1.0 INTRODUCTION
1.1. An Overview of Multi-criteria Decision-making Process

Decision analysis (DA) is a logical and systematic way to analyze and evaluate a wide variety of complex decision-making problems in an uncertain environment. DA mostly refers to those methods and tools which are used for identifying, clearly representing and formally assessing some feasible alternatives which involve quantified evaluations with respect to certain pre-defined criteria. DA is undoubtedly based on Operations Research (OR), and can also be extensively applied in other fields and areas, like psychology, sociology, economy, computer science etc. It contains both psychological and rational factors. For a satisfactory decision, these two factors must be consistent. Decision theories study the rational factors in order to clarify a decision-making situation to increase reliability. A decision-making situation is characterized by decision alternatives, states of nature and resulting payoffs. The decision alternatives are the different possible strategies that the decision maker (DM) can make use of. The states of nature refer to those future events which are not under control of the DM, but ultimately affect the decision consequences.

Evaluation of the decision alternatives often includes an assessment of probabilities and preference elicitation using some mathematical approaches. Differences between the desired and actual state of real world system can be systematically approached by means of DA techniques. Multiple-criteria decision-making (MCDM) is a general class of OR and a sub-discipline of DA that unambiguously considers multiple criteria in conflicting decision-making environments. MCDM process deals with situations involving selection, sorting and ranking of a best alternative from several suitable options, subject to two or more conflicting tangible or intangible criteria or attributes with the help of some strong mathematical modeling. The mathematical treatments to decision-making problems were started in the mid 19th century by some economists and applied mathematicians. It is commonly assumed that MCDM was originated at the beginning of 1960s. Most of the MCDM practitioners consider that it stems from the revolutionary work on goal programming by Simon [1]. Since its beginning, MCDM has become one of the most dynamic and interdisciplinary fields of study in management science and O.R. MCDM is basically an analytical approach which evaluates the pros and cons of each alternative based on multiple criteria. In the context of the present era, MCDM paradigms are gaining more and more popularity in management sciences as potential tools for analyzing complex real time decision-making problems due to their innate capability to judge different alternatives based on various selection attributes having different units of measurement while identifying the most suitable alternative. The key attribute of these paradigms is that a DM does not optimize a single defined objective, but aims for the accomplishment of satisfying all levels in the goals and seeks the most
favorable compromise between several, often conflicting objectives. It establishes preferences among alternatives to a precise set of objectives and quantifiable criteria. The general purpose of MCDM is to serve as an aid for decision-making, but not to take the decision. In the manufacturing environment, effective decisions are intended for achieving lower manufacturing costs, higher productivity, proper production planning and scheduling systems. Evaluation and selection of manufacturing strategies in the presence of multi-ambiguous criteria and performance measures involving trade-offs between the decisive factors, such as desired properties, operating environment, production process and cost, make the process a very difficult task. Due to these reasons, decision analysis techniques have been well acknowledged as a fundamental and essential module in the success of an organization. Any decision involves a choice, which is selected from a number of feasible alternatives. Decisions that are based on foundation of understanding and sound reckoning of information can escort any organization towards a long-standing prosperity, while decisions made on the basis of inconsistent or uncertain judgments and partial information situate an organization out of competition.

In its most basic form, MCDM assumes that a DM must choose the best solution among a set of alternatives whose objective function values or attributes are known with certainty. MCDM techniques are capable of dealing with multifaceted problems that are characterized by mixture of both ordinal and cardinal objectives. This is achieved by first recognizing the problem to be analyzed and developing alternative solutions to the problem based on some decision rules and problem constraints. In the next phase, the target problem is fragmented into some convenient small parts to allow data and judgments to be brought in. This step is basically known as the development of decision matrix which indicates the influencing alternative options and respective attribute values. Finally, reassembling the broken parts by the application of an analytical model is performed [2]. By doing these, a logical and consistent recommendation picture can be presented to the DM, as shown in Figure 1.1.

