A MCDM Methodology to Analysis Strategies and Factors of Lean Production in Sustainability Development

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Abstract

Increases in sustainability performance and the adoption of innovative strategies for continuous improvement were driven by the need for production companies to compete in an increasingly globalized economy. Better operational performances are achieved when sustainable Production is included in industrial processes because wastes, costs, and environmental effects are reduced, and ergonomic requirements are met. To improve their performance and maintain a leading position in the market, several companies have turned to sustainable production practices. The study's goal is to improve the implementation of traditional Lean Production (LP) by creating an integrated Single valued neutrosophic Potentially All Pairwise RanKings of all possible Alternatives (PAPRIKA) method. The PAPRIKA is extended under a neutrosophic set. PAPRIKA is used to compute the weights of criteria by comparing the criteria. Also, the PAPRIKA method is used to rank and select the best strategy. The application is performed on the steps of the PAPRIKA method.

Keywords: Neutrosophic Sets; PAPRIKA MCDM, Lean Production; Sustainability; Industry

1. Introduction

As an approach to incorporating sustainable development ideas into the industry, sustainable Production has evolved in recent years. To overcome obstacles associated with adopting sustainable production practices, businesses need to use cutting-edge management strategies. That's why production companies need to work harder on finding the right method of improvement if they want to boost their sustainability results. Lean Production, Lean Six Sigma, and Life Cycle Assessment (LCA) are just a few of the improvement concepts that may be used to bring production procedures into a state of sustainable equilibrium[1], [2].

The LP is a mechanism for making production chains more efficient by getting rid of various forms of waste. Multiple methods may be used in the eradication of garbage. With the LP strategy, manufacturers may boost their competitiveness by providing more value to their consumers. For any particular production method, there are typically three phases that make up a Lean improvement project: First, a map of the present situation must be created; second, it must be analyzed, and the waste pinpointed. Third, choose the right resources to create the road map to the future. Traditional metrics, including cycle time, delivery time, value, and prices, have all improved because of the implementation of the procedures in a variety of industries. Several investigators have taken advantage of the

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possibilities presented by the rise of novel approaches to management, like Green Production and Sustainable Manufacturing, to study the benefits of LP methods in improving the financial, ecological, and social performance of production organizations[3], [4].

Since PAPRIKA requires more decisions than conventional scoring techniques, is easier to apply, and correctly reflects the choices of decision-makers, it has largely replaced other MCDM techniques. It is also more cost-effective, reproducible, and less mentally burdensome for decision-makers[5]–[7]. In contrast to other MCDM approaches, which merely provide summary statistics, this one generates a set of weightings for every choice maker. This paves the way for a comparison of relative weights across various participant subsets. Figure 1 shows the research design. This paper used the single-valued neutrosophic set to overcome the uncertain information[8]–[10].

