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PRODUCTION & MANUFACTURING | RESEARCH ARTICLE

Application of Fuzzy TOPSIS MADM approach in ranking & underlining the problems of plywood industry in India

Kapil Mittal[1]*, Puran Chandra Tewari[1], Dinesh Khanduja[1] and Prabhakar Kaushik[2]

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*Corresponding author: Kapil Mittal, Department of Mechanical Engineering, National Institute of Technology, Kurukshetra, Haryana 136119, India
E-mail: kapilmittal007@gmail.com

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Abstract: The manufacturing of plywood consists of simple procedural steps, but the range of problems associated with the plywood manufacturing industries, especially in the case of small-scale industries (SSI), is large. This paper describes the major problems faced by the plywood SSIs along with their cause and the ultimate effect, i.e. pruning the profits. Many cogent tools and techniques are present for the task, but an attempt has been made to apply multiple attribute decision-making (MADM) approach in ranking the problems in order of their extent on the basis of various parameters. Some suggestions for the improvement purposes have also been made to overcome the top-ranked problem. The study is the first of its type in a plywood industry, although same can be applied to other similar small-scale cluster industries like steel, textile, pharmaceutical, and automobile.

Subjects: Engineering Productivity; Manufacturing Technology; Operations Management; Operations Research

Keywords: fuzzy logic; TOPSIS; plywood industry

1. Introduction

Today India is one of the fastest growing economic countries of the world. In India the plywood manufacturing sector accounts for about 6% of GDP and its contribution is likely to increase with the passage of time. It employs approx. 50 million workmen, and is the second largest sector employing skilled and semiskilled labor after the agriculture sector in India. The annual turnover of Indian plywood industry is approximately $100 billion. Out of which unorganized sector is 90% and organized sector is only limited to 10%, e.g. Green ply, Century ply, Kit ply, Duro ply, Uni ply, and Virgo ply. India has emerged as one of the biggest consumers of tropical timber in the world, with sizeable imports

ABOUT THE AUTHORS

Kapil Mittal is pursuing his PhD in mechanical engineering from National Institute of Technology, Kurukshetra, India, an institution of national importance. He has completed his masters from the same institute. His area of research interests includes quality management & production, production planning & control, APQP, Fuzzy logic and its application, and decision-making. He has published 6 papers in international journals and 5 in national journals and having 27 citations in his name. He has attended many national conferences also. He has also received an outstanding paper reward from Emerald Publishers for his paper in 2012.

PUBLIC INTEREST STATEMENT

The study depicted in the paper has been channeled out in Jagadhri City (District Yamunanagar, State Haryana, India), which is a hub for the small-scale plywood industries. It is the Asia's largest market for the sale and purchase of woods in monetary terms. It includes the in detail study of the plywood industry and will be of great interest for the public related to the plywood industry.

from Malaysia, Indonesia, New Zealand, etc. India has 17.5% of the world population, but only 2% of the world's forest. So annual industrial round wood imports have tripled in the last five years to over 2 million cubic meters and estimated that by the year 2020 this round wood import may touch 20 million cubic meters.

One of the most consumed natural resource for various domestic and industrial requirements is wood. It has wide applications such as fuel, raw material for various constructions, fitting purpose, furniture, paper, and cardboard as a result of which the natural resources of wood, i.e. forests are quickly being cut and are getting depleted. The net direction it takes is very vital because that cannot only near the future sustainability of the industry, but also the very future of India or of the issues, which are linked to the global warming. This has raised a worldwide awareness of forest conservation. One of the major steps taken toward it is the introduction of the agroforestry, i.e. agriculture of wood. e.g. popular and Eucalyptus trees; to fulfill various "Industrial and domestic consumption and needs." In India, district Yamunanagar under the sate Haryana has emerged as a hub of the wood industry. The total forest area in Haryana at present is only 3.47% of the total geographical area. However, Haryana could increase the total trees covered lands to about 8% of the total geographical area by adopting social forestry. Growing trees on farm boundaries, marginal lands, and waste lands available in villages (Panchayat lands, village common lands, etc.) has enabled Haryana to reach a stage where certain classes of wood have become surplus. The surplus wood production in Haryana has attracted many new industrial ventures for the manufacture of fiber boards, plywood, packing cases, crates, batons for textile industries, wool manufacturing, etc. Yamunanagar is now considered the biggest cluster of wood industry, a distinction earlier enjoyed by district Pathankot in the state of Punjab. The main products of these industries are plywood of different grades and block boards of different types and sizes (Table 1).

