Introduction To Decision Support System

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PREFACE

Praise belongs only to God Almighty, who has given His grace and guidance so that this textbook with the title "Decision Support System" can be completed. The author would also like to thank several parties who have helped in the completion of this paper.

This book is expected to help students, especially students in the field of information technology or related fields with informatics who are currently taking this course. This book discusses technology for developing decision support system applications to support management in making decisions. Decision-making is not only supported by the intuition of the leadership but is supported by the results of analyzing a set of data using certain methods.

The author realizes that this book still has some in-depth discussions. This is because the theory and implementation of the Decision Support System are very broad in shaping human activities in all fields of society. Therefore, the author expects criticism and suggestions both in writing and orally. so that the author can develop knowledge, especially in the field of decision support systems.

Malang, July 2022

Authors

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CHAPTER 1
OPENING INSIGHT

A. The Need for Decision Support System

In an organization, the decision support system has a priority in planning various things that have to do with manager decisions in overcoming semi-structured or unstructured problems. Managerial matters are the main things in an organization to be considered and look for the root of the problem and what kind of solution to the problem. For example, in managerial organizational matters, the decision support system can be used to solve sales or marketing problems, inventory problems, land clearing problems, and other things.

Decision support systems have the flexibility of time and place to provide decision recommendations. This is interesting because the conditions of the era that demand information quickly, have distance barriers, recommendation conditions that cannot be decided directly, the need for data confidentiality, and access anytime anywhere can be overcome by the decision support system. For example, there are problems regarding timeliness if data access is done in real time. Several things in the field of organization require conditions like this, for example, in the field of handling sales or marketing problems. Customers need certainty quickly and precisely because they have limited time for their respective activities. So, this is where the role of the decision support system can be seen.

A decision support system is a form of unified computer and decision logic that is arranged in such a way that it can solve problems effectively and efficiently. From this one circle, the form of an unorganized managerial arrangement can be neater and not only become information but also become a recommendation for a decision. The recommendations are also strongly influenced by subjective data or things in accordance with the conditions and policies that were in effect at the time the decision was made. Since in the beginning, the decision support

system handled organizational problems related to managerial matters, many business organizations have used decision support systems to support problems in their organizations.

Decision support systems are not new but increasing year after year. The technology used is also constantly being upgraded and the amount of data involved can also increase and even be associated with big data, which not only handles information in bytes or kilobytes, but can be up to terabytes and petabytes. It is conceivable, for data of such large size, how much information can be collected, organized, and processed so that it can become sub-recommendations that can be used in solving overall problems within an organization. In addition, the data that is processed as decision support also has time series information that can reveal trends that are very useful for the progress of the organization in the future.

The idealistic form that is expected with decision recommendations can lead to maximum profits, minimal losses, saving resources, selecting the right expenses, expanding sales networks, increasing collaboration relationships, and also other things that were unexpected before if an organization did not use a decision support system.

The input data in the decision support system has the form of alternative weights and criteria. Alternatives are several options that will be decided as a solution and are usually sorted in ascending order. While the criteria are the determining factors or attributes in the selection of the selected alternative, The criteria also have their own weights that are adjusted to the decision maker's priorities in choosing alternatives. It should be noted that subjectivity is very influential in determining decision recommendations using a decision support system. The form of presentation of input data varies depending on the logic of the calculation method used. various, but all share the same concept of alternative weights per criterion and/or criterion weights. The output, or what is expected from the decision support system, can be stated clearly. It is hoped that it will provide recommendations to the decision maker regarding which alternative has a tendency to be chosen in order until the

last data point is recommended to be selected. After the recommendation is complete, it can be continued with a final decision by the decision maker to choose an alternative in accordance with the recommendation of the decision support system or not. Because human intuition can still not be replaced by technology.

The concept and implementation of the decision support system are quite simple and easy to do. Therefore, now other fields are also interested in making recommendations for solving their respective problems using the decision support system. The following is an explanation of simple examples that are often encountered when discussing decision support systems. Even in other sub-chapters in this chapter, their role in important fields in our society is explained.

A brief explanation of some examples of implementing a decision support system are as follows:

1) Hotel selection
   Hotel recommendations are needed for domestic and foreign tourists who do not have knowledge of tourist destinations or already have knowledge of tourist attractions but want to try hotel destinations that have never been visited. The selection of this hotel has various criteria, it can even be different from one person to another. Therefore, it is necessary to consider how the form of the user interface developed to decide support system regarding the selection of hotels will be considered.

2) House selection
   Choosing a house is not an easy thing. Confusion often occurs because of the limitations or many determinants of home buying. Road conditions, budget, facilities, and many other things can be considered when buying a house. So, for individuals or families who are going to buy a house, to help them solve these problems, a decision support system is needed that can provide quick recommendations to potential

buyers. Making a system with interactive user dialog is needed in this case.

3) Selection of Majors in Higher Education
   The more modern times, the more reforms that are carried out by universities both domestically and abroad as an effort to answer the challenges of the times in the field of education. In addition, career needs in accordance with job vacancies are also a core consideration in the selection of majors for prospective college students. To help recommend a suitable place, a dynamic decision support system is also needed which is adapted to the curriculum and the needs of today's industry.

4) Selection of Tourist Places
   The selection of tourist attractions has a relationship with the selection of hotels that have been described previously. The selection of these tourist attractions can also be determined by the purpose of the tour and the number of people who participate in tourism activities. The more people involved, the more criteria or considerations in deciding the best tourist attractions according to them. Decision support systems can also provide a solution to this problem.

5) Employee Performance Assessment
   Each organization that employs employees has different standards in terms of providing salaries to employees. Therefore, a decision support system is needed with a different set of criteria that supports the problem of evaluating employee performance. This can also be modified not only in terms of money, but also the position of an employee in a particular company or organization.

6) Teacher Certification Assessment
   At different times, it could be that the prerequisites for assessing teacher certification may vary. However, they have similarities in the complexity of the assessment

because it involves quite a lot of determining factors. Many criteria or determining factors, as well as many teachers also require a decision support system in terms of teacher certification assessments so that they can be carried out quickly, and although there is a decision maker subjectivity, they are limited fairly because each criterion already has a standard range of assessment. pre-arranged and agreed upon.

7) Toddler Health Handling
   The health of toddlers is also very important to be assisted with a decision support system. This is due to the condition of toddlers who are still prone to disease and as an indication if there are abnormalities or severe conditions can also be known since toddlers. Therefore, there is also a government posyandu program which is carried out regularly once a month for checking the condition of toddlers (no need to wait for illness). From this kind of activity, information is obtained for toddlers including the criteria for determining the condition of toddlers' health.

8) Appointment of principal
   The principal as the highest position in terms of school management is very core to be assisted with a decision support system. Determining factors such as achievement, discipline, firmness, and other things really need to be considered in the selection of the principal position. This selection is certainly not easy and complicated and will become lighter with the recommendations provided by the system.

B. Difference between Management Information System and Decision Support System

Management information system is a unit consisting of people, procedures, software, databases that give and receive

information or exchange information in a single environment and the same routine. The information in this environment can be used as the basis for taking an action for all users involved, especially for the highest managers or decision makers.

Management information systems are very important in a company or institution, especially in terms of managing operations. Management, and other Steps to a condition encountered. An example can be seen in Figure 1.

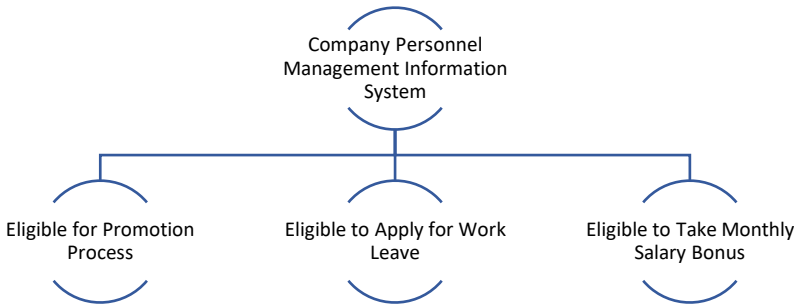

Figure 1. Overview About Company Personnel Management Information System

Figure 1 describes the Company's Personnel Management Information. Some information is available there, including information on the condition of personnel so that promotions can be processed, data on personnel discussing the terms and conditions for allowing employee leave; and information on determining employee monthly bonuses. These three things are examples of a lot of information available in the company's personnel management information system.

A decision support system can also be defined as a collection of people, procedures, software, and databases that

are also supported by tools related to information technology that support a decision. The application of a decision support system in the life of a company organization, for example, is very much needed in supporting decisions to solve employee problems or other management strategies, for example in terms of marketing or cooperation.

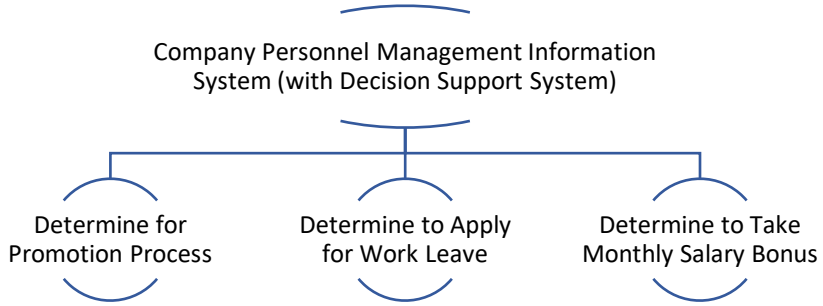

Figure 2. Overview About Company Personnel Management Information System

Figure 1 and Figure 2 are related if the first picture is an example of the things or information available in the Management Information System in a company, especially in terms of staffing. The first picture focuses on the use of information in the Management Information System to be used as a supporter to decide on several things, such as determining the Employee Promotion Process, determining to apply for work leave, and determining to take a monthly salary bonus. So, if it is abbreviated, actually a decision support system is something that can be added to the Management Information System by utilizing existing information. It is processed by certain methods so that it the relationship between the feasibility of the production decision support system, as illustrated in Figure 3.