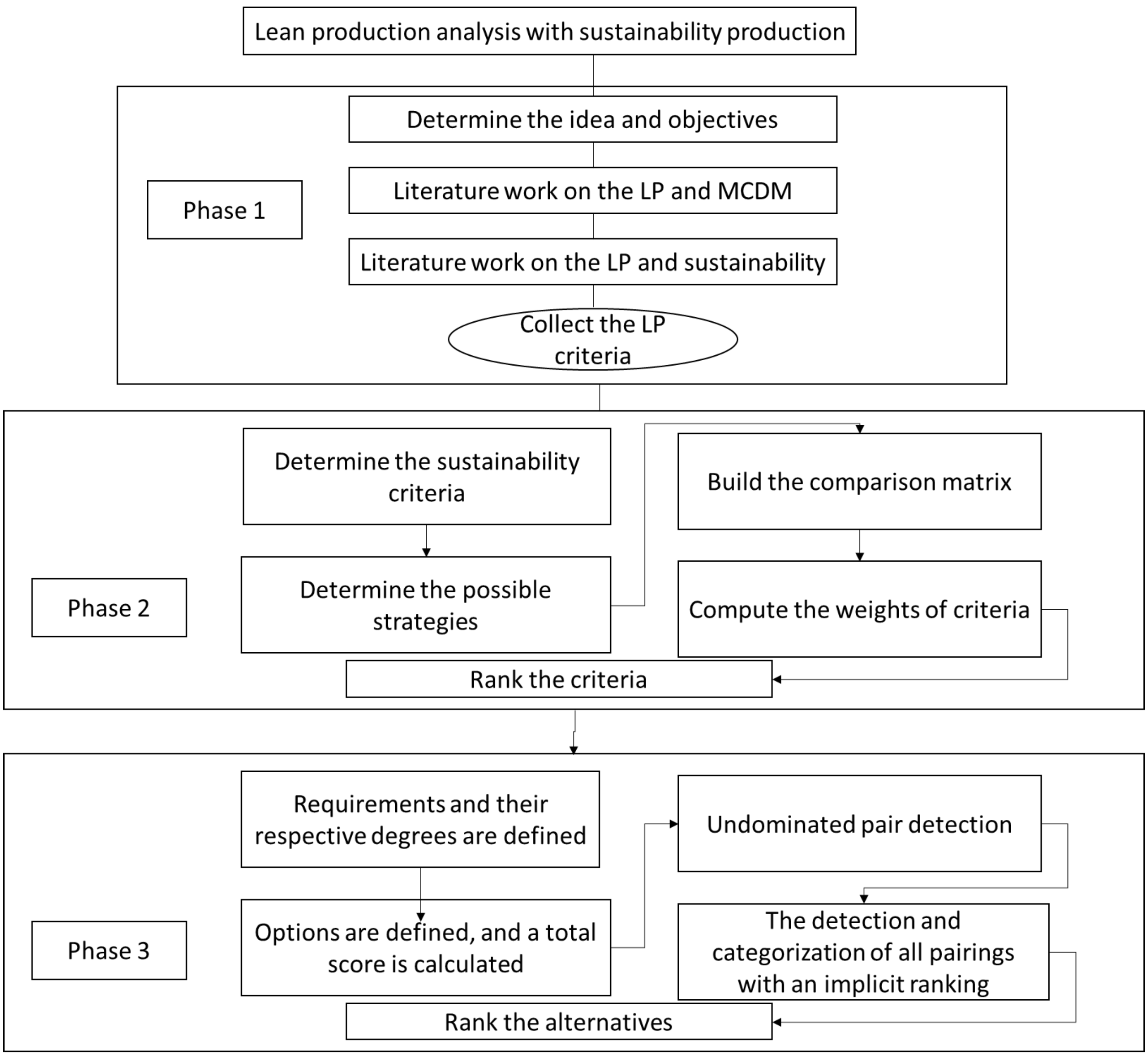

Figure 1: The research designs.

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1.1 Lean Production (LP)

Toyota's LP structure was established so that it could continue competing with American firms. In order to further enhance their competitiveness, a wide variety of sectors, executives, academics, and practitioners have widely created and adopted the LM idea. While minimizing waste, LP strives to be very responsive to client needs. In addition, it delivers its wares at the most affordable prices and by the requirements of its clientele.

1.2 Factors of LP

Businesses use lean concepts to optimize their supply chains. The choice of a lean supplier involves numerous considerations, such as quality, delivery, and pricing. Quality, subsequent to price and timeliness, was found to be the most important factor when choosing a provider. The selection of a lean provider might be based on a variety of factors. To measure how "lean" a supplier is, you may look at three things: increased supplier efficiency, the presence of lean society, and timely delivery. Figure 2 shows the LP criteria.