Over the years, different behavioral scientists, operational researchers and decision theorists have proposed a variety of ways to describe how a DM might arrive at a preference judgment while choosing the best from a finite set of feasible alternatives [3]. However, it should be noted that a ‘properly formulated’ decision problem from a mathematical standpoint, does not mean that it is ‘well structured’ in regards to the given reality. A ‘well structured’ problem can be easily understood and an appropriate solution procedure may be formulated [4]. From a mathematical standpoint, a ‘well structured’ MCDM process starts with identifying and accumulating all the relevant information. The possible options (alternatives) are defined by eliminating those alternatives that should not be worthy for further considerations. This procedure is often called as screening. Screening helps the DM to concentrate on a smaller set that contains
the most favourable alternatives. Many approaches for screening the available alternatives, like sequential approach, decision information-based screening, Pareto optimality-based screening, trade-off weight-based screening, aspiration level-based screening, distance-based screening and non-trade-off weight-based screening have been adopted by the past researchers [5]. Next, the criteria aiming at evaluating the performance of the screened alternatives are identified. A criterion can be defined as a customary statute depending upon which a decision can be made and which relates the process capabilities to the intended goals.

In practical decision-making situations, defining a set of criteria often becomes a critical task. Completeness, mutual exclusiveness, reliability, precision, independency and non-redundancy are the most important requirements for defining the criteria. Next, the alternatives’ performance in terms of the criteria scores are modelled. This is expressed in a matrix form, known as the decision matrix. The decision matrix contains the alternative’s performance with respect to different criteria values. A typical decision matrix for multiple criteria problems has m number of
alternatives \((i = 1, 2, \ldots, m)\) and \(n\) number of evaluation attributes or criteria \((j = 1, 2, \ldots, n)\), on the basis of which the alternatives would be evaluated and selected. Thus, a decision problem can be represented by the following decision matrix:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>(\ldots)</th>
<th>Alternative (j)</th>
<th>(\ldots)</th>
<th>Alternative (n)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>(x_{11})</td>
<td>(x_{12})</td>
<td>(\ldots)</td>
<td>(x_{1j})</td>
<td>(\ldots)</td>
<td>(x_{1n})</td>
</tr>
<tr>
<td>2</td>
<td>(x_{21})</td>
<td>(x_{22})</td>
<td>(\ldots)</td>
<td>(x_{2j})</td>
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<td>(x_{2n})</td>
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<td>(\ldots)</td>
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<tr>
<td>(i)</td>
<td>(x_{i1})</td>
<td>(x_{i2})</td>
<td>(\ldots)</td>
<td>(x_{ij})</td>
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<td>(\ldots)</td>
</tr>
<tr>
<td>(m)</td>
<td>(x_{m1})</td>
<td>(x_{m2})</td>
<td>(\ldots)</td>
<td>(x_{mj})</td>
<td>(\ldots)</td>
<td>(x_{mn})</td>
</tr>
</tbody>
</table>

where \(x_{ij}\) is the rating of \(i^{th}\) alternative on \(j^{th}\) criterion. These ratings can take different forms depending upon the nature of the problem and available information. The most common format of rating is cardinal mode, for which \(x_{ij}\) is always a real number. But if the DM feels that it is hard to obtain cardinal data or direct measurable values, then it can be measured ordinally. Linguistic grades can be used by the DM to assess the alternatives’ ratings ordinally. Sometimes, uncertainty may have to be considered in rating measurement. This type of information may be expressed as interval data, fuzzy data or in some other suitable mode reflecting uncertainty. Different methods examine these judgments and aggregate them into an overall score for each alternative using some multi-criteria aggregation procedures. One very interesting fact about the decision matrix is that it may consist of criteria with different units. So in order to avoid these difficulties caused by the different units or dimensions of the criteria values, a transformation (called normalization) of the criteria values is used in the modeling process for unification by making the criteria values dimensionless. Several vector and linear transformation techniques have been proposed by the past researchers to transform the different units into dimensionless values. In vector normalization procedure, each element of the quantified decision-making matrix is divided by its own Euclidian norm. The norm represents the square root of the addition of element value squares, according to each criterion. Euclidean normalization is a non-linear transformation leading to scales in which the minimum and maximum values for each criterion are different. In case of linear normalization, the scale transformation is done by dividing a criterion value by its corresponding range between the maximum and minimum values. This method considers the upper and lower bounds of each criterion value during normalization and due to the presence of linear character function, ratios and intervals between the transformed values remain unaffected [6]. In most of the normalization techniques, normalized values either range from 0 to 1 or the
values are less than one. After the scale transformation process, the overall evaluation of each alternative is done, leading to a final ranking of the alternatives. The main objective of any MCDM approach is to convert the performances of each alternative into a single value (aggregated value) to facilitate the ranking process which is the heart of any MCDM approach. Since there is no single method of aggregation which is universally acceptable for any kind of decision problem, the DM has to choose the method which best corresponds to his/her purpose.

