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AN INTEGRATED MCDM METHOD IN RANKING THE MAJOR LEAN PRACTICES BASED ON FOUR ATTRIBUTES

Seyed Mohammad Hossein Hojjati*
*Assistant Professor, Department of Industrial Engineering, College of Engineering, Shiraz Branch, Islamic Azad University, Shiraz, IRAN

ABSTRACT

Lean tools selection is one of the critical factors for decision makers in competitive environment. This research aims at integrating two methods to evaluate the lean tools and techniques, and ranking aspect of efficacy under four criteria: lead time, cost, defects, and value. The proposed model is applied in lean tools selection problem. The methodology is based on SAW, and TOPSIS, techniques by Borda.

We suggest a logical procedure to measure the efficacy of lean tools on leanness and prioritize them as decision maker. A case study is used to demonstrate the lean implementation in companies. The results show obtained scores level of tools was different aspect to four criteria.

The integration of these approaches has created synergy and shown to be even more powerful. So, the proposed integrated SAW-TOPSIS model can evaluate and rank different alternatives, whereas considering various criteria in the production processes. A hybrid model can take advantage of various methodologies. The hybrid model will be more helpful in assisting integrated decision making for the purpose of tools evaluation and selection.

KEYWORDS: Lean manufacturing, lean tools selection, SAW, TOPSIS, Borda

INTRODUCTION

Lean tools selection is one of the major challenges that lean practitioners face, because it is the most important factor in the success or failure to leanness, so it is important to choose the most popular and useful tools [1]. Consequently, leanness is tied to tools and techniques, and without implementing a proper technique, a leanness level cannot be achieved. It is frequently difficult to select the right tool for leanness from the enormous tool box [2]. Selecting proper initiatives and creating an achievement plan still requires concentrated knowledge and experience on lean implementation [2]. It is not a practical alternative clearly, it should be improved.

Moreover, a number of methods can be applied. In this study, Simple Additive Weighting (SAW), Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), and Borda methods are used.

The SAW method is based on the weighted average. An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by the decision maker (DM) followed by summing of the products for all criteria [3][4]. The TOPSIS method is one of the best models of MADM (Multiple Attribute Decision Making). In this method, m alternative is evaluated by n criteria. This technique is based on the concept that the selected alternative should have the nearest distance with ideal positive solution (best possible manner) and farthest distance with ideal negative solution (worst possible manner). It is supposed that the popularity of every index is regularly increasing or decreasing [5]

Decision makers are not limited to one method of MADM in critical methods, because various MADM methods attain different results. In order to get over this problem, aggregate method (Borda method) has been introduced [5]. In the Borda method each MADM method ranks all of the alternatives. If there are k alternatives, each alternative receives k points for the first choice, $k-1$ point for the second choice, and so on. The alternative with the most points is declared the winner [6]. So, in this method, we need a complete preference ranking from all voters over all candidates. It then computes the mean rank of each candidate over all voters [7]. Subsequently, after determining the alternatives (lean tools and techniques), and criteria (lean attributes: lead time, cost, defects, and value); the alternatives are prioritized by using MADM methods.

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After this brief introduction, the next section reviews the lean tools selection of manufacturing systems, the definition of major tools and techniques, and lean attributes.
Applications of the SAW, TOPSIS and Borda methods are introduced in Section 3, followed by the weighted measure. Finally, the contributions, and future extensions of this research are concluded in the last section.

LEAN TOOLS SELECTION

Lean tools selection is one of the major challenges that lean practitioners, are facing and because of this, lean tools selection is the most important in the success or failure to leanness. In other words, tools selection and implementation play critical role to leanness level, so it is important to choose the most popular and useful tools [8]. Consequently, leanness is knotted to tools and techniques, and without implementing a proper technique, leanness level cannot be achieved. Successful level in implementing techniques and achieving desired goals can be defined to leanness level. Also, applying lean tools incorrectly results in a waste of time and money as well as reduced trust and assurance by people in lean environments [9]. As a result, implementing the right tool, in right time for the right type of company is significant.

