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Bachelor Thesis

Use of MADM in the purchase of new equipment

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Objectives of thesis

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5. Calculate the relative closeness to the positive ideal solution.

6. Finding the rank of the preference order.

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Declaration

I declare that I have worked on my bachelor thesis titled "Use of MADM in the purchase of new equipment" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any kind of copyrights.

In Prague on 15/3/2022 ______________________________

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Use of MADM in the purchase of new equipment

Abstract

Purchasing goods from numerous options is very difficult in this modern era. Because options are laid very closely for their similar pricing and specifications. For getting the solution in this condition we need something that can provide us solution according to our given priority attributes and affordability. When writing individual options, this task can greatly simplify the model of multicriteria analysis of variants (VAV). VAV theory is a discipline aimed at helping decision-makers who face a large number of competitive opportunities to make the right decision. To achieve this goal, two questions need to be answered. (1) What is the preferential structure? (2) What are the weights of the criteria? As a result, researchers over the past 50 years have presented a number of functions describing the true preferential structure of decision-makers and the ability to create accurate weights. This effort will certainly continue for the next 50 years. This work is divided into two parts theoretical and practical. The author focuses on explaining the theoretical foundations of individual methods in the methodological part of the work. To understand the individual VAV approaches by the reader, a numerical calculation solved on a computer and then presented. Another great interest of this work is the integration of theory and practice of used VAV models. Numerous possibilities of use in solving realistic problems of VAV are shown.

Keywords: MADM, MCDM, TOPSIS, VIKOR, PROMETHEE, Fuzzy Multiple Criteria Decision Making, Analytic Hierarchy Process.

Využití MADM při nákupu nového vybavení

Abstrakt

Nákup zboží v moderní éře je díky mnoha volbám velmi obtížný. Možnosti jsou si totiž velmi blízké z důvodu obdobných cen a specifikací. Abychom získali řešení za těchto podmínek, potřebujeme nástroj, který nám může poskytnout řešení podle našich daných prioritních atributů a cenové dostupnosti. Při sepsání jednotlivých možností nám může tento úkol velmi zjednodušit model vícekriteriální analýzy variant (VAV). Teorie VAV je disciplína zaměřená na pomoc těm, kdo rozhodují, kteří čelí velkému množství konkurenčních možností tak, aby provedli správné rozhodnutí. K dosažení tohoto cíle je nutné zodpovědět dvě otázky. (1) Jaká je preferenční struktura? (2) Jaké jsou váhy kritérií? Výsledkem je, že vědci za předchozích 50 let předložili řadu funkcí popisujících skutečnou preferenční strukturu osob s rozhodovací pravomocí a možnosti tvorby přesných vah. Toto úsilí bude jistě následujících 50 let pokračovat. Tato práce je rozdělena do dvou částí – teoretické a praktické. Autor se soustředí na vysvětlení teoretických základů jednotlivých metod v metodologické části práce. Pro pochopení jednotlivých VAV přístupů čitatelem je následně předložen numerický výpočet řešený na počítači. Dalším velkým zájmem této práce je integrace teorie a praxe použitých modelů VAV. Jsou ukázány četné možnosti využití při řešení realistických problémů VAV.

Klíčová slova: MADM, MCDM, TOPSIS, VIKOR, PROMETHEE, fuzzy rozhodování podle více kritérií, proces analytické hierarchie.

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List of abbreviations

MCDM	Multiple Criteria Decision Making
MADM	Multiple Attribute Decision Making
ANP	Analytic Network Process
AHP	Analytic Hierarchy Process
DEA	Data Envelopment Analysis
FAHP	Fuzzy Analytic Hierarchy Process
NDP	Network Discovery Protocol
UNDP	United Nations Development Program
HDI	Human Development Index
GDP	Gross Domestic Product
SAW	Simple Additive Weighting
LA	Linear Assignment
OWA	Ordered Weighted Averaging
ERP	Enterprise Resource Planning
WPM	Weighted Product Method
VBA	Visual Basic for Applications
IDE	Integrated Development Environment
RAM	Random Access Memory
CZK	Czech Koruna
WH	Watt Hours
GH	Giga Hertz
VIKOR	VIekriterijumsko KOmpromisno Rangiranje
PPI	Pixels Per Inch
GB	Giga Bites

1 Introduction

1.1 Motivation

Purchasing decision-makers usually confront the challenge of evaluating a wide range of different possibilities and pick one based on a set of competing criteria. It should be highlighted that there is rarely a single definitive criterion for selecting the best option, and decision-makers must consider a variety of criteria, including technological, economic, ethical, political, legal, and social issues. Simple, systematic, and logical solutions are required techniques or mathematical tools to assist decision-makers in weighing a variety of options of criteria for selection and their interrelationships. Any selection technique has the goal of identifying acceptable selection criteria and obtaining the best combination of criteria with the real demand. To reinforce existing selection procedures, efforts should be expanded to identify those characteristics that impact alternative selection for a particular problem using simple and logical techniques, eliminate inappropriate alternatives, and pick the most acceptable alternative. Identifying problems, creating preferences, evaluating options, and finding the best alternatives are all steps in the decision-making process (Raiffa, 1988). Bell (Bell, 1988) defined three types of formal analysis that can be used to solve decision-making problems: The problems that decision-makers actually address are the focus of descriptive analysis. The approaches that decision-makers should take to improve their decisions are considered in the prescriptive analysis. The problems that decision-makers should ideally address are the topic of normative analysis. When dealing with single-criterion problems, decision-making is extremely intuitive because we only need to choose the option with the highest preference rating. When decision-makers evaluate alternatives with numerous criteria, however, various issues, such as criterion weights, preference dependence, and criteria conflicts, appear to exacerbate the issues, necessitating the use of more advanced approaches.

2 Objective and Methodology

2.1 Objectives

The main aim is to use a multi-attribute decision-making approach or MADM for the purchase of new equipment using the TOPSIS method. The second goal is to show the limitations of the proposed methods.

2.2 Methodology

MADM has proved itself as a viable strategy for addressing a wide range of multi-criteria decision-making and ranking issues. For data collection, we will use an e-commerce company from the Czech Republic. We are using the TOPSIS method for making decisions. The best alternative is picked from a set of alternatives whilst the performance of the alternatives is determined based on some attributes. The methodology consists of these computational steps mentioned below:

1. Calculate the normalized decision matrix.
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3 Literature review

3.1 Decision Making

3.1.1 Introduction

Every individual in his life will face occasions that he or she needs to make decisions about. Some of the decisions will have a small effect on life and some will affect the whole life. Decisions are so important that they may lead to success or failure for in case of managers and organisations. This chapter is a literature review of the theory of decision making. Section 3.1.2 discusses the different definitions of the term decision and the nature of decision making. The process of making decisions is covered in section 3.2.3, while section 3.2.4 presents the different approaches of decision making and representative methods of some decision-making approaches.

3.1.2 Definitions

Before discussing the process of decision making, it is important to explorethe different definitions of the term decision. (Ofstad,1961) stated three alternative definitions: "*To say that a person has made a decision may mean that he has started a series of behavioural reactions in favour of something, or it may mean that he has made up his mind to take a specific action, which he is certain he should take*". The most typical application of this term, however, is to decide on measures.To make a decision about what one should do in a situation after considering several options. According to Baron "*A decision is a choice of actions to achieve goals based on beliefs about those actions and their potential to accomplish those goals*" (Baron, 2000). According to Harrison "*A choice is a point in a continuing process of evaluating alternatives for reaching an aim, at which expectations about a particular course of action propel the decision maker to choose the course of action most likely to achieve the target*" (Harrison, 1999).Other authors debated the process of decision-making. (Simon, 1960) views decision-making as a three-phase process. The first step is to identify decision-making opportunities; the second is to identify decision-making opportunities following:

- Intuitive decisions are those choices that individuals make almost instinctively and people just know what to do in certain situations.
- Programmed decisions occur when a defined set of guidelines or instructions is present when deciding.
- Analytical decisions are those important ones about which one must think carefully. Decision making could be normative, descriptive, or prescriptive. According to (Bell, 1988) if the decision maker prefers alternative A to B, and prefers B to C, then the normative decision-making means that he or she will also have a preference for A over C. This shows how the decision maker "ought" to decide. Sometimes in reality, a decision maker may have cyclical preferences: A over B, B over C, and C over A. This is descriptive decision making that shows how a decision "is" made. If the decision maker have two alternatives: A and C, and he/she must choose one of them, introducing a hypothetical alternative B for which the decision maker finds it comfortable to say that he or she prefers A to B and B to C may help the decision maker to believe that A is better than C. This sort of decision making is not normative (A is preferred to C if and only if there exists B) or descriptive (the decision maker could do this for himself). It is called prescriptive decision making. Before making any decision, the decision maker must have a clear grasp of the context surrounding a decision problem. It is important to explore in detail the context in which managerial decision problems arise. Ignoring the nature and environment of decision problems result in poor planning, fire-fighting and crisis management. Jennings (Jennings, 1998) states four aspects that are almost always important in determining the nature of a decision problem as follows:
- **The level of decision-making:** There are three levels of decision making. Strategic decision making where decisions are likely to have a significant impact on the whole system over time, and tactical decision making where only elements of the system are likely to be affected. Between these two levels there is a whole range of operational decision making in most management environment which is often associated with management functional areas such as finance or production. The effects of tactical or operational decisions may affect the whole system over time and there are links between the three levels of decision-making and the other factors discussed below.

- **The time horizon:** There are two phases for time horizon, the period available for decision making and the planning period over which decision making is effective. Considering the period available for decision-making, it is one of the resources available to aid decision making. Some decisions must be made immediately. These are usually tactical decisions that will not affect the whole system but managers should not make such decisions if they are strategic decisions. The categorisation into short, medium, and long term is frequently made when considering the planning period. Exact length of each category depends on the nature of business but rough estimation might be less than 6 months for short term, between 6 and 24 months for medium term, and more than 24 months for long term periods. Long term periods are very difficult because of the difficulty of forecasting future needs and changes in the market.
- **Frequency:** There are two types of decisions based on frequency, one-off and recurrent decisions. Higher-level longer-term courses of action at the strategic level are the association of one-off decisions. Recurrent decisions are associated with lower level tactical decision making and shorter time horizon. If the important decisions are recurrent, it is important to develop strategies and solution approaches that are rational, effective and consistent.
- **Resources:** These are the resources available for decision making not the resources about which decisions may be made. Resources such as personnel, budget, information, analytic skills, and consultants must be available to make the quality of decisions much better.

3.1.3 The Process of Making Decisions

Most of the decision-making approaches deal with decision making as a process. Clemen describe this process as a six-phases process if the decision maker develops the alternatives (CLEMEN, 2001). These phases are shown in Figure 1. The first phase for a decision maker is to identify the decision situation and understand the objectives in that situation. The trouble is not in finding the problem, the decision-maker sometimes has trouble with identifying the exact problem and verifying its boundaries, and may, therefore, treat the wrong problem.

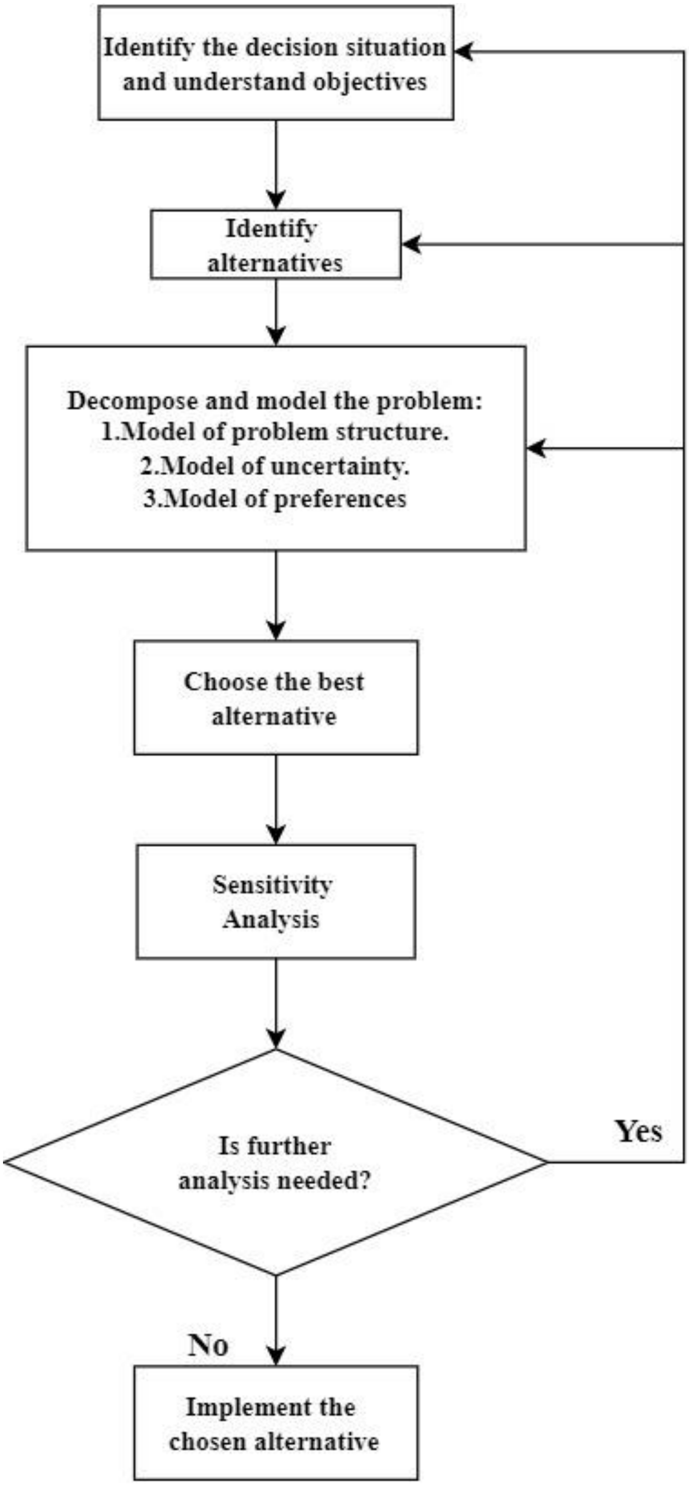

Figure 1: Decision making process (CLEMEN, 2001).