Finally, a sensitivity analysis examines how robust the recommendation is even under a small change in the preference value expressed by the DM. If no further analysis is required, then the final recommendation can be made based on the observed results. Figure 1.2 illustrates these basic steps as involved in an MCDM process.

In a situation where there is a number of DMs involved in the decision-making process, the individual decisions are also to be taken into account and an optimal option is to be chosen representing a group negotiation decision.

![Diagram of MCDM process](image)

**Figure 1.2** Basic steps of an MCDM process
1.2. Background and Classification of Multi-criteria Decision-making Methods with Application Domain

MCDM has been one of the fastest growing areas of Operations Research, as it is often realized that many concrete real life problems can be represented by several mutually conflicting criteria. ‘International Society on Multiple Criteria Decision Making’ defined MCDM as the study of methods and procedures by which concern about multiple conflicting criteria can be formally incorporated into the management planning process. The result of a multi-criteria analysis process is a function of the criteria values. These criteria are simultaneously optimized in a feasible set of alternatives. In a general case, there does not exist any particular alternative which optimizes all the criteria. Thus, the vital part in MCDM situations is to find a ‘good compromise solution’ that performs best satisfying all the objectives simultaneously. There is a set of alternatives where an improvement in the value of one criterion leads to worsening of the value of another criterion. This set of alternatives is called as a set of non-dominating or Pareto optimal alternatives (solutions). Each alternative in this set can be a solution of the multi-criteria problem. In order to choose only one alternative, it is essential to have some supplementary information from the DM. The information that the DM provides reflects the global preference with respect to the quality of the alternative sought. As mentioned earlier, an MCDM problem consists of some alternatives and a number of evaluating criteria, so it becomes very significant to understand whether a particular decision-making problem is single or multiple criteria-based. While formulating a multi-criteria problem, the DM must consider the relevant criteria (or criterion) which generally depend on the nature of the problem to be analyzed [7]. If any decision problem has a single criterion or a single assessment, then the decision can be made by searching the alternative with the best value of that criterion. This situation can be said to be a traditional optimization problem where the objective function is the single criterion and the constraints are the criteria values of the alternatives. The case when the decision problem has a finite number of criteria but the number of feasible alternatives is infinite, belongs to the field of multiple criteria optimization (MCO). Depending on the form and functional portrayal of the optimization problem, different optimization techniques, like linear programming, non-linear programming and discrete optimization can be adopted for solution. MCO techniques can also be used when the number of feasible alternatives is finite but they are expressed only in implicit form [8]. In this way, it can be said that the three major influencing factors to be observed in an emblematic decision-making problem are objectives, alternatives and attributes. More generally, there exist two distinctive types of MCDM problems due to different problem settings, involving finite number of alternative solutions and infinite number of solutions. Normally in problems associated
with selection and assessment of alternatives, the number of alternative solutions is limited. In problems related to design, an attribute may take any value in a range. Therefore, the potential alternative solutions can be infinite. Based on this, MCDM problems can be classified into two preliminary categories, i.e. multi-objective decision-making (MODM) and multi-attribute decision-making (MADM). The basic difference between MODM and MADM problems is that the former concentrates on a continuous decision space subject to problem specific constraints, while the later aids to evaluate alternatives in a discrete decision space of predetermined set of alternatives. In real time decision-making situations, MODM often demands the formulation of a decision model based on the target objectives and interrelationship between the evaluating criteria, whereas, MADM usually consists of identification of the alternatives, specification of each alternative with respect to each evaluating criterion indicating the relative preference of each alternative over another and finally, scoring the alternatives according to the decision criteria. In a nutshell, MADM methods select the best alternative among a finite number of choices, unlike MODM where the best alternative is designed with multiple objectives based on continuous decision variables subject to constraints. Table 1.1 summarizes the main features of these two approaches [9].

