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Validation of Optimal Feasibility for Waste Minimization

[1]Gantavya Vivek Punj, [2]Arvind Meena,

[1]Student, [2]Assistant Professor

[1]Department of Mechanical Engineering

[1]Netaji Subhas University of Technology, New Delhi, India

gantavyavpunj@gmail.com

Abstract : As being considered as the central phase of business functions, Supply Chain Management (SCM) is concerned with operational performance at each stage of a production process. In the present context, it has been an emerging topic of academia and industry as it can further improvise sustainable development of production processes across companies around the globe (1). It provides an integrated pathway to connect concerns for cost reduction, profit enhancement along with social, environmental and other societal benefits. The research objective revolves around peer review of selected literatures focusing their study on specific domains and organisations and their supply chain and processes which would entail to have an understanding of furthering our study to determine optimal feasibility for waste minimization of Siemens Ltd which is a German conglomerate having its arena in Industrial Manufacturing. The research would primarily focus in the field of Fire Detectors and other associated components in order to determine optimal feasibility for the company. It would be done by initial formulation of objective function and selection of most suitable decision variables along with consideration of potential constraints (2). The corresponding Decision Variables have been selected by Multi Criteria Decision Making method by employing the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The Objective Function is Waste Minimization with shortlisted Decision Variables as Target Audience, Transportation Mode (Road), Manpower Requirement and Inventory Management. The potential constraints include Machine Operation Time and Distances of Distribution Units from Manufacturing Location. The determination of optimal feasibility will pave way for achieving minimum waste disposal leading to inclusion as well as process efficiency. A multi objective optimization technique would be employed for the same. In such problems, the objective functions may be in conflict with each other. For simplification of solution process, the additional objective functions are generally handled as constraints. Such a kind of research will lead to emphasis on similar study on other components and organisations working in this or similar domain.

Keywords- TOPSIS, Waste Minimization, Multi Objective Optimization, Sorting Analysis

1.0 INTRODUCTION

Waste is any step or action or process that is not required to complete a process successfully. It can be termed as a "Non Value Adding" activity or component. In order for efficient production systems with minimum waste generation, it is essential to eliminate all such non value adding components from the process (3). In any Industrial Establishment, Wastes are broadly classified into 7 major categories as Over Production (Producing in excess of Demand), Inventory (Having more than required at a particular time and place),Waiting (Includes Products to enter into successive production step in an assembly line), Motion (Manpower moving more than required in the process constitutes waste of motion), Transportation (Movement of Products actually not required in the process), Rework from Defects (Not-Right First Time) and Over Processing (Unnecessary work elements). The Research aims to consider all such wastes in order to obtain waste generation corresponding to each selected decision variable. In order to determine optimal feasibility, the selected variables will be subjected to a multi objective optimization method namely Non Dominated Genetic Algorithm Technique. It rests on the notion that at least a single objective function to return a better value with no other function becoming worse off (4). It would be trifurcated into three phases notably Non Dominated Sorting, Crowding Distance Function and Tournament Selection Method which would lead us to know the variables which are relatively producing minimum wastes and those which require immediate emphasis to work upon to optimize them eventually.

~LITERATURE SURVEY

1.1 Pankaj M Madhani, **Supply Chain Strategy Selection: A Multi-Criteria Decision- Making Approach:** The IUP Journal of Supply Chain Management, Vol. 14, No. 2, 2017

In this, The author tries to study and compare Lean and Agile Supply Chain Strategies thereby focusing on their key determinants and finally discussing about a hybrid approach to both of them i.e Leagile Supply Chain Strategy. The final conclusion points over the fact that Lean Supply Chain Strategy is suited for competitive markets whereas the latter for volatile markets. The difference also lies that cost links to leanness whereas availability to agility. Leagile Supply Chain Strategies leads to enhancement of affordability as well as availability.

1.2 Joby George & V. Madhusudanan Pillai, **A Study of Factors affecting Supply Chain Performance:** International Conference on Aerospace & Mechanical Engineering: 1355 (2019) 012018

The study provides various factors affecting the production chain such as Supply Chain Structure, Inventory Control Policy, Information Sharing, Customer Demand, Forecasting Method, Lead Time and Review Period Length. The concluding remarks points out a linear relationship between Bullwhip Effect and Supply Chain Structure Complexity. In a supply chain, the biggest performance driver is attributed to Information Sharing. Nevertheless, A shorter Lead Time and Longer Review Period should be preferred.