Objectives must be defined and expressed in broad terms. It is also needed at this phase to establish some performance measures to test the effectiveness of the process to solve the problem. Factors, variables, and data relevant to the problem are also identified at this phase.

After establishing the decision situation and objective, the second phase is to discover and create alternatives. Understanding objectives and careful examination of them help the decision maker to identify different alternatives. Modelling is an important feature of the process of decision making. Analogue and symbolic models are used widely. Mathematics has a role to play in modelling, and the development of computers and computer systems has had a big impact on decision making. The decision maker can use decision trees and hierarchies to structure the problem and represent relationships between different objectives and performance measures. Models of uncertainty use probabilities to inherent the uncertainty in the problem. Mathematical representation of subjective preferences can help indicating a "preferred" alternative. The decision maker implements decision models in the next phase to choose the best alternative. The fifth phase is to apply sensitivity analysis, which answers "what if" questions. It shows the consequences of selecting an alternative solution if the decision maker applied small changes to some aspects of the decision model. If these changes lead to changing the selected alternative, the decision is considered sensitive and the decision maker may need to reconsider more carefully those aspects to which the decision is sensitive. The process allows the decision maker to return back to the first, second and third phase to make modifications. If the decision maker reaches satisfaction about an alternative, the final phase is to implement the chosen alternative. This decision process is iterative. The decision maker may develop or change his or her perception of the decision problem, objectives or models while going through the different phases of the process. However, returning back to some phases, like redefinition of the problem after modelling, may be costly and may cause negative consequences. The basic idea for a decision-making process is similar for most of the authors. Elbing suggested five steps for a decision-making process (Elbing, 1978):

- **Perception of the environment or situation**: Observing and becoming sensitive to potential sproblem situations.
- **Diagnosis**: Attempting to understand what is happening in a particular problem situation.
- **Definition of the problem to be solved**: Identifying and stating a problem in relation to organisational and personal goals.
- **Determination of alternative methods and solutions and choice of the best solution**: selecting a course of action from a series of alternatives.

- **Implementation of the chosen solution**: The entire process of actualising the chosen solution.

All the decision makers prefer a decision-making process that will guide them directly to the solution of their decision problem, which does not exist. The process of decision making has some limitations to be straightforward due to several factors that influence the decision maker, information needed, and the organisation. Clarity of the problem and objectives is very important. The decision maker may decide the suitability of an alternative over other alternatives based on a wrong understanding of the problem. Some problems involve a group of people to make decisions and the compatibility of the understanding of the problem and objectives between these people is also very essential. Decision makers always set time limits to each step in the decision making process. It is important to set these time limits accurately and also, accomplish each step in its scheduled duration. If the decision maker could not meet the scheduled time for any step, the following step and the whole process will be affected. Decisions will be made based on intuition because the decision makers do not have enough time. Cost is another factor that may limit the decision-making process. It is not easy to obtain information needed to make decisions within organisations and the only way is to "buy" this information from those who have it. If the information is very costly and the decision makers cannot acquire it, the decision making process is surely affected.

3.1.4 Approaches to Decision Making

There are a variety of decision-making approaches, all of which are based on the views and opinions of academics and authors. Some methodologies will be covered in this study, including behavioural, organizational, and operational research, as well as multiple-criteria decision making.

3.1.5 Behavioural Decision Making

This strategy is based on the acts of the decision maker.Some causes and goals always generate a motive force that can explain why a person chooses a particular decision. Modeling human behavior's main goal is to create a business process that promotes employee excitement by taking into account all aspects of human behavior, such as group dynamics, project work climate, and organizational culture. The purpose of behavioral decision making is to learn how people make decisions and how they may make the process more effective and efficient. The behavioral sciences can be applied to decision-making processes in both quantitative and qualitative ways to strengthen the foundation for better decision-making.

3.2 Multi Criteria Decision Making (MCDM)

According to (Xu, 2001) Multiple Criteria Decision Making (MCDM) is an emerging discipline that assists decision makers who are faced with multiple and often conflicting criteria. It also has a relatively short history, spanning around three decades, and its growth is closely linked to advancements in computer science and information technology, particularly in complex MCDM problems.

The key components of MCDM are Multi-Objective Decision-Making (MODM) and Multi-Attribute Decision-Making (MADM). MCDM allows decision makers to pick and rank options based on different and competing criteria (Pirdashti, 2009) Single-Objective Decision-Making (SODM), Decision Support Systems (DSS), and Multi-Criteria Decision-Making (MCDM) are the three primary groupings (Figure 2) that (Zhou, 2006) have grouped Decision Analysis (DA) methodologies into (MCDM).

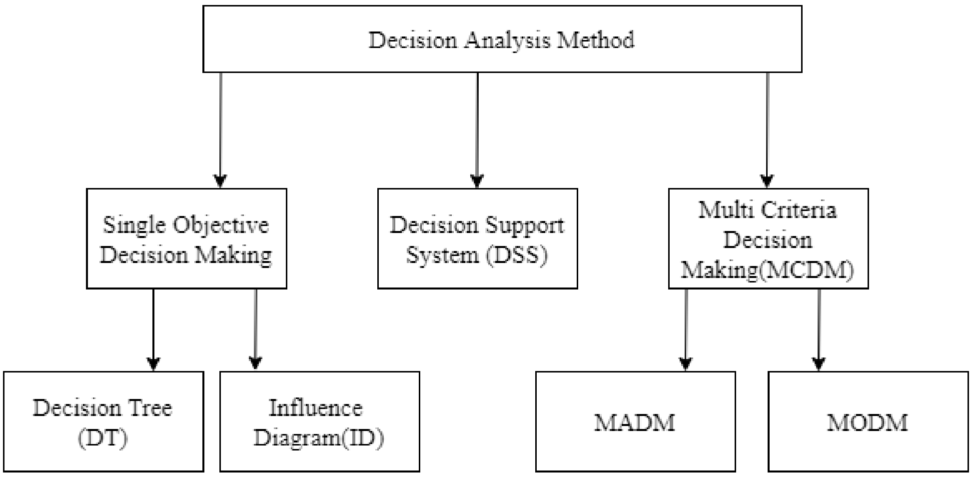

Figure 2: Classification of decision analysis methods(Zhou, 2006).

MODM is similar to traditional optimization models, except instead of maximizing a single goal function, it focuses on optimizing several. In MADM, on the other hand, numerous possibilities are chosen and ranked based on a set of criteria. Simply expressed, decision-makers will use information and expertise to rank and select among choice alternatives specified by certain criteria (Devi, 2009). The distinction between MADM and MODM is based on the evaluation of criteria as attributes (properties of elements in an applied system) and objectives (a statement about the desired and favourable state of the system, respectively). Figure 3 (Malczewski, 2006) depicts a taxonomy of Multi-Criteria Decision Problems:

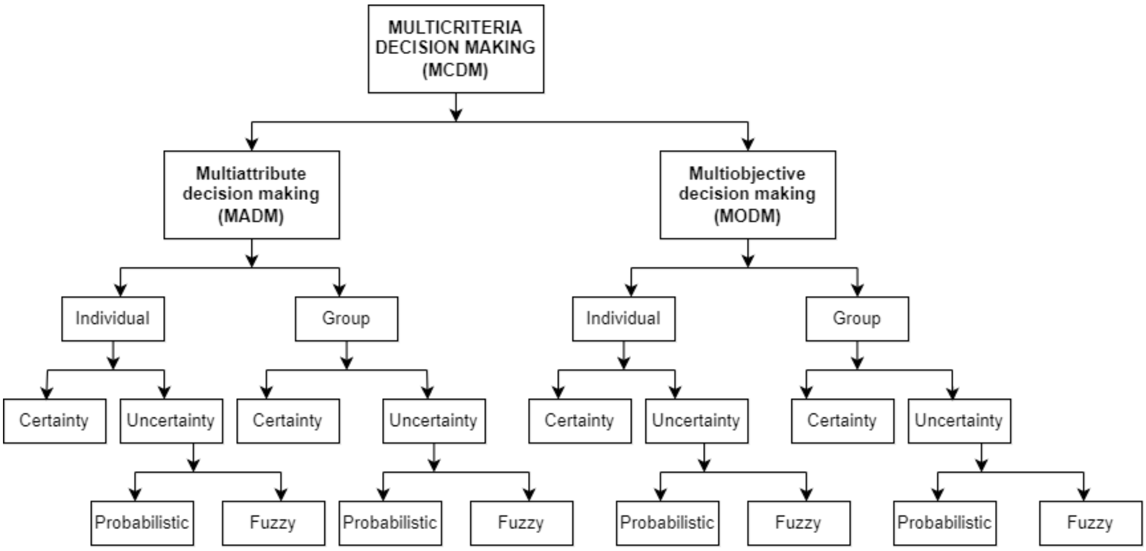

Figure 3: Classification of Multi-Criteria Decision Problem(Malczewski, 2006).

Another point of view showed in Table 1 (Hwang, 1981) by a comparison of MADM and MODM approaches:

	MODM	**MADM**
Criteria defined by:	Objective	Attributes
Objective defined:	Explicitly	Implicitly
Attributes defined:	Implicitly	Explicitly
Constraints defined:	Explicitly	Implicitly
Alternative defined:	Implicitly	Explicitly
Number of alternatives:	Infinite(large)	Finite(small)
Decision maker’s control:	Significant	Limited
Decision modeling paradigm:	Process-oriented	Outcome-oriented
Relevent to:	Design/search	Evaluation/choice
Relevence of geographical data structure:	Vector-based GIS	Raster-based GIS

Table 1: Comparison of MODM and MADM approaches(Hwang, 1981).

3.3 Multi-attribute Decision making

"*MultI-Attribute Decision Making (MADM) is the most well-known branch of decision making*", according to (Devi, 2009). It is a subset of a larger class of operations research models that handles with situations involving several decision criteria. The MADM method necessitates choosing from a set of choice options based on their qualities. A preset, limited number of decision possibilities is anticipated in MADM situations. Sorting and ranking are required to solve a MADM problem. MADM approaches can be thought of as alternate strategies for integrating the information in a problem's decision matrix with additional information from the decision maker to arrive at a final ranking or choice among the alternatives. Aside from the information in the decision matrix, all but the simplest MADM approaches require the decision maker to provide extra information in order to arrive at a final ranking or selection. A MADM problem with m criteria and n alternatives can appear as... and..., respectively, as criteria and alternatives. Furthermore, the MADM approach is depicted as a "decision table" (Table 2). The alternatives and criteria are presented in each row and column, accordingly. In comparison to criterion, the score describes the value and amount of alternative. Weights... should also be assigned to each criterion. The importance of a criterion to the decision is represented by its weight, which is believed to be positive. After the decision table has been filled with decision-maker experience, a MADM technique to rank and pick alternatives must be chosen.

	W_1	-	-	W_m
	C_1	-	-	C_m
A_n	A_{11}	-	-	A_{n1}
-	-	-	-	-
-	-	-	-	-
A_n	A_{n1}			Amn

Table 2: Decision table

Multiple attribute-based decision issues should be solved using one of the numerous ways available, however, the great number of MADM problem-solving strategies available creates a paradox between MADM method selections (Triantaphyllou, 2000). There are a variety of MADM strategies for dealing with decision-making issues. In the same issue domain, various applied methodologies will yield different solutions. These inconsistencies may arise from variances in the application of weights, the approach to selecting the "best" solution, the scaling of objectives, and the addition of additional parameters (Lezzi, 2006). Making decisions in the presence of many, frequently contradictory criteria is referred to as multiple criterion decision making (MCDM). Depending on whether the challenge is a selection problem or a design problem, Multiple attribute decision making (MADM) and multiple objective decision making (MODM) are the two types of MCDM challenges. The decision variable values in MODM approaches are decided in a continuous or integer domain, with an infinite or large number of alternatives, the best of which should fulfill the decision maker's restrictions and preference priorities. MADM approaches, on the other hand, are usually discrete, with only a few fixed options. MADM is a method for solving problems that require choosing between a limited number of options. An MADM method explains how attribute data will be processed in order to make a decision. MADM techniques necessitate both inter and intra-attribute comparisons, as well as proper trade-offs. In MADM approaches, each decision table (also known as a decision matrix) includes four major components: (a) alternatives, (b) attributes, (c) weight or relative relevance of each attribute, and (d) measures of alternative performance with regard to the attributes. The table of decisions is as follows:

Table 1.1 The decision table shows

Alternatives	Attributes					
	B_1 (W_1)	B_2 (W_2)	B_3 (W_3)	- (-)	- (-)	B_M (W_M)
A_1	m_{11}	m_{12}	m_{13}			m_{1M}
A_2	m_{21}	m_{22}	m_{23}			m_{2M}
A_3	m_{31}	m_{32}	m_{33}			m_{3M}
-	-	-	-	-	-	-
-	-	-	-	-	-	-
A_N	m_{N1}	m_{N2}	m_{N3}			m_{NM}

Table 3: Detailed decision table

alternatives, A_i (for i = 1, 2, ….. , N), attributes, B_j (for j = 1, 2, ….. , M), weights of attributes, wj (for j=1, 2, ….., M) and the measures of performance of alternatives, m_{ij} (for i = 1, 2, ….., N; j =1, 2, ….., M). Given the decision table information and a decision-making method, the task of the decision maker is to find the best alternative and to rank the entire set of alternatives. It may be added here that all the elements in the decision table must be normalized to the same units, so that all possible attributes in the decision problem can be considered. Of the many MADM methods reported in the literature (Saaty, 1980) few important methods that have a higher potential to solve decision-making problems in the manufacturing environment are presented in this chapter.