Lean Tools and Techniques

Many studies show that various research works notified so many lean tools [10 to 19]. According to Delphi method thirteen lean tools and techniques were recognized, the most important of them are as follows:
5S/Workplace Organization: 5S is a visual management tool consisting of elements developed to create a lean work environment. Various housekeeping activities (Sort-out; Set in order; Shine / cleanliness; Standardize; Sustain) are often used for continuous improvement.
6 Sigma: A methodology used to improve quality to 3.4 defects per million or better.
Cellular manufacturing: the layout of machines of different types performing different operations in a tight sequence (typically in a U-shape) to permit single piece flow and flexible deployment of human effort.
Continuous flow: producing and moving one item / items at a time through a series of processing steps as continuously as possible, with each step making just what is requested by the next step.
Jidoka, or autonomation, refers to a designing equipment and operations so that the operators are not tied to the machines with the operators being free, they can perform other value-added multiple tasks while a machine runs, improving their productivity.
Leveling: Smoothing out the production schedule by averaging out both the volume and mix of products.
Multi skill workers/Skill matrix: this encourages people to adapt to planned changes or occurrence of unanticipated events.
Poka-yoke: another useful tool under the Jidoka umbrella is poka-yoke (mistake proofing). This concept literally means a device, which prevents errors from occurring.
Pull system: a method of production control in which downstream activities signal their needs to upstream activities.
Set up reduction: the ability to change tooling and fixtures rapidly, so multiple products can be run on the same machine.
Standardized work: Operations are organized in the safest, best known sequence using the most effective combination of resources. Jobs are broken down into elements and examined to determine best and safest method for each.
Synchronize/Line balancing: bringing together of materials information and anything else needed in a coordinated manner such that no part is waiting long for another.
Total productive maintenance (TPM): TPM consist of companywide equipment maintenance program that covers the entire equipment life cycle and requires participation by every employee.

Lean attributes

To evaluate performance of the flow of manufacturing systems, lead time, cost and value were selected by Wan and Chen [2]; and a fourth factor named defect that is developed. This is supported by others. [20,21]
The study is not followed by the level of lean measurement in a company, but would take the role and contribution of the tools and techniques being measured (based on lead time, cost, defects, and value) to leanness. As a result, in this study after the definition and concepts of the main LM tools and techniques, measurable quantitative factors are explained. We consider cost, lead time, defects and value in this research.

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Lead time: The time which a customer needs to wait to receive product/service. Lead time is the “key” measure of leanness.
Cost: The total amount of budget which should be paid for per product/service. So, determination of the cost of a product/service by evaluating the use of resources in its manufacturing has always been a matter of great importance for companies.
Defects: Defects are products which do not match the desired design in properties and/or quality. There is the product defect that are defined here as defects in goods produced that are not caught by in-line or end-of-line inspections and are therefore passed on to customers.
Value: The customer’s perspective is that value, the customer is willing to pay for.

METHODS APPLIED

The methods were applied in this study are: SAW, TOPSIS, and Borda; the procedure of integrating MADM methods is shown in Figure 1.

