitivity analyzes were done and it has been revealed that even if the criteria's value has changed, the ranking does not change.

For future studies criteria related to crisis management for the Covid-19 pandemic can be enlarged also can be determined for the specific business area. Different methods can be used to evaluate criteria for further studies. As it is a newly developed method, spherical fuzzy AHP has been used. Pythagorean, hesitant, picture fuzzy, intuitionistic methods can also be used to examine the consistency of the results.

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Corresponding author
Ezgi Demir can be contacted at: dem_ezgi@hotmail.com