3.4 Multi-attribute Decision Making: A Classification of Methods

MADM approaches can be classed as compensatory or non-compensatory. The decision maker may believe that great performance in one attribute can at least partially compensate for bad performance in another, especially if an initial screening study has ruled out any options that do not fulfill any minimum performance standards. "Compensatory" methods are those that incorporate trade-offs between high and low performance into the study. "No compensatory" procedures are those that do not. Hwang (Hwang, 1981) present 14 MADM approaches. These strategies are briefly described below. In addition, there are five other methods listed below.

Dominance: An alternative is said to be "dominated" if another option exceeds it in at least one attribute while performing equally well in the other attributes. Alternatives are screened using the dominance method, and all dominated alternatives are eliminated. As the number of independent qualities grows bigger, this method's screening power decreases.

Maximin: The maximin technique is based on the notion that "*a chain is only as strong as its weakest link*". The approach effectively assigns a score to each alternative based on the strength of its weakest connection, where the "links" are the qualities. As a result, performance in all attributes must either be assessed in comparable units (unusual for MADM problems) or be normalized prior to using the algorithm.

Maximax: The Maximax technique is based on a viewpoint that gives the most weight to the attribute in which each alternative performs the best. Maximax performs as if one were comparing alternative chains in search of the best link, extending the "chain" analogy used to describe the maximin approach. Each chain's (alternative) score is determined by the performance of its strongest link (attribute). Maximax, like the maximin technique, requires that all attributes be equal or renormalized.

Conjunctive (Satisficing): The conjunctive approach is solely for the purpose of screening. The conjunctive screening approach embodies the condition that an alternative must exceed set performance levels for all attributes to be acceptable. The qualities (and hence the thresholds) do not have to be measured in the same units as the thresholds.

Disjunctive: The disjunctive method is merely a screening technique as well. It's the inverse of the conjunctive approach, but instead of "and," it uses "or". That is, for an alternative to pass the disjunctive screening test, it must outperform the performance criterion for at least one attribute. The disjunctive approach, like the conjunctive method, does not require that qualities be measured in equivalent units.

Lexicographic: The most well-known application of the lexicographic approach is alphabetical ordering in dictionaries, as the name implies. Attributes are ranked in order of relevance using this procedure. The option that performs the best on the most essential attribute is chosen. If there are any ties in this attribute, the next most important attribute is taken into account, and so on. There are two significant differences between MADM tasks and alphabetizing dictionary words. For starters, there are many fewer options in a MADM problem than there are words in a dictionary. Second, when the decision matrix comprises quantitative attribute values, there are practically an infinite number of alternative scores, resulting in a smaller chance of ties.

Lexicographic Semi-Order: This is a modest variant on the lexicographic technique, in which "near-ties" might count as ties without penalizing the alternative, which scores slightly lower inside the tolerance "tie" window. The lexicographic method becomes less of a "knife-edged" ranking method and more appropriate for MADM problems with quantitative data in the decision matrix when close ties are counted as ties. However, the approach can produce intransitive results, such as A preferring B, B preferring C, and C preferring A.

Elimination by Aspects: The "process of elimination" is a well-known heuristic, and this method formalizes it. This evaluation, like the lexicographic method, goes over each attribute one at a time, starting with the most significant ones. Then, as with the conjunctive technique, any alternatives that do not meet the minimum performance requirements in this case, for the sole attribute of interest are discarded. The procedure usually continues until only one option remains, though in some circumstances, adjusting the performance criterion may be necessary to get a unique solution.

Linear Assignment Method: In addition to the decision matrix data, this method requires cardinal significance weights for each attribute as well as rankings of the alternatives. With regard to each attribute these are intermediate information requirements. Between the eight approaches previously outlined and the five the approaches that follow, in that they necessitate the use of ordinal numbers (but not cardinal) rankings of the alternatives based on their preferences for each attribute. The major purpose of the new data is to enable compensating rather than preventative measures than enabling good performance on one task without compensatory analysis trait to make up for a lackluster performance on another.

Note that numerical attribute values (data in the decision matrix) do not equal cardinal preference rankings at this time. Attribute values are not always comparable across attributes, preference does not always increase linearly with attribute values, and preference for attribute values of 0 is not always zero. If the decision maker can define an ordinal correspondence between attribute values and preference, such as "more is better" or "less is better" for each attribute, the linear assignment method's ordinal alternative rankings for each attribute can be specified uniquely. As a result, the linear assignment method's evaluation or performance rankings are simpler to calculate than the evaluation or performance ratings required by the five approaches that follow. The disadvantage of utilizing ordinal rankings rather than cardinal ratings is that the approach is only "semi-compensatory," meaning that incremental improvements in an alternative's performance will not be considered unless they are significant enough to change the rank order of the alternatives.

Additive Weighting: The weighted total of an alternative's cardinal evaluation or preference ratings, where the weights are the importance weights associated with each attribute, equals the alternative's score. The cardinal scores obtained for each alternative might be used to rank, screen, or select an option. The analytical hierarchy process (AHP) is a method of additive weighing that takes a different approach.

Weighted Product: The additive weighting approach is similar to the weighted product. Instead of multiplying performance scores by attribute importance, performance scores are raised to the power of the attribute importance weight to get "sub-scores." Then, rather than adding the sub-scores across attributes to get the overall score for the alternative, the scores are multiplied to get the final alternative scores. The additive weighting approach penalizes poor performance on one attribute more harshly than the weighted product method.

Non-traditional Capital Investment Criteria: Pairwise comparisons of performance increases (over a baseline alternative) among qualities for a specific alternative are used in this method. One characteristic must be quantified in monetary terms. The (monetary) value given to each performance improvement is estimated using these comparisons, and the aggregate of these values yields the overall implied worth of each alternative. These suggested values can be used to choose an alternative, rank alternatives, and possibly screen alternatives.

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution): TOPSIS is founded on the simple premise that the chosen alternative should be as close to the ideal as possible while being as far away from the negative-ideal as possible.The best performance values demonstrated (in the decision matrix) by any alternative for each attribute are combined to generate the optimal solution. The poorest performance numbers are combined to generate the negative-ideal solution. Each attribute's weighting is optional, and proximity to each of these performance poles is measured in a Euclidean sense (e.g., square root of the sum of the squared distances along each axis in the "attribute space").

Distance from Target: This strategy and its outcomes are also simple to depict graphically. First, goal values for each attribute are determined, which do not have to match any existing alternative. Then, in "attribute space", the alternative with the shortest distance (again in the Euclidean sense) to this target point is chosen. Weighting of qualities is possible once more. Screening, ranking, and selecting a preferred alternative can all be done with distance scores.

Analytic Hierarchy Process (AHP): Saaty was the one who invented the analytical hierarchy approach (Saaty, 1980). The additive weighting method (AHP) is a form of additive weighting method. It has been extensively reviewed and applied in the literature, and various commercially accessible, user-friendly software tools support its use. It is typically difficult for decision makers to appropriately establish cardinal importance weights for a group of traits at the same time. When the problem is reduced to a series of pairwise comparisons as the number of attributes grows, better results are produced. The attribute weighting problem is transformed into a more tractable problem of making a series of pairwise comparisons among competing attributes using AHP. In a "Matrix of pairwise comparisons," AHP presents the outcomes of pairwise comparisons. The decision maker makes a judgment about "*how much more essential one attribute is than the other*" for each pair of attributes. Each pairwise comparison necessitates the decision maker's response to the question: "*How much more essential is Attribute A than Attribute B, in terms of the overall objective*?"

Multi Attribute Utility Models: The maximization of satisfaction gained from the choosing of a satisfactory solution is described by utility theory. The option that maximizes utility for the decision maker's stated preference structure is the best. There are two types of utility models: additive and multiplicative utility models.

Analytic Network Process: In some practical decision issues, it appears that the local weights of criteria for each alternative are different. In such a circumstance, AHP has difficulties dealing since it utilizes the identical local weights of criteria for each alternative. (Saaty, 1980) suggested the analytic network process to solve this problem (ANP). Different weights of criteria for alternatives are allowed in ANP.

Data Envelopment Analysis: Charnas et al. brought data envelopment analysis (DEA) into the operations research literature as a nonparametric approach of analyzing the efficiency of a decision-making unit such as a corporation or a government agency (Charnes, 1978).DEA is a method of calculating the weights allocated to the inputs and outputs of the production units under consideration using operations research approaches. The efficiency scores are derived by multiplying the actual input/output data values by the calculated weights. The DEA technique is a nonparametric multiple criteria method that does not estimate a production, cost, or profit function from the data.

Multi-Attribute Fuzzy integrals: Consider that the utility function is additive and takes the form of a weighted sum where mutual preference independence among criteria may be established. In practice, however, the notion of mutual preference independence among criteria is rarely tested. It has been proposed to replace the weight vector involved in the calculation of weighted sums with a monotone set function on characteristics set N dubbed the fuzzy measure in order to account for interaction phenomena among criteria. This strategy considers the importance of each subset of criteria as well as the relevance of each criterion. The Choquet integral is a natural extension of the weighted arithmetic mean (Grabisch, 1992).

3.5 Popular Concept and theory of MADM

3.5.1 Analytic Hierarchy Process:

According to (Saaty, 2000) AHP is "*a logic and problem-solving framework that spans the spectrum from instant awareness to fully integrated consciousness by organizing perceptions, feelings, judgments, and memories into a hierarchy of forces that impact decision outcomes*". From the application of paired comparisons in multilevel hierarchic structures, AHP is utilized to produce ratio scales on a number of tangible and immaterial qualities. Actual measurements or a fundamental scale that expresses the relative strength of preferences and sentiments are used to make the comparisons. By arranging these aspects in a hierarchical framework, the decision problem can be broken down into smaller components, leading to straightforward paired comparison judgments and the hierarchy's priorities. The fundamental scale of absolute values for reflecting the strength of judgments is shown in Table 2-1.Costs and benefits are frequently related with decision possibilities. In this case,Separate cost and benefit hierarchies are useful in this scenario, with the On the bottom level of each, the same decision alternatives exist. The cost/benefit ratio The vector is created by dividing the priority of the benefits by the priority of the costs.Prioritize each option, with a larger ratio indicating the preferred option.alternative. The following is an example of how to use the benefit/cost ratio in an AHP. Appendix A is a list of references.In many decision-making situations, tangible and intangible criteria or traits are used.Tangibles are physical (numerically measurable) criteria that represent objective reality outside of the one making the assessment. Intangibles are psychological factors that include the decision maker's subjective thoughts, feelings, and beliefs.

The AHP is a way for establishing measurements in both the physical and psychological realms. When making a decision, decision makers examine both favorable and unfavorable concerns (attributes). Some of these issues are unquestionably valid. Others, on the other hand, are less convinced. Benefits are a term used to describe the positive aspects of a situation. The unfavorable ones are referred to as expenses. It's possible that the decision will result in less. Positive opportunities and negative hazards are two major issues. Each of these factors contributes to the decision's merit and must be addressed. Individually assessed (graded) on a set of prioritized characteristics that are used to Any other decision should be weighed as well. The elements that are prioritized are referred to as crucial the four qualities' factors. For frequent usage of all decisions, the main factors must be prioritized. The pairwise evaluation of the features and their major factors is based on the fundamental scale, with the total priority of each decision alternative calculated using the following expression:

$$\textbf{Priority} = \frac{\textbf{(Benefits)}\ x\ \textbf{(Opportunities)}}{\textbf{(Costs)}\ x\ \textbf{(Risks)}} \qquad (3.1)$$

The method for computing the priorities is complicated, and converting a super matrix to a stochastic matrix will take time. After all of the comparisons have been done, the ANP's computer program performs these calculations automatically. The Analytic Network Process, established by Dr. Thomas Saaty, is implemented in this tool, which is dubbed Super decisions. The tool was written by the ANP Team for the Creative Decisions foundation, and this research uses it to compare decision qualities and their critical components. The AHP approach has demonstrated its effectiveness in predicting the outcome of US presidential elections, sports tournament results, and chess match winners (Saaty, 2000). AHP has been used in the past. decision-makers in a variety of fields, such as accounting, finance, and marketing planning of energy resources, microcomputer selection, sociology, and architecture as well as political science (Triantaphyllou, 2000). AHP, on the other hand, has its detractors.in terms of the philosophy underlying it.

3.5.2 VIKOR

Yu (Yu, 1973) and Zeleny (Zeleny, 1982) laid the groundwork for the compromise solution, which was later endorsed by Oprocovic and Tzeng (Opricovic, 2002). The compromise option is the most close to the ideal answer, and it is also the most practical. The VIKOR method's compromise ranking algorithm consists of the following steps: The rating of the jth characteristic is written as f_{ij} for alternative A_i.