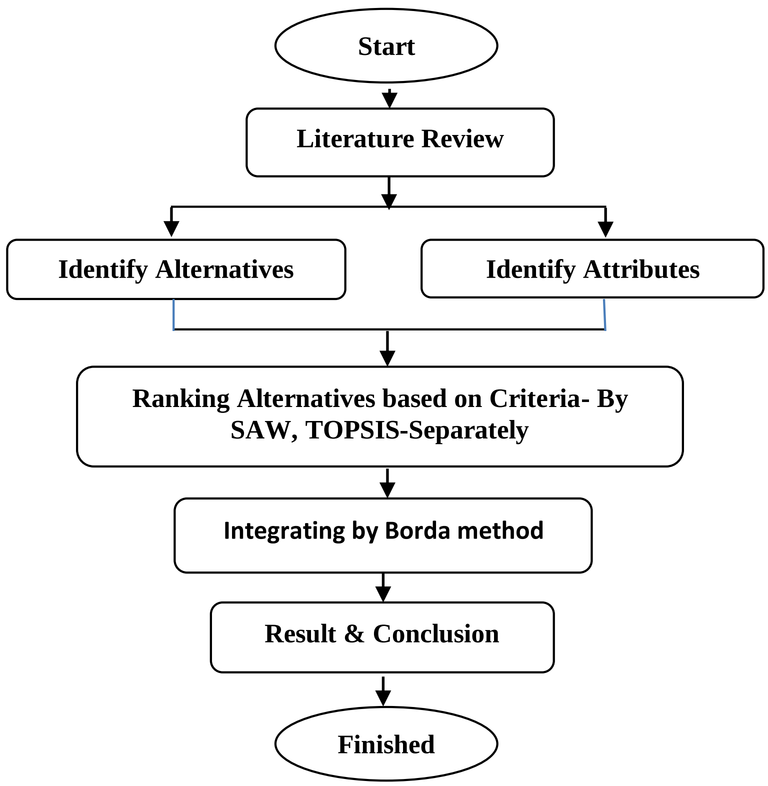

Figure 1. An integrated method for ranking alternatives

Tables 1 and 2 indicate the identification and determination of criteria and alternatives, and their weights based on experts’ opinions. Criteria C_1 to C_4 are allocated to four attributes to leanness; alternatives A_1 to A_{13} are allocated to 13 “tools and techniques” of LM; and experts E_1 to E_5 (Table 3) belong to five numbers of “a panel of experts” in LM. The separate evaluations and ratings of the alternatives under four criteria separately were achieved using a group of ordinal ranking methods: SAW, and TOPSIS, The ratings were then finalized by an aggregating method (Borda).
We made pair wise comparisons of four criteria to assess the leanness by construct a pair wise comparison matrix (n × n) for each criterion with every other criterion, one-by-one, with respect to objectives by using Saaty's 1–9 scale of pair wise comparisons. Table 1 shows the evaluation matrix with response of five experts to the goal.

Table 1. Rating weights of criteria by comparison matrix

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	Lead time	Cost	Defects	Value
Lead time	(1,1,1,1,1)	(3,3,2,4,3)	(1,1/2,1/3,1/3,1/2)	(1/3,1/2,1/5,1/2,1/4)
Cost	(1/3,1/3,1/2,1/4,1/3)	(1,1,1,1,1)	(2/5,1/2,1/2,1/4,1/2)	(1/5,1/3,1/5,1/4,1/5)
Defects	(1,2,3,3,2)	(5/2,2,2,4,2)	(1,1,1,1,1)	(1/3,1/3,1/5,1/2,1/5)
Value	(3,2,5,2,4)	(5,3,5,4,5)	(3,3,5,2,5)	(1,1,1,1,1)

The result of the evaluation of criteria is that the final weights of lead time, cost, defects, and value are 0.18, 0.09, 0.22, and 0.51 respectively.

Table 2 shows multiple criteria, which are shortlisted for the selection of lean tools to leanness. We made pair wise comparisons of the thirteen alternatives based on the four criteria effect on leanness. This Table (2) shows the evaluation matrix with response (five experts) to leanness.

Table 2. Scores of 13 alternatives by decision makers under all criteria

Alternatives	Lead time	Cost	Defects	Value
5S	(1,2,1,2,3)	(3,4,3,2,7)	(5,5,5,3,7)	(3,3,3,2,3)
Six sigma	(3,2,3,2,3)	(4,5,4,4,3)	(5,4,8,5,3)	(5,4,5,2,3)
Cellular manufacturing	(4,5,4,4,7)	(4,4,4,3,3)	(2,3,2,2,3)	(3,2,2,2,7)
Continuous flow	(5, 5,5,4,9)	(5,4,5,3,7)	(3,3,3,2,5)	(5,4,4,2,9)
Jidoka	(3,3,2,2,5)	(5,5,5,2,3)	(5,5,5,4,3)	(3,2,4,3,3)
Leveling	(5,0,5,2,7)	(5,3,5,3,3)	(3,2,2,2,3)	(4,4,5,2,7)
Multi--skill workers	(4,3,4,3,3)	(4,4,4,3,5)	(4,5,4,3,7)	(3,2,2,2,3)
Poka-yoke	(1,2,1,3,2)	(3,4,2,3,3)	(5,5,7,5,5)	(2,1,3,2,3)
Pull system	(5, 5,7,4,3)	(5,3,5,5,5)	(2,2,2,2,5)	(5,5,6,3,3)
Set up reduction	(5,5,5,4,5)	(5,3,6,2,5)	(3,4,2,2,1)	(5,5,5,2,3)
Standard works	(2,4,1,3,3)	(3,4,3,3,3)	(5,4,5,2,5)	(3,2,3,2,3)
Synchronize	(2,3,2,2,5)	(3,5,2,2,3)	(4,5,4,3,2)	(1,1,2, 2,5)
TPM	(3,5,3,4,3)	(4,5,4,3,7)	(5,5,5,2,5)	(3,5,4,2,3)

Application of SAW method

SAW is a simple scoring method which is one of the methods of MADM. In this section each of the comparison matrixes, under the four criteria (lead time, cost, defects, and value), are resolved by the SAW method. Hence priority alternatives based on lead-time criteria are as follows:

Step 1: construct a pair wise comparison matrix for criteria and calculate the consistency ratio. Prepare collected data from experts, and compute weights of criteria and consistency ratio. First of all it is necessary to calculate the consistency rate (Table 3).

