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Prioritizing Scheduling Parameters in the Automotive Industry Using Fuzzy TOPSIS-DEMATEL Model

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ABSTRACT

The Automotive industry is one of the biggest emerging sectors in terms of revenue. Every automotive industry has an indispensable need for optimum manufacturing scheduling systems for generating good revenues and profits. This need can be pulled off by identifying and prioritizing the scheduling parameters. Multi-criteria decision making (MCDM) is one of the best techniques of operation research in selecting the best parameters or factors among the various alternatives. This study includes the identification and prioritization of the various important scheduling parameters (SPs) in the Indian automotive industry. The twelve scheduling parameters have been identified in this study and these parameters are prioritized by the fuzzy- Technique for order preference by similarity to ideal solution (TOPSIS) and Decision Making Trial and Evaluation Laboratory Model (DEMATEL). The expert's views are gathered from the five automobile industries. Makespan, energy consumption, due date, and travel time are the crucial parameters obtained using Fuzzy TOPSIS. The least important parameters obtained using Fuzzy TOPSIS are work in process, flow time, and release date. The most influential parameters identified using the DEMATEL method are completion time and processing time. This study is valuable for every industry and research organization in the field of the automobile industry.

Keywords: Scheduling; Automotive industry; Fuzzy TOPSIS; Ideal solutions; DEMATEL.

INTRODUCTION

In today's scenario, the desideratum of every manufacturing firm is scheduling. Scheduling means the fulfilling the different performance criteria or factors by distributing the available production resources over time (Akyol et al., 2007). Production Scheduling is a very important decision-making process that includes the proper allocation of all the available resources for performing all tasks (R. Agrawal et al., 2012). On-time delivery of products or services provides customer satisfaction and scheduling helps in achieving on-time delivery (M. Pinedo, 1996). The primary objective of scheduling includes determining the job processing time, sequence, and due date of jobs (Tavakkoli-Moghaddam et al., 2010). The complexity of each production scheduling problem depends on different objectives, environmental conditions, and process constraints. The manufacturing schedule depends not only on production but also depends on scheduling parameters (Coudert et al., 2002). Prioritizing scheduling parameters is the need of every industry for optimum schedule because, without an optimum schedule, industries can't increase the profit and productivity on a full scale. Most of the industries only work in the area of improving the work culture, surrounding conditions, and performance of workers and machines, etc. But for every industry, it is important to identify and prioritize the critical scheduling parameters or most influential scheduling parameters of their respective area or field. By identifying the critical scheduling parameters, we can generate the most effective scheduling system. So, there is an immense need of prioritizing these parameters. These parameters can be effectively prioritized using the MCDM approach. This study includes the identification of scheduling parameters and finding the criticality of these parameters in the automobile industry.

Due to uncertainty and ambiguity in human judgment decisions, all values corresponding to scheduling parameters in the decision set can't be crisp. So, some linguistic variable or fuzzy variable must be taken to deals with all the criteria (Zhao et al., 2014). Therefore, fuzzy TOPSIS methodology is used in this study for prioritizing the SPs for an optimum schedule in the automotive industry, and the DEMATEL method is used for identifying the most influential parameters and also finds cause criteria and effect criteria group. DEMATEL is the structural modeling approach used in finding the relationship between the cause and effect criteria. Many researchers have used fuzzy TOPSIS and DEMATEL methodology separately in various scheduling problems as discussed in the literature part. But the first time, both these approaches are applied simultaneously in prioritizing the scheduling parameters and identify the most influential parameters for an optimum schedule in the automotive industry.