Step 1. The first step is to determine the objective, also determine the best, i.e., f_j^+ and the worst, i.e. f_j^-, values of all attributes.

$$f_j^+ = \max_i f_{ij}, j = 1, 2, 3 \dots \dots m \qquad (3.2)$$

$$f_j^- = \min_i f_{ij}, j = 1, 2, 3 \dots \dots m \qquad (3.3)$$

Step 2: Compute the values S_j and R_j, i = 1, 2, …, n.

$$S_i = \sum_{j-1}^{n} w_j(f_j^* - f_{ij})/(f_j^* - f_j^-) \qquad (3.4)$$

$$R_i = \max_j w_j(f_j^* - f_{ij})/(f_j^* - f_j^-) \qquad (3.5)$$

where w_j, are the weights of the attribute expressing the relative importance.

Step 3: Compute the values Q_i, i = 1, 2, …, n by the following relation

$$Q_i = v(S_i - S^*)/(S^- - S^*) + (1 - v)(R_i - R^*)/(R^- - R^*) \qquad (3.6)$$

where S^* is the minimum value of Si i.e. S^* = min i S_i and S^- is the maximum value of S_i i.e. S^- = max i S_i Similarly, R^+ is the minimum value of the R_i i.e. R^+ = min i R_i and R^- is the maximum value of Ri i.e R^- = maxi R_i υ is introduced as the weight of strategy of "the majority of attribute" (or the maximum group utility), usually υ = 0.5.

Step 4: By arranging the alternatives in the ascending order of S, R and Q values, the three ranking lists can be obtained. The compromise ranking list for a given υ is obtained by ranking with Q_i measures. The best alternative, ranked by Q_i, is the one with the minimum value of Q_i.

Step 5: Propose a compromise solution for alternative A_k Under a given weight of attribute, alternative A_k is the best ranked by Q value (Minimum) if the following two conditions are satisfied (Tzeng, 2005):

Condition1: "Acceptable advantage ":

$$Q(A_K) - Q(A_1) \geq DQ \qquad (3.7)$$

$$DQ = \frac{1}{(N-1)} \qquad (3.8)$$

where, A_1 the second-best alternative in the ranking list by Q. N is the number of alternatives. Condition 2: 'Acceptable stability in decision making': Alternative A_k must also be the best ranked by S and R. This compromise solution is stable within a decision-making process, which could be ''voting by majority rule'' (when $\upsilon > 0.5$ is needed), or ''by consensus'' ($\upsilon \approx 0.5$), or ''with veto'' ($\upsilon < 0.5$). Here, υ is the weight of the decision-making strategy ''the majority of attribute'' (or ''the maximum group utility''). If one of the prerequisites isn't met, a series of compromise options are suggested,which consists of: 1- Alternatives A_k and A_1 if only condition 2 is not satisfied 2- Alternatives A_k, A_1, ... A_p if condition 1 is not satisfied; A_p is determined by the relation

$$Q(A_P) - Q(A_1) < DQ \qquad (3.9)$$

3.5.3 TOPSIS

In some geometrical sense, the chosen option should be the furthest away from the ideal solution and the closest to the negative-perfect solution., according to TOPSIS (Triantaphyllou, 2000). By combining the proximity to the positive-ideal solution and the distance from the negative-ideal solution, it creates an index called "similarity index" (or relative closeness) to the positive-ideal solution. The approach then selects the alternative that is the most comparable to the positive ideal answer. TOPSIS predicts that as the attribute outcome increases, the preference for benefit characteristics increases and the choice for cost attributes decreases (Yoon, 1995).TOPSIS is a concept that can be stated in a number of ways:

Step 1: Collect performance data for n different options with m different qualities. Ordinarily, raw measurements are normalised by transforming raw measures x_{ij} to normalised measures r_{ij} as follows:

$$r_{ij} = (x_{ij})/\sqrt{\Sigma x^2} i, i = 1, \ldots, m, j = 1, \ldots, n \qquad (3.10)$$

Step 2: Calculate weighted normalised ratings:

$$Weighted\ r_{ij} = w_j r_{ij} \qquad (3.11)$$

Where w_j is the weight of the j^{th} attribute. The basis for these weights can be anything, but, usually, is *ad hoc* reflective of relative importance. Scale is not an issue if normalising was accomplished in Step 1.

Step 3: Identify the positive-ideal alternative (extreme performance on each criterion) A^+.

Step 4: Identify the negative-ideal alternative (reverse extreme performance on each criterion) A^-.

Step 5: Develop a distance measure over each criterion to both positive-ideal (S_i^+) and negative-ideal (S_i^-).

Step 6: For each alternative, determine a ratio C_i^+ equal to the distance to the negative-ideal divided by the sum of the distance to the negative-ideal and the distance to the positive-ideal,

$$\boldsymbol{C_i^+} = \boldsymbol{S_i^-}/(\boldsymbol{S_i^-} + \boldsymbol{S_i^+}) \qquad (3.12)$$

Step 7: Rank order alternatives by maximizing the ratio in Step 6. (Yoon, 1995) presented a good example that illustrates the TOPSIS method.

3.5.4 ELECTRE

The basic concept of the ELECTRE (also for Elimination and Choice Translating Reality; English translation from the French original) method is to deal with "outranking relations" by using pairwise comparisons among alternatives under each one of the attributes separately. This method is most popular in Europe, especially among the French-speaking community. Suppose that there are two alternatives A_p and A_p, the notion (A_p R A_q) or ($A_p \rightarrow A_q$) means that A_p outranks A_q. Formally, an outranking relationship of (Ap R Aq) states that even though two alternatives A_p and A_q do not dominate each other, it is realistic to accept the risk of regarding A_p as almost surely better than A_q. Accordingly, the outranking relationship R is not required to be transitive. For example, the following assessments (A_1 R A_2) and (A_1 R A_3) do not necessary imply (A_1 R A_3). (Yoon, 1995)describe this kind of outranking relationship as “both ambiguous and practical”. The basic idea of the ELECTRE method comes from pairwise comparisons of alternatives under each attribute. The decision maker then asserts that he is unconcerned about the options, that he has a weak or stringent preference for one of them, or that he is unable to express any of these preference connections. As a result, the list of outranking linkages generated could be comprehensive or partial. The following are the steps of the ELECTRE method (the first two are the same as the first two steps of TOPSIS):

Step 1: Obtain performance data for n alternatives over m attributes. Raw measurements are usually normalised by converting raw measures xij into normalised measures rij as follows:

$$\boldsymbol{r_{ij}} = \frac{(\boldsymbol{x_{ij}})}{\sqrt{\boldsymbol{\Sigma x^2 i}}}, \boldsymbol{i} = \boldsymbol{1}, \dots, \boldsymbol{m}, \boldsymbol{j} = \boldsymbol{1}, \dots, \boldsymbol{n} \qquad (3.13)$$

Step 2: Calculate weighted normalised ratings:

$$\textbf{Weighted } \boldsymbol{r_{ig}} = \boldsymbol{w_j r_{ig}} \qquad (3.14)$$

where w_j is the j^{th} attribute's weight. These weights might be based on anything, although they are frequently ad hoc and indicate relative importance. If normalisation was completed in Step 1, scale is not an issue.

Step 3: Determine the sets of concordance and discordance. A_p and A_q are the two choices for each pair. ($p, q = 1, 2, \ldots, n$ and $p \neq q$), There are two unique subsets of attributes in the collection. All attributes for which alternative A_p is preferable to alternative A_q make up the concordance set. In other

words, the concordance set $C_{(p, q)}$ is the collection of attributes where A_p is

better than or equal A_q. The discordance set $D_{(p, q)}$ is the complement of $C_{(p, q)}$, and it contains all characteristics for which A_p is worse than A_q.

Step 4: Calculate the indexes of concordance and discordance. The concordance index is used to determine the relative power of each concordance collection.The concordance index C_{pq} represents the degree of confidence in the pairwise judgments of ($A_p \rightarrow A_q$). The concordance index of $C_{(p, q)}$ is defined as:

$$\boldsymbol{C_{pq}} = \sum \boldsymbol{w_{j*}} \qquad (3.15)$$

Where $j*$ are attributes contained in the concordance set $C_{(p, q)}$. On the other hand, the discordance index measures the power of $D_{(p, q)}$. The discordance index of $D_{(p, q)}$, which represents the degree of disagreement in ($A_p \rightarrow A_q$), can be defined as:

$$\boldsymbol{D_{pq}} = \left(\sum \left|\boldsymbol{v_{pj^*}} - \boldsymbol{v_{q^*}}\right|\right) / \left(\sum \left|\boldsymbol{v_{\rho j}} - \boldsymbol{v_{qq}}\right|\right) \qquad (3.16)$$

Step 5: Find the outranking relationships. The method defines that A_p outranks A_q When $C_{pq} \geq C$ and $D_{pq} < D$, where C and D are the averages of C_{pq} and D_{pq}, respectively.

3.6 Application of MADM

Building hierarchical structure of evaluation criteria:

Numerous criterion decision making (MCDM) is an analytical method for weighing the benefits and drawbacks of various options using multiple criteria. Multiple objective programming and multiple criteria evaluation are the two broad categories of MCDM challenges (Hwang, 1981). The second group is highlighted because this study focuses primarily on the evaluation difficulty. To identify a priority ranking for alternative implementation, a typical multiple criteria evaluation problem reviews a collection of feasible alternatives and considers more than one factor. When forming criteria, (Keeney, 1976) recommend that five principles be considered: completeness (the criteria must encompass all of the important characteristics of the decision making problems), operational ability (the criteria must be meaningful for decision makers and available for open study), decomposability (the criteria can be decomposed from higher hierarchy to lower hierarchy to simplify evaluation processes), non-redundancy (the criteria must not be redundant), and decomposability (the criteria can be decomposed from higher hierarchy to lower hierarchy to Figure 5 depicts the hierarchical structure used in this study to address the issues of production and development assessment for public buildings. The criteria's most important dimensions. The criteria for evaluating and selecting building production and development solutions were developed after extensive research and collaboration with a number of professionals, including one professor in the field. Architectural engineering, one civil engineering professor, and one experienced architect and five experienced staff in the Taipei City Public Works Department's professional services procuremen Bureau of Labor. These persons were asked to grade the criteria and dimensions for accuracy, appropriateness, and relevance, as well as to validate their "content validity" in terms of establishing production and development evaluation. The expert and government staff opinions supplied the basis for establishing the hierarchical structure used in this study, which was based on the literature review (Chen, 1978) Furthermore, the production and development of public building evaluation criteria in this study were developed using Keeney and Raiffa's (Keeney, 1976)five criteria selection principles. The six dimensions are the following: building lot layout, two-dimensional planning, appearance modeling, electrical and mechanical systems, structural systems, and degree of requirement fulfillment. From these, twenty evaluation criteria for the hierarchical structure were applied in this study.

Determining the evaluation criteria Weights: We cannot presume that each evaluation criteria is of equal value because the criteria for evaluating building production and development have varying significance and implications. There are a few the eigenvector method, weighted least-square method, entropy method, analytic hierarchy process (AHP), and linear programming techniques for multidimensional analysis of preference can all be used to determine weights in a hierarchical structure for building planning and design alternatives assessment (Hwang, 1981). The method chosen is determined on the nature of the problem. Building production and development evaluation is a complicated and wide-ranging topic that necessitates the most inclusive and adaptable solution possible.

