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COMPARATIVE ANALYSIS OF TECHNOLOGY PUSH STRATEGIES INFLUENCING SUSTAINABLE DEVELOPMENT IN MANUFACTURING INDUSTRIES USING TOPSIS AND VIKOR TECHNIQUE

Abstract: *The objective of study is to analyze the significance of various Technology Push (TP) strategies affecting sustainable development in Indian manufacturing organizations. An extensive survey of 92 companies has been executed for the present context. The study examines the use of Multiple-Attribute Decision Making (MADM) and Multi-Criteria Decision Making (MCDM) method for evaluation of substantial TP strategies. For the purpose, a comparative analysis of various TP strategies using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) technique has been executed in the study. The outcomes of empirical calculations signify that the proposed techniques are appropriate to analyze the significance of TP strategies. The comparison of results exhibit that ranking of TP strategies evaluated using VIKOR technique is similar to the ranks obtained by TOPSIS. The focus of the paper is on the distinguishable contributions made by TP strategies like, innovative capability, research and development, corporate strategy and export orientation, for realization of sustainable development in manufacturing industries. It has been acknowledged in the investigation that manufacturing enterprises need to work more actively on managing certain TP strategies.*

Keywords: *Technology Push strategies, Multiple-Attribute Decision Making, Multi-Criteria Decision Making, Technique for Order Preference by Similarity to Ideal Solution, VIKOR technique*

1. Introduction

A number of definitions exist for technology, most of which gives an account of manufacturing and product development industries. Martino (1983) stated that technology is overall utilization of means to provide commodities essential for corporal sustainability and contentment. Zhao and

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Reisman (1992) contribute to the definition of technology as per social planning, management and business. On the whole, technology denotes a vast area of persistent application of dimensions of the real life. It contains the whole thought of methodology applied on different spheres with their aggregate hardware and programming elements. Genus and Kaplani (2002) proposed cooperation among operations, innovation control and HR administration using a review of operational development in companies. Riccaboni and Pammolli (2003) analyzed connection among technical systems, local correspondence, and the global network of industries. As per Gregson (1994) new technology is frequently used to displace the old one. Technology is a stimulant for change. However, the change that results can be observed separately (as positive or negative) by different individuals or groups depending upon their approach with reference to change.

The TP strategy drives the product coordination philosophy of 'if we build it, they will adopt it' owing to a number of fields. The TP strategies set up a discussion among technology managers about the fundamental principles and their driving forces. It was inferred that innovation is motivated by science and that consecutively stimulate technology (Chidamber & Kon, 1994). Technology Push indicates that technology has independent objectives, which depends on determinants of technology (Howells, 1997).

As per today's dynamic scenario, the international competition between industries exhibits higher demands in manufacturing sector and in society as at large. The welfare of a community is affected by how appropriately its economy conducts its exercises. The condition of life, accordingly, depends on the degree to which an economy exploits its resources and attains its ambition successfully. Achieving Sustainable Development is important for any society, particularly a developing one; however, industrial growth may not be enough to bring about Sustainable Development. On one side, development means an increase in per capita income of a nation, whereas development is a medium to uplift the financial and social status of impoverished economies, raise the level of employment, make improved exploitation of resources and stimulate social equality (Salih, 2003).

There are many definitions of sustainability which have been proposed by various researchers over the time. According to The World Commission on Environment and Development, 'Sustainable Development is a procedure of advancement where the utilization of assets, command on investments, arrangement of technological development and corporate revolution, are made persistent with subsequent and existing requirements. It is important to underline that nations show different levels of development, from economic growth to economic development and beyond. Sustainable Development is arising as a world-wide key perception that we must acknowledge to accommodate socio-economical, technological and environmental challenges (Jovane et al., 2008).

The manufacturing industries have witnessed many challenges in last four decades, involving drastic changes in innovative capability, research and development corporate strategy, export orientation, flexibility, customer satisfaction and other related issues. These challenges are compelling the manufacturing organizations to adopt innovative methodology to develop new products, and to exploit sustainable manufacturing tools and techniques efficiently. Manufacturing performs a crucial operation in the business of the globally industrialized countries but its impact on the environment has become a matter of concern, which requires industries to adopt sustainable manufacturing. In other words it is a matter of doing more with less, i.e. increasing productivity meanwhile utilizing minor resources and creating negligible waste. Sustainable manufacturing also encloses the aspects of product design; for instance, ease of dismantling for recycling and minimizing the usage of dangerous materials (Bogue, 2014).