1.3 KEYS, A. BALDWIN, A.N and AUSTIN, S.A, 2000: **Designing to Encourage Waste Minimisation in Construction Industry**. Proceedings of CIBSE National Conference, CIBSE 2000, Dublin, September

The Study concluded the fact that focus towards waste minimization should move from 'Site Phase' to 'Design Phase'. It laid emphasis on having contractual arrangements based on Design, Manage and Construct philosophy which would lead to formation of in-house working groups.

1.4 Punita Rajendran & Dr. Christy Pathrose Gomez: **Implementing BIM for Waste Minimisation in the Construction Industry.** 2nd International Conference on Management Proceeding. June 2012

This research illustrates the scope and process of Building Information Modelling which is basically a parametric modelling and allows the project personnels to virtually design and construct the building. It would provide a variety of benefits, some of which notably are building fundamental Intelligence into Drawings, providing seam-less information flow, facilitation of off-site fabrication and many more.

1.5 Galan, B., Dosal, E,. Andres, A. et al: **Optimisation of the Building and Demolition Waste Management Facilities location in Cantabria (Spain) under economical and environmental criteria**, Waste Biomass Valor 4, 797-808 (2013).

In this Study, the formulated model is Mixed Integer Linear Programming where Modelling System is General Algebraic Modelling System for resolution mechanisms. It shows that when facilities reduce with cost minimization and the former increases when medium transport distance is minimized.

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2.0 PLAN OF INVESTIGATION

1) Consideration of Initial Decision Variables
2) Initial TOPSIS Table
3) Methodology of Problem Solving
4) Calculation of Weighted Normalized Table
5) Formulation of Final TOPSIS Table
6) Choosing Final Decision Variables
7) Assignment of Wastes for Individual Decision Variables
8) Estimation of Variables for Minimum Waste Generation
9) Results & Conclusions

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2.1 CONSIDERATION OF INITIAL DECISION VARIABLES

. In order to determine optimal feasibility for waste minimization, it is initially essential to analyse and determine the most suitable decision variables which impact the supply chain to a highly substantive level. This would further enable to utilise those variables in order to determine the feasibility (5). The above problem will be solved by utilising a Multi-Criteria Decision Analysis Method known as the The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. This is mainly a comparative analysis between selected alternatives in order to determine a ranking among them in terms of impact and importance. In order for its application, some initial decision variables have been chosen enlisted in below mentioned table.

Table 2.1

Serial No	Decision Variables
1	Target Audience
2	Manpower Requirement
3	Inventory Management
4	Transportation Mode (Air)
5	Transportation Mode (Road)
6	Feedback Mechanism

2.2 INITIAL TOPSIS TABLE

In order to determine the hierarchy, It is essential to include those common attributes among the above decision variables which have a direct impact on the production process or supply chain of an organization (6). In the above study, 2 sets of functions have been included namely **Monetary Impact** and **Time Impact**. The corresponding data has been included on annual basis in units of **Crores (Rupees)** and **Days** respectively. It was compiled after utilising suitable written reports of the organisation and in expert consultation with the Head Personnels of the same. After compilation, The TOPSIS Table was prepared as given below.

Table 2.2

Decision Variables	Monetary Impact	Time Impact
Target Audience	150	365
Manpower Requirement	2.52	213
Inventory Management	27	65.7
Transportation Mode (Air)	15	16.3
Transportation Mode (Road)	7.5	912.5
Feedback Mechanism	0.38	12

2.3 Methodology of Problem Solving

1) Calculation of Vector Normalised Value

2) Dividing Performance Value by Normalised Value

3) Equating Subsequent Value by Weightage of Individual Decision Variables

4) Calculation of Ideal Best and Ideal Worst Value

5) Finding Euclidean Distance from Ideal Best and Ideal Worst

6) Obtaining Performance Score of each Decision Variable

7) Ranking the Variables in terms of Score

8) Selection of First Four Decision Variables for Further Research

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2.4 Calculation of Weighted Normalized Table

Upon applying the above methodology, we now obtain the normalized matrix after equating with the weighted averages.

Table 2.4 (Weighted Normalized Table)

Decision Variables	Monetary Impact	Time Impact
Target Audience	0.485	0.18
Manpower Requirement	0.008	0.105
Inventory Management	0.085	0.032
Transportation Mode (Air)	0.048	0.008
Transportation Mode (Road)	0.025	0.45
Feedback Mechanism	0.0001	0.005
Ideal Best Value (V_j^+)	0.0001	0.005
Ideal Worst Value (V_j^-)	0.485	0.45

Equation 2.4 for Normalized Matrix

$$R_{ij} = x_{ij} \div [\sum_{\square=1} \square_{ij}^2]^{0.5}$$

2.5 Formulation of Final Table

Upon Finding the Ideal Best & Ideal Worst Value, It is essential to find the Euclidean Distance from the Ideal Best and Ideal Worst. In Mathematical Perspective, it is basically the distance between two points in the Euclidean Space.