Table3. An illustration of rating criteria and calculating CR

	Lead time	Cost	Defects	Value		Weights	
Lead time	1	2.930	0.4883	0.3341		0.175902	C.R= 0.073/0.9= 0.08
Cost	0.3413	1	0.4163	0.2316		0.087615	
Defects	2.0476	2.402	1	0.2947	×	0.223401	
Value	2.9925	4.317	3.393	1		0.513082	

CR = 0.08<0.1; then the CR is accepted. This indicates that the opinion of experts is sufficient.

Step 2: calculate the normalized decision matrix for criteria, and calculate w_j based on Entropy method $n_{ij}=r_{ij}/\sum r_{ij}$

The main objective of this section is to separately rank the lean tools and techniques based on lean attributes. Due to the hierarchy the alternatives under lead-time criteria, Table 4, is extracted from Table 2.

Table 4. Weights of lead-time criteria based on scale values (1–9)

Alternatives		E_1	E_2	E_3	E_4	E_5
A_1	5S	1	2	1	2	3
A_2	Six sigma	3	2	3	2	3
A_3	Cellular man	4	5	4	4	7
A_4	Continuous flow	5	5	5	4	9
A_5	Jidoka	3	3	2	2	5
A_6	Leveling	5	1	5	2	7
A_7	Multi--skill workers	4	3	4	3	3
A_8	Poka-yoke	1	2	1	3	2
A_9	Pull system	5	5	7	4	3
A_{10}	Set up reduction	5	5	5	4	5
A_{11}	Standard works	2	4	1	3	3
A_{12}	Synchronize	2	3	2	2	5
A_{13}	TPM	3	5	3	4	3

So, according to step 2 of SAW method, data on table 4 should be normalized, which are shown in Table 5.

Table 5. Normalized decision matrix under lead-time criteria from Table 3 – SAW method

	E_1	E_2	E_3	E_4	E_5
A_1	0.023256	0.044444	0.023256	0.051282	0.051724
A_2	0.069767	0.044444	0.069767	0.051282	0.051724
A_3	0.093023	0.111111	0.093023	0.102564	0.12069
A_4	0.116279	0.111111	0.116279	0.102564	0.155172
A_5	0.069767	0.066667	0.046512	0.051282	0.086207
A_6	0.116279	0.022222	0.116279	0.051282	0.12069
A_7	0.093023	0.066667	0.093023	0.076923	0.051724
A_8	0.023256	0.044444	0.023256	0.076923	0.034483
A_9	0.116279	0.111111	0.162791	0.102564	0.051724
A_{10}	0.116279	0.111111	0.116279	0.102564	0.086207
A_{11}	0.046512	0.088889	0.023256	0.076923	0.051724
A_{12}	0.046512	0.066667	0.046512	0.051282	0.086207
A_{13}	0.069767	0.111111	0.069767	0.102564	0.051724

Step 3: calculate weights of criteria, which determines the amounts of E_j, d_j *and* w_j.

	E_1	E_2	E_3	E_4	E_5
E_j	0.959196	0.965774	0.938538	0.983016	0.962478

	E_1	E_2	E_3	E_4	E_5	Total
d_j	0.040804	0.034226	0.061462	0.016984	0.037522	0.190998

	E_1	E_2	E_3	E_4	E_5	Total
W_j	0.213638	0.179194	0.321792	0.088924	0.196452	1

The SAW method evaluates each alternative under lead-time criteria as illustrated in Table 6.