Most of the plywood and board manufacturing industries register under the act of small-scale industries (SSI). Major advantages of these industries are very low capital–output and capital–labor ratios. This means that capital investment required per unit of output and per unit employment is very low. This is of particular importance to a labor abundant and capital scarce economy like India.

Table 1. Common problems in plywood manufacturing along with their cause and effect

S. No.	Problems	Description of causes	Effects
1	Quality defects	Defects such as bonding problem, waviness, core crack, frame crack, face cracking, warpage, bubbles, moisture content, and core thickness	Low productivity, poor quality, low price of finished products
2	Workers' absenteeism	Due to the huge availability of labor on low price, the workers are employed off role on daily wage basis which causes the absenteeism	Low productivity, accidents
3	Raw material quality	The quality of raw material varies day by day as the industry has to purchase the new lot each day due to lack of storage area and huge demand of the plywood	Low productivity, poor quality
4	Delay in dispatch	Due to huge demand and various tangible/intangible ambiguities, like machine breakdown, labor shortage, electricity problem, high demand to production ratio, and low productivity, the delay in shortage is a common phenomenon	Lower brand value, loss of faith among customer, low sales volume
5	Wastage of material	The use of conventional machinery and unskilled labor leads to the wastage of wood	Low productivity / tons of wood used, high cost, low profit
6	Energy consumption	The use of old machinery and idle running of machinery leads to more energy consumption	High monthly energy consumption, higher expenses, low profitability

Table 2. Parameters and sub-parameters

S. No.	Parameters	Code	Sub-parameters
1	Cost	C1	Cost of poor quality, loss of brand value
2	Safety	C2	The safety of the humans and assets involved
3	Maintenance	C3	Maintainability, down time
4	Environment	C4	Health hazards, pollution
5	Feasibility	C5	Cost of implementation, time for implementation
6	Automation	C6	Degree of automation, human resistance to automation

SSI contributes almost 40% of the gross industrial value added in the Indian economy. This demotes and discourages deforestation also by enabling availability of wood-based construction materials abundantly and cheaply available in standardized forms, especially supporting modular construction methods.

The plywood SSIs discussed above employs the low/unskilled workers under their premises causing the industry with a low yield output. The culture of these SSI is the focus on quantity and not on the quality causing a lot to their exchequer. A survey was conducted among 150 SS plywood industries to know the common problems faced by them in routine work. These problems along with their causes and effects are listed in the table. An attempt has been made to highlight the problem which intern is causing the most of the damage. The approach used in decision-making is the renowned Fuzzy MADM approach. Fuzzy MADM approach was selected as the no of parameters on the basis of which the ranking was to be performed, were too many. In such cases, the Fuzzy MADM has a proven potential with the history of outstanding results. Of the many MADM approaches available TOPSIS was selected because, in the problems where preferences or ranking function is to be performed, TOPSIS is the most preferred technique as per the literature survey.

1.1. Parameters and sub-parameters

Six parameters were selected which has very strong relation to the common problems, listed above. Further each parameter was defined with the help of sub-parameters for more clarification (Table 2). These essential identified parameters were taken out from the literature survey and from the views of various technical experts, machine operators in the industry, and based upon the requirements and expectations of the system (Ayağ & Özdemir, 2006).

2. The approach

(a) Modified digital logic

Among the six parameters discussed above, each has its own prominence. Every parameter will have different effects on the prospective indices of alternatives and hence cannot be allotted equal weights. Thus, it becomes important to find out the primacies of each parameter. In present work MDL approach had been used for calculating an assured weightage for each parameter to define the individual prominence in a numeric value.

In this context, a pairwise comparison decision matrix is formed by the decision accumulator on the bases of discussion with various decision-makers (technical, financial, environment, and policy-makers). The matrix is filled using 1, 2, and 3 for less, equal, or more important parameters, respectively. MDL provides an opportunity to evaluate the maximum number of possible positive decisions as $N = n(n-1)/2$, where n is the number of parameters. Further summation of all positive decisions (E) for a particular parameter on normalization leads to final weightage (W_j) as follows:

$$W_j = \frac{P_j}{\sum_{j=1}^{n} P_j}$$

(b) Fuzzy logic

This concept was introduced by Lotfi A. Zadeh in 1965 (Zadeh, 1975) to tackle the problems where there are no clear margins between the two or more parameters (Dengfeng & Chuntian, 2002). It deals with the problems where it is very difficult to find an outcome because of the presence of number of alternatives with number of parameters affecting them. Fuzzy approach was used for multiple attribute decision-making (MADM) where the stress is on possibility rather than probability (Ribeiro, 1996). It is based on a set theory and is comprises a membership function within the interval (0,1) which describes the extent of relevance of an element for being the member of the set (Bevilacqua, Ciarapica, & Giacchetta, 2006). Linguistic variables are used for all the comparisons which are assigned numerical values without any paradox. These are the variables whose values is based on the grade given in natural or artificial language (Zadeh, 2008). For illustration, quality is a linguistic variable if its values are assumed to be the fuzzy variables labeled as "good," "bad," and "worst" rather than the actual numbers. The main application of the linguistic approach lie in the domain of humanistic system particularly in the fields of artificial intelligence, linguistics, human decision processes, pattern recognition, psychology, brain research, economics, and related areas (Bellman & Zadeh, 1970).

Various types of membership functions such as triangular, trapezoidal, and Gaussian are available for describing the information under the Fuzzy set theory. In the present work, trapezoidal fuzzy numbers (TFN) are used. Figure 1 shows a typical TFN (b_1, b_2, b_3, b_4) for $\{b_1, b_2, b_3, b_4 \in R; b_1 \leq b_2 \leq b_3 \leq b_4\}$ (Laukkanen, Kangas, & Kangas, 2002). The membership function $\mu_b(x)$ for TFN is defined as follows:

$$\mu_b(x) = \begin{cases} \frac{x-b_1}{b_2-b_1}, & x \in [b_1, b_2] \\ 1, & x \in [b_2, b_3] \\ \frac{b_4-x}{b_4-b_3}, & x \in [b_3, b_4] \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

(c) TOPSIS method

TOPSIS stands for technique for order performance by similarity to ideal solution. It was first proposed by Hwang and Yoon in 1981 (Hwang, Paidy, Yoon, & Masud, 1980; Rathi, Khanduja, & Sharma, 2015). It is one of the most traditional methods used to solve MADM problems by identify the solutions from a finite set of alternatives. It is a perfect logic-based computation method that can be simply performed, which represents sensible decision-making, preferences, and provides an index that all together accounts for the most excellent and poor alternatives (Kim, Chung, Jun, & Kim, 2013). In TOPSIS the selected alternative should have the shortest distance from the positive ideal solution, and also have the longest distance from the negative ideal solution, to resolve the MADM problems (Yong, 2006). The positive ideal solution boosts the profit criteria and sinks down the cost

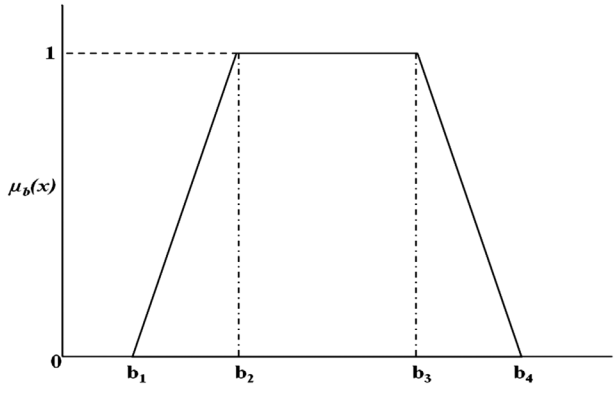

Figure 1. Trapezoidal fuzzy numbers.

criteria, where the negative ideal solution boosts the cost criteria and sinks the profit criteria (Wang & Elhag, 2006). A lot of case studies on project selection, based on TOPSIS method, are reported in literature (Amiri, 2010; Mahmoodzadeh, Shahrabi, Pariazar, & Zaeri, 2007).

2.1. Steps involved in Fuzzy TOPSIS methodology

This section explains the steps involved in the particular fuzzy TOPSIS approach for right project selection in a plywood industry. The approach utilizes MDL weights for pairwise comparison among all considered criteria followed by a fuzzy logic approach with TOPSIS method to obtain ideal alternatives. It includes the following steps:

Step 1*:* Calculation of MDL weights.