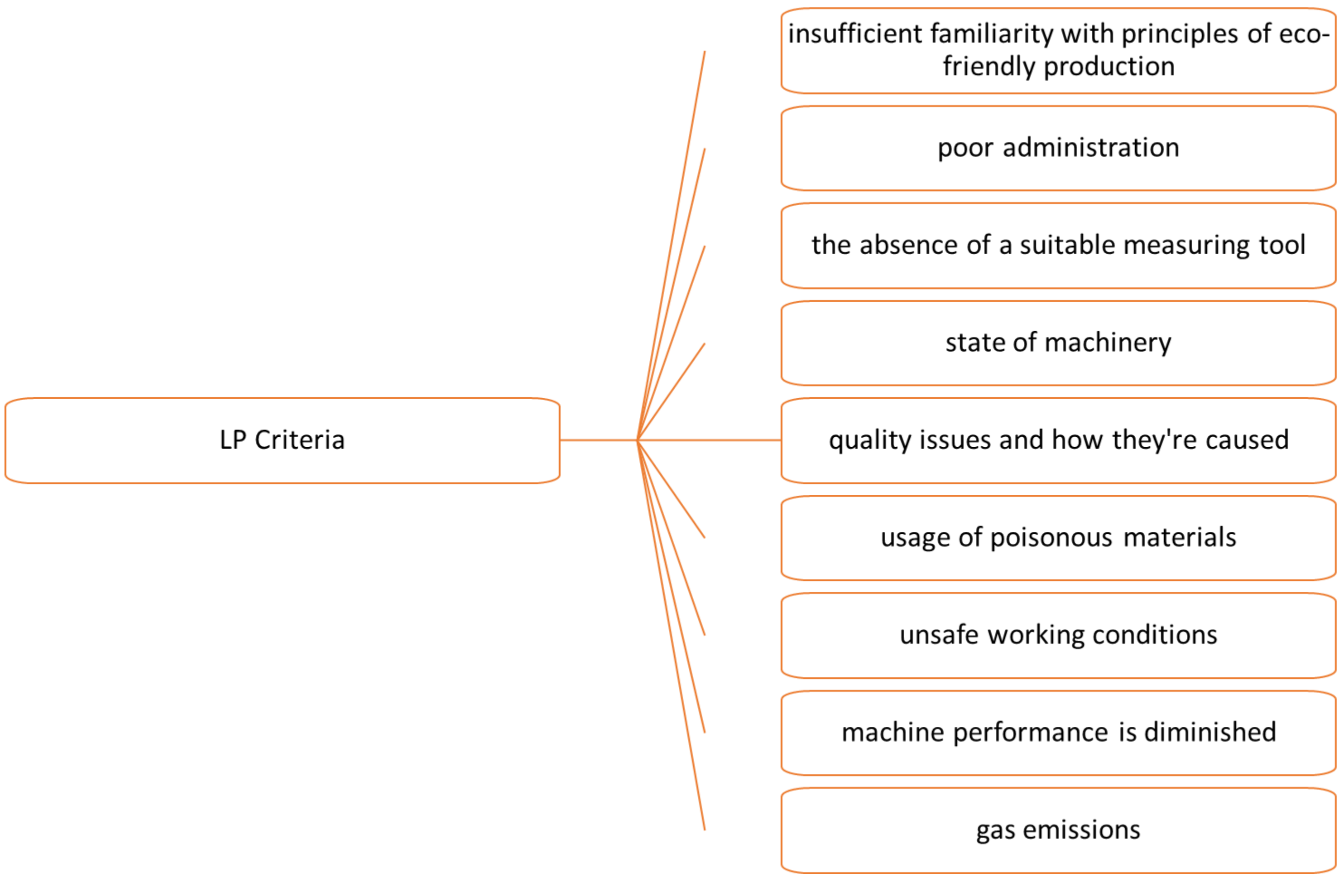

Figure 2: The criteria of LP.