Table 6. Calculating weight of the 13 alternatives based on lead-time criteria – SAW method

Wj	0.213638	0.179194	0.321792	0.088924	0.196452		
A_1	0.2	0.4	0.142857	0.5	0.333333		0.270322
A_2	0.6	0.4	0.428571	0.5	0.333333	=	0.447717
A_3	0.8	1	0.571429	1	0.777778		0.775706
A_4	1	1	0.714286	1	1		0.908059
A_5	0.6	0.6	0.285714	0.5	0.555556		0.481242
A_6	1	0.2	0.714286	0.5	0.777778		0.676586
A_7	0.8	0.6	0.571429	0.75	0.333333		0.594485
A_8	0.2	0.4	0.142857	0.75	0.222222		0.270725
A_9	1	1	1	1	0.333333		0.869032
A_{10}	1	1	0.714286	1	0.555556		0.820748
A_{11}	0.4	0.8	0.142857	0.75	0.333333		0.406958
A_{12}	0.4	0.6	0.285714	0.5	0.555556		0.438514
A_{13}	0.6	1	0.428571	1	0.333333		0.599696

According to SAW method (Table 6), for "tools and techniques" under lead-time criteria, the ranking order of the 13 candidates is shown in Table 7.

Table 7. Ranking of the 13 alternatives based on lead-time criteria – SAW method

Alternatives	A_4	A_9	A_{10}	A_3	A_6	A_{13}	A_7	A_5	A_2	A_{12}	A_{11}	A_8	A_1
Ranked	1	2	3	4	5	6	7	8	9	10	11	12	13

The SAW method is used in a similar way to prioritize the alternatives with respect to the other criteria. Similarly, data was extracted from Table 2, as weights of "Cost criteria", "defects criteria" and "value criteria", based on scale values (1–9). Then, calculation based on steps of 2 and 3 of SAW method as shown in Tables 4-7. Therefore, the results of rating the alternatives under four various criteria by SAW method are shown in Table 8.

Table 8. Matrix of alternatives priority (tools and techniques) – SAW method

Alternatives		Ranking within four criteria			
		Lead time	Cost	Defects	Value
5S	A_1	13	6	2	8
Six Sigma	A_2	9	7	3	5
Cellular manu	A_3	4	10	11	7
Continuous flow	A_4	1	1	9	1
Jidoka	A_5	8	9	5	9
Leveling	A_6	5	8	12	3
Multi--skill workers	A_7	7	5	4	11
Poka-yoke	A_8	12	12	1	12
Pull system	A_9	2	2	10	2
Set up reduction	A_{10}	3	4	13	4
Standard works	A_{11}	11	11	7	10
Synchronize	A_{12}	10	13	8	13
TPM	A_{13}	6	3	6	6

TOPSIS method

The application of TOPSIS method (using Table 2) is as follows in Tables 9-14 within these six steps:
Step 1: calculate the normalized decision matrix.

Table 9. Weighted normalized decision matrix with respect to lead time

Alternatives	E_1	E_2	E_3	E_4	E_5
A_1	0.07692308	0.148659	0.073521	0.177471	0.169842
A_2	0.23076923	0.148659	0.220564	0.177471	0.169842
A_3	0.30769231	0.371647	0.294086	0.354943	0.396297
A_4	0.38461538	0.371647	0.367607	0.354943	0.509525
A_5	0.23076923	0.222988	0.147043	0.177471	0.283069
A_6	0.38461538	0.074329	0.367607	0.177471	0.396297
A_7	0.30769231	0.222988	0.294086	0.266207	0.169842
A_8	0.07692308	0.148659	0.073521	0.266207	0.113228
A_9	0.38461538	0.371647	0.51465	0.354943	0.169842
A_{10}	0.38461538	0.371647	0.367607	0.354943	0.283069
A_{11}	0.15384615	0.297318	0.073521	0.266207	0.169842
A_{12}	0.15384615	0.222988	0.147043	0.177471	0.283069
A_{13}	0.23076923	0.371647	0.220564	0.354943	0.169842

Step 2: calculate the weighted normalized decision matrix. $A = \pi r^2$

Table 10. Leveled weighted normalized decision matrix with respect to lead time

Alternatives	E_1	E_2	E_3	E_4	E_5
A_1	0.016434	0.026639	0.023659	0.015781	0.033366
A_2	0.049301	0.026639	0.070976	0.015781	0.033366
A_3	0.065735	0.066597	0.094634	0.031563	0.077853
A_4	0.082168	0.066597	0.118293	0.031563	0.100097
A_5	0.049301	0.039958	0.047317	0.015781	0.05561
A_6	0.082168	0.013319	0.118293	0.015781	0.077853
A_7	0.065735	0.039958	0.094634	0.023672	0.033366
A_8	0.016434	0.026639	0.023659	0.023672	0.022244
A_9	0.082168	0.066597	0.16561	0.031563	0.033366
A_{10}	0.082168	0.066597	0.118293	0.031563	0.05561
A_{11}	0.032867	0.053278	0.023659	0.023672	0.033366
A_{12}	0.032867	0.039958	0.047317	0.015781	0.05561
A_{13}	0.049301	0.066597	0.070976	0.031563	0.033366

Step 3: determine the positive ideal and negative ideal solution as shown in Table 11.