As discussed in Subsection 2.1, MDL weights (*Wj*) are calculated for all project selection parameters. This gives the weights of different criteria.

$$W_j = \frac{P_j}{\sum_{j=1}^{n} P_j}$$

Step 2*:* Describe linguistic variables, membership function, and equivalent fuzzy numbers.

A set of fuzzy rates is required in order to compare all the alternatives for each criterion. These fuzzy terms are assigned by the decision-makers and responsible for intra-criterion comparisons of the alternatives.

Step 3: Construction of decision matrix.

Let *p* be the parameters and *q* be the alternatives for *k* number of decision-makers/team members in the proposed model. The aggregated fuzzy rating for C_j criterion is represented as $x_{ijk} = \{x_{ijk1}, x_{ijk2}, x_{ijk3}, x_{ijk4}\}$. For $i = 1, 2, \ldots p; j = 1, 2, \ldots q$ and $k = 1, 2, \ldots k$, x_{ijk} are calculated as follows (Kahraman, Beskese, & Kaya, 2010; Kwong & Bai, 2003):

$$\left\{ \begin{array}{c} x_{ij1} = min_k \left\{ b_{ijk1} \right\} \\ x_{ij2} = \frac{1}{k} \sum b_{ijk2} \\ x_{ij3} = \frac{1}{k} \sum b_{ijk3} \\ x_{ij4} = min_k \left\{ b_{ijk4} \right\} \end{array} \right\}$$

Thus, the obtained decision matrix (*Z*) is shown as follows:

$$Z = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ x_{q1} & x_{q2} & \cdots & x_{qp} \end{bmatrix}$$

Step 4: Defuzzification.

Defuzzification is a method of converting the fuzzy output to crisp value (quantified result) in fuzzy logic by real-valued functions. It is performed to obtain the crisp values for each criterion corresponding to each alternative. The input for the procedure is the cumulative set and the output is a single number. This provides a quantitative value for the linguistic variables and fuzzy numbers assigned based on the verbal reasoning of the decision-makers. Following equation lead to the crisp values:

$$f_{ij} = \text{Defuzz}\left(x_{ij}\right) = \frac{\int \mu(x) \cdot x\, dx}{\int \mu(x) \cdot dx} A = \pi r^2$$

$$= \frac{\int_{x_{ij1}}^{x_{ij2}} \left(\frac{x - x_{ij1}}{x_{ij2} - x_{ij1}}\right) \cdot x\, dx + \int_{x_{ij2}}^{x_{ij3}} x\, dx + \int_{x_{ij3}}^{x_{ij4}} \left(\frac{x_{ij4} - x}{x_{ij4} - x_{ij3}}\right) \cdot x\, dx}{\int_{x_{ij1}}^{x_{ij2}} \left(\frac{x - x_{ij1}}{x_{ij2} - x_{ij1}}\right) dx + \int_{x_{ij2}}^{x_{ij3}} dx + \int_{x_{ij3}}^{x_{ij4}} \left(\frac{x_{ij4} - x}{x_{ij4} - x_{ij3}}\right) dx}$$

$$= \frac{-x_{ij1}x_{ij2} + x_{ij3}x_{ij4} + \left(\frac{1}{3}\right)(x_{ij4} - x_{ij3})^2 + \left(\frac{1}{3}\right)(x_{ij2} - x_{ij1})^2}{-x_{ij1} - x_{ij2} + x_{ij3} + x_{ij4}}$$

Step 5: *Normalized the matrix as given below:*

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{i=1}^{m} (f_{ij})^2}}; \forall_j$$

Step 6: *Calculate the weighted normalized decision matrix as given below:*

$$V_{ij} = [r_{ij}]_{m*n} * [W_j]_{n*m}^{diagonal}$$

Step 7: *Calculate the positive ideal and negative ideal solutions:*

The positive ideal solution +jV and negative ideal solution −jV are as given below:

$$V_j^+ = \{(\max V_{ij}, j \in J_1), (\min V_{ij}, j \in J_2), i = 1, 2, 3 \quad \ldots\ldots\ldots\ m\}, \forall_j$$

$$V_j^- = \{(\min V_{ij}, j \in J_1), (\max V_{ij}, j \in J_2), i = 1, 2, 3 \quad \ldots\ldots\ldots\ m\}, \forall_j$$

where J1 and J2 represents higher best and lower best criteria, respectively.