2. LP with the MCDM

This section introduces lean Production with the various MCDM methods. To improve the implementation of the standard lean production method, Soltani et al. [11]created a combined Pythagorean Fuzzy MCDM framework. The authors recommend using an expanded Value Steam Mapping to evaluate the production method's sustainability and pinpoint the root causes of waste from a green perspective. Pythagorean DEMATEL was used to examine the connection between the knowns. To combat the identified barriers and improve the production procedures over time,

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the Pythagorean Fuzzy TOPSIS method was used. To help lean producers choose vendors and divide up orders, Rezaeia et al. [12]created an MCDM and bi-objective mathematical framework. Lean-picking suppliers and order allocation has received less attention in the past literature despite the abundance of studies on Lean Production and its associated techniques. This research is divided into four sections to address this deficiency. The first step is to compile a baseline set of slimming criteria based on existing research. The next step involves analyzing these requirements for potential use in a procurement procedure by use of an AHP. The vendors are then chosen using a Fuzzy AHP that is informed by lean choice of supplier's principles. Finally, the optimal order distribution is calculated using a bi-objective mathematical framework. To improve the foundry's efficiency, Kannan et al.[13] identified and ranked the failure mechanisms that were having the most detrimental effect on casting quality. The fishbone diagram is used by Kannan et al. in the foundry sector to analyze the sources, consequences, and reasons for casting motor casing flaws. They utilized fuzzy decision-making to classify the major contributors. They used five major failure mechanisms. The Fuzzy AHP and TOPSIS methods are used by Kannan et al. to determine the order of importance. They determine customers' needs, and the corresponding design criteria are established. Kazancoglu et al. [14] proposed a multi-stage strategy to examine and describe the eight wastes of the lean mindset. A fuzzy decision-making trial and evaluation laboratory is a special MCDM approach that the authors employed to examine the correlations and rankings of waste factors in higher education institutions. The eight wastes of lean were used by them to classify a total of 22 criteria. Aouag and Soltani et al.[15] developed a refined LP strategy to improve the environmental friendliness of production methods. The first of their suggested three stages makes use of an expanded value stream mapping approach to evaluate and quantify key production procedures and sustainability variables. Second, the entropy approach is utilized to calculate the relative importance of each indication. Finally, the entropy technique's weights are put to use in fuzzy EDAS and fuzzy TOPSIS to determine the relative merits of various events with respect to their impact on sustainable metrics.

3. LP with Sustainability

To remain competitive on a global scale and address contemporary issues, manufacturers must adopt a new paradigm known as environmentally friendly Production. The term "sustainable production" refers to both the creation of more environmentally friendly goods and the use of greener techniques within the framework of Production. Evaluating sustainability performance in terms of how well things are manufactured is crucial for achieving environmentally friendly Production. To be successful, businesses must abandon old approaches that exclusively consider financial and operational factors, such as minimizing costs and increasing efficiency.

Engineers and producers alike need a straightforward method for learning about and implementing ethical production practices in their factories. Decisions in the industrial sector may now be made with a single index in mind, helping to boost sustainability performance.

Lean and green ideas are combined in a process called sustainable-value stream mapping, which Hartini et al. [16]used to create the Manufacturing Sustainability Index (MSI). Delphi-AHP qualitative evaluation and sustainable-value stream mapping quantitative evaluation formed the basis of their technique for establishing MSI. Selecting the most important indicators is done using the Delphi technique, and their efficiency scores are then determined using sustainable-value stream mapping and the AHP technique.

3.1 LP with Financial Sustainability

Sustainability in the Economy and Lean Production. Extant literature credits a wide variety of operational advantages to the deployment of LP concepts and practices, including a decrease in production costs and enhancements in the speed of manufacturing, quality, reliability, and adaptability. Few academics have attempted to convert operational gains into monetary and financial measures, and their findings have been varied. Most known research implies that synergies exist within lean practice packages. Additionally, JIT, which is an element of LP but not synonymous with LP, is often the only focus of the conception of LP when investigating its link to financial success[17], [18].