Table 2.5 (Final Table)

Decision Variables	S_i^+	S_i^-	Pi	Rank
Target Audience	0.51	0.27	0.653	1
Manpower Requirement	0.1	0.58	0.147	3
Inventory Management	0.09	0.57	0.136	4
Transportation Mode (Air)	0.046	0.62	0.06	5
Transportation Mode (Road)	0.44	0.46	0.48	2
Feedback Mechanism	0	0.65	0	6

Equation 2.5

$$S_i^+ = [\sum_{j=1}^{m} (V_{ij} - V_j^+)^2]^{0.5}$$

$$S_i^- = [\sum_{j=1}^{m} (V_{ij} - V_j^-)^2]^{0.5}$$

$$P_i = S_i^- \div (S_i^+ + S_i^-)$$

2.6 Choosing Final Decision Variables

Upon Finding the distances, they are utilised to obtain the performance score of each decision variable which in turn would provide us the hierarchy or the relative importance of each of them. Among them, the chosen variables are mentioned below.

Table 2.6

Final Decision Variables	Rank
Target Audience	1
Transportation Mode (Road)	2
Manpower Requirement	3
Inventory Management	4

These variables would in turn be utilised in order to determine optimal feasibility for waste minimization. The potential constraints as specified are **Machine Operation Time** and the **Distance of Distribution Units from Manufacturing Location.**

2.7 Assigning of Wastes for Individual Decision Variables

In order to proceed for waste minimization, it is essential to assign the individual waste generation from each Decision Variable. As previously mentioned, all types of wastes have been grouped under two main categories of waste in order to quantify the waste and provide the possibility to solve in the form of a mathematical problem (7). The two types included are notably Waste of Time and Waste of Money in Days and Crores respectively. The above grouping is done in lieu of considering an organizational perspective along with simplification of problem solving. Individual values of waste from each variable are mentioned below.

Table 2.7

Decision Variables	Monetary Impact(Crores)	Waste of Money	Time Impact(Days)	Waste of Time
Target Audience	150	12	365	91.2
Manpower Requirement	2.5	0.25	213	63.9
Transportation Mode(Road)	7.5	0.67	912.5	255.5
Inventory Management	27	2.7	65.7	16.42

2.8 Estimation of Variables for Minimum Waste Generation

In order to find out relative performance of the selected decision variables in lieu of their annual wastes generation, the technique to be used is Non Dominated Genetic Algorithm Technique which is basically a Multi Objective Optimization Method (8). As earlier stated, It would be trifurcated in three phases namely Non Dominated Sorting Technique, Crowding Out Method (Diversity Preservation) and later Tournament Selection Method.

(1) Non Dominated Sorting Method

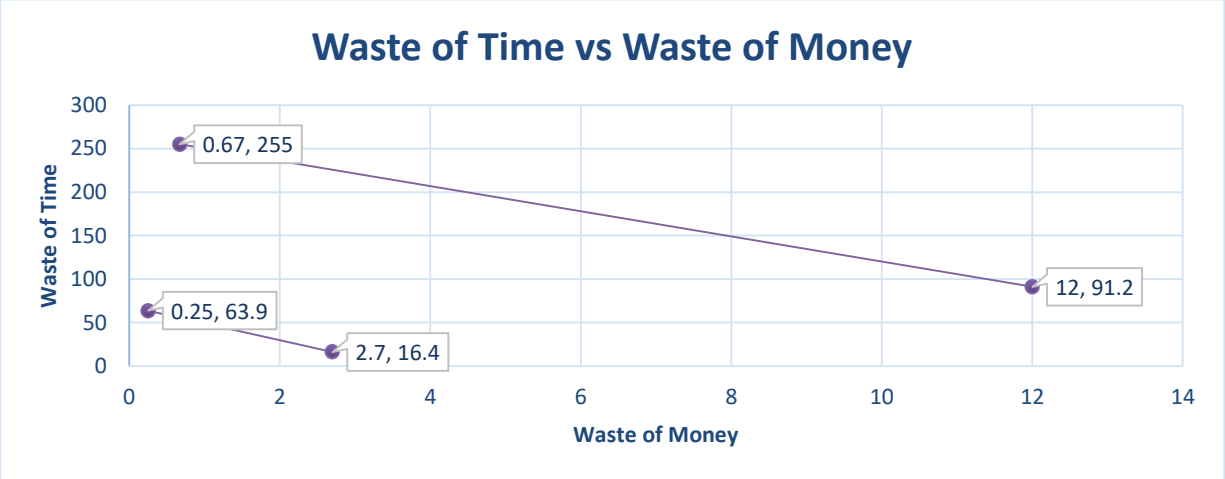
This method or strategy is employed in order to evaluate each variables' dominating status and on the basis of the same, Division of Subgroups which is an essential way to calculate the fitness of each variable and eventually to assess the quality (9). It involves calculation of each variables' corresponding solutions dominating number and the variables number itself. In present scenario, both the types of wastes have to be minimized. This would in turn signify the respective Dominating as well as Non-Dominating Status and this method would eventually choose those variables who would be on the non dominated front depicted on a single curve which would be taken to the second phase which is the Crowding Distance Function. As per the data mentioned in Table 3.4, in order to simplify the procedure, the variables would be assigned an alphabet. The variables namely Target Audience(A), Transportation Mode(B), Manpower Requirement(C) and Inventory Management(D) would be assessed in terms of their Dominating and Non-Dominating Status. The following Analysis is mentioned below:

Sorting Analysis

A & B	Non-Dominated
C	Dominates A
C	Dominates B
D	Dominates A
B & D	Non-Dominated
C & D	Non-Dominated
A, B, C & D	All on Non-Dominated Fronts

Hence, all Decision Variables have passed the first phase and will be taken further for assessment in the next method which is the Crowding Distance Function. It can also be seen from graphical perspective, the placement of variables in respective fronts.

Graph 2.8



2) Crowding Out Method:

Under this method, the calculation of congestion degree of each variable is made while avoiding any local aggregates by any certain method or strategy. It is done for the cause of finding an unform distribution series of the solution. The function can be expressed as mentioned below:

$$CD_{im} = [f_m(x_{i+1}) - f_m(x_{i-1})] \div [f_m(x_{max}) - f_m(x_{min})]$$

Such a formula iterates the fact that higher the Crowding Distance (CD), higher degree of chance for retainment of a solution for facilitation of diversity preservation (10). It is to be noted that values of Crowding Function for all variables in such a typical problem would turn out to be infinite due to virtue of the fact that each of the variables have no immediate neighbor on the other side. However , it can be asserted by the graph that variables denoted as C and D correspond to lower Non -Dominated front as compared to other variables i.e A and B. This signifies that decision variables with lower non-dominated ranks would be preferred as they correspond to higher fitness than others. Hence, Decision Variables notably Manpower Requirement and Inventory Management would be assessed for phase 3 i.e Tournament Selection Method.

3) Tournament Selection Method

Also known as Environment Selection Method, the variables denoted as C & D would be ranked amongst themselves on basis of Non Dominating Rank and Crowding Distance Values. It has been seen from the phase 1 analysis that the decision variable D known as Inventory Management has a higher non dominating rank whereas both the variables (C & D) have the same crowding out values termed as infinite. Hence, the variable with a higher non dominating rank would be selected as the most optimal variable or solution.

Table 3.5

Decision Variable	Non Dominating Rank	Crowding Distance Value
Inventory Management	1	Infinite
Manpower Requirement	2	Infinite

2.9 Results and Conclusions

1) Each decision variable corresponding to a particular department of an organization depicted their individual efficiencies on annual basis. The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was beneficial in order to gauge relative importance of the decision variables from an organizational perspective.

2) The Non Dominated Genetic Algorithm Technique paved the way to determine the level of optimal feasibility for each of these decision variables for Waste Minimization. It even provided the clarity as to where the organization has to work upon in order to achieve efficiency by virtue of minimizing their wastes.

3) Decision Variables namely Inventory Management and Manpower Requirement can be considered to be operating on optimal lines in lieu of annual waste generation. However by virtue of the fact that the latter had a less non-dominating rank, it can be optimized by Manpower Forecasting Analysis. It would involve detailed scrutiny of the organisations' production line in order to assess the Cycle and Takt Time which would provide for Ideal Manpower Requirement. On comparision with the actual manpower, suitable steps can be taken by the organization.

4) Decision Variables namely Target Audience and Transportation Mode (Road) corresponding to the Marketing and Distribution Division have to be immediately worked upon in order to achieve their optimality.

5) The Marketing Division should focus on those customers which are in genuine need of the product. They may enhance their reach in Tier 2 and 3 areas by the fact that due to ongoing infrastructural development inn various sectors of economy, such regions have started getting demand of such products which can therefore be an encouraging aspect for the organization.

6) Lastly, in case of Distribution Department, as a total of five distribution centres are being utilized by the organization at Chennai, Mumbai, Bangalore, Calcutta and Delhi and the parent production factory is situated in Pondicherry, the company has to strategize accordingly about distributing the products in lieu of units of demand and return on value.

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