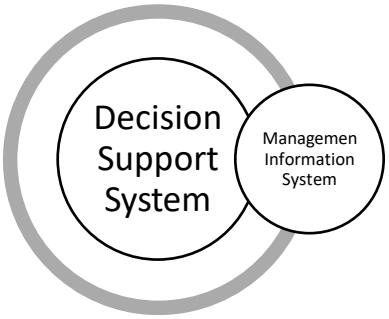

Figure 3. The Relationship Between The Feasibility of The Production Decision Support System

C. Clinical Decision Support System

A clinical decision support system (CDSS) is very much needed, especially when a pandemic hits the world early in 2018. Knowledge of patient health information as well as clinical knowledge of patient care history is needed to decide the right steps to take for patient care. in advance. This type of decision support system integrates patient information so that it is useful for health workers, including doctors, to get recommendations on what steps or actions can be taken based on the information available in the system.

The combination of the knowledge possessed by the doctor and the decision recommendations from the CDSS enables the final decision on the patient's action to be carried out more quickly. A series of CDSS systems involves computer technology, websites, and database settings that are connected to each other to be able to get output recommendations for patient care. But again, the CDSS recommendation can't beat the intuitive role of a doctor. Therefore, combining with the doctor's subjectivity, the use of both kinds of information is very necessary.

According to Sutton et al., health service providers have improved services due to CDSS. Health services are of high quality thanks to advances in information technology that utilizes electronic medical record information, which affects several factors such as speed, ease of disseminating information, and the absence of space and time limitations in exchanging information on patients' medical records. According to Figure 4, CDSS not only have rules that come from expert knowledge or rules that are determined by artificial intelligence technology.

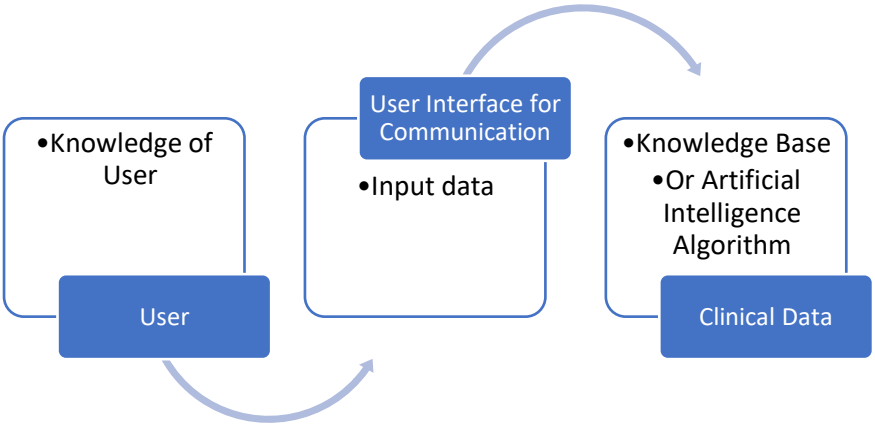

Figure 4. Clinical Decision Support System Oeverview

CDSS has the following functions and advantages:

1) Patient safety
   Patient safety in CDSS is defined by possible outcomes of strategies to reduce the rate of medication errors.

2) Clinical management
   Clear standards in the CDSS help with patient management as well as the care process.

3) Cost containment

CDSS can have the effect of reducing the number of hospitalizations and can also suggest cheaper treatment in conditions where it is still possible.

4) Administrative functions
   Administrative functions in the form of clinical coding, diagnostics, ordering procedures and tests as well as patient triage.

5) Diagnostics support
   Provide a computerized patient consultation place so as to produce an output of possible diagnoses.

6) Patient-facing decision support
   Using personal health records, information about patients is integrated as a supporting tool for making joint decisions between patients and providers.

D. Decision Support System for Business Intelligence

Information technology associated with business practices can be said to be data warehousing. Management of data related to business data is indeed very large and certainly requires management techniques that are clearly targeted so that they can be converted into good information and be distributed at any time. Business is closely related to time and cannot wait because the process and competition quickly move every day. Slow conditions in business can have fatal effects, even to losses, because as we know, business, especially the sales department, of course, every day, every hour, even at any time can be carried out or transactions occur.

As a solution, a business data repository is needed to support this need. New data settings or historical data can be used as useful reporting material. Information in the form of linguistic, numeric, categorical, or other forms can also be the basis for determining the layout, arrangement, and form of data storage in the database. Another thing that needs to be ensured

is that the regulation of incoming and outgoing data in the database that is passed should be able to occur smoothly.

Handling these solutions can be found in the business intelligence decision support system. The relationship between these two things can be seen in Figure 5. In the business intelligence or data warehouse environment, there are several decision factors that are then included in the decision support process that is supported by decision support tools. After the materials and tools are ready, the result can be processed, considering the interrelationships between the determinants of the desired solution. Then the outcome will be in the form of recommendations for the desired business problem.

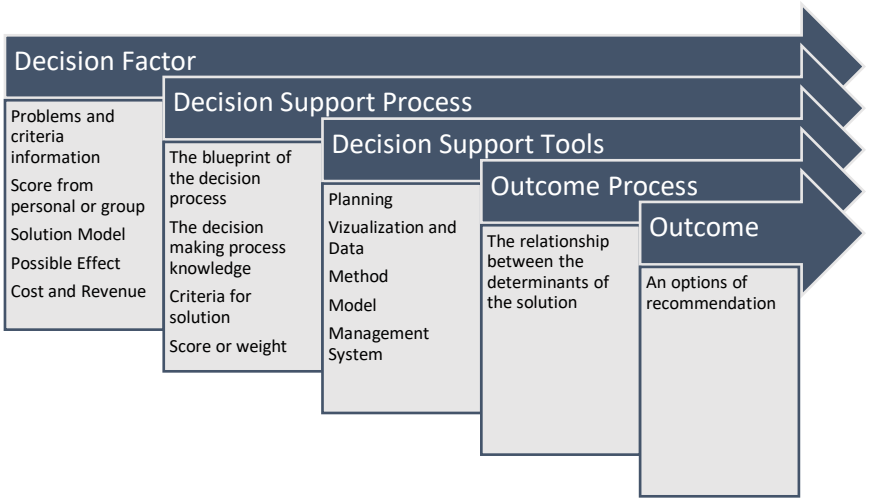

Figure 5. Decision Support System for Business Intelligence Overciew

E. Relation of Decision Support System with Artificial Intelligence

Decisions are taken by considering the influence of bad or good. The best decision for the decision maker is the one with the highest hope. Before deciding, it is necessary to study the characteristics of the decision by considering the category of decisions, including unstructured or semi-structured decisions. Only two types of categories were mentioned, because only these two categories were resolved by the decision support system. Problem-solving techniques in decision support systems are quite diverse. Using basic techniques in overcoming the conditions of multi-criteria decision making or using other techniques Another way that can be done is by utilizing artificial intelligence. This method imitates human intelligence in solving a problem. Artificial Intelligence is included in the field of Computer Science, which consists of Expert Systems, Fuzzy Logic, Neural Networks, Natural Language, Digital Image Processing, or Robotics.

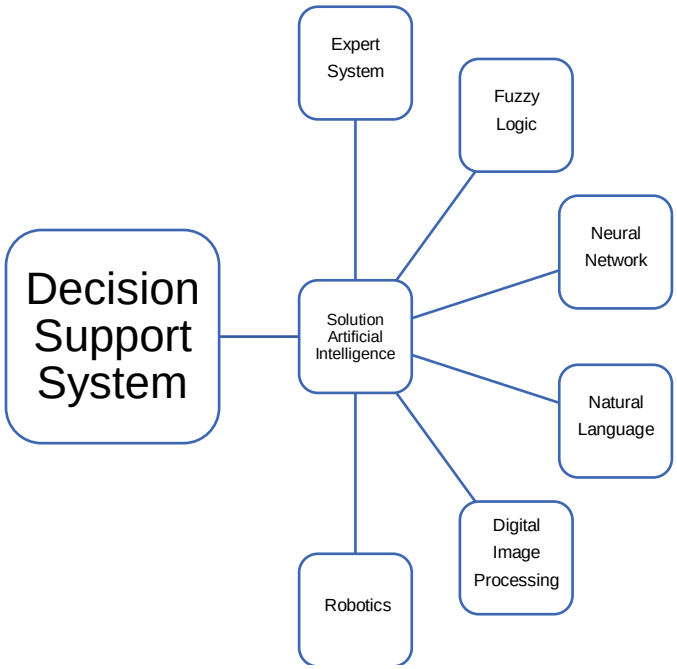

Figure 6. Decision Support System with Artificial Intelligence Overview

Combining decision support systems and artificial intelligence according to Figure 6 gives the system extra capabilities to solve problems in real time and intelligently. Problems that have a large number of solutions and require a complex solving process can be overcome by this merger.