3.2 LP with Ecological Sustainability

Sustainable production practices and lean Production. Businesses might utilize LP as a stimulus to enhance their ecological practices. This link is strengthened by Carvalho and Cruz-Machado, who define lean and green practices as a complementary relationship between ecological and operational management. Although several studies have shown a good correlation between lean practices and ecological outcomes, some academics have pointed out

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contradictions and tradeoffs between the two methods. Therefore, it is vital to analyze the link between LP and the surroundings in a systematic and integrated manner, avoiding focusing the emphasis on a single lean bundle or on a few ecological elements to prevent contradicting findings and non-conclusive conclusions[19], [20].

3.3 LP with Social Sustainability

Sustainability in society and lean Production. There are no conclusive findings in the literature connecting LP with ecological sustainability. On the one side, lean has been claimed to improve employee morale by providing them with more responsibility, autonomy, and opportunities to develop their drive. However, many writers emphasize the increased stress, monotony, and standardization of labor, as well as the attendant loss of individual agency and the accompanying increase in workload. Instead, there seems to be unanimity that LP is beneficial to employees' health and safety, particularly when it comes to the implementation of environmental requirements in the design of workplaces[21]–[23].

4. The proposed Methodology

In this section, we introduced the Potentially All Pairwise RanKings of all Possible Alternatives (PAPRIKA) method to compute the weights of criteria and rank the alternatives. The PAPRIKA is a MCDM method. This method is used with the single-valued neutrosophic set (SVNS). The SVNS used to overcome the uncertain data. The SVNS has three functions truth, indeterminacy, and falsity functions[24], [25].

By comparing all feasible non-dominated pairings about all of the options in the framework, PAPRIKA makes it possible to sort the various options. For a pair of options to be categorized by pairwise comparisons, one of them must be ranked greater on at least one criterion and less in a minimum of one additional requirement, a situation known as a "non-dominated pair." However, the comparison is unnecessary in the case of dominated pairs, which are groups of two options, one of which has the highest class in at least one criterion and none of a lower rank in the other requirement[26]–[29]. An approach that finds all pairings categorized as obvious inside the explicit pair rating reduces the overall quantity of pairwise comparisons.

The steps of the

I. Requirements and their respective degrees are defined.
II. Options are defined, and a total score is calculated.
III. Undominated pair detection.
IV. The detection and categorization of all pairings with an implicit ranking.
V. Finding out where a solution fits in a worldwide ranking.

The first thing PAPRIKA does is find all the possible combinations of alternatives that are specified for both requirements concurrently and entail payment. Each decider must choose from a random sequence of paired choices. Every time the decision maker categorizes a set of two alternatives, all the other hypothetical sets of choices that may be categorized by pairs by transitivity are found and discarded. If one decider gives preference to A Over B and subsequently to B over C, then A has precedence over C through transitivity.

By following these steps, we can ensure that the decision-maker will be asked as few questions as possible. The decision maker, however, categorizes all the options that are differed in two criteria in a simultaneous, implicit, and transitive fashion by pairing them together. The number of factors and the corresponding levels for each criterion determine the total number of queries presented to the decision-maker. If there are four criteria and three to four categories for each, then there will be around 30 evaluations to do. A few questions are asked more than once to ensure uniformity. 1000Minds derives the weights of the requirements from the categories by explicit pairings using linear programming.

The global values of each strategy can be computed as:

$$GV_1 = \sum_i w_i \times A_{ij} \quad (1)$$

$$GV_2 = \sum_i w_i \times B_{ij} \quad (2)$$

Where A_{ij} refers to the performance value and B_{ij} Valued with criteria.

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5. Application

This section introduces the application of the proposed method with the weights of criteria and rank of alternatives.

5.1 Weighting Application

In the first step, we compute the weights of the criteria. We build the pairwise comparison matrix between criteria by using the single-valued neutrosophic numbers. Then we apply the steps of the PAPRIKA method to compute the weights of the criteria. We use the 1000Minds software to build the trade between various criteria. We build this tradeoff between two criteria, then between three criteria, then four criteria, and so on. Then obtain the weights of the criteria as shown in Table 1.