MCDM is a branch of operation research in dealing with complex multi-criteria or specifications. This technique helps in obtaining the best choice among the various alternatives in these fluctuating real-world problems. The fuzzy TOPSIS technique is one of the best techniques of MCDM used by various researchers in past studies in dealing with uncertainty (Chawla et al., 2019 & Yong, 2006). This method has been applied in reverse logistics (S. Agrawal et al., 2016), material selection (Maity et al., 2013), project selection (Taylan et al., 2014), warehouse location selection (Ashrafzadeh, 2012), plant location selection (Yong, 2006), supplier selection (Daneshvar et al., 2014), machine tool selection (Yurdakul et al., 2009) and wireless network selection (Mansouri et al., 2020). The fuzzy TOPSIS technique can be effectively used for prioritizing the critical factors for implementing the reverse logistics (S. Agrawal et al., 2016). S. Maity et al. solved the grinding material selection problem using Fuzzy TOPSIS (Maity et al., 2013). Construction projects are dynamic in nature and consist of high risks and uncertainty. Their high risks can be effectively evaluated by fuzzy TOPSIS (Taylan et al., 2014). The warehouse location selection problem also consists of uncertainty and vagueness. M. Ashrafzadeh et al. utilized this approach for solving the warehouse location problem (Ashrafzadeh, 2012).

DEMATEL method is another effective approach that can be applied for prioritizing the critical parameters or risk factors in the automobile spare industry (Wu et al., 2011), project management (Zhang et al., 2019), waste management (Chauhan et al., 2018), maintenance management (Vujanovic et al., 2012), product design (Ibrahim et al., 2018), remanufacturing (Singh et al., 2018), service quality improvement (Chu et al., 2017) and supplier selection (Chiou et al., 2011). Hsin-Hung Wu et al. identified the technological capability, organization, and service as the three most critical dimensions in the automobile spare industry using the DEMATEL method. They identified the five most influential criteria among thirty criteria for improvement (Wu et al., 2011). Lin Zhang et al. identified the critical risk factors in urban projects for controlling the flooding and water shortage using the DEMATEL method (Zhang et al., 2019). Ankur Chauhan et al. identified and prioritized the barriers of waste recycling management using this methodology (Chauhan et al., 2018). Davor Vujanovic et al. solved the vehicle fleet management problem and evaluated its indicators by ANP (Analytic Network Process) and DEMATEL method (Vujanovic et al., 2012). Jianjie Chu et al. enhanced the air travel service quality by prioritizing the key service criteria using DEMATEL and gray theory (Chu et al., 2017). The above studies show that scheduling parameter prioritization in the automobile industry is an untouched area of research and the Fuzzy TOPSIS and DEMATEL methods are effective in the identification and prioritization of the critical parameters or risk factors of various industries problems.

IDENTIFICATION OF SCHEDULING PARAMETERS

Twelve Scheduling parameters are identified from previous studies and industry expert's reviews. These parameters are discussed below. Makespan is one of the strongest performance measures in all types of scheduling problems and it represents the total time to process all the jobs (Pinedo, 1996). For minimizing the makespan, machine speed can be increased but it increases energy consumption. The tradeoff is required between these parameters (Gong et al., 2015). Makespan or tardiness is taken as the main parameter for a single optimality criteria problem. Flow time represents the size of the average inventory. Flow time can be significantly reduced by minimizing the average inventory. Lateness indicates the condition of completing the orders near the due date. Processing time depends on the starting time in machine scheduling problems. Processing time can be linear or exponential in time-dependent problems (Cheng et al., 2004).The release date shows the value before which a job cannot be processed on a machineA job must be entered at the date and leaves at the due date. Earliness represents the negative lateness and shows the condition of completing the orders earlier to the due date (Alharkan, 2005).

FUZZY TOPSIS METHOD FOR PRIORITIZING SCHEDULING PARAMETERS

TOPSIS technique was the first time applied in the fuzzy environment for the group decision making in 1997 by Chen –Tung Chen. In fuzzy TOPSIS methodology, the linguistic variable is used with a fuzzy number on a point scale (Chen, 2000). The methodology is shown as follows:

Step 1: Fuzzy TOPSIS starts with the establishment of a committee of decision-makers.

Step 2: Define Linguistic Variable terms with their Fuzzy Number on the point scale. This scale is defined in Table 1 using the linguistic terms which are negative low (NLO), low (LO), average or arithmetic mean (AM), high (HI), and positive high (PHI).