**Table 1.1** Differences between MADM and MODM techniques

<table>
<thead>
<tr>
<th>Feature</th>
<th>MADM</th>
<th>MODM</th>
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<tbody>
<tr>
<td>Criteria defined by</td>
<td>Attribute/Criterion</td>
<td>Objective</td>
</tr>
<tr>
<td>Model basis</td>
<td>Alternative identification and specification</td>
<td>Target objectives and interrelationship between evaluating criteria</td>
</tr>
<tr>
<td>Objectives</td>
<td>Implicit</td>
<td>Explicit</td>
</tr>
<tr>
<td>Alternatives</td>
<td>Finite number</td>
<td>Infinite number</td>
</tr>
<tr>
<td>Attributes</td>
<td>Finite field</td>
<td>Infinite field</td>
</tr>
<tr>
<td>Decision space</td>
<td>Discrete</td>
<td>Continuous</td>
</tr>
<tr>
<td>Decision maker’s control</td>
<td>Limited</td>
<td>Significant</td>
</tr>
<tr>
<td>Decision-making paradigm</td>
<td>Outcome oriented</td>
<td>Process oriented</td>
</tr>
<tr>
<td>Relevant application</td>
<td>Selection/Evaluation</td>
<td>Design/Research</td>
</tr>
</tbody>
</table>

There are several methods in each of the above-mentioned categories. Each method has its own characteristics, and can also be classified as deterministic, probabilistic and fuzzy. There may be combinations of these methods. Depending upon the number of DMs, these methods can be further classified as single or group decision-making techniques. Decision-making under uncertainty and decision support systems are also prominent decision-making techniques [10]. Depending upon the mathematical modelling and operational procedures, MADM tools can be categorized as elemental approaches, unique synthesising approaches and outranking approaches. Elementary methods are projected to reduce the intricate problems to singular basis for selection
of a preferred alternative. Elementary approaches are simple and analysis can be done without much help of computer software, and these methods are best suited for single-decision maker problems with few alternatives and criteria [11]. Simple additive method, weighted sum method and weighted product method are the unique examples of elementary methods. Unique synthesising approaches use some special mathematical and analytical techniques in the modelling and execution phase. There are several methods in this category, such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Grey Relational Analysis (GRA) methods which use ideal, anti-ideal and reference point concepts to arrive at a preference order of the considered alternatives [12]. The positive-ideal or the reference point solution is an imaginary solution for which all the criteria values correspond to the maximum values in the decision matrix comprising of the satisfying solutions and the negative or anti-ideal solution is an imaginary solution for which all the criteria values correspond to the minimum values in the decision matrix. The outranking approaches use a series of pair-wise comparisons of the alternatives with respect to each criterion to build an outranking relation indicating the degree of dominance of one alternative over the other [13,14]. Some popular outranking approaches are Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE), ELimination and Et Choice Translating REality (ELECTRE), Organization Rangement Et Synthese De Donnes Relationnelles (ORESTE) etc., and the most commonly used MODM tools are linear programming, goal programming and lexicographic vector-max approaches. Based on the above discussions, MCDM methods can be classified, as shown in Figure 1.3. As the present research work is based on the applications of some particular type of MADM tools in diverse manufacturing decision-making situations, so further discussions are restricted only to MADM tools. In all the above-mentioned MADM methods, decision regarding the best alternative amongst the available ones is obtained by giving some mathematical treatments to the decision matrix. MADM covers a wide range of techniques for assessing the decision problems characterized by a large number of diverse attributes consisting of cardinal and ordinal data and preferences regarding the relative importance of the evaluating criteria. The relative importance of the evaluating criteria in terms of criteria weights in MADM though do not have any clear economic significance, but it plays an important role by providing the opportunity to represent the actual aspects of decision-making (the preference structure). Criteria weight indicates a criterion’s relative importance over the others. It often becomes difficult for the DM to provide exact values for criteria weights due to the existence of imprecision, contradiction, arbitrariness and lack of consensus [15].
Several approaches have been developed and proposed for determining the criteria weights. Analytic Hierarchy Process (AHP) [16] is the vastly applied tool for determining criteria weights subjectively, whereas entropy method [17] can be used objectively. A multi-criteria problem may involve both cardinal or physical (numerically measurable in some units) and ordinal (linguistic or subjective) criteria. These criteria can again be beneficial or non-beneficial in nature. For beneficial criteria (like profit, efficiency), higher values are always desirable, whereas, in case of non-beneficial criteria (like cost), smaller values are always preferable. An ideal solution to any MADM problem would maximize all profit criteria and minimize all cost criteria. Normally this type of ideal solution is often unobtainable. If an ideal solution is not obtainable, the DM may look for some non-dominated solutions. An alternative (solution) is dominated if there are other
alternatives that are better than the solution on at least one attribute and as good as it on other attributes. An alternative is called non-dominated if it is not dominated by any other alternative on any criteria. A preferred solution is a non-dominated solution that best fulfills the DM’s expectations and objectives. Due to these inherent properties, MADM tools are vastly being used in many industrial applications, including manufacturing, integrated technology investment decisions, flexible manufacturing system selection, environment management, plant layout design selection, supplier evaluation, energy management, maintenance strategy selection, materials selection for specific industrial applications, transportation, logistics, project investment decision, financial and strategic decision-making situations, enterprise resource planning (ERP) system selection, water management, agricultural and forestry management [18].