Table 1: Weights of criteria.

	Weight	Min	Max
LPC_1	1.60%	1.60%	1.70%
LPC_2	1.60%	1.60%	1.70%
LPC_3	3.30%	3.20%	3.40%
LPC_4	31.30%	30.50%	32.30%
LPC_5	4.90%	4.80%	5.10%
LPC_6	9.90%	9.70%	10.20%
LPC_7	4.90%	4.80%	5.10%
LPC_8	28.80%	28.30%	29.50%
LPC_9	9.90%	9.70%	10.20%
LPC_{10}	3.70%	3.20%	4.10%

Table 2: Assessment of the Strategies for all criteria by the first decision maker.

	LPC_1	LPC_2	LPC_3	LPC_4	LPC_5	LPC_6	LPC_7	LPC_8	LPC_9	LPC_{10}
LPS_1	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.8,0.20,0.25)	(0.75,0.25,0.20)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.75,0.25,0.20)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.9,0.10,0.15)
LPS_2	(0.8,0.20,0.25)	(0.35,0.60,0.75)	(0.8,0.20,0.25)	(0.8,0.20,0.25)	(0.6,0.30,0.35)	(0.6,0.30,0.35)	(0.8,0.20,0.25)	(0.35,0.60,0.75)	(0.8,0.20,0.25)	(0.75,0.25,0.20)
LPS_3	(0.6,0.30,0.35)	(0.9,0.10,0.15)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.9,0.10,0.15)	(0.35,0.60,0.75)	(0.35,0.60,0.75)	(0.8,0.20,0.25)
LPS_4	(0.75,0.25,0.20)	(0.35,0.60,0.75)	(0.75,0.25,0.20)	(0.8,0.20,0.25)	(0.6,0.30,0.35)	(0.75,0.25,0.20)	(0.8,0.20,0.25)	(0.25,0.90,0.85)	(0.75,0.25,0.20)	(0.6,0.30,0.35)
LPS_5	(0.8,0.20,0.25)	(0.25,0.90,0.85)	(0.6,0.30,0.35)	(0.8,0.20,0.25)	(0.75,0.25,0.20)	(0.8,0.20,0.25)	(0.9,0.10,0.15)	(0.35,0.60,0.75)	(0.6,0.30,0.35)	(0.9,0.10,0.15)
LPS_6	(0.75,0.25,0.20)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.35,0.60,0.75)	(0.9,0.10,0.15)	(0.6,0.30,0.35)	(0.6,0.30,0.35)	(0.8,0.20,0.25)	(0.75,0.25,0.20)	(0.75,0.25,0.20)
LPS_7	(0.8,0.20,0.25)	(0.25,0.90,0.85)	(0.8,0.20,0.25)	(0.6,0.30,0.35)	(0.75,0.25,0.20)	(0.6,0.30,0.35)	(0.75,0.25,0.20)	(0.8,0.20,0.25)	(0.6,0.30,0.35)	(0.8,0.20,0.25)
LPS_8	(0.9,0.10,0.15)	(0.35,0.60,0.75)	(0.6,0.30,0.35)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.8,0.20,0.25)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.75,0.25,0.20)	(0.9,0.10,0.15)

Table 3. Assessment of the Strategies for all criteria by second decision maker.