MADM is a decisive approach for the determination of significant factors in different fields. It selects an option from an array of options, characterized in terms of their characteristics (Hwang & Yoon, 1981). A ranking for the attributes (as weights) is then expressed by the decision maker. Finally, an optimum alternative having highest degree of satisfaction for all of the suitable characteristics is determined. MCDM method selects the perfect solution from various options. Every option solution has numerous characteristics having distinctive effects; every characteristic is pertinent to some criteria. A perfect solution is unable to gratify all criteria if contradictory criteria is present. Moreover, MCDM methods consider both qualitative and quantitative parameters. It includes many solution techniques such as Analytic Hierarchy Process (AHP) (Saaty, 1980). To figure out the degree of practicing various TP strategies to achieve sustainable development, a five point Likert scale is selected for investigation. The intention of investigation is to assess significant TP practices and compare their rankings using TOPSIS and VIKOR techniques. The weights of evaluation criteria are obtained from AHP. TOPSIS and VIKOR techniques are utilized to compare the ranks of different TP practices.

2. Literature review

Today, universal rivalry has entered each and every portion of the planet and field of business (Koberg et al., 2003). Prosperity is created through industrialization and development of economy is well recognized by growth of manufacturing corporations. Moreover, the prosperity of a country depends on the excellence of its production capacity and that those who over come manufacturing will eventually succeed in technological innovation (Yamashina, 2000). Kocak et al. (2017) reported that dedicated technology orientation lead to radical innovation, while responsive market regulation actively affects incremental innovation. Technology Push is regarded as a fundamental practice for the development and diffusion of technical improvements in manufacturing industries. TP uses an adopter to accept the technology (Drury & Farhoomand, 1999). The manufacturing industries prosper in the light of market needs, whereas according to technical experts the change in technology is the critical factor for development (Chidamber & Kon, 1994). Manufacturing, stated as conversion of materials and data into assets for the contentment of human wants is the fundamental wealth-creating exercises in a country. Encouraging perfection in manufacturing arises as a vital objective of industry along-with society (Chryssolouris et al., 2013). Technology has led to reduced manufacturing times, which proves to be more fruitful for a fundamental format. It helps in lessening set-up and processing time variability (Li, 2003). According to Gilgeous and Gilgeous (1999), there are activities practiced in industries which governs working condition of the business and contribute most to the manufacturing significance. Abbasi et al. (2017) discussed the findings of research conducted between 2013 and 2016, based on the promotion of technology layout for the Creative Industries. The roadmap presented in their work was built based on input from communities of creative and Information and Communication Technologies (ICT) during the validation phases of the research. Therefore, the study is directed towards the development of latest technologies and related business models and expertise, and provides guidance for making strategies in this regard.

The concept of Technology Push was primarily given by Schon (1967) as the basic motivation and driving force at the back of innovation of new technologies. Innovation is guided by science and hence impels technology. TP strategy originates from acknowledgment of new technological methods for improving the performance of manufacturing industries (Chau & Tam, 2000). To compete globally, companies must become more efficient, flexible and customer oriented. The government plays a significant part in determining the competitiveness of firms. Furthermore, it provides supportive infrastructure and flexibility to firms that help them compete in the international market (Halachmi, 2002). The companies based on technology incorporate TP practices but these practices cannot be proclaimed as suitable or inaccurate to deal with Sustainable Development in manufacturing industries. It depends upon standardized framework, for instance, a particular business, an organization's history and so on (Brem & Voigt, 2009). An important understanding is that the low product cost is the main focus in deciding the foremost ability of technological innovation (Kim & Lee, 2009).

TP strategies prompt innovation and benefit the national innovators (Peters et al., 2012). Innovation is a precise approach and regulated measure that encompasses all exercises to prosper and offer latest commodities and operations in an industry. It plays a significant role to achieve the requisite goals and Sustainable Development in the industries. It has been observed that the decision of a company to adopt new technologies is closely based on the entrepreneurial characteristics rather than managerial. It may be that decision makers are not susceptible to different models while an entrepreneur knows the basic conditions of the technologies in order to relate to technological experts. The adoption of latest technology by companies should be examined as an entrepreneurial activity more than as the result of a long term development. Furthermore, the developing economies are likely to face challenges in future, as the multinational companies, hamstrung by the moderate development in their home markets are focusing towards emerging industries (Krishnan, 2012). Today's manufacturing scenario is illustrated by accelerated changes in market and enhanced competitive strategies. Majority of the companies are using similar manufacturing techniques, therefore the struggle is not only based on manufacturing approach, but how strongly a firm governs technology apropos its consumers (Singla et al., 2017).