Table 1. Linguistic Variable terms with their Fuzzy Number

Linguistic term	Fuzzy number
Negative low (NLO)	1,1,3
Low (LO)	1,3,5
Average (AM)	3,5,7
High (HI)	5,7,9
Positive high (PHI)	7,9,9

Step 3: Find the decision matrix (DM) = $[x_{ij}]_{mxn}$, $x_{ij} = (a_{ij},b_{ij},c_{ij})$ which is a fuzzy number with i =1,2,...,m number of decision maker of various automobile companies and j = 1,2,...,n number of scheduling parameters.

Step 4: Find the Normalized fuzzy decision matrix R_{ij}

Equation 1 is showing a normalized decision matrix for non-beneficial criteria. For beneficial criteria, larger R_{ij} is desirable, whereas, for cost criteria, smaller R_{ij} is desirable.

$$NDM = [R_{ij}]_{mxn}, \ R_{ij} = \left(\frac{C^*_j}{C^*_{ij}}, \frac{C^*_j}{b^*_{ij}}, \frac{C^*_j}{a^*_{ij}} \right), \ C^*_j = \min_i c \tag{1}$$

Step 5: Determine the weightage normalized fuzzy decision matrix *V* which is obtained by multiplying the weightage w_j given to the decision makers with matrix R_{ij}.

$$V = v_{ij} = w_j \times R_{ij} \tag{2}$$

Step 6: Calculate the Fuzzy positive from the A^+ and s^-_i separation from the A^-

$$A^+ = \{v_1^+, v_2^+ ...., v_n^+\}, \qquad A^- = \{v_1^-, v_2^- ...., v_n^-\} \tag{3}$$

Step 7: Calculate the separation from the A^+ and s^-_i separation from the A^-

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v^+_j - v_{ij})^2}, \ s_i^- = \sqrt{\sum_{j=1}^{n} (v^-_j - v_{ij})^2}, \qquad i=1,2,...,m \tag{4}$$

Step 8: Calculate the relative closeness coefficient C_j

$$C_j = \frac{s^+_i}{s^+_i + s^-_i} \qquad C_j = 1 \text{ if } A_i = A^+ \quad C_j = 0 \text{ if } A_i = A^- \tag{5}$$

$s^-_i \geq 0$ and $s+i \geq 0$, then clearly $0 \leq C_j \leq 1$

Step 9: The ranking of alternatives is obtained using relative closeness values.

APPLICATION OF FUZZY TOPSIS METHODOLOGY

Literature review and experts view from various decision-making companies help us in identifying the main twelve scheduling parameters for the optimum schedule in automotive part manufacturing companies. The twelve scheduling parameters identified are makespan, flow time, lateness, processing time, due date, energy consumption, earliness, travel time, work in process, tardiness, completion time, and release date. Profiles of the various crankcase automotive part manufacturing companies are illustrated in Table 2.

Table 2. Profile of various Decision maker companies

Companies	Product Manufactured	Material	Annual Turnover (USD)	No. of Branches in India	Manufacturing Facility Setup in India
Super Auto India limited (CPY 1)	Motorcycle crankcase	Aluminum	70 Lakh	3	Faridabad, Pune
Shiv Shakti Engineering Co. (CPY 2)	Ingersoll Rand Crank Case	CIFC225	1.4 Lakh	1	Ahmedabad (Gujarat, India)
Kolben Compressor Spares (India) Private Limited (CPY 3)	Vilter 440 Crankcase	Steel	35 Lakh	1	Churchgate, Mumbai, Maharashtra
Industrial Spare Syndicate Limited (CPY 4)	ISS Crank Case For KG2	Cast Iron	4.9 Lakh	1	Mori Gate, Delhi
Shanirajeshwar Die Casting Pvt. Ltd. (CPY 5)	Black Automobile Crankcase	Aluminum Alloy	24.5 Lakh	1	Moshi, Pune, Maharashtra

Scheduling parameters for optimum schedule with their symbols are represented as makespan (Mk), flow time (Ft), lateness (Lt), processing time (Pt), due date (Dd), energy consumption (Ec), earliness (E), travel time (Tt), work in process (Wp), tardiness (T), completion time (Ct), and release date (Rd). Table 3 is showing the linguistic variable as well as the fuzzy number-based decision matrix. A linguistic variable-based matrix is developed on the five-point linguistic scale as discussed in Table 1.