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	LPC_1	LPC_2	LPC_3	LPC_4	LPC_5	LPC_6	LPC_7	LPC_8	LPC_9	LPC_{10}
LPS_1	(0.25,0.90,0.85)	(0.35,0.60,0.75)	(0.8,0.20,0.25)	(0.35,0.60,0.75)	(0.35,0.60,0.75)	(0.25,0.90,0.85)	(0.35,0.60,0.75)	(0.25,0.90,0.85)	(0.75,0.25,0.20)	(0.35,0.60,0.75)
LPS_2	(0.8,0.20,0.25)	(0.35,0.60,0.75)	(0.8,0.20,0.25)	(0.8,0.20,0.25)	(0.6,0.30,0.35)	(0.6,0.30,0.35)	(0.8,0.20,0.25)	(0.35,0.60,0.75)	(0.8,0.20,0.25)	(0.75,0.25,0.20)
LPS_3	(0.6,0.30,0.35)	(0.9,0.10,0.15)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.35,0.60,0.75)	(0.35,0.60,0.75)	(0.35,0.60,0.75)	(0.8,0.20,0.25)
LPS_4	(0.75,0.25,0.20)	(0.35,0.60,0.75)	(0.75,0.25,0.20)	(0.35,0.60,0.75)	(0.6,0.30,0.35)	(0.35,0.60,0.75)	(0.35,0.60,0.75)	(0.25,0.90,0.85)	(0.75,0.25,0.20)	(0.35,0.60,0.75)
LPS_5	(0.8,0.20,0.25)	(0.25,0.90,0.85)	(0.25,0.90,0.85)	(0.25,0.90,0.85)	(0.75,0.25,0.20)	(0.8,0.20,0.25)	(0.9,0.10,0.15)	(0.35,0.60,0.75)	(0.6,0.30,0.35)	(0.9,0.10,0.15)
LPS_6	(0.25,0.90,0.85)	(0.9,0.10,0.15)	(0.75,0.25,0.20)	(0.35,0.60,0.75)	(0.9,0.10,0.15)	(0.6,0.30,0.35)	(0.6,0.30,0.35)	(0.8,0.20,0.25)	(0.75,0.25,0.20)	(0.75,0.25,0.20)
LPS_7	(0.8,0.20,0.25)	(0.25,0.90,0.85)	(0.8,0.20,0.25)	(0.6,0.30,0.35)	(0.75,0.25,0.20)	(0.25,0.90,0.85)	(0.35,0.60,0.75)	(0.8,0.20,0.25)	(0.6,0.30,0.35)	(0.8,0.20,0.25)
LPS_8	(0.25,0.90,0.85)	(0.35,0.60,0.75)	(0.35,0.60,0.75)	(0.9,0.10,0.15)	(0.35,0.60,0.75)	(0.8,0.20,0.25)	(0.35,0.60,0.75)	(0.75,0.25,0.20)	(0.75,0.25,0.20)	(0.35,0.60,0.75)

5.2 MCDM Application

Then apply the PAPRIKA method to compute the rank of alternatives. This paper used the eight strategies to select the best one, as shown in Figure 3. First, build the decision matrix between criteria and alternatives, as shown in Tables 2 and 3. The two decision-makers who have expertise in the field of the LP industry ranked the criteria and alternatives. The rank of alternatives is shown in Figure 4. From Figure 4, Participatory management is the best, and economic saving is the worst.

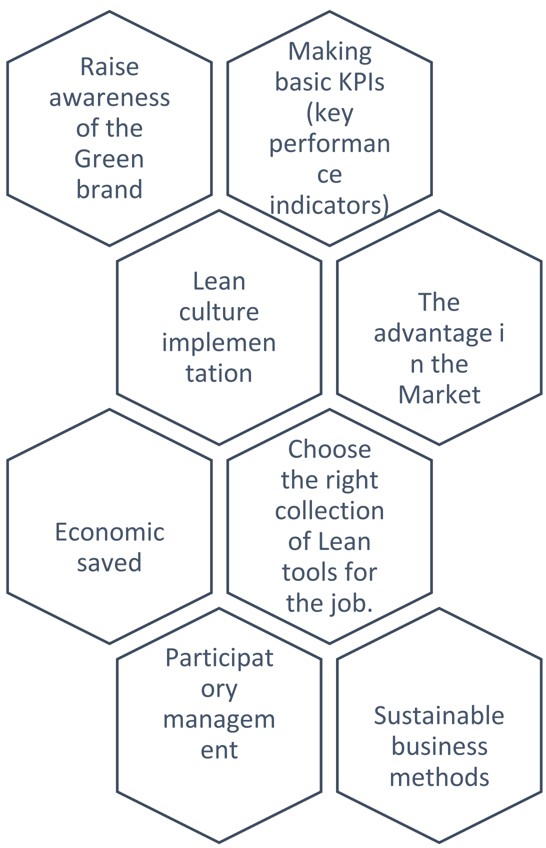

Figure 3: The eight strategies.