A procedure for an ethical-constructive technology assessment approach (eCTA) to relate ethics of technology precisely, along with practices of technological advancement in manufacturing enterprises was recommended by Kiran et al. (2015). The approach developed incorporates four criterion; first, technology not only have ramifications for schemes and social systems on large-scale, but also for the routine lives of its users; second, eCTA must be limited in terms of technology development instead of judgment; third, eCTA must target on the development of both plan and requirement of technical support. Noh et al. (2016) proposed a model for services relevant to technology which leads to the Sustainable Development in industries. The pace at which changes in technology take place has been accelerated since few decades. In addition, service also has changed frequently because of closely affiliated technology-market-service system. In this connection, technological refinement and dynamic market needs can aid uncertain competitive situations in service oriented industries. A methodology is provided by the model to endorse new ideas which can be properly utilized to accomplish adequate service innovation. The results of the review were useful not only for directors who wish to merge research and management outcomes and service development approach, although for engineers who wish to draft a novel technology. While, Taticchi et al. (2013) stated that the industrial societies are leading the development of technological frameworks for Sustainable Development in manufacturing organizations.

Herrona & Braiden (2006) presented a model to execute and setup profitability change in a cluster of manufacturing companies. The methodology was tried on 15 manufacturing enterprises of all sizes, which have consented to be included in an extensive study. The result is the capacity to relegate an exponential worth to likeness among the issues of a specific organization and a chosen suite of lean manufacturing instruments and procedures. As per Dell'Era et al. (2016) in the current industry and academia, design is mostly considered as an essential strategic resource. The connection of design with innovation and competitive advantage is investigated by the researchers. The research identified three plans which direct the decision makers for expansion of technological exposure: viewing technology as an active stage, fabricating dual structure and accessing current spheres of achievements. The development of technology desires a strong discussion among technology partners and designers. Hemphill (2016) described the technique of RI (Responsible Innovation) for development of enterprises. The study focused on the devotion of industry and idea of CSR (Corporate Social Responsibility) that represents administrative ideology to improve RI in industries. It was concluded that expansion of CSR to innovation will influence both the beginners and necessary firms performing at the leading edge of innovation.

According to Baumers et al. (2016) in the field of advanced manufacturing technology, Additive Manufacturing (AM) methodology is manufacturing three-dimensional products instantly from raw materials and data. The approach does not need the use of tools and other equipments. It was speculated by technology managers that Additive Manufacturing intend to exhibit a severe fiscal effect on manufacturing industries as well as over the society at large. Fatima (2017) investigated the role of globalization in the progression and circulation of technology across manufacturing industries operating in emerging and developing economies. The study analyzed the feasibility of different mediums of international technology transference, whether they push the firms operating in developing countries to innovate and as a result push them closer to the international technology sphere.

According to Ndubisi (2012) achievement of high-quality and reliability standards demonstrates organizational capabilities which provide enormous advantages. Achieving high quality standards by acquiring and practicing latest technologies is the primary motive of manufacturing companies. Industries try to regulate the cost and strengthen their corporate strategies and worth by terminating unwanted deviation in quality of products and services.

3. Description of TOPSIS and VIKOR technique

3.1. TOPSIS technique

TOPSIS is one of the valuable MADM techniques which are easily understandable. It is executed when the decision maker adopts a simple weighting method. On the flipside, AHP supports a decision hierarchy and shows a pair-wise comparison between criteria (Lee et al., 2001). TOPSIS technique was initially suggested by Hwang & Yoon (1981). As per this methodology, best option would be the one which is closest to positive ideal solution and most distant from negative ideal solution (Benitez et al., 2007). The positive ideal solution escalates the benefit criteria and curtail the cost criteria, whereas the negative ideal solution raises the cost criteria and lessen the benefit criteria (Wang & Chang, 2007; Wang & Lee, 2007; Wang & Elhag, 2006; Lin et al., 2008). Hence, positive ideal solution contains all perfect values obtainable of criteria, whereas negative ideal solution incorporates all the worst values attainable of criteria (Ertuğrul & Karakasoğlu, 2009).

A problem related to MADM with *m* options (alternatives) (A_1, A_2,…., A_m) that are evaluated by *n* characteristics (attributes) (C_1, C_2,…., C_n) can be perceived as a geometric arrangement with *m* points in *n*-dimensional space. An element x_{ij} of the matrix reveals the performance rating of the i^{th} option, A_i, with respect to the j^{th} characteristic, C_j, as portrayed in equation (1).

A summary of the terminology used in this research is described as follows:

Characteristics: Characteristics (C_j, $j = 1, 2, \ldots, n$) serve as a means to assess the levels of an ambition. Every option can be described by many characteristics.

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ . \\ . \\ . \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccccc} C_1 & C_2 & C_3 & . & . & . & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & x_{13} & . & . & . & x_{1n} \\ x_{21} & x_{22} & x_{23} & . & . & . & x_{2n} \\ x_{31} & x_{32} & x_{33} & . & . & . & x_{3n} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ x_{m1} & x_{m2} & x_{m3} & . & . & . & x_{mn} \end{bmatrix} \end{array} \quad (1)$$

Options: Options (A_i, $i = 1, 2, \ldots, m$) are affirmatively independent of one another.