1.3. Advantages of MCDM Methods

MCDM methods provide a quantitative resource to aid in decision-making situations where there are multiple and conflicting goals measured in different units. The major advantages of MCDM include making a decision more lucid to others, providing a means of problem structuring and working through the information, and helping people better recognize a problem from their own and others’ perspectives. The overall advantages of MCDM approaches are enlisted as below:

a) It is open and explicit.
b) The choice of objectives and criteria for any decision-making problem are open to analysis and change, if it is felt to be inappropriate.
c) It enables a number of different objectives to be considered simultaneously.
d) Being a multi-disciplinary approach, it can be applied to a wide field of real life decision-making situations.
e) It provides a systemic approach that demonstrates trade-offs (compromises) between the conflicting issues.
f) It provides an important way of communication within the decision-making group and sometimes, between a wider community.
g) Its scores and weights, when used, are also explicit and are developed according to established techniques. Those can also be cross-referenced to other sources of information on relative values, and amended if necessary.
h) It provides a practical decision-making process by facilitating to incorporate real life subjectivity and experience of the decision makers.
i) It helps to see what would be the consequences of giving different order of importance to different objectives or making different assessments to the performance of the available options against different objectives.

j) It is easier to adopt appraisal-led design, the appraisal being refined as the design process develops.

k) It helps to properly structure a management problem.

l) It provides a model that can serve as a focus for discussion.

m) It offers a process that leads to rational, justifiable and explainable decisions.

n) It speeds up problem solving procedure in any organization.

o) It deals with mixed sets of data involving quantitative and qualitative measurements.

p) It is structured to enable participative planning and decision-making system.

q) The arrived decision is transparent and constructive, as it enables the DM to better understand the situation and helps to arrive at a better and negotiated solution.

r) It effectively eliminates personal favorism in the choice of any particular alternative.

s) It improves better understanding of goals and issues.

t) It properly evaluates the selected decision criteria.

u) It promotes the identification of an option about which a consensus is developed as it is the best option.

v) It also measures a DM’s preference towards each decision criterion and makes a balance between the conflicting criteria while providing the most cost effective decision.

w) It helps to build consensus among the DMs, facilitating compromise among them which favors in competing alternatives.

In order to have a greater impact on practical decision-making situations, decision-making methodologies need to be further exploited which can help the DMs for complex business decisions and make a sufficient coverage of the problem’s facets.