Table 11. The positive and negative ideal solution

	E_1	E_2	E_3	E_4	E_5
A^+	0.082168	0.066597	0.16561	0.031563	0.100097
A^-	0.016434	0.013319	0.023659	0.015781	0.022244

Step 4: calculate the separation measures, using the n-dimensional Euclidean distance. The separation of each alternative (d_{i+} *and* d_{i-}) from the ideal solution is given in Table 12.

Table 12. Separation of each alternative from the ideal solution

d_1+	0.17541419	d_1–	0.017352
d_2–	0.12780743	d_2–	0.060169
d_3+	0.07617365	d_3–	0.116825
d_4+	0.04731724	d_4–	0.149751
d_5+	0.13420636	d_5–	0.058846
d_6+	0.07629717	d_6–	0.127942
d_7+	0.1026285	d_7–	0.091454
d_8+	0.17941964	d_8–	0.015481
d_9+	0.06673143	d_9–	0.166381
d_{10}+	0.06494666	d_{10}–	0.132203
d_{11}+	0.16514732	d_{11}–	0.045307
d_{12}+	0.13914625	d_{12}–	0.051504
d_{13}+	0.12037039	d_{13}–	0.080811

Step 5: calculate the relative closeness to the solution according to this formula:
cl_{i+} = d_{i-} / (d_{i+} +d_{i-}); as presented in Table 13.
Step 6: rank the preference order (Table 13).

Table 13. The relative closeness to the solution and ranking of the preference order

	CL_{i}+	Rank
CL_1	0.090017	13
CL_2	0.320087	8
CL_3	0.605316	5
CL_4	0.759894	1
CL_5	0.30482	9
CL_6	0.626432	4
CL_7	0.471211	6
CL_8	0.079431	12
CL_9	0.713737	2
CL_{10}	0.670571	3
CL_{11}	0.21528	11
CL_{12}	0.27015	10
CL_{13}	0.401683	7

According to the closeness coefficient, for the lean tools the ranking order of the 13 candidates is: A_4>A_9>A_{10}>A_6>A_3>A_7>A_{13}>A_2>A_5>A_{12}>A_{11}>A_8>A_1
The TOPSIS method is used in a similar way to prioritize the alternatives with respect to the other criteria. Similarly, data was extracted from Table 2, as weights of "Cost criteria", "defects criteria" and "value criteria", based on scale values (1–9). Then, calculation based on steps of 1-6 of TOPSIS method as shown in Tables 9-13. Therefore, priority of the alternatives under all of criteria (lead time, cost, defects and value), is determined, and shown in Table 14.

Table 14. Matrix of alternatives priority (tools and techniques) by TOPSIS method

Alternatives		Ranking within four criteria			
		Lead time	Cost	Defects	Value
5S	A_1	13	13	2	8
Six sigma	A_2	8	2	3	6
Cellular manu	A_3	5	9	11	7
Continuous flow	A_4	1	4	8	1
Jidoka	A_5	9	11	7	9
Leveling	A_6	4	5	12	2
Multi--skill workers	A_7	6	7	4	11
Poka-yoke	A_8	12	12	1	13
Pull system	A_9	2	1	10	3
Set up reduction	A_{10}	3	8	13	4
Standard works	A_{11}	11	6	6	10
Synchronize	A_{12}	10	10	9	12
TPM	A_{13}	7	3	5	5

Borda method

Decision makers are not limited just to one method of MADM in critical issues, because it is possible that various MADM methods attain different results. In order to get over this problem, aggregate method (Borda method) has been introduced [5]. In the Borda methodology each MADM method ranks all of the alternatives. If there are k alternatives, each alternative receives k points for the first choice, k –1 point for the second choice, and so on. The alternative with the most points is declared the winner. [6]

So, this method needs a complete preference ranking from all voters over all candidates. Then it computes the mean rank of each candidate over all voters [7]. In this method, every DM ranks alternatives based on attribute/criteria. The priorities (which have been done by DMs) are not the same. So zero-one programming model is used to rank all the alternatives. The main procedure and more examples of the Borda method for the selection of the best alternative based on group agreement among those available alternatives is described by [3]. The simple Borda's method to generate a combined ranking for the pool of match results:

1. Each candidate in the pool is assigned a score of the number of candidate ranked blow it. Its total score across the different ranking list is finally sorted in a descending order.
2. A good approximation to rank aggregation, which finds the median permutation of the rank lists to be combined.