Characteristic weights: Weight values (w_j) represent the comparative significance of every characteristic to other ones.

$W = (w_j, j = 1, 2, \ldots, n)$.

Normalization: It retrieves relative scales, which permits characteristic identification. The vector normalization method segregates the rating of every characteristic by its norm to evaluate the normalized value of x_{ij} as represented by equation (2).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2{}_{ij}}}, \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n \quad (2)$$

With reference to the terms discussed a fixed procedure of TOPSIS technique is explained step-by-step as follows:

1. First of all, build a normalized decision matrix. It converts different characteristic dimensions into non-dimensional characteristics, which represents comparisons across criteria.

2. Secondly, build a weighted normalized decision matrix. Assume a set of weights (using AHP) for each criteria w_j for $j = 1,\ldots,n$. Then, multiply each column of the normalized decision matrix by its corresponding weight. Hence, an element of the new matrix is given by:

$$v_{ij} = w_j\, r_{ij}, \text{ for } i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \quad (3)$$

3. Now, figure out positive ideal (A^*) and negative ideal (A') solutions. A^* and A' are expressed in terms of weighted normalized values:

Positive Ideal solution:

$$A^* = \{v_1, \ldots, v_n\}, \text{ where } v_j^* = \{max\,(v_{ij}) \text{ if } j \in J \,;\, min\,(v_{ij}) \text{ if } j \in J'\} \quad (4)$$

Negative ideal solution:

$$A' = \{v_1', \ldots, v_n'\}, \text{ where } v_j' = \{min\,(v_{ij}) \text{ if } j \in J \,;\, min\,(v_{ij}) \text{ if } j \in J'\} \quad (5)$$

where, J is a set of benefit characteristics (larger-the-better) and J' is a set of cost characteristics (smaller-the-better).

4. Evaluate separation measures for each option.

The separation of every option from positive ideal option is represented by S_i^*:

$$S_i^* = \sqrt{\sum_{j=1}^{n}\left(v_j^* - v_{ij}\right)^2} \ , \quad i = 1, \dots, m \tag{6}$$

Correspondingly, the separation of each alternative from negative ideal option is:

$$S_i' = \sqrt{\sum_{j=1}^{n}\left(v_j' - v_{ij}\right)^2} \ , \quad i = 1, \dots, m \tag{7}$$

5. Evaluate the comparative closeness to ideal solution or similarities to ideal solution C_i^*:

$$C_i^* = S'_i / (S_i^* + S'_i) \ , \qquad 0 < C_i^* < 1 \tag{8}$$

6. Lastly, compare the C_i^* values, to decide the ranking of options. Select an option with maximum C_i^* or rank options corresponding to C_i^* in descendent form.

3.2. VIKOR technique

A problem related to MCDM is easily formulated by a matrix, in which columns show characteristics (criteria) under consideration; and rows show the competing options. Specifically, a MCDM problem with m options ($A_1, A_2, \dots, A_m$) that are evaluated by n characteristics ($C_1, C_2, \dots, C_n$) can be perceived as a geometric structure with m points in n-dimensional space. An element x_{ij} of the matrix reveals the performance rating of the i^{th} option, A_i, with respect to the j^{th} characteristic, C_j, as portrayed in equation (9).

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ . \\ . \\ . \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccccc} C_1 & C_2 & C_3 & . & . & . & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & x_{13} & . & . & . & x_{1n} \\ x_{21} & x_{22} & x_{23} & . & . & . & x_{2n} \\ x_{31} & x_{32} & x_{33} & . & . & . & x_{3n} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ x_{m1} & x_{m2} & x_{m3} & . & . & . & x_{mn} \end{bmatrix} \end{array} \tag{9}$$

VIKOR technique was recognized as a significant method to apply in MCDM (Opricovic, 1998). It determines the rank by choosing from a set of options in the presence of contradictory characteristics. The compromise solution (Yu, 1973 and Zeleny, 1982) is an appropriate solution, which is nearest to the ideal, and here "compromise" means an understanding acknowledged by common adjustments.

Furthermore, VIKOR technique evaluates compromised ranks and the compromise solution using MCDM based on a particular measure of "closeness" to the "ideal" solution. The MCDM for compromise ranking is originated from *Lp-metric* used as a combined function in a compromising methodology.