F. Decision Support System for Forest Management

The stability of the biophysical system so that the results of natural resource management can meet the community's needs for goods and services. Therefore, in order to regulate and study the trend of the data, a decision support system is needed. This is very useful because we know that forest land in certain countries and even throughout the world is very large and the existence of information in it also needs to be managed and also given certain recommendations quickly to meet the needs of the community. Some examples that can be seen are ecosystem management decision support and also landscape management systems.

CHAPTER 2
INTRODUCTION

A. Definition

Decisions are decisive steps to find out what steps to take. According to experts, the decisions are:

1) What is mentioned in connection to a plan must be addressed by the decision. A totally different action from the original plan's implementation could also be taken in response to the decision (Ralp C. Davis).

2) The decision is a law or a law of the situation, claims Mary Follett. It is not the same as obeying an order if all the relevant information can be gathered and all parties, including implementers and supervisors, are prepared to abide by the law or its provisions. The exercise of authority continues, but it is now based on the applicable legal requirements.

3) A decision, in the words of James A.F. Stoner, is a choice among options. There is a decision based on reasoning or consideration, according to one of the three definitions in this phrase. There are various options available, and the best one is selected. The decision is moving in the right direction toward a goal that needs to be accomplished.

Management decisions to overcome problem conditions that have more complexity so that special handling and special strategies are also needed. According to the management hierarchy, according to Figure 7, the problems are hierarchically divided into: strategic management, tactical management, operations management. Operations management is at the lowest level because the things that are included in this level of management have the greatest number. However, it is in the lowest position because even though there are many things to

handle, the decision-making is easier than the 2 management levels above it. Problems at the lowest level are related to everyday things or routines in an organization. The second level, namely tactical management, can solve quite complex problems and requires special handling. The number of problems at this level is less than in operations management. The top level of the management hierarchy is strategic. Problems at this level are at least very complex and require special handling in solving. Decisions taken at this level can be the core of the sustainability wheel of an organization.

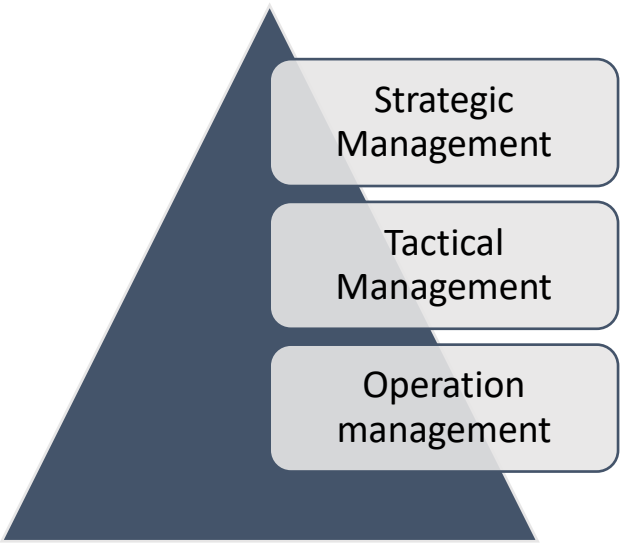

Figure 7. Management Hierarchy

Decisions have 3 types, namely: structured, semi-structured, and unstructured. The following is a brief definition and example of the three types:

- Structured Decision
  Decisions that have already been faced by the organization are referred to as structured or programmed decisions. Additionally, the staff is experienced in handling these issues. For instance, a company might

hire new IT expertise. Many analysts divide decisions into different categories based on how structured the decision-making process is. A structured choice is one in which the facts, procedure, and evaluation are all predetermined, according to business experts. In commercial settings, structured judgments are frequently made, therefore it makes sense to set up a relatively tight framework for the decision-making process.

- Semi-structured Decision

  decisions that fall in between structured and unstructured, requiring some human judgment but also having some consensus on the approach. area of most DSSs' attention. Semi-structured decisions fall in the middle of the continuum, and this is where the majority of what are regarded as real decision support systems are concentrated. These decisions are defined by some degree of consensus regarding the data, procedure, and/or evaluation to be employed, but they are also characterized by an attempt to retain some degree of human discretion in the decision-making process. Understanding where the decision maker's limits may manifest is the first step in determining which assistance system is necessary.

- Unstructured Decision

  Unstructured decisions are located at the other end of the spectrum. There is little consensus regarding the nature of these, even though they share the same elements as structured ones data, procedure, and evaluation. For instance, when making unstructured judgments, each decision-maker may utilize several sources of information and thought processes. There may also be a small number of individuals within the organization equipped to analyze the decision according to the decision's nature.

Decision-making by the manager has a basis or guidelines in the process. According to George R. Terry, the basics of decision making are as follows:

1. Intuition
   Making decisions based on feelings or intuition is very susceptible to influence.

2. Experience
   Based on practical knowledge, making decisions based on experience offers benefits. One can quantify the benefits and drawbacks of the decisions that will be taken because one's expertise allows one to foresee how something will turn out.

3. Facts
   Fact-based decision-making can result in strong and good conclusions. The level of confidence in making decisions can be increased with facts, allowing people to accept the decisions made voluntarily and cheerfully.

4. Authority
   Authority is typically exercised by the leader over his superiors or subordinates, and persons in higher positions toward those in lower positions.

5. Rational
   Decisions made as a result are more rational, clear, and consistent with maximizing

In addition, John D. Miller states in Imam Murtono (2009) that the factors that affect decision-making are restricted capacity, decision-making role, and male or female gender.

Three primary aspects—individual values, personality, and propensity for taking risks—have an impact on how an individual makes decisions.

The fundamental assumption that a person employs when he is presented with a dilemma and must make a decision is the value of the individual decision maker. Since early childhood, these values have been taught through a process of learning from the family and social surroundings. In many cases, the person is more lured by the possibility to win and does not even consider accumulating or judging the bad.

Personality comes next. Psychological aspects like personality can also have an impact on a person's decisions. Decisions are influenced by two major personality traits, such as the conflict between ideology and power and the tension between emotion and objectivity. Some decision-makers are ideologically oriented, which indicates that their choices are shaped by a certain ideology or set of values. In the meanwhile, those making decisions or other people base their choices on factors that will improve their political influence.

Third, a propensity towards taking chances. Nurses must distinguish between risky and unclear scenarios in order to develop their decision-making abilities because each condition calls for a different type of decision. Risk is the absence of control over the outcome of the action and the assumption that the decision-maker knows the outcome of the action even though he cannot control it. Uncertainty is the lack of knowledge of the outcome of the action. Making decisions is more challenging in uncertain situations than in dangerous ones. When faced with uncertainty, the decision-maker lacks a rational foundation for selecting one tactic over another.

As with other references, personal circumstances have an impact on decision-making as follows :

- Cognition, which refers to one's level and breadth of information. For instance, the capacity for logical thought, the capacity for reasoning, etc.

- Motive is a psychological pressure that influences, sustains, and guides action toward a goal.

- Attitude, how courageous we are when making judgments, selecting the appropriate emotional setting and timing, and taking into account potential outcomes.

A decision support system or decision support system is an information system that combines data and sophisticated analytical models or data analysis tools to support semi-structured and unstructured decision making.

A decision support system or decision support system (DSS) is generally defined as a system that can provide problem solving and communication skills for semi-structured problems (Turban, 2005).

A Decision Support System (DSS) is part of a computer-based information system, including a knowledge-based system to support decision making in an organization or company (Asfi, 2010: 2). A DSS is a computer-based information system that can utilize data and models to solve problems and provide alternative solutions to facilitate decision-making on a problem.

B. Decision Making Process

Decision-making is the process of determining among several actions for the purpose of achieving a target or multiple targets. According to Herber A. Simon (1977), managerial decision-making is the same as using all management processes in the company. To illustrate the point, it is very crucial to plan managerial functions. Planning involves a series of decisions. What to do? When? How? Where? By whom?

Another part of the managerial process, such as organizing and controlling, also involves making decisions.

According to the Figure 8, conflict occurs when a system does not fulfill its intended purpose, does not provide output such as what is needed, or does not operate as desired. Case resolution is not only concerned with the area of solution according to the dispute but also examines the opportunities that may occur. Understanding decision making and conflict resolution can be confusing. One way to tell the difference is to use testing at each stage according to the decision-making process. The decision-making stages are intelligence, design, choice, and implementation.