Here it is shown how alternatives are determined based on attributes, and how the matrix is formed. Consequently, the results of the ranking of criteria based on the two methods were extracted in Tables 8 and 14 as shown in Table 15.

Table 15. The rating of 13 tools under four criteria by Borda method

Alternatives	Criteria				Method
	Lead time	Cost	Defects	Value	Borda
A_1	13	7	2	8	7
A_2	8	3	3	5	3
A_3	4	9	10	7	7
A_4	1	1	8	1	1
A_5	9	8	5	9	8
A_6	5	6	10	3	5
A_7	7	5	4	11	6

A_8	12	10	1	13	9
A_9	2	1	9	2	2
A_{10}	3	4	11	4	4
A_{11}	11	8	6	10	10
A_{12}	10	10	7	12	11
A_{13}	6	2	5	6	3

Table 16. Finalized ranking of four lean attributes

Criteria	Tools Priority
Lead time	$A_4 > A_9 > A_{10} > A_3, A_6, A_{13} > A_7 > A_2 > A_5 > A_{12} > A_{11} > A_8 > A_1$
Cost	$A_4, A_9 > A_{13} > A_2 > A_{10} > A_7, A_6 > A_1 > A_5, A_{11} > A_3 > A_8, A_{12}$
Defect	$A_8 > A_1 > A_2 > A_7, A_5 > A_{13} > A_{11} > A_{12} > A_4 > A_9 > A_3, A_6 > A_{10}$
Value	$A_4 > A_9 > A_6 > A_{10}, A_2 > A_{13}, A_3 > A_1 > A_5 > A_{11} > A_7 > A_{12} > A_8$
Total	$A_4 > A_9 > A_2 > A_{13} > A_{10} > A_6 > A_7 > A_1, A_3 > A_5 > A_8 > A_{11} > A_{12}$

The results (Table 16) show that some tools and techniques including: Continuous flow, Pull system, Set up reduction, Cellular manufacturing, TPM, for decreasing lead time; Continuous flow, Pull system, TPM, Six sigma, Set up reduction, for reducing cost; Poka-yoke, 5S, Six sigma, Multi--skill workers, Jidoka, for eliminating defects, obtained more scores; meanwhile, Continuous flow, Pull system, Leveling, Set up reduction, Six sigma, achieved highest score for increasing value. Totally, Continuous flow, Pull system, Six sigma, TPM, Set up reduction, Leveling, have gotten maximum score to leanness.

DISCUSSION AND CONCLUSION

The definition of objectives for LM is determined as a result of the prioritization and comparisons of possible solutions and the overall strategy. The implementation of LM tools and techniques development assists in determining how the implementation of the tools and techniques will fit into the process and how several concepts can be followed as guidelines to help ensure the success of the implementation, needed to select the properties of the tools.

The problem addressed by this research is to lean help tools selection in implementing leanness in manufacturing companies. Lean tools and techniques have been mandated as critical factors to lean implementation. Practitioners must define the objectives and potential of LM and deploy the tools to specific work cells respectively. The evaluation and comparison of lean tools and techniques must be done fairly and the results must represent the actual and correct picture of the performance of the LM. In the context of LM, the performance of LM tools is generally measured and compared on the basis of reduction lead time, cost, defects; and increasing value.

In this study an integrated algorithm simultaneously considered SAW–TOPSIS-Borda method for assessment and optimization of lean tools selection has been proposed. The results show that obtained scores level of tools was different (e.g. the highest score for decreasing lead time, cost, belong to: Continuous flow; Pull system . . . meanwhile highest score for reducing defects belong to Poka yoke). By the way, a hybrid model can take advantage of various methodologies. The hybrid model will be more helpful in assisting integrated decision making for the purpose of tools evaluation and selection.

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