The levels of regret in VIKOR may be defined as:

$$L_{p,i} = \left\{\sum_{j=1}^{n}\left[w_j\left(x_j^* - x_{ij}\right)/\left(x_j^* - x_j^-\right)\right]^p\right\}^{\frac{1}{p}} \ , \quad 1 \le p \le \infty \tag{10}$$

where,
$i = 1, 2, \ldots, m$.
$L_{1,i}$ = maximum group utility
$L_{\infty,i}$ = minimum individual regret of the opponent

A step-by-step process of VIKOR technique for ranking alternatives is explained in the following steps (Huang et al., 2009):

1. Adjudge that best x_j^* and the worst x_j^- values of all characteristic functions, where $j = 1, 2, \ldots, n$. If j^{th} characteristic represents a benefit then:

$$x_j^* = \max_i f_{ij}$$
$$f_j^- = \min_i f_{ij}$$

$$S_i = L_{1,i} = \sum_{j=1}^{n} w_j (x_j^* - x_{ij})/(x_j^* - x_j^-) \tag{11}$$

$$R_i = L_{\infty,i} = \max_j \left[\sum_{j=1}^{n} w_j (x_j^* - x_{ij})/(x_j^* - x_j^-)\right] \tag{12}$$

where, w_i is the weight of the j^{th} characteristic which indicates the comparative significance of a characteristic.

3. Calculate the value Q_i , $i = 1, 2, \ldots, m$, using equation (13):

$$Q_i = v \frac{(S_i - S^*)}{(S^- - S^*)} + (1 - v) \frac{(R_i - R^*)}{(R^- - R^*)} \tag{13}$$

where,

$$S^* = \min_i S_i$$
$$S^- = \max_i S_i$$
$$R^* = \min_i R_i$$
$$R^- = \max_i R_i$$

4. Rank the options by sorting *S*, *R*, and *Q* values in descendent form. Three rankings will be shown by the results.

5. Present a compromise solution of options (A') which are ranked perfect by minimum *Q* if the below mentioned two conditions are fulfilled:

I. "Acceptable advantage"

$Q(A'') - Q(A') \geq DQ$, where A'' is the option with second place in ranking by *Q*; $DQ = 1/(m - 1)$ and *m* is the number of options.

II. "Acceptable stability in decision making"

Option A' must also be best ranked by *S* or/and *R*. This compromise solution is stagnant within a decision making mechanism, which may be: "voting by majority rule" ($v > 0.5$ is required), or "by consensus" ($v \approx 0.5$), or "with vote" ($v < 0.5$). Here, *v* is the weight of the decision making mechanism "the majority of criteria" ("the maximum group utility"). $v = 0.5$ has been considered in this empirical study (by VIKOR technique).

If one of the conditions is not fulfilled, a set of compromise solutions is planned (Huang et al., 2009). Currently, VIKOR technique has been extensively applied on MCDM problems in various spheres, for instance, environmental policy (Tzeng et al., 2002) and data envelopment analysis (Tzeng & Opricovic, 2002).

Coefficient of Variation (CV)

In MCDM, weight of the characteristic shows its significance. In the present investigation weights are allocated in MCDM problems without any choice. The methodology relies on the (CV) to assign the weights of various characteristics. Range standardization is accomplished to convert various scales and units between different characteristics into common measurable units in order to analyze their weights.

$$x_{ij}^{'} = \frac{x_{ij} - \min_{1\le j\le n} x_{ij}}{\max_{1\le j\le n} x_{ij} - \min_{1\le j\le n} x_{ij}} \tag{14}$$

Further;

$D^{'} = (x^{'})_{m\times n}$ is a matrix obtained after range standardization;

$\max x_{ij}$, $\min x_{ij}$ are the maximum and the minimum values of the characteristics (j) respectively, where, all values in D' are ($0 \le x'_{ij} \le 1$).

Hence, according to the normalized matrix $D^{'} = (x^{'})_{m\times n}$ the Standard Deviation (σ_j) is evaluated for each characteristic individually, as represented by equation (15).

$$\sigma_j = \sqrt{\frac{1}{m}\sum_{i=1}^{m}\left(x_{ij}^{'} - \overline{x^{'}_{j}}\right)^2} \tag{15}$$

where, $\overline{x^{'}_{j}}$ = mean of the values of j^{th} characteristic after normalization and j = 1, 2,…, n.

After evaluating (σ_j) for all characteristics, CV of the characteristic (j) will be as exhibited in equation (16).

$$CV_j = \frac{\sigma_j}{\overline{x^{'}_{j}}} \tag{16}$$

The weight (W_j) of the characteristic (j) is prescribed as:

$$W_j = \frac{CV_j}{\sum_{j=1}^{n} CV_j} \tag{17}$$

where, j = 1, 2,…, n.

4. A comparative analysis of TP practices

In order to analyze the inputs made by TP practices towards achieving sustainable development, a comprehensive “TP questionnaire” has been fabricated for accessing technological proficiencies in manufacturing industries. In this study, a questionnaire investigation approach has been deployed to seek information on the situation of TP practices in manufacturing enterprises for sustainable development. To carry-out the examination appropriately, a TP questionnaire has been drafted by executing thorough literature survey. The research has been conducted at medium as well as large scale manufacturing industries practicing TP strategies or currently on different levels of practicing them. In this investigation, substantial number of manufacturing companies (92) has been appropriately surveyed, to examine the effects of TP practices in the manufacturing commercials towards achieving sustainable development.