Table 3. Linguistic Variable & Fuzzy number Based Decision Matrix

	Linguistic Variable Based Decision Matrix					Fuzzy number based Decision matrix				
	CPY 1	**CPY 2**	**CPY 3**	**CPY 4**	**CPY 5**	**CPY 1**	**CPY 2**	**CPY 3**	**CPY 4**	**CPY 5**
M_k	HI	HI	PHI	HI	PHI	5,7,9	5,7,9	7,9,9	5,7,9	7,9,9
F_t	NLO	AM	LO	NLO	LO	1,1,3	3,5,7	1,3,5	1,1,3	1,3,5
L_t	LO	AM	LO	LO	AM	1,3,5	3,5,7	1,3,5	1,3,5	3,5,7
P_t	HI	HI	AM	HI	AM	5,7,9	5,7,9	3,5,7	5,7,9	3,5,7
D_d	HI	PHI	AM	HI	AM	5,7,9	7,9,9	3,5,7	5,7,9	3,5,7
E_c	HI	AM	AM	LO	AM	5,7,9	3,5,7	3,5,7	1,3,5	3,5,7
E	LO	AM	LO	LO	LO	1,3,5	3,5,7	1,3,5	1,3,5	1,3,5
T_t	AM	HI	AM	HI	AM	3,5,7	5,7,9	3,5,7	5,7,9	3,5,7
W_p	NLO	AM	NLO	NLO	LO	1,1,3	3,5,7	1,1,3	1,1,3	1,3,5
T	HI	AM	AM	HI	AM	5,7,9	3,5,7	3,5,7	5,7,9	3,5,7
C_t	LO	AM	AM	LO	AM	1,3,5	3,5,7	3,5,7	1,3,5	3,5,7
R_d	LO	AM	LO	NLO	LO	1,3,5	3,5,7	1,3,5	1,1,3	1,3,5

For calculating the normalized fuzzy decision matrix, we have assumed all criteria to be non-beneficial (cost) criteria. The matrix will be the same as the matrix because, for this study, equal weights are considered for all the decision-makers. Table 4 shows the matrix with the fuzzy ideal solutions. The distances or separation from the ideal solutions are calculated in Table 5.

Table 4. Matrix *V* with ideal solutions

	CPY 1	**CPY 2**	**CPY 3**	**CPY 4**	**CPY 5**
M_k	0.11,0.14,0.2	0.33,0.42,0.6	0.11,0.11,0.14	0.11,0.14,0.2	0.11,0.11,0.14
F_t	0.33,1,1	0.42,0.6,1	0.2,0.33,1	0.33,1,1	0.2,0.33,1
L_t	0.2,0.33,1	0.42,0.6,1	0.2,0.33,1	0.2,0.33,1	0.14,0.2,0.33
P_t	0.11,0.14,0.2	0.33,0.42,0.6	0.14,0.2,0.33	0.11,0.14,0.2	0.14,0.2,0.33
D_d	0.11,0.14,0.2	0.33,0.33,0.42	0.14,0.2,0.33	0.11,0.14,0.2	0.14,0.2,0.33
E_c	0.11,0.14,0.2	0.42,0.6,1	0.14,0.2,0.33	0.2,0.33,1	0.14,0.2,0.33
E	0.2,0.33,1	0.42,0.6,1	0.2,0.33,1	0.2,0.33,1	0.2,0.33,1
T_t	0.14,0.2,0.33	0.33,0.42,0.6	0.14,0.2,0.33	0.11,0.14,0.2	0.14,0.2,0.33
W_p	0.33,1,1	0.42,0.6,1	0.33,1,1	0.33,1,1	0.2,0.33,1
T	0.11,0.14,0.2	0.42,0.6,1	0.14,0.2,0.33	0.11,0.14,0.2	0.14,0.2,0.33
C_t	0.2,0.33,1	0.42,0.6,1	0.14,0.2,0.33	0.2,0.33,1	0.14,0.2,0.33
R_d	0.2,0.33,1	0.42,0.6,1	0.2,0.33,1	0.33,1,1	0.2,0.33,1
A^+	0.33,1,1	0.42,0.6,1	0.33,1,1	0.33,1,1	0.2,0.33,1
A^-	0.11,0.14,0.2	0.33,0.33,0.42	0.11,0.11,0.14	0.11,0.14,0.2	0.11,0.11,0.14