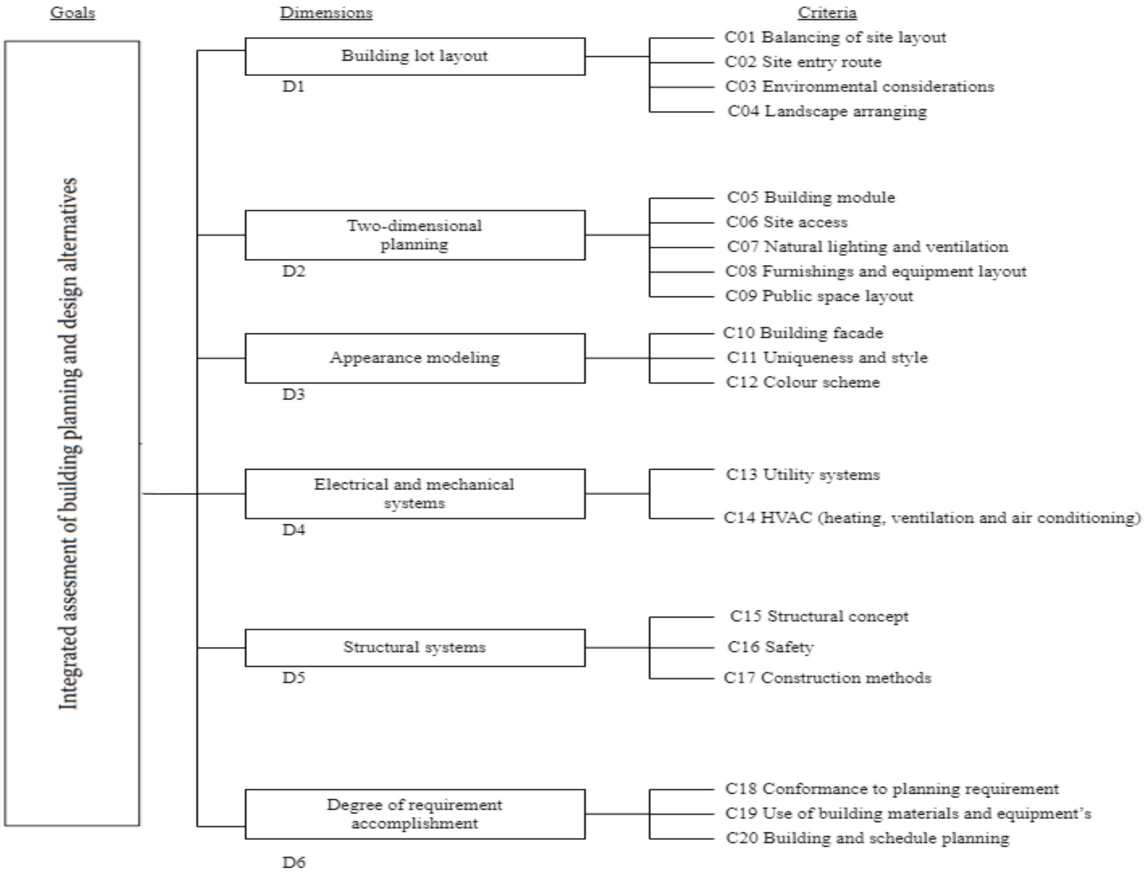

Figure 4: The hierarchical structure for building planning and design alternatives

Saaty's (Saaty, 1980) AHP is a very valuable decision-making tool when dealing with several variables.challenges with deciding on criteria and has been effectively used in a variety of construction projects decision-making areas in the industry. However it is easier and faster to employ the AHP approach during the operation process."*Crterion A is much more essential than criteria B*," rather than "*the importance of principle A and principle B is seven," is more humane for evaluators,one to one*." As a result, (Buckley, 1985) expanded Saaty's AHP to the case where evaluators can use fuzzy ratios instead of exact ratios to deal with the challenge of people assigning exact ratios when comparing two criteria and deriving the result. The geometric mean method produces fuzzy weights for criterion.As a result, we use Buckley's FAHP approach to fuzzify hierarchical analysis by permitting fuzzy integers for pairwise comparisons and calculating fuzzy weights.

Evaluation Criteria: The evaluation of alternative fuel modalities can be done from a variety of perspectives. This section considers four types of evaluation criteria: social, economic, technological, and transportation. Eleven assessment criteria have been devised to evaluate alternatives:

- **Energy supply**: This criterion is based on the annual amount of energy that can be delivered, energy supply reliability, energy storage reliability, and energy supply cost.
- **Energy efficiency**: The efficiency of fuel energy is represented by this criterion.
- **Air pollution:** This criterion refers to how much a fuel mode contributes to air pollution, because vehicles with different fuel modes have varying effects on the air.
- **Noise pollution:** This criterion pertains to the noise generated by the vehicle while it is in operation.
- **Relationship to other industrial production:** The conventional vehicle industry is a locomotive industry, and it is closely linked to other industrial production; the relationship of each option to other industrial production is used as a criterion.
- **Implementation costs**: This criterion refers to the expenses of alternate vehicle manufacture and implementation.
- **Maintenance expenses**: The criterion is the maintenance costs for alternative cars. This criterion shows the cruising distance, slope climbing, and average speed of the vehicle.
- **Road facility**: This criterion refers to the road features required for alternate vehicle operation (like pavement and slope).
- **Traffic flow speed**: This criterion compares the average speed of alternative cars in a given traffic situation. If the vehicle speed exceeds the speed of the traffic flow, the car will be unable to function on specific routes.
- **Sense of comfort**: This criterion pertains to the issue of comfort, as well as the fact that users tend to focus on the vehicle's accessories (air-conditioning, automatic doors, etc.)
- **Designing Multiple-Objective Equilibrium Networks**: The majority of NDPs have traditionally been characterized as a single-objective management issue. The branch-and-bound technique was initially used to tackle the discrete network optimal design problem of a fixed investment budget by (LeBlanc, 1975). The design's overall goal is to reduce users' overall travel costs, with the full budget functioning as a limit. Abdulaal and LeBlanc devised a network design strategy based on constant choice criteria(Abdulaal, 1979). After the objective function was transformed into journey

time units, the budget constraint was enforced. A predetermined budget may throw out many potentially good concepts that only slightly exceed the budget.

It will be difficult to interpret such a design if it is placed under budgetary limitations or given with a parameter and then placed into the objective function after being converted into a time unit because the parameter value is arbitrary. The number of objectives should be as many as necessary to express the complete behavior value of the system. Any attempt to translate these variably measured and scaled objectives into equal units is erroneous since each target played a unique role in the decision-making process.The easiest way to deal with this issue is to analyze each aim separately and assign each one a proportionate relevance (weight) throughout the management process.

Modelling the Network Improvement Problem with Multi objective Decision Making:

The goal of this chapter's examination of the NDP is to find feasible alternatives at a bottleneck link within existing network structure and travel demands, such as link capacity expansion and each link flow under the specified alternative. Then, using Roy's (Roy, 1989) ELECTRE III multicriteria decision making and Cook and Seiford's (Cook, 1978) group decision making, a compromise alternative among feasible projects is evaluated and selected. To create a continuous network design model, multi-objective mathematical programming is used in the design process. To solve the discrete NDP, multicriteria evaluation decision making is performed in the evaluation step. The concept of bilevel programming is used to address the project search stage. When a connection improvement is going to begin to reduce total system costs, the preferences of users are provisionally affected after the opinions of government and users have been considered. In terms of journey time, the decision is made based on how people choose their routes (Tzeng, 1989).Following the establishment of criterion weights and project performance, project evaluation and selection are carried out using various criteria and group decision making to arrive at a compromise option. Figure 5 depicts a model of the framework.

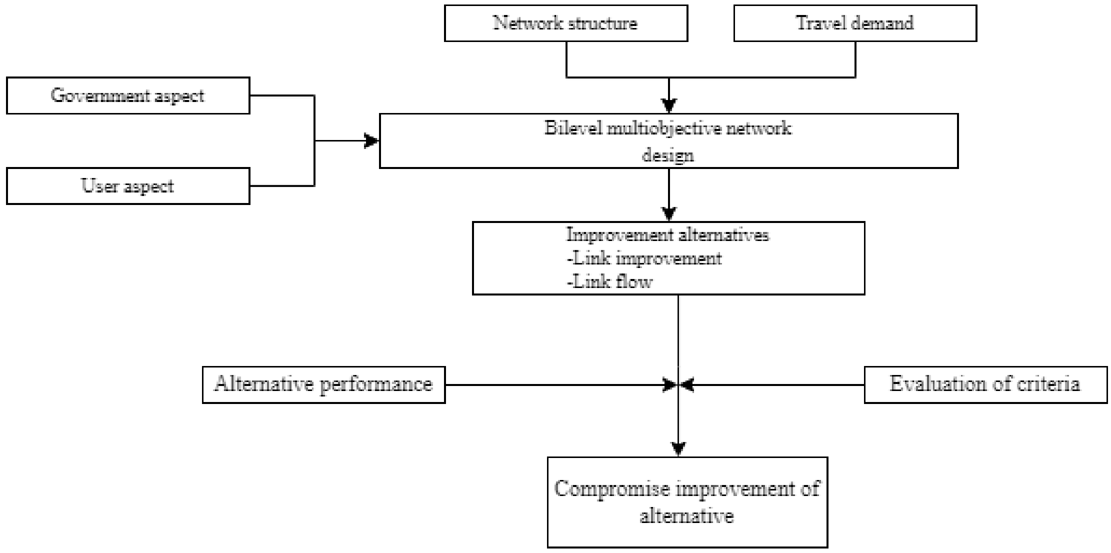

Figure 5: Framework of the network improvement model with multi objective decision making.

3.7 Related Works

This section contains some related research on the use and comparison of Multi Attribute Decision Making (MADM) methodologies for alternative ranking, as well as their outcomes. Soltanpanah (Soltanpanah, 2010) analyzed MADM Techniques for nations based on their human development rate. They claim that the United Nations Development Program's (UNDP) Human Development Index (HDI) has become a valuable instrument for determining where countries rank in terms of human development. Researchers have criticized the use of the HDI, which is calculated by multiplying the arithmetic average of each person's life expectancy at birth, education, and GDP by the same weight.

As a result, they used Entropy and AHP approaches to determine the weights of HDI indexes, and SAW, TOPSIS methodologies, and Numerical Taxonomy analysis to substitute the arithmetic average method for re-ranking countries based on human development levels. Their re-ranking research found that the TOPSIS model produces more acceptable outcomes. Furthermore, when it comes to the use of Entropy and AHP procedures for obtaining index weights, the entropy method has a unique ability to rank entries. As Inducted, Afshar & Mianabadi (Afshar, 2008) used and surveyed three MADM approaches. To rank, use OWA, LA, and TOPSIS (Ordered Weighted Averaging, Linear Assignment, and TOPSIS). Schemes for urban water supply. Their findings demonstrated that when MADM approaches were used to solve the identical problem, the final ranking of options differed significantly.

As a result, considering characteristics of the problem, kind of data set, assessment criteria, and lastly comparing and analyzing results will be required when selecting acceptable MADM approaches for problem solving in a certain domain. Then, based on the evaluation of the aforementioned requirements and the application of various decision-making procedures to the problem, a final ranking and selection of options in terms of various criteria can be formed. The use of MADM approaches in Enterprise Resource Planning (ERP) software decisions was given by Bernroider & Mitlöhner (Bernroider, 2005). Based on 209 datasets derived from a main, national, and industry-independent survey, this study attempted to use MADM approaches in the context of ERP programs in terms of empirical insights. The results show that the ERP decision problem can be structured as a formal method using MADM techniques. In firms, desired expectations were met to a high degree, particularly in terms of financial firm level effect and service quality, as measured by a formal MADM technique. To examine the performance of four imaging approaches for breast cancer screening, Azar (Azar, 2000) employed three alternative multi attribute ranking methods: Simple Additive Weighting (SAW), Weighted Product Method (WPM), and Order Preference Method based on Similarity to Ideal Solution (TOPSIS). He discovered that the SAW approach appears to be the most reliable way for a new ranking of four imaging techniques. The cost element played a crucial effect in the TOPSIS method's ultimate ranking. We should be cautious while utilizing the WPM approach because it uses weights as exponents in mathematical computations, and exponential functions are likely to play a substantial impact in the obtained findings.Practical part

4 Practical Part

4.1 Selected tools descriptions

Excel: Microsoft Excel is a spreadsheet program that allows you to create tables and manage the data within them. Excel is simple to use and provides a wide range of tools for processing data. With practice, Excel can be utilized in a more complicated fashion with functions and macros to personalize how a user uses it. Microsoft Excel has a variety of tools for doing tasks such as computations, pivot tables, graphing tools, macro programming, and more. It works with a variety of operating systems, including Windows, Mac OS X, Android, and iOS. Microsoft Excel is a cutting-edge spreadsheet application. Spreadsheet programs are extremely useful tools for numerical computations, and they are computationally equivalent to many programming language-based numerical computation software systems.
Spreadsheet programs are distinguished by several essential characteristics:

- Iteration and numerous computations by copying formulae.
- Automated recalculation when input values change.
- Relative and absolute cell references instead of named variables.
- Iteration and multiple computations by copying formulas.

These characteristics result in a style of interacting with data. Because changing cell contents directly affects computed results, spreadsheets allow for a very exploratory approach to data analysis. Spreadsheets are more accessible to a broader audience than programming languages for numerical computations since algebraic notation is not the primary manner of engaging with formulas. Furthermore, changing formulas is not difficult for the average user, and hence spreadsheet programs are not closed application programs (like accounting systems), but rather provide end users with a simplified version of programming and even software creation. These features of modeling enable for a smooth transition from simple activities such as invoicing, bookkeeping, and very basic statistics to more complicated statistical and mathematical models. Nardi (Nardi, 1993) discusses these end-user programming concepts, and Neuwirth and Arganbright provide a full treatment of the modeling features of spreadsheets (Neuwirth, 2003). Excel also has the benefit of being integrated into the windows desktop. It's simple to transfer data and images between Excel and other apps, and you can even embed parts of Excel sheets inside text documents so that the text document is automatically updated when the Excel sheet contents change. Excel does provide some statistics support, both in the form of spreadsheet functions and menu-based operations, however the statistical community does not embrace these methods. Some of these methods have poor numerical precision (for example, methods based on matrix inversion), and the parametrization of the arguments of the functions is often odd. Using Excel without any addons to perform advanced statistical studies is not recommended. Excel includes an Add-In technique to help with this problem. Microsoft Office applications come with a built-in programming language (VBA) and an integrated development environment (IDE) for this language in all current editions. The language is rather comprehensive, and it provides access to other libraries that are installed on the same or a separate machine via a network connection. The Add-In technique enables programmers to create new worksheet functions that are smoothly incorporated into Excel (and can be used in the same way as the core engine's functions). Add-Ins can also add menus and dialog boxes to Excel, allowing other libraries' operations to be accessed through an extension of Excel's user interface.