1.4 Objectives and Scope of the Present Research Work

Rapid technological and economic growth over the last few decades have created an unparallel change in human lives and made modern society face complex decision-making problems. In global manufacturing scenario, production managers always search for dynamic strategies to accomplish lower manufacturing costs, high class products, quicker responses to customer demands and flexibility to produce a variety of products, leading to a world-class performance through continuous improvement in products and processes. These numerous concerns have proved useful in enhancing organization’s global competitive position and profitability by designing a proper production array, and determining numerous planning and
control strategies. In this context, the aim of modern manufacturing systems has become to achieve overall performance improvement by proper utilization of resources, design development, production, delivery and support to products. Decision-making in the manufacturing environment becomes a strategic issue, especially in association with the complexity of motivating forces and factors influencing the manufacturing system dynamics. The decision-making exercise can be implemented in the manufacturing environment at different stages, if appropriate tools and techniques are made available to the designers, manufacturing planners and production managers. Finally, while formulating a manufacturing strategy, trade-offs among cost, quality dependability and flexibility are explicitly considered. These trade-offs determine the unique positioning of an organization within the industry. For a specific industrial scenario, an organization may place higher importance (weight) on cost criterion and gear its manufacturing activities according to the set objective, whereas, another organization may put emphasis on customization and therefore, will prefer a flexible process and emphasize on flexibility in its production planning methods. 

The background for this research work is based on the assumption that the success of manufacturing decision-making problems depends on the assessment and integration of all the different design and selection objectives, called ‘criteria’. These criteria can be used to denote both the problem objectives and attributes. These criteria often cause difficulties to deal with and they may also be conflicting in nature. The different design issues and available alternatives call for varying levels of expertise to be involved in the entire decision-making process. This makes it difficult to evaluate the overall acceptability of a proposed alternative. The relative weights placed on different criteria may also decide many other intermediate manufacturing positions. As already mentioned, MADM is an integral part of modern decision science which aims at supporting the decision makers faced with multiple decision criteria and diverse alternatives. The development of MADM methods has been motivated not only by a variety of real life problems, requiring the consideration of multiple criteria, but also by the practitioners and researchers, desired to propose enhanced decision-making tools using recent advancements in mathematical optimization, scientific computing and computer-based technologies. From an exhaustive literature survey and review of the past researches, it is observed that the earlier researchers have already proposed and applied a number of MADM tools and other exclusive mathematical techniques for decision-making in conflicting manufacturing environments. The aim of all those researchers has been to deploy more and more simpler and appropriate methods with higher reliability and accuracy in the solution. According to ambiguity of real life, those methods may not be appropriate for all types of decision-making situations. So, the question here is that which MADM method is compatible with most of the real life problems? Though a number of
approaches have already been introduced by the past researchers, most of them did not address the compatibility of their proposed approaches to varying decision-making situations. One of the main features of these methods is that they cannot deal well with non-cardinal data and cardinal data simultaneously. Diverse examples from real time manufacturing situations are studied and a number of attempts are made for evaluation, selection and justification of manufacturing strategies. It is a well known fact that no single method of analysis is sufficient to deal with all the different types of decision problems that occur in the manufacturing organizations. Based on the nature of the decision problem and type of information available, different methods may be suitable for different problems. Keeping in view the above-cited opportunities and for ensuring the best alternative strategies for various manufacturing processes to ensure higher productivity with minimum cost and risk involvement with the aim to help the manufacturing organizations to better evaluate and select the most suitable alternative for production, this research work focuses on introducing some sophisticated and multi-advantageous MADM methods that can make the decision-making process easier and to be compatible with most of the situations. A special class of MADM tools, popularly known as ‘preference ranking-based methods’, is applied to various real life manufacturing decision-making problems. These methods are some special class of MADM tools in which the decision makers’ preferences and preferences on alternatives’ performances are aggregated together to reach the final evaluation and decision. The past researchers have adopted different decision-making tools for evaluating, justifying and selecting materials and advanced manufacturing technologies, but all those methods have been either complicated or require lengthy computations. Also, for the decision-making problems with large number of attributes and smaller number of alternatives, those approaches may occasionally provide worse results. The present research work takes this opportunity to explore the application feasibility and potentiality of some preference ranking-based methods to provide more precise and accurate ranking of the feasible alternatives. According to the best knowledge of the author, there are very few applications of these preference ranking-based methods in manufacturing environment. Few successful implementations of these methods can be found in construction engineering, financial analysis and waste water management. However, most of these preference ranking-based methods have never been applied in any of the manufacturing decision-making situations. Even, till date, very less effort has been devoted to study the relative performance of several MADM methods employed in discrete manufacturing environments. No generic sensitivity analysis approach has been proposed by the past researchers to study the ranking robustness of MADM methods under disparate manufacturing circumstances. Furthermore, no
attempt has been made to map/match any industrial or manufacturing decision-making situation (selection problem) to different MADM methods.