Table 5. Separation from each parameter to the FPIS & FNIS

	Separation from each parameter to the FPIS					Separation from each parameter to the FNIS				
	CPY 1	**CPY 2**	**CPY 3**	**CPY 4**	**CPY 5**	**CPY 1**	**CPY 2**	**CPY 3**	**CPY 4**	**CPY 5**
M_k	0.689	0.258	0.725	0.689	0.515	0	0.116	0	0	0
F_t	0	0	0.394	0	0	0.689	0.373	0.515	0.689	0.515
L_t	0.394	0	0.394	0.394	0.395	0.477	0.373	0.515	0.477	0.122
P_t	0.689	0.258	0.612	0.689	0.395	0	0.116	0.122	0	0.122
D_d	0.689	0.373	0.612	0.689	0.395	0	0	0.122	0	0.122
E_c	0.689	0	0.612	0.394	0.395	0	0.373	0.122	0.477	0.122
E	0.394	0	0.394	0.394	0	0.477	0.373	0.515	0.477	0.515
T_t	0.612	0.258	0.612	0.689	0.395	0	0.116	0.122	0	0.122
W_p	0	0	0	0	0	0.689	0.373	0.725	0.689	0.515
T	0.689	0	0.612	0.689	0.395	0	0.373	0.122	0	0.122
C_t	0.394	0	0.612	0.394	0.395	0.477	0.373	0.122	0.477	0.122
R_d	0.394	0	0.394	0	0	0.477	0.373	0.515	0.689	0.515

S^+, S^-, and C_j values are calculated using Equations 6 and 7. Based on Cj values, priority values are given. Table 6 shows the Priority Matrix Based on Closeness Coefficient Values. The most important SPs obtained is makespan and the least important SPs is work in process.

Table 6. Priority Matrix Based on Closeness Coefficient Values

	M_k	F_t	L_t	P_t	D_d	E_c	E	T_t	W_p	T	C_t	R_d
S^+	2.87	0.39	1.57	2.64	2.75	2.09	1.18	2.56	0	2.38	1.79	0.78
S^-	0.11	2.78	1.96	0.36	0.24	1.09	2.35	0.36	2.99	0.61	1.57	2.56
C_j	0.96	0.12	0.44	0.88	0.91	0.65	0.33	0.87	0	0.79	0.53	0.23

DEMATEL METHODOLOGY

DEMATEL methodology is based on the causal relationship and provides visual graphical relations between the complex criteria. This method also identifies the cause and effect groups among the various criteria. It is the only method that provides visualization to researchers about interrelations among criteria. For providing visualization, it uses the basics of graph theory (Ibrahim et al., 2018). The steps involved within the DEMATEL methodology are as follows.

Step 1: Set up a pairwise comparison scale of the DEMATEL method which includes the terms with numeral like no effect (0), low effect (1), medium effect (2), high effect (3), and very high effect (4).

Step 2: Compute the initial direct relation matrix which is a matrix generated from a comparison scale in terms of numerical and it shows the influences of all criteria on each another. is a square matrix in which diagonal elements are zero.