4.2 Data Source company

www.alza.cz: Alza.cz a.s. is a well-known Czech retailer of a wide range of products, including computers, household appliances, electronics, and so on. This is a retail business. This business offers a diverse product catalog and strives to keep as many products in stock as possible. Their products are also available for immediate pickup or delivery to the customer's doorstep. Alza began its adventure in 1994, and its customers are mostly end-users, with corporate clients receiving equal attention. The main selling medium consists of a mix of the same-named online shop or e-shop www. alza. cz and a large network of branches throughout the Czech Republic. Alza.cz has been the market leader in the Czech Republic for a long time. In addition, he is a pioneer in the field of internet retail. Alza.cz achieved this position as a result of their excellent technical requirements for online stores, large stock levels and lastly, a unique approach to clients and desire to match their preferences at a reasonable price. Alza.cz is a powerful and dependable partner for both clients and major corporations as a result of all of this. This is a retail company with the largest electronics store and the largest online store in the Czech Republic selling their numerous products. The enormous choice of products accessible for fast collection or home delivery to clients is a key component in Alza.cz's success. The best e-shop with cutting-edge shopping tools. With a massive storage area of about 12000sqm. Alza PayBox has a digital cash desk that is operated by a computer. A large team of more than 300 specialists in their discipline. A massive branch network throughout the Czech Republic. Customers can contact Alza.cz for assistance. They collaborate with suppliers and manufacturers in the areas of business, marketing, and product design to meet the needs of customers. It contains about 36000 different goods. Financing, technical help, home delivery, product installation, and daily special prices for chosen products are just some of the services available.

4.3 Data Gathering procedure

Quantitative observation method: Observation is a technique that entails selecting, observing, listening, reading, touching, and recording the behavior and characteristics of live creatures, objects, or occurrences in a systematic manner. Using this strategy, researchers aim to comprehend behavior and cultures by learning about the individuals involved, as well as their values, rituals, symbols, beliefs, and emotions. When a methodology is specifically developed to address a research issue and is methodically planned and conducted with sufficient controls, it qualifies as a scientific method of data collecting. The fundamental benefit of observation is that it is straightforward. We can capture data as soon as it happens. The observer is not required to question people about their actions or hear reports from others. Anyone can simply observe how people act and speak. While survey respondents may have a foggy or lapse memory about events that occurred in the distant past, the observer is paying attention to what is happening right now.

4.4 Data collection & preparation

For data collection, we will use alza.cz e-commerce website. As a data collection profile, we consider a student who recently got admitted to a university, who needs a laptop, mobile, and monitor. So that we will collect data for 3 products laptop, mobile, and monitor. For all products, we will first select them and add them in comparison and then we will take data altogether from compare section of that website. We will choose similar kinds of products with similar costs; this will provide us perfect case for selecting the right product using MADM. As a student profile we are considering an affordable range during choosing the product, for a laptop, it’s near 19,000-26000 czk, for mobile, it is 14,000-19,000 czk and for Monitor, it is 4,000-6,000 czk.

Weight distribution: For the laptop, we will use the scoring method for getting the weight out of a number, and then we will make it normalized and we will use it for weight.

Price(czk)	Storege(GB)	RAM(GB)	Processore(GHZ)	Core	Display(HZ)	Battery capacity(WH)	Weight(KG)	Dimention(cm^3)	Total
20	10	15	15	10	10	10	5	5	100
0.2	0.1	0.15	0.15	0.1	0.1	0.1	0.05	0.05	

Picture 1: Weight distribution calculation for laptop selection

For the mobile, we will use the scoring method for getting the weight out of a number, and then we will make it normalized and we will use it for weight.

Price(czk)	Storege(GB)	RAM(GB)	Processore(GHZ)	Rear camera(px)	Front camera(px)	Display size(inch)	Display pixel(ppi)	Batery capacity(wh)	Total
25	10	10	10	15	10	5	5	10	100
0.25	0.1	0.1	0.1	0.15	0.1	0.05	0.05	0.1	

Picture 2: Weight distribution calculation for mobile selection

For the monitor, we will use the scoring method for getting the weight out of a number, and then we will make it normalized and we will use it for weight.

Price(czk)	Display size(cm)	Refresh rate(HZ)	Response time(s)	Power cosumption(W)	Total hdmi port	Total
40	20	15	10	5	10	100
0.4	0.2	0.15	0.1	0.05	0.1	

Picture 3: Weight distribution calculation for monitor selection

Laptop: For laptop we are selecting from 8 laptop for our case studies. First, we will select 8 laptops from our choice in similar cost range and will add them in compare. Then we will select attributes for those Laptops to choose. Some of them will be Beneficial attributes and some of them will be non-beneficial attributes. Price, weight, and dimension will be non-beneficial attributes. Storage, RAM, Processor, Core, Display and Battery capacity will be Beneficial Attributes. We will Divide the weight among them according to our weight calculation.

Weight	0.2	0.1	0.15	0.15	0.1	0.1	0.1	0.05	0.05
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(HZ)	Core	Display(HZ)	Batery capacity(WH)	weight(KG)	Dimention(cm^3)
MSI Katana GF66 11SC-685CZ	23527	512	8	4.5	6	144	53.5	2.25	2315.22
ASUS Zenbook 14 UM425QA-KI075T	25990	512	16	4.4	8	60	63	1.3	1058.44
Huawei MateBook 14	25804	512	16	4.2	8	60	56	1.49	1094.21
Acer Spin 3 Pure	25067	512	8	4.2	4	60	56	1.4	1068.4
Dell Inspiron 14	24572	512	8	4.2	4	60	52	1.3	1282.07
Microsoft Surface Laptop Go	19900	128	8	3.6	4	60	39.7	1.1	897.67
HP ProBook 450	24463	512	8	4.2	4	60	45	1.74	1672.877
Lenovo Yoga Duet 7 13ITL6	22489	256	8	4.2	4	60	41	0.8	566.85

Picture 4: Collected data for laptop selection(Source:Alza.cz)

Mobile: For Mobile we are selecting from 7 Mobile for our case studies. First, we will select 7 Mobile from our choice in similar cost range and will add them in compare. Then we will select attributes for those Mobile to choose. Some of them will be Beneficial attributes and some of them will be non-beneficial attributes. Price will be non-beneficial attributes.

Storage, RAM, Processor, Rear camera, Front camera, Display size, Display pixel and Battery capacity will be Beneficial Attributes. We will divide the weight among them according to our weight calculation.

Weight	0.25	0.1	0.1	0.1	0.15	0.1	0.05	0.05	0.1
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(GHZ)	Rear camera(px)	Front camera(px)	Display size(inch)	Display pixel(ppi)	Batery capacity(WH)
Oneplus 9	14999	128	8	2.8	48	16	6.55	402	4500
Asus Zenfone 8	17516	128	8	2.84	64	12	5.92	446	4000
Samsung Galaxy S21	18395	128	6	2.9	12	32	6.4	401	4500
Google Pixel 6	18762	128	8	2.28	50	8	6.4	411	4614
Motorola EDGE 20	15299	256	12	3.2	108	32	6.7	394	4500
VIVO x60	16999	256	12	3.2	48	32	6.57	398	4200
Xiaomi 11T	14999	256	8	2.84	108	16	6.67	395	5000

Picture 5: Collected data for mobile selection(Source:Alza.cz)

Monitor: For Monitor we are selecting from 8 Monitor for our case studies. First, we will select 8 Monitor from our choice in similar cost range and will add them in compare. Then we will select attributes for those Monitor to choose. Some of them will be Beneficial attributes and some of them will be non-beneficial attributes. Price will be non-beneficial attributes. Display size, refresh rate, response time, power consumption, total HDMI port will be Beneficial Attributes. We will Divide the weight among them according to our weight calculation.

weight	0.4	0.2	0.15	0.1	0.05	0.1
	price/cost(czk)	Display size(cm)	Refresh rate(HZ)	response time(s)	Power consumption(W)	Total HDMI port
ASUS TUF Gaming VG249Q	5358	60.96	144	1	16	1
HP E23 G4	5442	58.42	60	5	51	1
LG Ultragear 24GN650	5320	60.4	144	1	32	2
Lenovo ThinkVision T23i-20	5074	58.42	60	4	14.5	1
Dell P2319HE Professional	5190	58.42	60	8	16	1
Samsung S24R650	5227	60.96	75	5	18	1
AOC 24G2U/BK	4908	60.4	144	1	21	2
Acer CB242Y	4890	60.45	75	1	16	1

Picture 6: Collected data for monitor selection(Source:Alza.cz)

4.5 Case studies

4.5.1 Case study 1:

Calculation of normalized decision matrix: First we will make the matrix normalized according to this formula.

$$\bar{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{j=1}^{n} X_{ij}^2}} \qquad (4.1)$$

For that we will first square all attributes value X_{ij}^2 of each option. Then We will calculate sum of each column $\sum_{j=1}^{n} X_{ij}^2$ and will get the root of that sum this will give us the value of

$\sqrt{\sum_{j=1}^{n} X_{ij}^{2}}$. Then we will divide each cell value with that will give the value of each cell's X_{ij} values.

Weight	0.2	0.1	0.15	0.15	0.1	0.1	0.1	0.05	0.05
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(HZ)	Core	Display(HZ)	Batery capacity(WH)	weight(KG)	Dimention(cm^3)
MSI Katana GF66 11SC-685CZ	0.345866109	0.398014876	0.267264	0.379277843	0.3846154	0.67187087	0.368402262	0.537849806	0.610354324
ASUS Zenbook 14 UM425QA-KI075T	0.38207422	0.398014876	0.534527	0.370849447	0.5128205	0.27994619	0.433819486	0.310757665	0.27903328
Huawei MateBook 14	0.379339868	0.398014876	0.534527	0.353992654	0.5128205	0.27994619	0.385617321	0.356176093	0.288463215
Acer Spin 3 Pure	0.368505366	0.398014876	0.267264	0.353992654	0.2564103	0.27994619	0.385617321	0.334662101	0.281659004
Dell Inspiron 14	0.361228462	0.398014876	0.267264	0.353992654	0.2564103	0.27994619	0.358073226	0.310757665	0.337988169
Microsoft Surface Laptop Go	0.292546247	0.099503719	0.267264	0.303422275	0.2564103	0.27994619	0.273375136	0.262948794	0.23664998
HP ProBook 450	0.359626073	0.398014876	0.267264	0.353992654	0.2564103	0.27994619	0.309871061	0.415937183	0.441015416
Lenovo Yoga Duet 7 13ITL6	0.330606661	0.199007438	0.267264	0.353992654	0.2564103	0.27994619	0.282326967	0.191235486	0.149436921

Picture 7: Calculation of normalized decision matrix for laptop slection (Source:Alza.cz)

Calculation of weighted normalized decision matrix: Then we will calculate the weighted normalized matrix by multiplying each column with respective weight given according to this formula:

$$\boldsymbol{V_{ij}} = \overline{\boldsymbol{X}}_{\boldsymbol{ij}} \times \boldsymbol{W_j} \qquad (4.2)$$

Weight	0.2	0.1	0.15	0.15	0.1	0.1	0.1	0.05	0.05
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(HZ)	Core	Display(HZ)	Batery capacity(WH)	weight(KG)	Dimention(cm^3)
MSI Katana GF66 11SC-685CZ	0.069173222	0.039801488	0.04009	0.056891676	0.0384615	0.06718709	0.036840226	0.02689249	0.030517716
ASUS Zenbook 14 UM425QA-KI075T	0.076414844	0.039801488	0.080179	0.055627417	0.0512821	0.02799462	0.043381949	0.015537883	0.013951664
Huawei MateBook 14	0.075867974	0.039801488	0.080179	0.053098898	0.0512821	0.02799462	0.038561732	0.017808805	0.014423161
Acer Spin 3 Pure	0.073701073	0.039801488	0.04009	0.053098898	0.025641	0.02799462	0.038561732	0.016733105	0.01408295
Dell Inspiron 14	0.072245692	0.039801488	0.04009	0.053098898	0.025641	0.02799462	0.035807323	0.015537883	0.016899408
Microsoft Surface Laptop Go	0.058509249	0.009950372	0.04009	0.045513341	0.025641	0.02799462	0.027337514	0.01314744	0.011832499
HP ProBook 450	0.071925215	0.039801488	0.04009	0.053098898	0.025641	0.02799462	0.030987106	0.020796859	0.022050771
Lenovo Yoga Duet 7 13ITL6	0.066121332	0.019900744	0.04009	0.053098898	0.025641	0.02799462	0.028232697	0.009561774	0.007471846

Picture 8: Calculation of weighted normalized decision matrix for laptop slection (Source:Alza.cz)

Determination of positive ideal solution and negative ideal solution: From each row's Value we will determine the positive ideal solution and negative ideal solution according to the nature of attributes. Those attributes are beneficial attributes their positive ideal solution V^+ will be max value from respective column and negative ideal solution V^- will be min value from respective column. Those attributes are nonbeneficial attributes their negative ideal solution V^- will be max value from respective column and positive ideal solution will be min value from respective column.