Step 8: *Calculate the distance +id and −id from the positive ideal solution and negative ideal solution, respectively.*

$$d_i^+ = \left[\sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^+\right)^2}\right], i = 1, 2, 3 \ldots\ldots\ldots .m$$

$$d_i^+ = \left[\sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^-\right)^2}\right], i = 1, 2, 3 \ldots\ldots\ldots .m$$

Step 9: *Calculation of TOPSIS rank index:*

$$C_i^+ = \frac{d_i^-}{d_i^- + d_i^+}$$

Ranking of alternatives with highest rank index C_i^+ at the top is performed.

3. Results and discussion

Ranking and highlighting the major problem for improvement was not a simple task as one has to overcome the pros and cons associated with each problem listed above in the table. Also, the alternatives have to be tested with each of the related parameters and sub-parameters. Therefore, a hierarchy chart was prepared as shown in Figure 2, showing the target, parameters, and alternative in the order of their linkage. Figure 3 shows the contribution of each parameter within plywood industry. It is clear from the figure that safety comes out to be the most with 25% and automation with the least 8% contribution. Table 3 shows the MDL weightage calculation. Corresponding weights are calculated by normalizing the positive decisions as discussed in Subsection 2.1.

In the next step, a comparison matrix was formed by comparing the parameters with each of the alternatives. Firstly, an attribute value in the form of linguistic variables was given to each alternative based on its relationship with the each parameter, as shown in Table 4. Then corresponding fuzzy numbers, shown in Table 5, were allotted to each alternative. Crisp values were calculated, as discussed in step 4 of Subsection 2.1, from the fuzzy numbers (Table 6).

In the next, step Fuzzy TOPSIS MADM approach as described in Subsection 2.1 was used and TOPSIS index and hence ranks were calculated using steps 5–9. The alternative with higher TOPSIS index was given the higher rank. Table 7 shows the alternatives with TOPSIS index and their

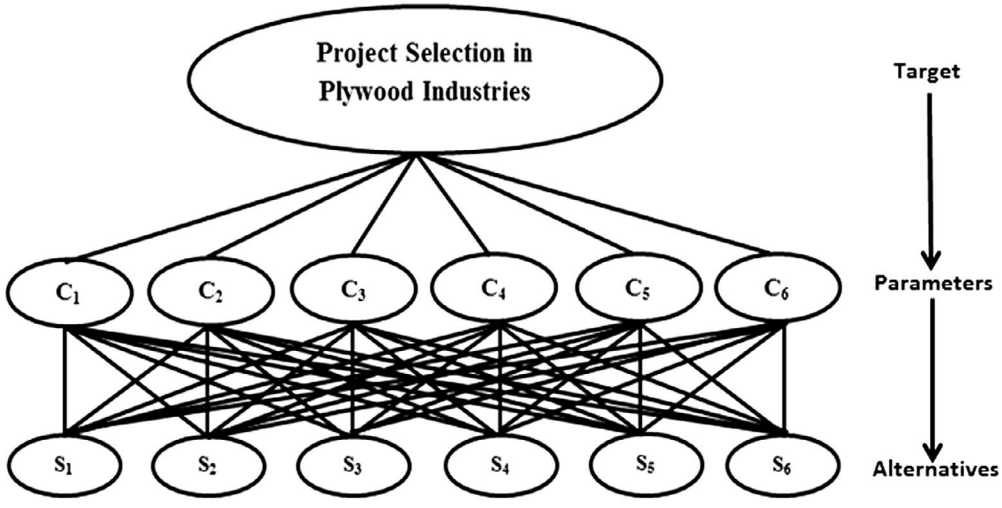

Figure 2. Hierarchy chart for the problem selection in the plywood industry.

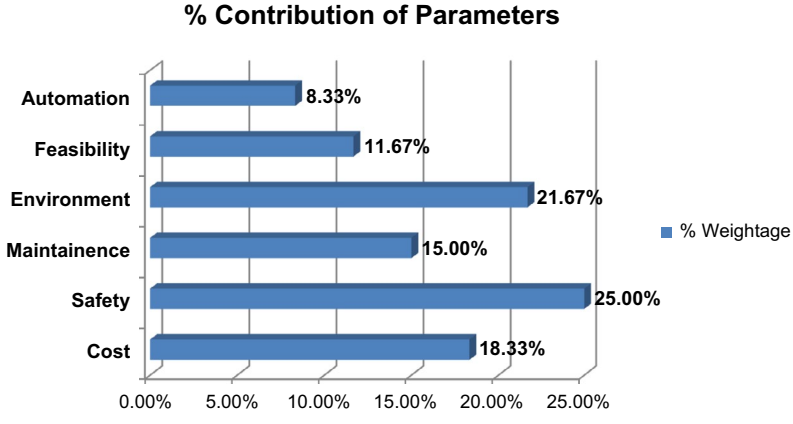

Figure 3. % Contribution of parameters.