Step 3: Calculate the Normalized direct relation matrix U i.e. $U = [U_{ij}]_{nxm}$ and $0 \leq U_{ij} \leq 1$. This matrix can be determined from the Equation 6. Set of elements contains in a system is

$$S = \{s_1, s_2, \ldots, s_n\}.$$

$$S = \frac{1}{\max_{1\le i\le n} \sum_{j=1}^{n} x_{ij}}, \quad U = S \times M \tag{6}$$

Step 4: Determine the total relation matrix *V* using Equations 7 and 8 in which identity matrix is denoted by 1 .

$$V = M + M^2 + \ldots + M^h = M\,(I - M^h)(I - M)^{-1} \tag{7}$$

when $\lim_{h \to \infty} M^h = [0]_{nxn}$,

$$V = (v_{ij})_{nxn} = M(I - M)^{-1} \tag{8}$$

Step 5: Defining the sum of rows (D) and sum of column(R) in the total relation matrix *V* as vector d and r through Equations 9.

$$D = (d_i)_{n\times 1} = \left[\sum_{j=1}^{n} v_{ij}\right]_{n\times 1}, \quad R = (r_i)_{1\times n} = \left[\sum_{i=}^{n} v_{ij}\right]_{1\times n} \tag{9}$$

Step 6: With the help of Equation 9, cause and effect diagram is generated to find the most affected criteria/parameter.

APPLICATION OF DEMATEL METHODOLOGY

The influence of each criterion on all other criteria is represented by the initial direct relation matrix in terms of numerical value as shown in Table 7. Data for Table 7 is collected from the literature review and industry experts. A total relation matrix is generated by using Equations 7, 8, and 9 as shown in Table 8. The positive and negative values of D-R represent the cause and effect criteria respectively as depicted in Table 9.

Estimate the threshold value (α=0.2689) of the total relation matrix. Then, compare all the matrix values with it and marked bold those values whose value is greater than threshold values. In the DEMATEL method, values with the highest prominence vector and relation vector are the most influential criteria. Completion time (C11) and processing time (C4) are the most influential criteria identified from the causal diagram as shown in Figure 1.

Table 7. Initial direct relation matrix (M)

	M_k	F_t	L_t	P_t	D_d	E_c	E	T_t	W_p	T	C_t	R_d
M_k	0	4	3	0	3	3	3	1	2	3	4	1
F_t	4	0	3	0	3	3	3	1	3	3	3	0
L_t	1	1	0	0	3	0	4	0	0	2	3	2
P_t	4	4	3	0	1	3	3	0	1	3	4	0
D_d	1	1	3	1	0	0	4	3	0	1	3	4
E_c	3	3	0	4	0	0	0	2	0	1	4	0
E	1	1	2	0	1	0	0	0	1	4	3	2
T_t	4	4	3	0	1	2	3	0	1	2	3	0
W_p	3	3	2	1	0	3	1	4	0	3	3	0
T	1	1	1	0	1	0	4	0	0	0	3	2
C_t	4	4	3	3	1	1	2	1	3	3	0	1
R_d	0	0	3	0	4	1	3	0	0	3	3	0

Table 8. Total relation matrix

	M_k	F_t	L_t	P_t	D_d	E_c	E	T_t	W_p	T	C_t	R_d
M_k	**0.317**	**0.446**	**0.427**	0.126	**0.344**	**0.279**	**0.489**	0.180	0.239	**0.465**	**0.568**	0.223
F_t	**0.439**	**0.310**	**0.415**	0.121	**0.333**	**0.277**	**0.475**	0.181	0.265	**0.453**	**0.526**	0.184
L_t	0.198	0.198	0.191	0.064	0.247	0.087	**0.365**	0.075	0.093	**0.281**	**0.345**	0.192
P_t	**0.456**	**0.456**	**0.425**	0.124	**0.278**	**0.288**	**0.485**	0.138	0.212	**0.468**	**0.571**	0.181
D_d	0.261	0.261	**0.357**	0.114	0.195	0.125	**0.437**	0.195	0.123	**0.318**	**0.427**	**0.285**
E_c	**0.368**	**0.368**	0.257	0.235	0.183	0.158	**0.292**	0.172	0.146	**0.314**	**0.467**	0.122
E	0.193	0.193	0.244	0.060	0.171	0.087	0.217	0.070	0.122	**0.333**	**0.331**	0.177
T_t	**0.419**	**0.419**	**0.392**	0.105	0.255	0.233	**0.446**	0.123	0.194	**0.395**	**0.489**	0.163
W_p	**0.407**	**0.407**	**0.363**	0.147	0.217	**0.279**	**0.383**	0.265	0.160	**0.430**	**0.499**	0.152
T	0.173	0.173	0.194	0.053	0.156	0.075	**0.322**	0.059	0.082	0.181	**0.304**	0.166
C_t	**0.456**	**0.456**	**0.432**	0.215	**0.283**	0.230	**0.462**	0.176	**0.276**	**0.472**	**0.442**	0.213
R_d	0.166	0.166	**0.291**	0.069	**0.279**	0.114	**0.338**	0.077	0.087	**0.310**	**0.349**	0.130