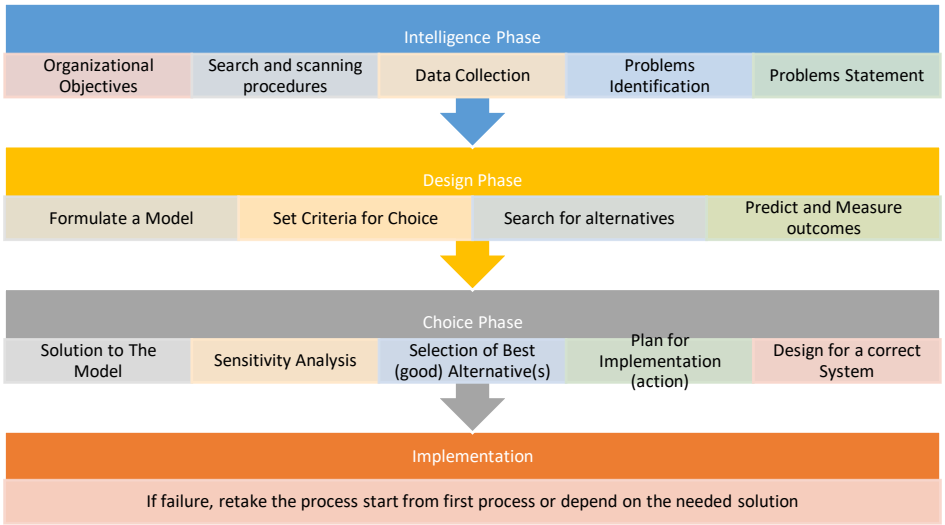

Figure 8. Decision Support System Process

C. Decision Support System Phase

The development approach utilized is called FAST (Framework for the Application System Techniques) Figure 9, which offers a variety of projects and tactics within a framework that is comparatively adaptable.

During the design phase, a decision maker works to develop alternatives and analyses the options to offer

knowledge about their pertinent implications. During this step, the decision-maker may learn that more information is needed. To fix the problems before moving on to the design step, the intelligence stage must be revisited.

During the choosing phase, the decision-maker selects one of the suggested alternatives that were considered during the design phase. The conditions of the decision as well as the decision maker's personality traits and eccentricities have an impact on the choice's outcome. It's possible that none of the solutions are suitable (return to the design phase), that several competing options obtain high grades, or that the situation has drastically changed.

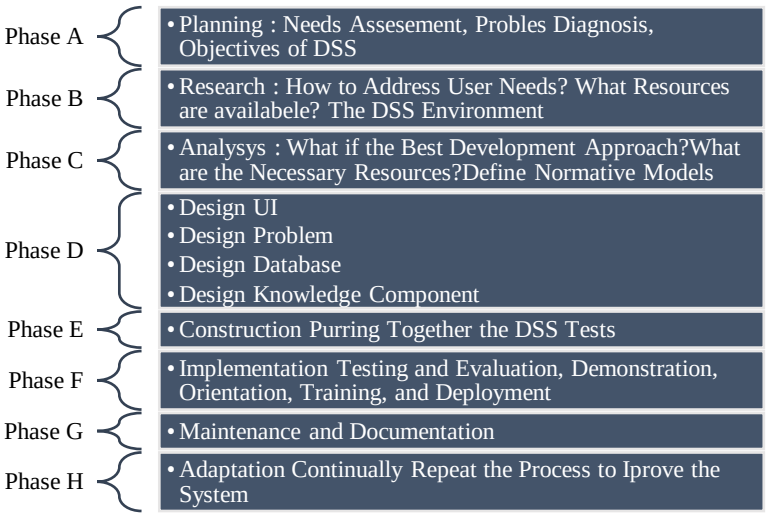

Figure 9. Decision Support System Phase

The FAST phases are as follows:

1) *Preliminary Investigation Phase*

In this stage, the author establishes the case, develops the scope, selects the methodology, and plans the research utilizing

methods for gathering data such interviews, observations, and documentation, while using PIECES of senses (Performance, Information, Economics, Control, Efficiency, and Service).

2) *Problem Analysis Phase*

   An evaluation of the current system will be done at this phase. This step provides a deeper knowledge of the five conflicts that are present, including case analysis, goal selection considering system restoration, and business process analysis.

3) *Requirements Analysis Phase*

   In this stage, the author understands and evaluates the system user's requirements before updating and improving the plans.

4) *Logical Design Phase*

   By using illustrative system examples to describe the new system requirements, this design phase explains how the advanced system design will be created. Examples of use-cases, logical data flow diagrams, data dictionaries, and ERD are the senses employed in this phase.

5) *Decision Analysis* Phase

   This stage updates the project plan, suggests changes to the plan, and suggests a system fix.

6) Physical Design and Physical Integration Phase

   A combination of physical design specifications, design prototypes, and business procedures are established during this

phase. Physical Data Flow Diagram (DADF), data dictionaries, and ERD are the senses that are utilized.

7) *Construction and Evaluation Phase*

In this sense, both the system and its individual components are tested. When this test is successful, the system can start to be used. Flowcharts, Microsoft Visual Basic 6.0 programs, databases from SQL Server 2000, ADO connections (ActiveX Data Control), and Crystal Reports are the senses employed.

8) Installation and Delivery Phase

The authors carry out testing and updates, install new databases and events, provide user training, and transition to the new system during this phase.

9) Operation and System Offer Phase

Once the system is running, ongoing system maintenance is necessary for residues with a useful and productive life cycle.

D. Decision Support System Components

Decision support system, several components of which are also included in the information system components. The database management, model basis, and software system/user interface make up the Decision Support System's three main building blocks.

1. Database Management

is a database-organized data subsystem. Information that supports decisions and can come from either the internal or external environment. DSS requires that information that is pertinent to the current issue be resolved through simulation.

2. Model Base

is a quantitative model that represents the problem as a basis for simulation or retrieval (mathematical models, for example) decisions, including the objectives of the problem (objective), the components related to it, existing constraints (constraints), and other related matters. Base Model allows decision makers to conduct a thorough analysis by developing and comparing alternative solutions.

3. User Interface / Dialog Management

It is sometimes referred to as the conversation subsystem and is made up of the two preceding components, database administration and model base, which were previously presented as computer-understandable models and combined into a third component (user interface). The Decision Support System gets input from the user through the User Interface, which also displays the system output for the user.

Based on the type of help, Daniel Power proposed another grouping for the DSS. He classifies DSS into several categories, including model-driven DSS, data-

driven DSS, document-driven DSS, and communication-driven DSS.

1) Communication-driven

   Collaboration is supported by DSS, allowing multiple people to work collaboratively. Examples include programs that are integrated, like Microsoft Groove or Google Docs.

2) Data-driven

   Access to and manipulation of internal time series data firms, as well as occasionally access to external data sources, are key components of data driven DSS.

3) Document-driven

   The management, retrieval, and manipulation of structured information in multiple electronic formats are all made possible by document driven DSS.

4) Knowledge-driven

   Specialized problem-solving abilities are provided by knowledge-driven DSS and can be stored as facts, rules, procedures, or other comparable structures.

5) Model-driven

   Model-driven DSS places a strong emphasis on model access and manipulation in the areas of finance, optimization, and simulation. User-provided data and

settings are used in this kind to assist decision makers in analyzing situations.

CHAPTER 3
WEIGHTED SUM MODEL OR SIMPLE ADDITIVE WEIGHTING AND WEIGHTED PRODUCT METHOD

A. Definition of Multi Criteria Decision Making

Multi-criteria Decision Making (MCDM) is used to make decisions with many criteria that usually confuse decision making. MCDM can be used in everyday life, such as in the case of deciding to buy a house or car with the criteria of comfort, safety, price, type, size, etc. MCDM in the company is used to decide problems on a large scale. For example, in the case of supplier selection with criteria for service, quality management, timeliness, etc.

The number of criteria requires normalization of criteria to be on the same scale. For that, we need normalization with the following technique:

Evaluation based on Rank

- With Rating Value
- Change the criteria in the same range

Some of the MCDM that will be explained are as follows:

- Weighted Sum Model (WSM) or Simple Additive Weighting (SAW)
- Weighted Product (WP)

B. Definition of WSM or SAW

WSM is the simplest MCDM. This method is used to evaluate several options based on the available alternatives. This method has the following formula:

$$P_i = \sum_{j=1}^{n} a_{ij} W_j \; for \; i = 1,2,3, \dots, m$$

This means that there is an alternative criterion weight matrix which will be multiplied by the criterion weight and accumulated

by the sum. This method is the simplest form of MCDM. In addition, WSM is usually used for initial calculations in other MCDM DSS methods.

The basic logic of the Simple Additive Weighting (SAW) method is to obtain the number of weighted performance ratings for each alternative on all attributes (Adriyendi, 2015). The SAW method is an example of the simplest Multi-Attribute Desicion Making (MADM) and Weighted Sum Model (WSM) methods.

SAW (*Simple Additive Weighting*) Equation:

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{Max_{\,x_{ij}}} & if\ j\ is\ the\ attribute\ of\ profit\ benefit \\ \dfrac{Min\ X_{ij}}{x_{ij}} & if\ j\ is\ a\ cost\ attribute\ (cost) \end{cases}$$

Information :

r_{ij} = Normalized performance rating (from alternative Ai on attribute Cj; i=1,2,...,m and j =1,2,...,n)

Max_{ij} = Maximum value of each row and column

Min_{ij} = Minimum value of each row and column

x_{ij} = Row and column matrix

$$V_i = \sum_{j=1}^{n} w_j\, r_{ij}$$

Information :

V_i = Rank each alternative

W_j = The value of the weight of each criterion

r_{ij} = Normalized performance rating value

Example 1 :

There are several alternatives in selecting agricultural products as follows: oil palm; paddy; teak. With capital criteria; profit; and cost. Assessment Method : Ordinal

1. Very less
2. Less
3. Ordinary
4. Good
5. Very Good

WSM Solution

Table 1. WSM Solution

Alternative	**Criteria**			**Alternative Value**	**Ranking**
	Capital	**Benefit**	**Cost**		
Palm oil	4	4	3	3,7	2
Paddy	4	5	2	3,8	1
teak	4	3	4	3,6	3
Criteria Weight	0,3	0,4	0,3		

Alternative Value 1 = 4(0,3) + 4(0,4) + 3 (0,3) = 3,7
Because the highest alternative value is rice, the 1st rank of agricultural selection product is rice.