The decision matrices for six different domains with the relevant alternatives and criteria are either taken from the data as given by the past researchers or are developed, taking guidance from different journals, websites and manufacturing databases. In a nutshell, the objectives of the present research work are set as follows:

a) to apply the following eight most prospective preference ranking-based MADM methods in solving some complex decision-making problems from the real time manufacturing environment:
   i) EVAluation of MIXed data (EVAMIX) method,
   ii) COmplex PRoportional ASsessment (COPRAS) method,
   iii) COmplex PRoportional ASsessment of alternatives with Grey numbers (COPRAS-G) method,
   iv) EXtended version of Preference Ranking Organization Method for Enrichment Evaluation (EXPROM2),
   v) Organization Rangement Et Synthese De Donnes Relationnelles (ORESTE) method,
   vi) Operational Competitiveness Rating Analysis (OCRA) method,
   vii) Additive Ratio ASsessment (ARAS) method, and
   viii) Preference Selection Index (PSI) method,

b) to solve two material selection problems to decide at the best choices using the above-mentioned preference ranking-based methods,

c) to apply these eight most potential MADM tools to evaluate and select flexible manufacturing systems for two given real time industrial applications,

d) to solve two industrial robot selection problems for evaluating and ranking of the considered robot alternatives under different manufacturing environments while applying the considered MADM methods,

e) to apply the eight preference ranking-based tools to identify the best suited rapid prototyping processes for the manufacturing organizations under two discrete environments,

f) to consider and solve two real time non-traditional machining process selection problems employing these MADM methods,

g) to consider two computerized machine selection problems for economic justification and selection in discrete manufacturing environments,

h) to study and explore the general ranking performance of the eight MADM methods using the following performance tests:
i) scatter diagrams to graphically show the rank similarities between different methods,
ii) determination of the overall ranking agreement among the considered methods using Kendall’s coefficient of concordance value,
iii) computation of the Spearman’s rank correlation coefficient values to measure the correlation of the ranked alternatives obtained using the preference ranking-based methods,
iv) determination of the 95% confidence intervals based on Fisher’s Z transformation model to assess the degree of association between the derived rankings,
v) determination of the agreement between the top three ranked alternatives as indicated by these methods, and
vi) calculation of the percentage of ranks matched for different methods,
i) to perform some exhaustive single dimensional non-proportional weight sensitivity analyses to study the robustness of the ranking performance of the considered preference ranking-based methods, and
j) to determine the most critical and the most robust criteria for the considered decision-making problems, which are further used for high-dimensional sensitivity analysis to compute the weight stability intervals for the preference ranking-based methods.

The future scope of this present research work may be diverse. At first, other decision-making problems from the real time manufacturing environments, such as selection of the most appropriate facility layout, supplier evaluation and justification, facility location selection, selection of the best product assembly sequence design, selection of an automated inspection device, selection of the best machining parameters etc. may also be taken into consideration. The applicability of other MADM methods, i.e. analytic network process (ANP), utility additive (UTA) method, linear programming technique for multi-dimensional analysis of preference (LINMAP), regret theory, axiomatic design principles, decision-making trial and evaluation laboratory (DEMATEL) technique, multi-objective optimization on the basis of ratio analysis (MOORA), potentially all pairwise rankings of all possible alternatives (PAPRIKA), dominance-based rough set approach (DRSA) etc. may be explored and validated. Hybrid decision-making models, integrating MADM methods with some sophisticated MODM tools, like genetic algorithm, particle swarm optimization and artificial neural network may also be developed for solving complex decision-making problems. The applicabilities of other ordinal MADM methods, like measuring attractiveness by a categorical based evaluation technique (MACBETH), for dealing with decision matrices with only ordinal data, may be explored. Fuzzy MADM methods may also be applied for solving the decision-making problems consisting of linguistic/fuzzy variables.