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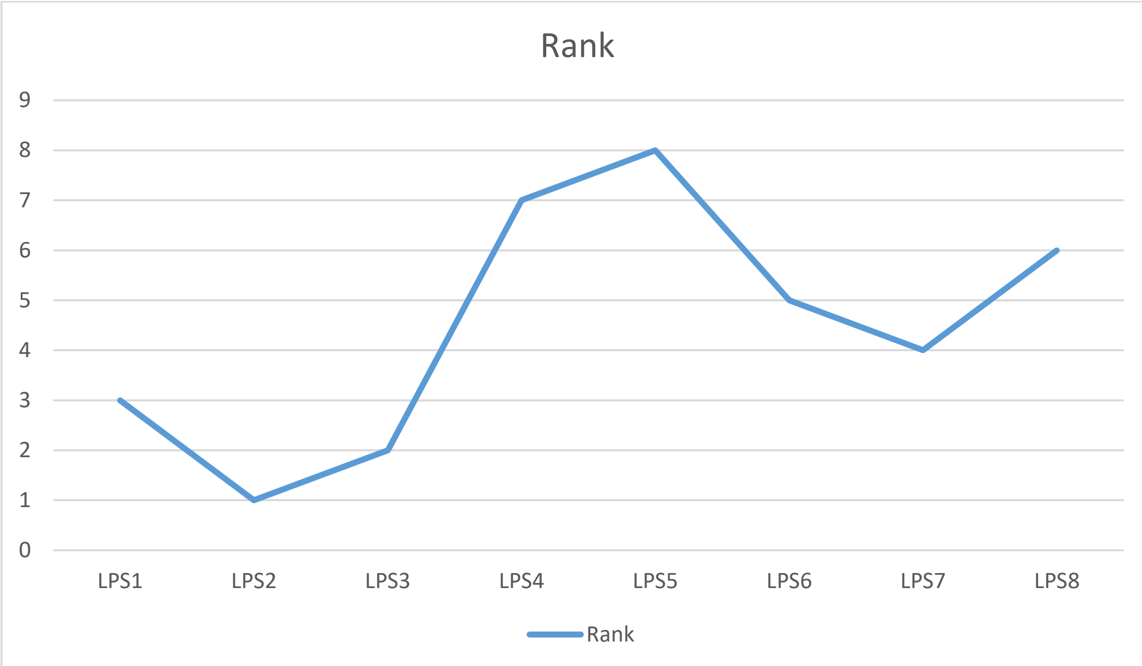

Figure 4: The rank of strategy.

6. Conclusion

It has become more important for manufacturing companies to use cutting-edge methods to improve the long-term viability of their production operations. Limitations in its implementation may be highlighted, particularly in the analysis and improvement stages, based on a thorough literature review assessment of the traditional and expanded LM technique. This is due to several reasons, including a wide variety of goals and key performance indicators. We also discussed the benefits and drawbacks of using MCDM approaches to enhance processes. This study, based on a survey of the relevant literature, introduces a cutting-edge, novel LM application technique meant to prolong the life of industrial processes. The suggested method begins with creating a current state map of the examined manufacturing process to gather data and determine the root reasons for the lack of sustainability. This study used the neutrosophic PAPRIKA to compute the weights of criteria and rank the alternatives. The experts used the single-valued neutrosophic numbers to assess the criteria and alternatives. There are ten criteria and eight strategies used in this paper.

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