Example 1:

The Putra Putri Pendidikan Foundation will build a new elementary school to meet the needs of the local community in Malang Regency. By using a decision support system using the SAW Method, which area was chosen as the location for the school to be built?

There are 6 criteria as determinants, namely land area, land security, building area, number of building floors, security, and distance to residents' houses.

Table of Criteria and Weights

Value of Criteria /Alternative

Table 2. Weight of Criteria /Alternative WSM

Alternative	**Criteria**					
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**
Area A	50	60	90	40	90	80
Area B	30	89	76	55	90	80
Area C	70	60	90	30	70	70
Area D	90	33	66	85	92	91

Weighting (W)

Table 3. Weighting (W) Criteria WSM

Criteria	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**
Weight Value	0,2	0,2	0,1	0,15	0,1	0,25

Normalization Calculation

First Criteria

- $R_{11} = \frac{50}{\max(50;30;70;90)} = \frac{50}{90} = 0{,}55$
- $R_{21} = \frac{30}{\max(50;30;70;90)} = \frac{30}{90} = 0{,}33$
- $R_{31} = \frac{70}{\max(50;30;70;90)} = \frac{70}{90} = 0{,}78$

- $R_{41} = \frac{90}{\max(50;30;70;90)} = \frac{90}{90} = 1$

Second Criteria

- $R_{12} = \frac{60}{\max(60;89;60;33)} = \frac{60}{89} = 0{,}67$
- $R_{22} = \frac{89}{\max(60;89;60;33)} = \frac{89}{89} = 1$
- $R_{32} = \frac{60}{\max(60;89;60;33)} = \frac{60}{89} = 0{,}67$
- $R_{42} = \frac{33}{\max(60;89;60;33)} = \frac{33}{89} = 0{,}37$

Third Criteria

- $R_{13} = \frac{90}{\max(90;76;90;66)} = \frac{90}{90} = 1$
- $R_{23} = \frac{76}{\max(90;76;90;66)} = \frac{76}{90} = 0{,}84$
- $R_{33} = \frac{90}{\max(90;76;90;66)} = \frac{90}{90} = 1$
- $R_{43} = \frac{66}{\max(90;76;90;66)} = \frac{66}{90} = 0{,}73$

Fourth Criteria

- $R_{14} = \frac{40}{\max(40;55;30;85)} = \frac{40}{85} = 0{,}47$
- $R_{24} = \frac{55}{\max(40;55;30;85)} = \frac{55}{85} = 0{,}64$
- $R_{34} = \frac{30}{\max(40;55;30;85)} = \frac{30}{85} = 0{,}35$
- $R_{44} = \frac{85}{\max(40;55;30;85)} = \frac{85}{85} = 1$

Fifth Criteria

- $R_{15} = \frac{90}{\max(90;90;70;92)} = \frac{90}{92} = 0{,}97$
- $R_{25} = \frac{90}{\max(90;90;70;92)} = \frac{90}{92} = 0{,}97$
- $R_{35} = \frac{70}{\max(90;90;70;92)} = \frac{70}{92} = 0{,}76$
- $R_{45} = \frac{92}{\max(90;90;70;92)} = \frac{92}{92} = 1$

Sixth Criteria

- $R_{16} = \frac{\min(80;80;70;91)}{80} = \frac{70}{80} = 0{,}875$
- $R_{26} = \frac{\min(80;80;70;91)}{80} = \frac{70}{80} = 0{,}875$
- $R_{36} = \frac{\min(80;80;70;91)}{70} = \frac{70}{70} = 1$
- $R_{46} = \frac{\min(80;80;70;91)}{91} = \frac{70}{91} = 0{,}76$

Normalized Factor Table

$$R = \begin{bmatrix} 0{,}55 & 0{,}67 & 1{,}00 & 0{,}47 & 0{,}97 & 0{,}87 \\ 0{,}33 & 1{,}00 & 0{,}84 & 0{,}64 & 0{,}97 & 0{,}87 \\ 0{,}78 & 0{,}67 & 1{,}00 & 0{,}35 & 0{,}76 & 1{,}00 \\ 1{,}00 & 0{,}37 & 0{,}73 & 1{,}00 & 1{,}00 & 0{,}76 \end{bmatrix}$$

Table 4. Normalized Factor Table

Criteria	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**
Weight Value	0,2	0,2	0,1	0,15	0,1	0,25

V_1 = (0,55*0,2)+(0,67*0,2)+(1*0,1)+(0,47*0,15)+(0,97*0,1)+(0,87*0,25)
= 0,729

Then we get the overall V Value as follows:

- $V_1 = 0,73$
- $V_2 = 0,7605$
- $V_3 = 0,7658$
- $V_4 = 0,787$

Conclusion Answer

So based on the SAW method, the regional recommendation for elementary school construction by the foundation for the sons and daughters of education is **area D**.

C. Definisi WP

The WP method is a way of making decisions with multiplication to connect attribute ratings, where the rating of each attribute must be raised first with the weight of the attribute in question (Yoon, 1989).

Equation :

$$S_i = \prod_{j=1}^{n} {x_{ij}}^{w_j}$$

$$w_j = \frac{w_j}{\sum w_j}$$

$$V_i = \frac{\prod_{j=1}^{n} {x_{ij}}^{w_j}}{\prod_{j=1}^{n} ({x_j}^*)^{w_j}}$$

Information :

V = Alternative preferences are analogous to vector V

X = Criteria Value

W = Criteria Weight / Sub Criteria

i = Alternative

j = Criteria
n = Number of Criteria

Example :
The AAA Polytechnic will select Outstanding Students in 2022. There are four criteria for determining the value, as follows:
C1 = Grade Point Average (GPA) (for example, if GPA ranges from 0 to 100:weight – Cumlaude
C2 = Good-Weight Scientific Writing
C3 = Preferred Ability/AchievementWeight-Very Good
C4 = Foreign Language Proficiency: Good

- Criteria Weight

Table 5. Criteria Weight WP

Value	Weight	Information
80-100	5	Very good
60-79	4	Well
40-59	3	Enough
20-39	2	Bad
0-19	1	Very bad

- The weight of the criteria above makes each decision support criteria grouped according to that level

Table 6. Weight of Criteria /Alternative WP

Alternative	Criteria			
	C_1	C_2	C_3	C_4
Ani	70	60	80	90
Budi	80	60	70	70
Candra	70	70	75	71
Dewi	64	92	86	77
Erik	78	65	96	78
Fahrur	78	59	70	71

- Preference Weight

Table 7. Preference Criteria Weight WP

Criteria	Weight
C_1	5
C_2	4
C_3	5
C_4	4

- Alternative Weight Result

Table 8. Alternative Weight Result WP

Alternative	Criteria			
	C_1	C_2	C_3	C_4
Ani	4	4	5	5
Budi	5	4	4	4
Candra	4	4	4	4
Dewi	4	5	5	4
Erik	4	4	5	4
Fahrur	4	3	4	4

- Weight Normalization

$C_1 = \frac{5}{5+4+5+4} = 0{,}278$

$C_2 = \frac{4}{5+4+5+4} = 0{,}222$

$C_3 = \frac{5}{5+4+5+4} = 0{,}278$

$C_4 = \frac{4}{5+4+5+4} = 0{,}222$

- S Vector Calculation

$S_1 = (70^{0{,}278})(60^{0{,}222})\ (80^{0{,}278})\ (90^{0{,}222}) = 74{,}23$

$S_2 = (80^{0{,}278})(60^{0{,}222})\ (60^{0{,}278})\ (90^{0{,}222}) = 70{,}20$

$S_3 = (70^{0{,}278})(70^{0{,}222})\ (75^{0{,}278})\ (71^{0{,}222}) = 71{,}58$

$S_4 = (64^{0{,}278})(92^{0{,}222})\ (86^{0{,}278})\ (77^{0{,}222}) = 78{,}46$

$S_5 = (78^{0{,}278})(65^{0{,}222})\ (96^{0{,}278})\ (78^{0{,}222}) = 79{,}35$

$S_6 = (78^{0{,}278})(59^{0{,}222})\ (70^{0{,}278})\ (71^{0{,}222}) = 69{,}67$

- Calculation of Preference Value (V)

$V_1 = \frac{74{,}23}{74{,}23+70{,}20+71{,}58+78{,}46+79{,}35+69{,}67} = 0{,}167$

$V_2 = \frac{70{,}20}{74{,}23+70{,}20+71{,}58+78{,}46+79{,}35+69{,}67} = 0{,}158$

$V_3 = \frac{71{,}58}{74{,}23+70{,}20+71{,}58+78{,}46+79{,}35+69{,}67} = 0{,}161$

$V_4 = \frac{78{,}46}{74{,}23+70{,}20+71{,}58+78{,}46+79{,}35+69{,}67} = 0{,}176$

$V_5 = \frac{79{,}35}{74{,}23+70{,}20+71{,}58+78{,}46+79{,}35+69{,}67} = 0{,}178$

$V_6 = \frac{69{,}67}{74{,}23+70{,}20+71{,}58+78{,}46+79{,}35+69{,}67} = 0{,}157$

- Conclusion Answer
  - ❖ So the greatest preference value is V5, namely a student named Erik
  - ❖ The student was the winner of the 2022 Outstanding Students at the AAA Polytechnic

D. Case Study Problem Solving with WSM or SAW

Case Study 1: Solving problems with the WSM or SAW method

Objective: Students understand the process of solving decision support using the WSM or SAW method

Solution Steps :

1. Make a program flowchart that represents WSM or SAW method.
2. Determine in the table which criteria include benefits and costs.
3. After the flowchart is complete, make a calculation of the WSM or SAW method in excel so that it becomes semi-automatic.