There are several issues that may affect decision-making in TP practices. In this research, four issues (options) are considered and their narration is provided in Table 1.

Table 1. Narration of Options

Options of TP practices	*Abbreviation*
Innovative capability	IC
Research and development	RD
Corporate strategy	CS
Export orientation	EO

4.1. Analytic Hierarchy Process

Saaty (1980) initiated and used AHP (Analytic Hierarchy Process). It is an analytical technique to organize and solve different forms of multi-criteria decision-making issues based on relative order appointed to individual criterion's part to achieve certain goal (Handfield et al., 2002). This methodology is based on mathematics and is most appropriate for complicated decisions, which includes thorough identification of alternatives. AHP is usually employed as a decision-making technique for research when a static (or one-time) choice is to be made in large-scale situations. Aim of this technique is to settle the comparative preferences for criterion to rank the alternatives. A basic design of AHP technique with multiple hierarchy positions of criteria is elaborated in Figure 1 (Buyurgan & Saygin, 2008).

Fundamentally, the decision-makers have to disintegrate the goal of decision activity into its basic segments, proceeding from common to particular viewpoint. AHP model must have a goal, criteria (issues) and alternatives arranged in an order. Each criterion is further linked to an alternative, recognizing that more criterions inculcated, less significant every particular criterion can become. As and when the hierarchy is planned, decision-makers evaluate the relevance of every criterion in pair-wise relation. Evaluation is carried out in the context of direct upper-level criterion. The last scoring is on comparative ground, comparing the relevance of one decision alternative with another. AHP holds both objective and subjective assessments and provides an effective system to check the flexibility of decision maker's interpretation. It is a subjective technique in which data and priority weights of issues are retrieved from decision-makers of an industry, using a questionnaire (Cheng & Li, 2001).

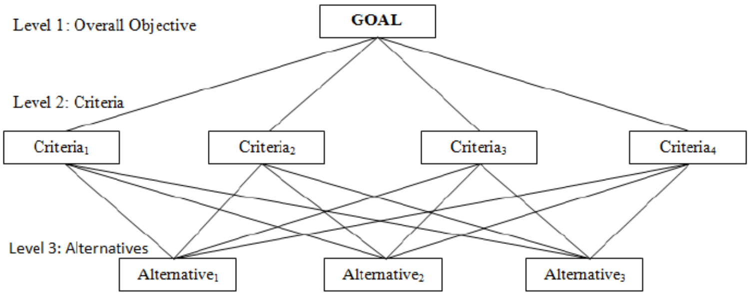

Figure 1. General structure of AHP with multiple hierarchy levels

The extent of choice of each pair-wise relation taken in this model is calibrated on a range of 1 to 9. The ranging mechanism is interpreted in priority weights (scores) to analyze the correlation of alternatives. Even number (2, 4, 6 and 8) represents adjustments among preferences. Terminology of numbers suggested to express the scale of priority is elaborated in table 2.

Table 2. Nine-point intensity of importance scale and its description

Definition	*Intensity of importance*
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values	2, 4, 6, 8

Furthermore, the following four hypothesis (H1, H2, H3 and H4) are also proposed to examine the level of association between various TP practices and Sustainable

Development indicators in manufacturing organizations.

H1. *There exists a firm alliance between 'Innovative capability' and 'Sustainable Development'*

H2. *A substantial relation exists between 'Research and development' and 'Sustainable Development'*

H3. *There exists an adequate association between 'Corporate strategy' and 'Sustainable Development'*

H4. *A strong confident partnership exists between 'Export orientation' and 'Sustainable Development'*

4.2. Pair wise Comparison of TP strategies

Six pair wise comparisons have been executed in the present study. Table 3 describes the importance of criterion with respect to Topsis and Vikor priorities. It measures the importance on a scale of 1 to 9, as represented in table 3.

Table 3. Pair wise comparison of Topsis and Vikor priorities

A - Importance - or B?			**Equal**	**How much more?**
1	◉ Innovative capability	○ or Research and development	○ **1**	○ **2** ○ **3** ○ **4** ○ **5** ○ **6** ○ **7** ○ **8** ○ **9**
2	◉ Innovative capability	○ or Corporate strategy	○ **1**	○ **2** ○ **3** ○ **4** ○ **5** ○ **6** ○ **7** ○ **8** ○ **9**
3	○ Innovative capability	○ or Export orientation	○ **1**	○ **2** ○ **3** ○ **4** ○ **5** ○ **6** ○ **7** ○ **8** ○ **9**
4	◉ Research and development	○ or Corporate strategy	◉ **1**	○ **2** ○ **3** ○ **4** ○ **5** ○ **6** ○ **7** ○ **8** ○ **9**
5	◉ Research and development	○ or Export orientation	◉ **1**	○ **2** ○ **3** ○ **4** ○ **5** ○ **6** ○ **7** ○ **8** ○ **9**
6	◉ Corporate strategy	○ or Export orientation	◉ **1**	○ **2** ○ **3** ○ **4** ○ **5** ○ **6** ○ **7** ○ **8** ○ **9**