Table 9. Calculation of prominence vector and relation vector

	Diagram Notations	D	R	D+R	D-R
M_k	C1	4.1076	3.8578	7.9654	0.2498
F_t	C2	3.9853	3.8578	7.8431	0.1275
L_t	C3	2.3418	3.9952	6.3370	-1.6534
P_t	C4	4.0887	1.4397	5.5284	2.6490
D_d	C5	3.1026	2.9455	6.0481	0.1571
E_c	C6	3.0865	2.2382	5.3247	0.8483
E	C7	2.2034	4.7154	6.9188	-2.5120
T_t	C8	3.6387	1.7174	5.3561	1.9213
W_p	C9	3.7134	2.0048	5.7182	1.7086
T	C10	1.9436	4.4260	6.3696	-2.4824
C_t	C11	4.1204	5.3226	9.4430	-1.2022
R_d	C12	2.3824	2.1939	4.5763	0.1885

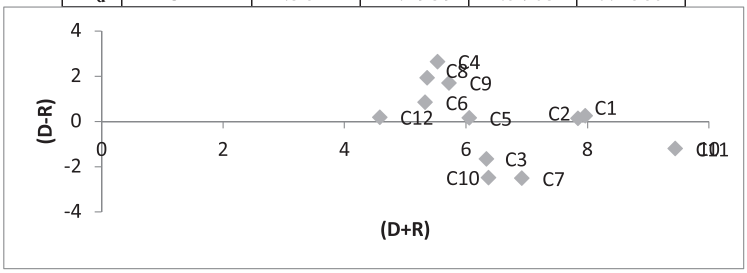

Figure 1. Causal diagram

CONCLUSION

Optimum Scheduling plays a major role in the effective manufacturing system. This scheduling can only be done by identifying the scheduling parameters. This study provides the methodology of identifying and prioritizing the twelve SPs for automotive part manufacturing. The most important four SPs identified for optimum scheduling using fuzzy TOPSIS are makespan, due date, processing time, and travel time. The least important SPs identified using fuzzy TOPSIS are work in process, flow time, and release date. Makespan (C1), flow time (C2), processing time (C4), due date (C5), energy consumption (C6), travel time (C8), work in process (C9), and release date (C12) are classified into cause criteria group, whereas effect criteria group consists of lateness (C3), earliness (C7), tardiness (C10) and completion time (C11). Cause criteria factors are more crucial than the effect criteria factors. So, all industries and research organizations must give more attention to these factors because cause criteria group improvement has a significant effect on the improvement of the effect criteria group. Results reveal that the completion time and processing time are the most influential criteria in optimum scheduling. This study is useful for all automotive part manufacturers as well as automobile-based research organizations. This study is based on the automobile crankcase cover with five point linguistic scale.

For further research, the Fuzzy VIKOR, and fuzzy PROMETHEE can be applied and comparison analysis can be done for the same problem. Future research can be carried out by taking any other automotive part with five or more linguistic scales and for a more generalized scheduling model, the number of experts can also be increased.

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