Question:

1. Give the best alternative using the WSM method in the questions below!

There are 4 criteria for assessing teacher performance.

Criteria

Table 9. WSM Criteria Task

Faithfulness (X)	Score	Work Performance	Score	Responsibility	Score	Lateness	Score
0% <X≤25%	1	0% <X≤25%	1	0% <X≤25%	1	0% <X≤25%	4
26% ≤X≤50%	2	26% ≤X≤50%	2	26% ≤X≤50%	2	26% ≤X≤50%	3
51% ≤X≤75%	3	51% ≤X≤75%	3	51% ≤X≤75%	3	51% ≤X≤75%	2
76% ≤X≤100%	4	76% ≤X≤100%	4	76% ≤X≤100%	4	76% ≤X≤100%	1

Data

Table 10. WSM Data Task

Alternative	Criteria			
	C1(%)	C2(%)	C3(%)	C4(%)
Ani	21	50	92	27
Budi	25	47	26	37
Cici	75	42	66	47

Dody	90	78	74	57
Emi	51	40	32	17
Fandy	57	98	87	60
Gani	58	79	29	23
Hari	66	92	35	11
Weight	15%	50%	15%	20%

.

1. Make a table of criteria (benefit or cost of the case in the question above!
2. What is the conclusion to solve the problem?

Case Study 2 : Solving problems with the WP Method

Objective : Students understand the process of solving decision support using the WP method

Solution Steps :

1. Make a program flowchart that represents WP method.
2. Determine in the table which criteria include benefits and costs.
3. After the flowchart is complete, make a calculation of the WP method in excel so that it becomes semi-automatic.

Question :

1. Give the best alternative with the WP method in the questions below!
2. Criteria

Table 11. WP Criteria Task

Age (X)	Crisp Number	Education	Crisp Number	Psychological Test	Crisp Number	Number Work Experience(Y)	Crisp Number
18 ≤X≤20	1 0,75	JUNIOR HIGH SCHOOL	0 0,25	Recommended Not recommended	1 0	Y=0 tahun 1≤Y≤3	0 0,25
21 ≤X≤23	0,5 0,25	SENIOR HIGH SCHOOL	0,5 0,75			4≤Y≤6 7≤Y≤9	0,5 0,75
24 ≤X≤26	0	DI-DIII DIV	1			Y≥10	1

27 ≤X≤30 31 ≤X≤35		Bachelor					

3. There are 4 criteria that are assessed in determining Indonesian Migrant Workers who are ready to be dispatched abroad.

Data

Table 12. WP Data Task

Alternative	Criteria			
	C1	C2	C3	C4
Ani	18	JUNIOR HIGH SCHOOL	recommended	4
Budi	30	BACHELOR	not recommended	0
Cici	24	SENIOR HIGH SCHOOL	recommended	1
Dody	21	SENIOR HIGH SCHOOL	not recommended	5
Emi	28	DIII		2
Weight	25%	15%	30%	30%

4. Make a table of criteria (benefit or cost of the case in the question above!
5. What is the conclusion of the completion of the case study?

E. Case Study Problem Solving with WP and SAW

Case Study 3 : Solving problems with the SAW and WP method

Objective : Students understand the process of solving decision support using the SAW method compared to WP

Solution Steps :

1. Determine in the table which criteria include benefits and costs.
2. After the flowchart is complete, make a calculation of the SAW method in excel so that it becomes semi-automatic.

Question :

1. Give the best alternative using the SAW and WP method in the questions below!

   Case study 1:
   There are 4 criteria for assessing teacher performance.

   Criteria
   Table 13. SAW and WP Criteria Task (1)

Loyalty (X)	Score	Work Performance	Score	Responsibility	Score	Lateness	Work Performance
0% <X≤25%	1	0% <X≤25%	1	0% <X≤25%	1	0% <X≤25%	4
26% ≤X≤50%	2	26% ≤X≤50%	2	26% ≤X≤50%	2	26% ≤X≤50%	3
51% ≤X≤75%	3	51% ≤X≤75%	3	51% ≤X≤75%	3	51% ≤X≤75%	2
76% ≤X≤100%	4	76% ≤X≤100%	4	76% ≤X≤100%	4	76% ≤X≤100%	1

   Data
   Table 14. SAW and WP Data Task

Alternative	Criteria			
	C1(%)	C2(%)	C3(%)	C4(%)
Ani	21	50	92	27
Budi	25	47	26	37
Cici	75	42	66	47
Dody	90	78	74	57
Emi	51	40	32	17
Fandy	57	98	87	60
Gani	58	79	29	23
Hari	66	92	35	11
Weight	15%	50%	15%	20%

Case Study 2

Criteria

Table 15. SAW and WP Criteria Task (2)

Age (X)	Crisp Number	Education	Crisp Number	Psychological Test	Crisp Number	Number Work Experience(Y)	Crisp Number
18 ≤X≤20	1	JUNIOR H.S	0	Disarankan	1	Y=0 tahun	0
21 ≤X≤23	0,75	SENIO H.S	0,25	Belum Disarankan	0	1≤Y≤3	0,25
24 ≤X≤26	0,5	DI-DIII	0,5			4≤Y≤6	0,5
27 ≤X≤30	0,25	DIV	0,75			7≤Y≤9	0,75
31 ≤X≤35	0	BACHELOR	1			Y≥10	1

There are 4 criteria that are assessed in determining Indonesian workers who are ready to be sent abroad.

Data

Table 16. SAW and WP Data Task

Alternative	Criteria			
	C1	C2	C3	C4
Ani	18	JUNIOR H.S	Recomended	4
Budi	30	BACHELOR	Not Recomended	0
Cici	24	SENIOR H.S	Recomended	1
Dody	21	SENIOR H.S	Recomended	5
Emi	28	DIII	Not Recomended	2
Weight	25%	15%	30%	30%

a. Make a table of criteria (benefit or cost of the case in the question above!
b. What is the conclusion?

CHAPTER 4
ANALYTIC HIERARCHY PROCESS

A. History of AHP

The Analytical Hierarchy Process (AHP) is a method that can be used for decision-making if the decision-making criteria are very diverse. This method was introduced by Thomas L. Saaty in 1971–75 at the Wharton School.

AHP is a measurement method used to determine the ratio scale of discrete or continuous pair comparisons. This comparison can be taken from the actual size or from a basic scale that reflects the strength of feelings and relative preferences.

B. AHP Principle

Decomposition refeal after the problem is defined, decomposition is carried out, namely breaking the whole problem into its elements. This is the reason why this process is called a hierarchy.

C. AHP Example

Using AHP, Enterprise BBB who establishes and manages malls in Indonesia. The company has identified three potential sites for its latest project namely Area A, Area B, and Area C. The company has also identified four main criteria as a basis for comparison of locations, namely:

(1) Customer market share; (2) income level; (3) infrastructure and (4) transportation. The overall company goal is to have the best location.

AHP Calculation Process

Pairwise comparison matrix

Table 17. Pairwise Comparition Matrix

Location	**Customer Market Share**		
	A	B	C
A	1	3	2
B	1/3	1	1/5
C	1/2	5	1

Income Level

$$\begin{matrix} A \\ B \\ C \end{matrix}\begin{bmatrix} 1 & 6 & 1/3 \\ 1/6 & 1 & 1/9 \\ 3 & 9 & 1 \end{bmatrix}$$

Infrastructure

$$\begin{matrix} A \\ B \\ C \end{matrix}\begin{bmatrix} 1 & 1/3 & 1 \\ 3 & 1 & 7 \\ 1 & 1/7 & 1 \end{bmatrix}$$

Transportation

$$\begin{matrix} A \\ B \\ C \end{matrix}\begin{bmatrix} 1 & 1/3 & 1/2 \\ 3 & 1 & 4 \\ 2 & 1/4 & 1 \end{bmatrix}$$

Solution
Synthesis Process

Table 18. AHP Synthesis Process

Location	**Customer Market Share**		
	A	B	C
A	1	3	2
B	1/3	1	1/5
C	1/2	5	1
	11/6	9	16/5

Table 19. AHP Synthesis Process Division Result

Location	**Customer Market Share**		
	A	B	C
A	6/11	3/9	5/8
B	2/11	1/9	1/16
C	3/11	5/9	5/16

Vector

Table 20. AHP Synthesis Process Division Result Vector

Location	**Customer Market Share**			**Row Average**
	A	B	C	
A	0,5455	0,3333	0,6250	0,5012
B	0,1818	0,1111	0,0625	0,1185
C	0,2727	0,5556	0,3803	0,3803
				1,0000

Customer Market ***Income Level***

$$\begin{matrix} A \\ B \\ C \end{matrix}\begin{bmatrix} 0{,}5012 \\ 0{,}1185 \\ 0{,}3803 \end{bmatrix} \qquad \begin{matrix} A \\ B \\ C \end{matrix}\begin{bmatrix} 0{,}2819 \\ 0{,}0598 \\ 0{,}6583 \end{bmatrix}$$