The questionnaire investigation approach has been deployed in the present context. The responses for Table 3 have been obtained from various manufacturing industries practicing TP strategies. Medium and large scale manufacturing industries were selected based on their annual turnover. Finally, valid responses from 92 companies were obtained. The study then analyzes various success factors of different TP practices to achieve sustainable development in manufacturing industries using TOPSIS and VIKOR technique.

4.3. Analysis of TP practices using TOPSIS technique

This section (Table 4-11) shows the analysis of TP practices and the various results obtained by the application of TOPSIS technique.

Table 4. Decision matrix for TOPSIS

	IC	RD	CS	EO
IC	1.000	2.000	1.000	1.000
RD	0.500	1.000	1.000	1.000
CS	1.000	1.000	1.000	3.000
EO	1.000	1.000	0.333	1.000

Table 5. Normalized decision matrix for TOPSIS

	IC	*RD*	*CS*	*EO*
IC	0.555	0.756	0.567	0.289
RD	0.277	0.378	0.567	0.289
CS	0.555	0.378	0.567	0.866
EO	0.555	0.378	0.189	0.289

Table 6. AHP weights and ranking

	IC	*RD*	*CS*	*EO*
AHP Weights	0.288	0.202	0.321	0.188
AHP Rank	2	3	1	4

Table 7. Weighted normalized decision matrix for TOPSIS

	IC	*RD*	*CS*	*EO*
IC	0.160	0.153	0.182	0.054
RD	0.080	0.076	0.182	0.054
CS	0.160	0.076	0.182	0.163
EO	0.160	0.076	0.061	0.054

Table 8. Positive ideal and negative ideal solutions for TOPSIS

	IC	*RD*	*CS*	*EO*
IC	0.160	0.153	0.182	0.054
RD	0.080	0.076	0.182	0.054
CS	0.160	0.076	0.182	0.163
EO	0.160	0.076	0.061	0.054
Maximum of each Column v_j^*	0.160	0.153	0.182	0.163
Mimimun of each Column $v_j^{'}$	0.080	0.076	0.061	0.054

Table 8. Positive ideal and Negative ideal solutions for TOPSIS

	IC	*RD*	*CS*	*EO*
IC	0.160	0.153	0.182	0.054
RD	0.080	0.076	0.182	0.054
CS	0.160	0.076	0.182	0.163
EO	0.160	0.076	0.061	0.054
Maximum of each Column v_j^*	0.160	0.153	0.182	0.163
Mimimun of each Column $v_j^{'}$	0.080	0.076	0.061	0.054

Table 9. Separation from Positive ideal alternative for TOPSIS

	IC	*RD*	*CS*	*EO*	S_i^*
IC	0.000	0.000	0.000	0.012	0.109
RD	0.006	0.006	0.000	0.012	0.155
CS	0.000	0.006	0.000	0.000	0.076
EO	0.000	0.006	0.015	0.012	0.180

Table 10. Separation from Negative ideal alternative for TOPSIS

	IC	*RD*	*CS*	*EO*	S'_i
IC	0.006	0.006	0.015	0.000	0.164
RD	0.000	0.000	0.015	0.000	0.121
CS	0.006	0.000	0.015	0.012	0.181
EO	0.006	0.000	0.000	0.000	0.080

Table 11. Relative closeness to the ideal solution C_i^*

	S_i^*	S'_i	$C_i^* = S'_i / (S_i^* + S'_i)$	*TOPSIS Rank*	*AHP Rank*
IC	0.109	0.164	0.602	2	2
RD	0.155	0.121	0.439	3	3
CS	0.076	0.181	0.703	1	1
EO	0.180	0.080	0.307	4	4

Henceforth, it has been cross-verified from AHP and TOPSIS technique (as per Table 9) that TP practices like, corporate strategy (rank = 1) plays a significant role, followed by innovative capability (rank = 2) for accomplishment of sustainable development in manufacturing industries, thereby validating the hypothesis H3 and H1. On the other hand, analysis reveals that TP practices like research and development (rank = 3) followed by export orientation (rank = 4) do not perform well in achieving the desired goal. Hence, hypothesis H2 and H4 are not validated in the present context. The manufacturing enterprises need to work hard to revitalize such practices of TP.

4.4. Analysis of TP practices using VIKOR technique

Analysis of four options to be ranked by studying four characteristics is portrayed in the tables below (12-16), to illustrate the technique projected. As elaborated in Table 12, the four options and their performance ratings with respect to all characteristics are shown.