Table 3. MDL weightage calculation

Parameters	C1	C2	C3	C4	C5	C6	Positive decisions	Weights	Ranks
Cost	2	1	3	1	3	3	11	0.183	3
Safety	3	2	3	3	3	3	15	0.250	1
Maintenance	1	1	2	1	3	3	9	0.150	4
Environment	3	1	3	2	3	3	13	0.217	2
Feasibility	1	1	1	1	2	3	7	0.117	5
Automation	1	1	1	1	1	2	5	0.083	6

Table 4. Linguistic decision matrix for each alternative

Alternatives	C1	C2	C3	C4	C5	C6
Quality defects (S1)	EH	A	EL	VH	H	VH
Workers' absenteeism (S2)	VH	A	EL	H	VH	EH
Raw material quality (S3)	EH	EL	EL	VL	EH	VH
Delay in dispatch (S4)	EH	EL	VL	VH	EH	AA
Wastage of material (S5)	VH	EH	H	VL	VH	EH
Energy consumption (S6)	VH	VL	EH	VH	VH	H

Table 5. Linguistic variables along with corresponding fuzzy numbers

Lingustic variable	Abbreviation	Fuzzy number
Exceptionally high (EH)	EH	(0.8, 0.9, 1.0, 1.0)
Very high (VH)	VH	(0.7, 0.8, 0.8, 0.9)
High (H)	H	(0.5, 0.6, 0.7, 0.8)
Above average (AA)	AA	(0.4, 0.5, 0.5, 0.6)
Average (A)	A	(0.2, 0.3, 0.4, 0.5)
Very low (VL)	VL	(0.1, 0.2, 0.2, 0.3)
Extremely low	EL	(0, 0, 0.1, 0.2)

Table 6. Calculated crisp values for corresponding assigned fuzzy numbers

Alternatives	C1	C2	C3	C4	C5	C6
S1	0.9444	0.3667	0.0778	0.8333	0.6667	0.8333
S2	0.8333	0.3667	0.0778	0.6667	0.8333	0.9444
S3	0.9444	0.0778	0.0778	0.2333	0.9444	0.8333
S4	0.9444	0.0778	0.2333	0.8333	0.9444	0.5333
S5	0.8333	0.9444	0.6667	0.2333	0.8333	0.9444
S6	0.8333	0.2333	0.9444	0.8333	0.8333	0.6667

corresponding rankings. As it evident from the table that wastage of material has emerged as a leading contender with the highest TOPSIS rank followed by energy consumption. The lowest TOPSIS index was attained by raw material quality showing it as the least of the problematic area.

After the ranking of the problems, various brainstorming sessions were performed by the experts in the field. Various surveys were performed within the cluster of the industries. A Fishbone diagram, as shown in Figure 4, was prepared for the highest ranked problem, i.e. wastage of material. The

Table 7. TOPSIS index and corresponding ranks

Alternatives	TOPSIS index	TOPSIS rank
Quality defects (S1)	0.379	3
Workers' absenteeism (S2)	0.342	4
Raw material quality (S3)	0.085	6
Delay in dispatch (S4)	0.281	5
Wastage of material (S5)	0.705	1
Energy consumption (S6)	0.466	2

Fishbone diagram shows the various causes related to man, machine, method, and material for the wastage of wood.

4. Conclusion

In industries, particularly SSIs, the success rate of any project depends highly upon the degree of proper project selection. In this perspective, the Fuzzy TOPSIS MADM approach has been used for problem selection in plywood industries in India. Modified digital logic (MDL) method is used to estimate weightage of all the influencing parameters for selection of the alternatives. A number of alternatives have been looked over and considered in terms of different criteria, which are mainly responsible for various types of problems in plywood industries. The priority order of alternatives is determined using fuzzy TOPSIS approach. Wastage of material comes out to be the most influencing problem and has lots of potential for improvement. Various strategic recommendations were made on both management and employees end to overcome the problem. These are as follows:

Recommendations for Managing Wastage of Material

(1) Purchasing of wooden log, which is the basic item, needs serious attention. The length and the diameter of the wooden logs should be such that, less material is wasted during further operations. The cutting of logs should also be of proper size. This will increase the availability of maximum wood for plywood and ply board manufacturing, which will ultimately reduce the wastage of the material.