Infrastructure ***Transportation***

$$\begin{matrix} A \\ B \\ C \end{matrix}\begin{bmatrix} 0{,}1780 \\ 0{,}6850 \\ 0{,}1360 \end{bmatrix} \qquad \begin{matrix} A \\ B \\ C \end{matrix}\begin{bmatrix} 0{,}1561 \\ 0{,}6196 \\ 0{,}2243 \end{bmatrix}$$

Preference Vector

Table 21. Preference Vector Alternative-Criteria AHP

Location	**Criteria**			
	Customer Market Share	**Income Level**	**Infrastructure**	**Transportation**
A	0,5012	0,2819	0,1790	0,1561
B	0,1185	0,0598	0,6850	0,6196
C	0,3803	0,6583	0,1360	0,2243

Criteria Ranking
Pair comparison matrix

Table 22. Pair comparison matrix AHP

Criteria	Customer Market Share	Income Level	Infrastructure	Transportation
Customer Market	1	1/5	3	4
Income Level	5	1	9	7
Infrastructure	1/3	1/9	1	2
Transportation	1/4	1/7	1/2	1

Converted normalized matrix

Table 23. AHP Converted Normalized Matrix

Criteria	Customer Market Share	Income Level	Infra-structure	Trans-portation	Row Average
Customer Market	0,1519	0,1375	0,2222	0,2857	0,1993
Income Level	0,7595	0,6878	0,6667	0,5000	0,6535
Infrastructure	0,0506	0,0764	0,0741	0,1429	0,0860
Transportation	0,0380	0,0983	0,0370	0,0714	0,0612

Preference Vector

Table 24. Preference Vector Criteria AHP

Criteria	line average
Market Share	0,1993
Income Level	0,6535
Infrastructure	0,0860
Transportation	0,0612

Developing Overall Rank

Criteria

Table 25. Developing Overall Rank of AHP

Location	Criteria			
	Market Share	Income Level	Infrastructure	Transportation
A	0,5012	0,2819	0,1790	0,1561
B	0,1185	0,0598	0,6850	0,6196
C	0,3803	0,6583	0,1360	0,2243

Location A Score =

0,1993(0,5012)+0,6535(0,2819)+0,0860(0,1790)+0,0612(0,1561)= 0,3091

Table 26. Final Rank of AHP

Location	Score
Area C	0,5314
Area A	0,3091
Area B	0,1595

	1,000

D. AHP Stages

The ranking process using the AHP method shown in Figure 10 requires several stages from input data to ranking of recommended alternatives in decision making.

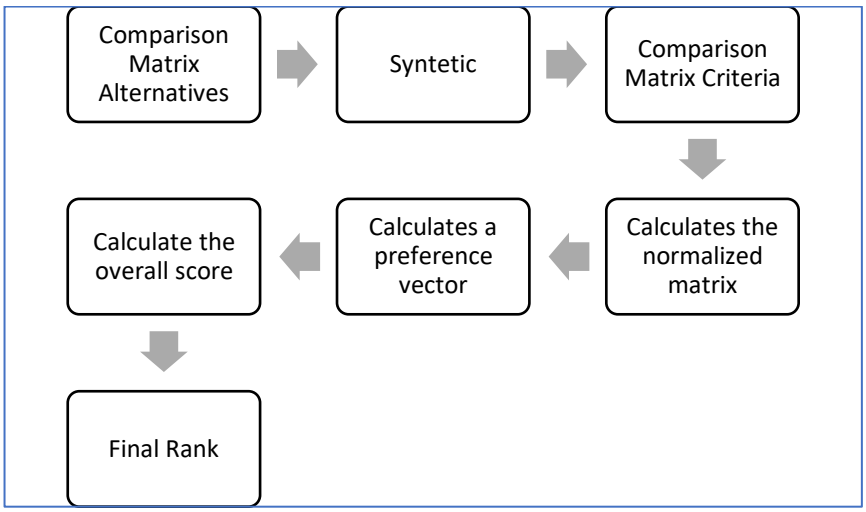

Figure 10. Ranking Process using AHP Method

Summary of the mathematical stages of making decision recommendations based on AHP:

- Develop a pair comparison matrix for each decision alternative (location) based on criteria.
  - Synthetic:
    - Sum the values in each column in the pair comparison matrix.
    - Divide the value of each column in the pair comparison matrix by the number of the corresponding column (normalized matrix)
    - Calculate the average value of each row in the normalized matrix called the preference vector

- Combine the preference vectors for each criterion into a preference matrix that shows the preferences of each location based on each

- ❖ Create a pair comparison matrix for criteria
- ❖ Calculates the normalized matrix by dividing each value in each column of the matrix by the number of related columns
- ❖ Create a preference vector by calculating the row average of the normalized matrix
- ❖ Calculate the overall score for each decision alternative by multiplying the criterion preference vector by the criteria matrix
- ❖ Ranking of decision alternatives based on alternative values

E. AHP Consistency

Calculation of Consistency Index (CI)

Table 27. Parwise Comparison Table Task

Criteria	Market Share	Income Level	Infrastructure	Transportation
Market Share	1	1/5	3	4
Income Level	5	1	9	7
Infrastructure	1/3	1/9	1	2
Transportation	1/4	1/7	1/2	1

The matrix above will be multiplied by the alternative eigenvector values per the following criteria

Table 28. alternative eigenvector values per the following criteria

Criteria	line average
Market Share	0,1993
Income Level	0,6535

Infrastructure	0,0860
Transportation	0,0612

Then the following multiplication results will be obtained
(1)(0,1993)+(1/5)(0,6535)+(3)(0,0860)+(4)(0,0612) = 0,8328

The result of dividing by preference vector

$$0.8328/_{0,1993} = 4,1786$$
$$0.8524/_{0,6535} = 4,3648$$
$$0.3474/_{0,0860} = 4,0401$$
$$0.2474/_{0,0612} = 4,0422$$
$$Total = 16,6257$$

Total Divide

$$16,6257/_{4} = 4,1564$$

Consistency Index (CI)

$$CI = \frac{4,1564 - n}{n - 1}$$
$$CI = \frac{4,1564 - n}{3} = 0,0521$$

From these calculations, the following are used as guidelines:

- If CI = 0 then the above case is a very consistent decision making.
- An acceptable level of consistency is obtained by comparing CI with RI (Random Index)

Random Indeks

Table 29. Random Index

n	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,51

$$\frac{CI}{RI} = \frac{0{,}0521}{0{,}90} = 0{,}0580$$

In general, the level of consistency is satisfactory if the CI/RI <= 0.10

F. Case Study Problem Solving with AHP

The following is an example of implementation and also questions in a decision support system using the AHP method

Case Study 1: Understand the AHP method and create a hierarchy

Objective : Students understand the problem to be solved using the AHP DSS method

Solution Steps :

1. Pay attention to the following questions:
   Romi is a final year POLINEMA student who wants to renew his smart phone. There are four determining criteria for buying a new smart phone, namely cost, display-resolution, battery-life, and internal-storage. These will be used to choose 3 types of smart phones that he likes.
2. Make a hierarchical chart of attributes for all the alternatives!
   Questions :

1. Based on the chart, make a list of the steps for completing your smartphone recommendation using the AHP method!
2. Why is it necessary to compare the CI with the RI method in the AHP method?

Study Case 2 : Calculating Paired Eigen Vector Matrix Between Criteria

Objective : Students know and are able to calculate paired eigenvector matrices between criteria.

Solution Steps:

1. Pay attention to the questions below:
   Based on the questions in experiment 1, it is known that the comparison matrix between criteria is

   Table 30. Comparison Matrix Between Criteria Study Case 2

Criteria	COST	DISPLAY-RESOLUTION	BATTERY-LIFE	INTERNAL-STORAGE
COST	1.00	0.33	0.25	0.50
DISPLAY-RESOLUTION	3.00	1.00	2.00	3.00
BATTERY-LIFE	2.00	0.33	1.00	3.00
INTERNAL-STORAGE	2.00	0.25	0.33	1.00

2. Calculate the Eigen Vector using the AHP method!

Questions :

1. Which criteria are the biggest determinants in purchasing a smart phone that Romi will buy?

Case Study 3 : Compute Eigen Vector Matrix Paired Criteria on All Alternatives

Objective : Students know and are able to calculate the eigenvector matrix paired criteria on all alternatives.

Solution Steps :

1. Pay attention to the questions below:
   Based on the questions in experiment 1, it is known that the criteria comparison matrix for all alternatives is

   Table 31. Comparison Matrix Between Alternatif Study Case 3 (Cost)

Smart Phone	COST		
	1	2	3
1	3.00	0.33	1.00
2	3.00	1.00	4.00
3	5.00	0.25	1.00

   Table 32. Comparison Matrix Between Alternatif Study Case 3(Display Resolution)

Smart Phone	DISPLAY-RESOLUTION		
	1	2	3
1	4.00	2.00	0.50
2	0.50	1.00	0.33
3	1.00	3.00	1.00

   Table 33. Comparison Matrix Between Alternatif Study Case 3(Battery-life)

Smart Phone	BATTERY-LIFE		
	1	2	3
1	1.00	4.00	2.00
2	0.33	1.00	0.33
3	0.50	3.00	2.00

Table 34. Comparison Matrix Between Alternatif Study Case 3(Internal-Storage)

Smart Phone	INTERNAL-STORAGE		
	1	2	3
1	1.00	1.00	0.25
2	4.00	1.00	0.25
3	4.00	4.00	1.00

2. Calculate the Eigenvectors of the three alternatives for each criterion using the AHP method!
3. Perform ranking calculations using the AHP method using the eigenvector calculation results of the comparison criteria matrix according to experiment 2!
4. Calculate the ratio of CI to RI value!