Certainly, it is evident from the analysis that the ranking of TP practices obtained from AHP, TOPSIS and VIKOR techniques is same. Therefore, it can be concluded that corporate strategy and innovative capability are substantial for achievement of sustainable development in manufacturing firms.

Table 12. Decision Matrix for VIKOR

	IC	*RD*	*CS*	*EO*
IC	1.000	2.000	0.500	3.000
RD	0.500	1.000	2.000	1.000
CS	2.000	0.500	1.000	3.000
EO	0.333	1.000	0.333	1.000

Table 13. Normalized Decision Matrix for VIKOR

	IC	*RD*	*CS*	*EO*
IC	0.432	0.800	0.216	0.671
RD	0.216	0.400	0.864	0.224
CS	0.864	0.200	0.432	0.671
EO	0.144	0.400	0.144	0.224
$\min_{1\le j\le n} x_{ij}$	0.144	0.200	0.144	0.224
$\max_{1\le j\le n} x_{ij}$	0.864	0.800	0.864	0.671
$\max_{1\le j\le n} x_{ij} - \min_{1\le j\le n} x_{ij}$	0.720	0.600	0.720	0.447

Table 14. Range Standardized Decision Matrix for VIKOR

	IC	*RD*	*CS*	*EO*
IC	0.400	1.000	0.100	1.000
RD	0.100	0.333	1.000	0.000
CS	1.000	0.000	0.400	1.000
EO	0.000	0.333	0.000	0.000
Average	0.375	0.417	0.375	0.500
σ_j	0.450	0.419	0.450	0.577
CV_j	1.200	1.007	1.200	1.155
Weights (W_j)	0.263	0.221	0.263	0.253

Table 15. Calculation of S_i and R_i

	IC	*RD*	*CS*	*EO*	S_i	R_i
IC	0.158	0.000	0.237	0.000	0.395	0.237
RD	0.237	0.147	0.000	0.253	0.637	0.253
CS	0.000	0.221	0.158	0.000	0.379	0.221
EO	0.263	0.147	0.263	0.253	0.926	0.263

Table 16. Calculation of Q_i and VIKOR Rank

	S_i	R_i	Q_i	*VIKOR Rank*
IC	0.395	0.237	0.204	2
RD	0.637	0.253	0.619	3
CS	0.379	0.221	0.000	1
EO	0.926	0.263	1.000	4

On the flipside, the performance of TP practices like research and development; and export orientation is low in achieving the organizational objective. The companies must give more attention to stimulate these strategies.

5. Conclusions

The present research emphasize on the contributions of TP practices for accomplishment of sustainable development in manufacturing industries. Owing to objective various TP strategies have been entrenched in the study. Empirical examination has been implemented in the research to seek the aspects of TP practices to achieve the desired goal. A comparative analysis has been executed to justify the rankings of TP practices. The analysis consists of two techniques, namely TOPSIS and VIKOR. The ranking evaluated using VIKOR technique is exactly the same as obtained from AHP and TOPSIS. Therefore, the comparison validates that TP strategies (considered in the study) are significant to companies trying to achieve sustainable development to deal with the challenges set by global markets. The ranks signify the importance of different TP practices towards recognition of organizational goals of prosperity and sustainability.

The study indicates that TP practices like, corporate strategy and innovative capability having rank 1 and 2, respectively play a significant role in accomplishing sustainable development in manufacturing commercials. Furthermore, the performance of manufacturing industries lacks in research and development and export orientation strategies. The industries need to work more aggressively to revamp such practices. This justifies the immense capability of TP practices in attaining complete organizational development. This investigation acknowledges that top management may adequately contribute towards recognition of sustainable development by indulging in competent TP practices in the industries and providing resources to manage changes. However, in present scenario, most of the manufacturing enterprises have taken initiatives enthusiastically in the manufacturing sector by introducing various TP practices, for the realization of sustainable development.

Further, it has been recognized from the present study that, TP practices do not return speedy success; it takes relevant preparedness and focus, adequately assisted by top management over a substantial duration to achieve the actual outcomes. Hence, it may be concluded that manufacturing industries must continue to accomplish genuine efforts in their attempt to realize enhanced sustainable development by practicing TP strategies.

The present study has few limitations also. Firstly, no study in the past has reported exactly the same constructs (TP practices) together, although all issues deployed in this study have been adapted from extensive literature review. Therefore, it is difficult to precisely correlate the equation coefficients with results of earlier studies. Another constraint is that the survey has been conducted in Indian manufacturing organizations only. Hence, the results obtained from the examination will need some modifications before applying to other geographical locations (countries). In future, studies could be undertaken in other emerging as well as developed economies to compare TP strategies influencing sustainable development in manufacturing industries.

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