Weight	0.2	0.1	0.15	0.15	0.1	0.1	0.1	0.05	0.05
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(HZ)	Core	Display(HZ)	Batery capacity(WH)	weight(KG)	Dimention(cm^3)
MSI Katana GF66 11SC-685CZ	0.069173222	0.039801488	0.04009	0.056891676	0.0384615	0.06718709	0.036840226	0.02689249	0.030517716
ASUS Zenbook 14 UM425QA-KI075T	0.076414844	0.039801488	0.080179	0.055627417	0.0512821	0.02799462	0.043381949	0.015537883	0.013951664
Huawei MateBook 14	0.075867974	0.039801488	0.080179	0.053098898	0.0512821	0.02799462	0.038561732	0.017808805	0.014423161
Acer Spin 3 Pure	0.073701073	0.039801488	0.04009	0.053098898	0.025641	0.02799462	0.038561732	0.016733105	0.01408295
Dell Inspiron 14	0.072245692	0.039801488	0.04009	0.053098898	0.025641	0.02799462	0.035807323	0.015537883	0.016899408
Microsoft Surface Laptop Go	0.058509249	0.009950372	0.04009	0.045513341	0.025641	0.02799462	0.027337514	0.01314744	0.011832499
HP ProBook 450	0.071925215	0.039801488	0.04009	0.053098898	0.025641	0.02799462	0.030987106	0.020796859	0.022050771
Lenovo Yoga Duet 7 13ITL6	0.066121332	0.019900744	0.04009	0.053098898	0.025641	0.02799462	0.028232697	0.009561774	0.007471846
V+	0.058509249	0.039801488	0.080179	0.056891676	0.0512821	0.06718709	0.043381949	0.009561774	0.007471846
V-	0.076414844	0.009950372	0.04009	0.045513341	0.025641	0.02799462	0.027337514	0.02689249	0.030517716

Picture 9: Determination of positive ideal solution and negative ideal solution for laptop slection (Source:Alza.cz)

Calculation of separation measures using the n-dimensional Euclidean distance: For calculating Euclidean distance we will take substitute each row value from positive ideal solution V^+ and negative ideal solution V^- and will square them and add them each row value together and will get S_i^+ and S_i^- using this formula.

$$S_i^+ = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^+ \right)^2 \right]^{0.5} \qquad (4.3)$$

$$S_i^- = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^- \right)^2 \right]^{0.5} \qquad (4.4)$$

Weight	0.2	0.1	0.15	0.15	0.1	0.1	0.1	0.05	0.05		
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(HZ)	Core	Display(HZ)	Batery capacity(WH)	weight(KG)	Dimention(cm^3)	Si+	Si-
MSI Katana GF66 11SC-685CZ	0.069173222	0.039801488	0.04009	0.056891676	0.0384615	0.06718709	0.036840226	0.02689249	0.030517716	0.052531	0.053514
ASUS Zenbook 14 UM425QA-KI075T	0.076414844	0.039801488	0.080179	0.055627417	0.0512821	0.02799462	0.043381949	0.015537883	0.013951664	0.044	0.0626
Huawei MateBook 14	0.075867974	0.039801488	0.080179	0.053098898	0.0512821	0.02799462	0.038561732	0.017808805	0.014423161	0.044624	0.060672
Acer Spin 3 Pure	0.073701073	0.039801488	0.04009	0.053098898	0.025641	0.02799462	0.038561732	0.016733105	0.01408295	0.064531	0.038148
Dell Inspiron 14	0.072245692	0.039801488	0.04009	0.053098898	0.025641	0.02799462	0.035807323	0.015537883	0.016899408	0.064697	0.036771
Microsoft Surface Laptop Go	0.058509249	0.009950372	0.04009	0.045513341	0.025641	0.02799462	0.027337514	0.01314744	0.011832499	0.071488	0.029303
HP ProBook 450	0.071925215	0.039801488	0.04009	0.053098898	0.025641	0.02799462	0.030987106	0.020796859	0.022050771	0.066989	0.03303
Lenovo Yoga Duet 7 13ITL6	0.066121332	0.019900744	0.04009	0.053098898	0.025641	0.02799462	0.028232697	0.009561774	0.007471846	0.067071	0.033087
V+	0.058509249	0.039801488	0.080179	0.056891676	0.0512821	0.06718709	0.043381949	0.009561774	0.007471846		
V-	0.076414844	0.009950372	0.04009	0.045513341	0.025641	0.02799462	0.027337514	0.02689249	0.030517716		

Picture 10: Calculation of separation measures using the n-dimensional Euclidean distance for laptop slection (Source:Alza.cz)

Calculation of relative closeness to the positive ideal solution: From S_i^+ and S_i^- we will calculate performance scoreP_i or relative closeness to the positive ideal solution using this formula.

$$P_i = \frac{S_i^-}{(S_i^+ + S_i^-)} \qquad (4.5)$$

Si+	Si-	Pi
0.052531	0.053514	0.504633
0.044	0.0626	0.587246
0.044624	0.060672	0.576203
0.064531	0.038148	0.371529
0.064697	0.036771	0.362392
0.071488	0.029303	0.290731
0.066989	0.03303	0.330236
0.067071	0.033087	0.33035

Picture 11: Calculation of relative closeness to the positive ideal solution for laptop slection (Source:Alza.cz)

Finding the rank of the preference order: From performance score or relative closeness to the positive ideal solution we will arrange them in rank.

	Si+	Si-	Pi	Rank
MSI Katana GF66 11SC-685CZ	0.052531	0.053514	0.504633	3
ASUS Zenbook 14 UM425QA-KI075T	0.044	0.0626	0.587246	1
Huawei MateBook 14	0.044624	0.060672	0.576203	2
Acer Spin 3 Pure	0.064531	0.038148	0.371529	4
Dell Inspiron 14	0.064697	0.036771	0.362392	5
Microsoft Surface Laptop Go	0.071488	0.029303	0.290731	8
HP ProBook 450	0.066989	0.03303	0.330236	7
Lenovo Yoga Duet 7 13ITL6	0.067071	0.033087	0.33035	6

Picture 12: Finding the rank of the preference order for laptop slection (Source:Alza.cz)

4.5.2 Case study 2:

Calculation of normalized decision matrix: First we will make the matrix normalized according to this formula.

$$\bar{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{j=1}^{n} X_{ij}^2}} \qquad (4.6)$$

For that we will first square all attributes value X_{ij}^2 of each option. Then We will calculate sum of each column $\sum_{j=1}^{n} X_{ij}^2$ and will get the root of that sum this will give us the value of

$\sqrt{\sum_{j=1}^{n} X_{ij}^2}$. Then we will divide each cell value with that will give the value of each cell's X_{ij} values.

Weight	0.25	0.1	0.1	0.1	0.15	0.1	0.05	0.05	0.1
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(GHZ)	Rear camera(px)	Front camera(px)	Display size(inch)	Display pixel(ppi)	Batery capacity(WH)
Oneplus 9	0.337917808	0.25	0.332181919	0.367469257	0.257766658	0.259827921	0.383039167	0.373262593	0.379400487
Asus Zenfone 8	0.394624197	0.25	0.332181919	0.372718818	0.343688877	0.194870941	0.346197232	0.414117205	0.337244877
Samsung Galaxy S21	0.4144275	0.25	0.24913644	0.380593159	0.064441664	0.519655842	0.374267278	0.372334079	0.379400487
Google Pixel 6	0.422695774	0.25	0.332181919	0.299224967	0.268506935	0.12991396	0.374267278	0.381619218	0.389011966
Motorola EDGE 20	0.344676615	0.5	0.498272879	0.419964866	0.57997498	0.519655842	0.391811057	0.365834481	0.379400487
VIVO x60	0.38297652	0.5	0.498272879	0.419964866	0.257766658	0.519655842	0.384208753	0.369548537	0.354107121
Xiaomi 11T	0.337917808	0.5	0.332181919	0.372718818	0.57997498	0.259827921	0.390056679	0.366762995	0.421556096

Picture 13: Calculation of normalized decision matrix for mobile slection (Source:Alza.cz)

Calculation of weighted normalized decision matrix: Then we will calculate the weighted normalized matrix by multiplying each column with respective weight given according to this formula:

$$\boldsymbol{V_{ij} = \overline{X}_{ij} \times W_j} \qquad (4.7)$$

Weight	0.25	0.1	0.1	0.1	0.15	0.1	0.05	0.05	0.1
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(GHZ)	Rear camera(px)	Front camera(px)	Display size(inch)	Display pixel(ppi)	Batery capacity(WH)
Oneplus 9	0.084479452	0.025	0.033218192	0.036746926	0.038664999	0.025982792	0.019151958	0.01866313	0.037940049
Asus Zenfone 8	0.098656049	0.025	0.033218192	0.037271882	0.051553332	0.019487094	0.017309862	0.02070586	0.033724488
Samsung Galaxy S21	0.103606875	0.025	0.024913644	0.038059316	0.00966625	0.051965584	0.018713364	0.018616704	0.037940049
Google Pixel 6	0.105673943	0.025	0.033218192	0.029922497	0.04027604	0.012991396	0.018713364	0.019080961	0.038901197
Motorola EDGE 20	0.086169154	0.05	0.049827288	0.041996487	0.086996247	0.051965584	0.019590553	0.018291724	0.037940049
VIVO x60	0.09574413	0.05	0.049827288	0.041996487	0.038664999	0.051965584	0.019210438	0.018477427	0.035410712
Xiaomi 11T	0.084479452	0.05	0.033218192	0.037271882	0.086996247	0.025982792	0.019502834	0.01833815	0.04215561

Picture 14: Calculation of weighted normalized decision matrix for mobile slection (Source:Alza.cz)

Determination of positive ideal solution and negative ideal solution: From each row's Value we will determine the positive ideal solution and negative ideal solution according to the nature of attributes. Those attributes are beneficial attributes their positive ideal solution V^+ will be max value from respective column and negative ideal solution V^- will be min value from respective column. Those attributes are nonbeneficial attributes their negative ideal solution V^- will be max value from respective column and positive ideal solution will be min value from respective column.

Weight	0.25	0.1	0.1	0.1	0.15	0.1	0.05	0.05	0.1
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(GHZ)	Rear camera(px)	Front camera(px)	Display size(inch)	Display pixel(ppi)	Batery capacity(WH)
Oneplus 9	0.084479452	0.025	0.033218192	0.036746926	0.038664999	0.025982792	0.019151958	0.01866313	0.037940049
Asus Zenfone 8	0.098656049	0.025	0.033218192	0.037271882	0.051553332	0.019487094	0.017309862	0.02070586	0.033724488
Samsung Galaxy S21	0.103606875	0.025	0.024913644	0.038059316	0.00966625	0.051965584	0.018713364	0.018616704	0.037940049
Google Pixel 6	0.105673943	0.025	0.033218192	0.029922497	0.04027604	0.012991396	0.018713364	0.019080961	0.038901197
Motorola EDGE 20	0.086169154	0.05	0.049827288	0.041996487	0.086996247	0.051965584	0.019590553	0.018291724	0.037940049
VIVO x60	0.09574413	0.05	0.049827288	0.041996487	0.038664999	0.051965584	0.019210438	0.018477427	0.035410712
Xiaomi 11T	0.084479452	0.05	0.033218192	0.037271882	0.086996247	0.025982792	0.019502834	0.01833815	0.04215561
V+	0.084479452	0.05	0.049827288	0.041996487	0.086996247	0.051965584	0.019590553	0.02070586	0.04215561
V-	0.105673943	0.025	0.024913644	0.029922497	0.00966625	0.012991396	0.017309862	0.018291724	0.033724488

Picture 15: Determination of positive ideal solution and negative ideal solution for mobile slection (Source:Alza.cz)

Calculation of separation measures using the n-dimensional Euclidean distance: For calculating Euclidean distance we will take substitute each row value from positive ideal solution V^+ and negative ideal solution V^- and will square them and add them each row value together and will get S_i^+ and S_i^- using this formula.

$$S_i^+ = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^+\right)^2\right]^{0.5} \qquad (4.8)$$

$$S_i^- = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^-\right)^2\right]^{0.5} \qquad (4.9)$$

Weight	0.25	0.1	0.1	0.1	0.15	0.1	0.05	0.05	0.1		
	price/cost(czk)	storage(GB)	RAM(GB)	Processore(GHZ)	Rear camera(px)	Front camera(px)	Display size(inch)	Display pixel(ppi)	Batery capacity(WH)	Si+	Si-
Oneplus 9	0.084479452	0.025	0.033218192	0.036746926	0.038664999	0.025982792	0.019151958	0.01866313	0.037940049	0.062941	0.039947
Asus Zenfone 8	0.098656049	0.025	0.033218192	0.037271882	0.051553332	0.019487094	0.017309862	0.02070586	0.033724488	0.059258	0.044438
Samsung Galaxy S21	0.103606875	0.025	0.024913644	0.038059316	0.00966625	0.051965584	0.018713364	0.018616704	0.037940049	0.087349	0.040116
Google Pixel 6	0.105673943	0.025	0.033218192	0.029922497	0.04027604	0.012991396	0.018713364	0.019080961	0.038901197	0.072192	0.032176
Motorola EDGE 20	0.086169154	0.05	0.049827288	0.041996487	0.086996247	0.051965584	0.019590553	0.018291724	0.037940049	0.005143	0.096404
VIVO x60	0.09574413	0.05	0.049827288	0.041996487	0.038664999	0.051965584	0.019210438	0.018477427	0.035410712	0.050134	0.062101
Xiaomi 11T	0.084479452	0.05	0.033218192	0.037271882	0.086996247	0.025982792	0.019502834	0.01833815	0.04215561	0.031287	0.08615
V+	0.084479452	0.05	0.049827288	0.041996487	0.086996247	0.051965584	0.019590553	0.02070586	0.04215561		
V-	0.105673943	0.025	0.024913644	0.029922497	0.00966625	0.012991396	0.017309862	0.018291724	0.033724488		

Picture 16: Calculation of separation measures using the n-dimensional Euclidean distance for mobile slection (Source:Alza.cz)

Calculation of relative closeness to the positive ideal solution: From S_i^+ and S_i^- we will calculate performance score P_i or relative closeness to the positive ideal solution using this formula.

$$P_i = \frac{S_i^-}{(S_i^+ + S_i^-)} \qquad (4.10)$$

Si+	Si-	P
0.062941	0.039947	0.388256
0.059258	0.044438	0.428544
0.087349	0.040116	0.314723
0.072192	0.032176	0.308297
0.005143	0.096404	0.94935
0.050134	0.062101	0.553311
0.031287	0.08615	0.733582

Picture 17: Calculation of relative closeness to the positive ideal solution for mobile slection (Source:Alza.cz)

Finding the rank of the preference order: From performance score or relative closeness to the positive ideal solution we will arrange them in rank.