(2) "*KAI + ZEN = Change for better*." Here, in this case the change indicated is from the conventional machinery to modern one. It has been observed that in most of the SSIs, a conventional mechanical peeling machine is in use for the purpose of core-making. Generally, a 1,270 mm

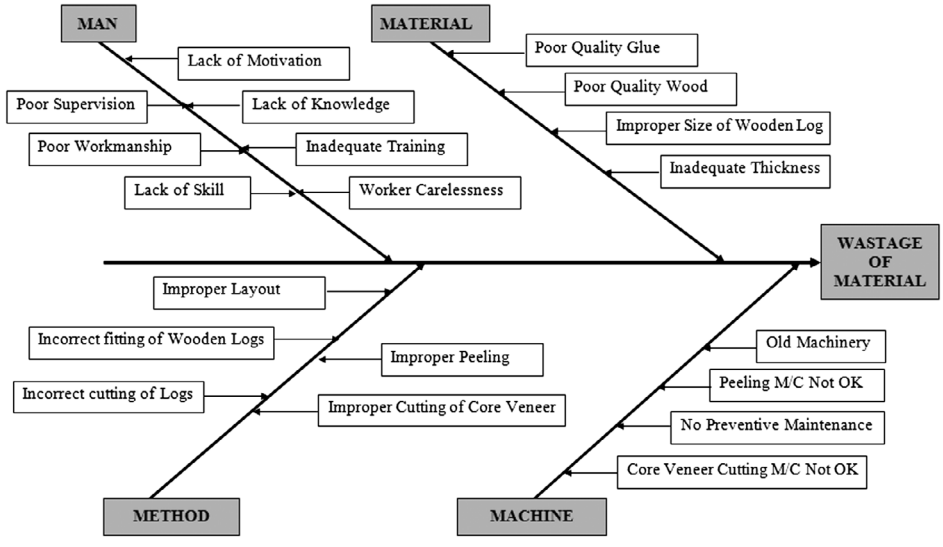

Figure 4. Fishbone diagram for wastage of material.

log length is input in a peeling machine for the purpose of core-making. At the end of peeling process, the log that is being left out by this machine is of roll diameter 80 mm, collars thickness of 30 mm, and collar diameter of 196 mm at both ends. It constitutes about 21% of the input material which is being sent for ignition purpose and ultimately got wasted. So, the machine should be replaced by a new technology hydraulic peeling machine. The hydraulic peeling machine has the capacity to reduce the wood wastage as the log that is being left out by this machine is of roll diameter 30 mm, collars thickness of 30 mm, and collar diameter of 196 mm on only one end. This constitutes about 4.65% of wood wastage. So, in this way the wood wastage can be minimized. Also, new machines require less maintenance and the efficiency of new machines is more. This increases the production and very less money is spent on the repair of new machines and which will increase the profit of the industry.

(3) Proper layout is always a boost. The machines should be placed in the proper process layout. It will help in easy material movement and the workforce required for the material movement can be used for another job. This will result in an increased production rate and also save the wastage of time and money.

Other recommendations

For employees

Workers must follow the standard practice mentioned in the control plan of the process. Any deviation from the same will lead to a defect or loss. Talking about the plywood industries and the processes associated with it, due attention should be given while fitting core veneer, wooden battens, glue spreading, and of course during the inspection.

For management

The role of management is very important for the progress of any industry. Management should always motivate their employees. It can be done either by the personnel development of the employees or by increasing their financial stature. Also, the sense of security and safety also boost employee's morale.

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Author details
Kapil Mittal[1]
E-mail: kapilmittal007@gmail.com
ORCID ID: http://orcid.org/0000-0001-8775-9236
Puran Chandra Tewari[1]
E-mail: kapil_6150038@nitkkr.ac.in
Dinesh Khanduja[1]
E-mail: dinesh.khanduja@yahoo.com
Prabhakar Kaushik[2]
E-mail: parbhakarkaushik@yahoo.com
[1] Department of Mechanical Engineering, National Institute of Technology, Kurukshetra, Haryana 136119, India.
[2] Department of Mechanical Engineering, UIET, Maharshi Dayanand University, Rohtak, Haryana 124001, India.

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