	Si+	Si-	P	rank
Oneplus 9	0.062941	0.039947	0.388256	5
Asus Zenfone 8	0.059258	0.044438	0.428544	4
Samsung Galaxy S21	0.087349	0.040116	0.314723	6
Google Pixel 6	0.072192	0.032176	0.308297	7
Motorola EDGE 20	0.005143	0.096404	0.94935	1
VIVO x60	0.050134	0.062101	0.553311	3
Xiaomi 11T	0.031287	0.08615	0.733582	2

Picture 18: Finding the rank of the preference order for mobile slection (Source:Alza.cz)

4.5.3 Case study 3:

Calculation of normalized decision matrix: First we will make the matrix normalized according to this formula.

$$\mathbf{\bar{X}_{ij}} = \frac{\mathbf{X_{ij}}}{\sqrt{\sum_{j=1}^{n} \mathbf{X_{ij}^2}}} \qquad (4.11)$$

For that we will first square all attributes value X_{ij}^2 of each option. Then We will calculate sum of each column $\sum_{j=1}^{n} X_{ij}^2$ and will get the root of that sum this will give us the value of $\sqrt{\sum_{j=1}^{n} X_{ij}^2}$. Then we will divide each cell value with that will give the value of each cell's X_{ij} values.

weight	0.4	0.2	0.15	0.1	0.05	0.1
	price/cost(czk)	Display size(cm)	Refresh rate(HZ)	response time(s)	Power consumption(W)	Total HDMI port
ASUS TUF Gaming VG249Q	0.365727742	0.360328908	0.496085941	0.086386843	0.218375351	0.267261242
HP E23 G4	0.371461435	0.345315203	0.206702475	0.431934213	0.696071432	0.267261242
LG Ultragear 24GN650	0.363133928	0.3570188	0.496085941	0.086386843	0.436750702	0.534522484
Lenovo ThinkVision T23i-20	0.346342397	0.345315203	0.206702475	0.34554737	0.197902662	0.267261242
Dell P2319HE Professional	0.354260354	0.345315203	0.206702475	0.69109474	0.218375351	0.267261242
Samsung S24R650	0.35678591	0.360328908	0.258378094	0.431934213	0.24567227	0.267261242
AOC 24G2U/BK	0.335011526	0.3570188	0.496085941	0.086386843	0.286617648	0.534522484
Acer CB242Y	0.333782877	0.357314345	0.258378094	0.086386843	0.218375351	0.267261242

Picture 19: Calculation of normalized decision matrix for monitor slection (Source:Alza.cz)

Calculation of weighted normalized decision matrix: Then we will calculate the weighted normalized matrix by multiplying each column with respective weight given according to this formula:

$$\boldsymbol{V_{ij}} = \boldsymbol{\bar{X}_{ij}} \times \boldsymbol{W_j} \qquad (4.12)$$

weight	0.4	0.2	0.15	0.1	0.05	0.1
	price/cost(czk)	Display size(cm)	Refresh rate(HZ)	response time(s)	Power consumption(W)	Total HDMI port
ASUS TUF Gaming VG249Q	0.146291097	0.072065782	0.074412891	0.008638684	0.010918768	0.026726124
HP E23 G4	0.148584574	0.069063041	0.031005371	0.043193421	0.034803572	0.026726124
LG Ultragear 24GN650	0.145253571	0.07140376	0.074412891	0.008638684	0.021837535	0.053452248
Lenovo ThinkVision T23i-20	0.138536959	0.069063041	0.031005371	0.034554737	0.009895133	0.026726124
Dell P2319HE Professional	0.141704142	0.069063041	0.031005371	0.069109474	0.010918768	0.026726124
Samsung S24R650	0.142714364	0.072065782	0.038756714	0.043193421	0.012283614	0.026726124
AOC 24G2U/BK	0.13400461	0.07140376	0.074412891	0.008638684	0.014330882	0.053452248
Acer CB242Y	0.133513151	0.071462869	0.038756714	0.008638684	0.010918768	0.026726124

Picture 20: Calculation of weighted normalized decision matrix for monitor slection (Source:Alza.cz)

Determination of positive ideal solution and negative ideal solution: From each row's Value we will determine the positive ideal solution and negative ideal solution according to the nature of attributes. Those attributes are beneficial attributes their positive ideal solution V^+ will be max value from respective column and negative ideal solution V^- will be min value from respective column. Those attributes are nonbeneficial attributes their negative ideal solution V^- will be max value from respective column and positive ideal solution will be min value from respective column.

weight	0.4	0.2	0.15	0.1	0.05	0.1
	price/cost(czk)	Display size(cm)	Refresh rate(HZ)	response time(s)	Power consumption(W)	Total HDMI port
ASUS TUF Gaming VG249Q	0.146291097	0.072065782	0.074412891	0.008638684	0.010918768	0.026726124
HP E23 G4	0.148584574	0.069063041	0.031005371	0.043193421	0.034803572	0.026726124
LG Ultragear 24GN650	0.145253571	0.07140376	0.074412891	0.008638684	0.021837535	0.053452248
Lenovo ThinkVision T23i-20	0.138536959	0.069063041	0.031005371	0.034554737	0.009895133	0.026726124
Dell P2319HE Professional	0.141704142	0.069063041	0.031005371	0.069109474	0.010918768	0.026726124
Samsung S24R650	0.142714364	0.072065782	0.038756714	0.043193421	0.012283614	0.026726124
AOC 24G2U/BK	0.13400461	0.07140376	0.074412891	0.008638684	0.014330882	0.053452248
Acer CB242Y	0.133513151	0.071462869	0.038756714	0.008638684	0.010918768	0.026726124
V+	0.133513151	0.072065782	0.074412891	0.069109474	0.034803572	0.053452248
V-	0.148584574	0.069063041	0.031005371	0.008638684	0.009895133	0.026726124

Picture 21: Determination of positive ideal solution and negative ideal solution for monitor slection (Source:Alza.cz)

Calculation of separation measures using the n-dimensional Euclidean distance: For calculating Euclidean distance we will take substitute each row value from positive ideal solution V^+ and negative ideal solution V^- and will square them and add them each row value together and will get S_i^+ and S_i^- using this formula.

$$\mathbf{S_i^+} = \left[\sum_{\mathbf{j=1}}^{\mathbf{m}} \left(\mathbf{V_{ij}} - \mathbf{V_j^+}\right)^{\mathbf{2}}\right]^{\mathbf{0.5}} \qquad (4.13)$$

$$\mathbf{S_i^-} = \left[\sum_{\mathbf{j=1}}^{\mathbf{m}} \left(\mathbf{V_{ij}} - \mathbf{V_j^-}\right)^{\mathbf{2}}\right]^{\mathbf{0.5}} \qquad (4.14)$$

weight	0.4	0.2	0.15	0.1	0.05	0.1		
	price/cost(czk)	Display size(cm)	Refresh rate(HZ)	response time(s)	Power consumption(W)	Total HDMI port	Si+	Si-
ASUS TUF Gaming VG249Q	0.146291097	0.072065782	0.074412891	0.008638684	0.010918768	0.026726124	0.071448	0.043584
HP E23 G4	0.148584574	0.069063041	0.031005371	0.043193421	0.034803572	0.026726124	0.059214	0.042596
LG Ultragear 24GN650	0.145253571	0.07140376	0.074412891	0.008638684	0.021837535	0.053452248	0.062953	0.052514
Lenovo ThinkVision T23i-20	0.138536959	0.069063041	0.031005371	0.034554737	0.009895133	0.026726124	0.066687	0.027796
Dell P2319HE Professional	0.141704142	0.069063041	0.031005371	0.069109474	0.010918768	0.026726124	0.056966	0.06087
Samsung S24R650	0.142714364	0.072065782	0.038756714	0.043193421	0.012283614	0.026726124	0.057001	0.036101
AOC 24G2U/BK	0.13400461	0.07140376	0.074412891	0.008638684	0.014330882	0.053452248	0.063848	0.053256
Acer CB242Y	0.133513151	0.071462869	0.038756714	0.008638684	0.010918768	0.026726124	0.078824	0.017148
V+	0.133513151	0.072065782	0.074412891	0.069109474	0.034803572	0.053452248		
V-	0.148584574	0.069063041	0.031005371	0.008638684	0.009895133	0.026726124		

Picture 22: Calculation of separation measures using the n-dimensional Euclidean distance for monitor slection (Source:Alza.cz)

Calculation of relative closeness to the positive ideal solution: From S_i^+ and S_i^- we will calculate performance scoreP_i or relative closeness to the positive ideal solution using this formula.

$$\mathbf{P_i} = \frac{\mathbf{S_i^-}}{(\mathbf{S_i^+} + \mathbf{S_i^-})} \qquad (4.15)$$

Si+	Si-	P
0.071448	0.043584	0.378885
0.059214	0.042596	0.41839
0.062953	0.052514	0.454794
0.066687	0.027796	0.294186
0.056966	0.06087	0.516565
0.057001	0.036101	0.387759
0.063848	0.053256	0.454778
0.078824	0.017148	0.178673

Picture 23: Calculation of relative closeness to the positive ideal solution for monitor slection (Source:Alza.cz)

Finding the rank of the preference order: From performance score or relative closeness to the positive ideal solution we will arrange them in rank.

	Si+	Si-	P	rank
ASUS TUF Gaming VG249Q	0.071448	0.043584	0.378885	6
HP E23 G4	0.059214	0.042596	0.41839	4
LG Ultragear 24GN650	0.062953	0.052514	0.454794	2
Lenovo ThinkVision T23i-20	0.066687	0.027796	0.294186	7
Dell P2319HE Professional	0.056966	0.06087	0.516565	1
Samsung S24R650	0.057001	0.036101	0.387759	5
AOC 24G2U/BK	0.063848	0.053256	0.454778	3
Acer CB242Y	0.078824	0.017148	0.178673	8

Picture 24: Finding the rank of the preference order for monitor slection (Source:Alza.cz)

5 Results & Discussion

Findings: In all three case studies we have applied the TOPSIS method for getting the best option for our purchasing purpose. In case study 1 this problem deals with the selection of laptops. The case considers a selection of data with 8 laptops evaluated across 9 attributes. The attributes for this study are price in czk, storage in GB, RAM in GB, the processor in GH, Core in number, display refresh rate in Hz, battery capacity in WH, weight in kg, Dimension in centimetre cube. Among them price, weight, dimension are non-beneficial attributes means if the value of these attributes is low then it is better and 6 of them are beneficial attributes means if the value of these attributes is high then it is better. After applying the TOPSIS method we can see option 2 from top ASUS ZenBook 14 UM425QA-KI075T is the best option among all 8 options. In case study 2 this problem deals with the selection of mobiles. The case considers a selection of data with 7 mobiles evaluated across 9 attributes. The attributes for this study are price in czk, storage in GB, RAM in GB, the processor in GH, rear camera in px, front camera in px, display size in inch, display pixel in PPI, battery capacity in wh. Among them price is non-beneficial attributes means if the value of these attributes is low then it is better and 8 of them are beneficial attributes means if the value of these attributes is high then it is better. After applying the TOPSIS method we can see option 5 from top Motorola EDGE 20 is the best option among all 7 options. In case study 3 this problem deals with the selection of monitors. The case considers a selection of data with 8 monitors evaluated across 6 attributes. The attributes for this study are price in czk, display size in cm, refresh rate in Hz, response time in second, power consumption in kWh. Among them price is non-beneficial attributes means if the value of these attributes is low then it is better and 5 of them are beneficial attributes means if the value of these attributes is high then it is better. After applying the TOPSIS method we can see option 5 from the top Dell P2319HE Professional is the best option among all 8 options.

Limitations: After all this benefit there is some limitations in TOPSIS method as well, these are below:

• Euclidean distance ignores the relationship between criteria.

• Consistency

• Vector normalization may be affected by the evaluation unit of a criterion function

• Rank reversal problem

• Maximum and minimum values must be identified

6 Conclusion

Decision-making can be an extremely daunting task because of the problem's complicated nature. MADM can be used as a decision aid to help analyze, prioritize, and pick suitable alternatives from a set of available options with often conflicting features.

According to our objective, our primary goal of this paper was to use a multi-attribute decision-making approach or MADM for the purchase of new equipment using the TOPSIS method. The literature review part discusses the process and approaches for decision making, different kinds of the ok decision-making process, and related works. We have also discussed some popular concepts and theories of MADM including AHP, VIKOR, TOPSIS, and MADM's applications.

We selected data collection methods and sources in the practical section. We have collected data from alza.cz e-commerce website and stored it in excel formats. We applied TOPSIS methods to find out the best option from them. Results are shown as rank in excel, best rank is the best option for purchase.

From our result, we can see among close cost and feature multi attributes decision making can provide pretty good result according to our needs in the purchase of new equipment.

Finally, we can say this MADM application can be utilized in other complex data environments and any 3rd party website or organization can use this procedure to assist their customers or users to find suitable products according to their needs. Furthermore, this procedure provides researchers with information on variables that are relevant to e-commerce companies looking for a new product to launch in their business.

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