Questions :

1. Based on the eigenvector values, which is the highest recommendation for a smart phone for each criterion?
2. Based on the ranking that has been done, which smart phone has the highest ranking?
3. Do the results of the CI/RI comparison show consistent results? If not, what should be done or if consistent what next step should take?

CHAPTER 5
ELIMINATION ET CHOIX TRADUISANT LA RÉALITÉ

A. Definition

ELECTREE (Elimination and Choix Traduisant la Réalité/ELimination and Choice Expressing Reality) is one of the methods in Multi Criteria Decision Making (MCDM). The ELECTREE method was introduced by Bernard Roy in 1965.

Initially, ELECTREE was used in selecting the best course of action from a proposed sample of actions, but later ELECTREE was developed in terms of three main problems: selection, ranking, and sorting. ELECTREE has several versions, namely ELECTREE I, ELECTREE II, ELECTREE III, ELECTREE IV, ELECTREE IS, and ELECTREE TRI (electree tree).

ELECTREE can naturally process discrete quantitative and qualitative criteria and provide full sequencing of samples (Karacasu and Arslan 2010). The ELECTREE method accommodates inaccuracies and uncertainties in the decision-making process using indifference, preference, and veto (Natividade-Jesus, Coutinho-Rodrigues et al. 2007). There are two important parts in ELECTREE: first, the construction of one or more outranking relationships that comprehensively compare each pair of actions; and second, the elaboration of procedures examining the recommendations obtained from the first phase. The nature of the recommendations depends on the type of problem at hand: selection, ranking, or sorting. Relying on the principles of concordance and non-discordance, ELECTREE determined that "sample A outranks sample B," which means that "A is better or equal to B" (Karacasu and Arslan 2010). The ELECTREE method has been widely used in decision-making processes, bus transportation systems (Yayla and Karacasu 2011), analysis of theoretical differences (Huang and Chen 2005), ranking of e-government (Jati 2011), and transportation project selection (Karacasu and Arslan 2010).

B. ELECTRE Method Stages

ELECTREE has positive things in handling alternatives that are not too many but have many criteria. The result of the ELCTREE process consists of the numbers 0 and 1 in the dominant matrix, which is sometimes applied to problems where the criteria for the dominant difference between 0 and 1 are not very visible. The steps for the ELECTRE method can be seen as follows:

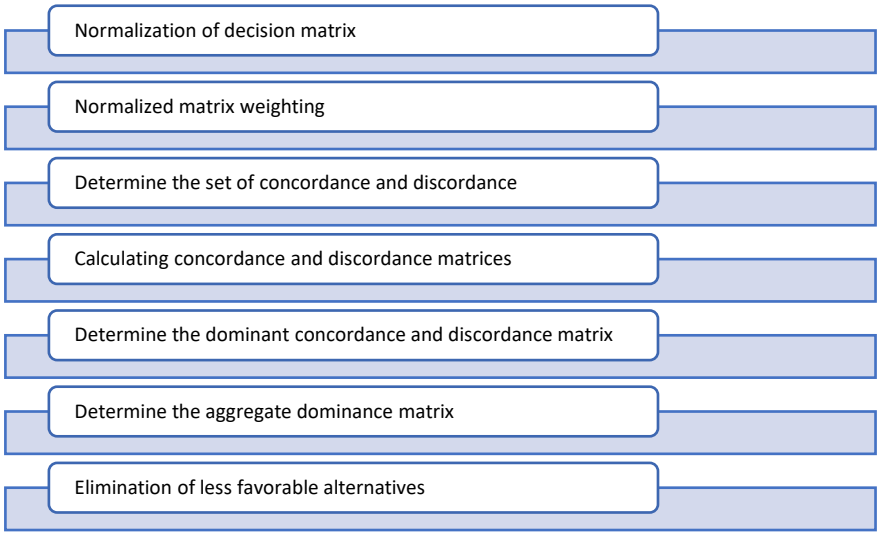

Figure 11. ELECTRE Steps

1) Normalization of the decision matrix

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^{2ij}}},$$

for *i = 1, 2, 3, ... , m* and *j = 1, 2, 3, ... , n*

Normalization can be done with the formula. So that the normalized matrix is obtained

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & & & \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

An example of normalization of a decision matrix

$$\begin{bmatrix} 4 & 4 & 5 & 3 & 3 \\ 3 & 3 & 4 & 2 & 3 \\ 5 & 4 & 2 & 2 & 2 \end{bmatrix}$$

$$r_{11} = \frac{x_{11}}{\sqrt{\sum_{i=1}^{m} x^2{}_{i1}}} = \frac{4}{\sqrt{4^2 + 3^2 + 5^2}} = \frac{4}{7{,}071}$$
$$= 0{,}5657$$
$$r_{12} = \frac{x_{12}}{\sqrt{\sum_{i=1}^{m} x^2{}_{i2}}} = \frac{4}{\sqrt{4^2 + 3^2 + 4^2}} = \frac{4}{6{,}403}$$
$$= 0{,}6247$$

$$R = \begin{bmatrix} 0{,}5657 & 0{,}6247 & 0{,}7454 & 0{,}7276 & 0{,}6396 \\ 0{,}4243 & 0{,}4685 & 0{,}5963 & 0{,}4851 & 0{,}6396 \\ 0{,}7071 & 0{,}6247 & 0{,}2981 & 0{,}4851 & 0{,}4264 \end{bmatrix}$$

2) Weighting on the normalized matrix. After normalization, each column of the matrix R is multiplied by the bobow W so, the calculation as follow:

$$V = R \,.\, W$$

$$V = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \cdots & & & \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix}$$

$$RW = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ \cdots & & & \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix}$$

An example of normalized matrix weighting

$$V = R \,.\, W$$

$$= \begin{bmatrix} 0{,}5657 & 0{,}6247 & 0{,}7454 & 0{,}7276 & 0{,}6396 \\ 0{,}4243 & 0{,}4685 & 0{,}5963 & 0{,}4851 & 0{,}6396 \\ 0{,}7071 & 0{,}6247 & 0{,}2981 & 0{,}4851 & 0{,}4264 \end{bmatrix} .$$

$$\begin{bmatrix} 5 & 0 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 & 0 \\ 0 & 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 0 & 2 \end{bmatrix}$$

$$= \begin{bmatrix} 2{,}8285 & 1{,}8741 & 2{,}9816 & 2{,}9104 & 1{,}2792 \\ 2{,}1215 & 1{,}4055 & 2{,}3852 & 1{,}9404 & 1{,}2792 \\ 3{,}5366 & 1{,}8741 & 1{,}1924 & 1{,}9404 & 0.8528 \end{bmatrix}$$

3) Concordance and discordance set
For each value pair of k and l (k, l = 1, 2, 3, ... , m and k≠1). The set of j criteria is divided into 2 subsets: concordance and discordance

Concordance

$$C_{kl} = \{j,\ v_{kj} \geq v_{ij}\},\ untuk\ j = 1,\ 2,\ 3,\ \ldots,\ n$$

Discordance

$$D_{kl} = \{j,\ v_{kj} < v_{ij}\},\ untuk\ j = 1,\ 2,\ 3,\ \ldots,\ n$$

Example of calculating concordance and discordance sets

$$\begin{bmatrix} 2{,}8285 & 1{,}8741 & 2{,}9816 & 2{,}9104 & 1{,}2792 \\ 2{,}1215 & 1{,}4055 & 2{,}3852 & 1{,}9404 & 1{,}2792 \\ 3{,}5366 & 1{,}8741 & 1{,}1924 & 1{,}9404 & 0.8528 \end{bmatrix}$$

$$C_{kl} = \{j,\ v_{kj} \geq v_{ij}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ n$$

$C_{12} = \{j,\ v_{1j} \geq v_{2j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{1,2,3,4,5\}$
$C_{13} = \{j,\ v_{1j} \geq v_{3j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{2,3,4,5\}$
$C_{21} = \{j,\ v_{1j} \geq v_{1j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{5\}$
$C_{23} = \{j,\ v_{2j} \geq v_{3j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{3,4,5\}$
$C_{31} = \{j,\ v_{3j} \geq v_{1j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{1,2\}$
$C_{32} = \{j,\ v_{3j} \geq v_{2j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{1,2,4\}$

$$D_{kl} = \{j,\ v_{kj} < v_{ij}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ n$$

$D_{12} = \{j,\ v_{1j} < v_{2j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{\ \ \}$
$D_{13} = \{j,\ v_{1j} < v_{3j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{1\}$
$D_{21} = \{j,\ v_{1j} < v_{1j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{1,2,3,4\}$
$D_{23} = \{j,\ v_{2j} < v_{3j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{1,2\}$
$D_{31} = \{j,\ v_{3j} < v_{1j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{3,4,5\}$
$D_{32} = \{j,\ v_{3j} < v_{2j}\},\ for\ j = 1,\ 2,\ 3,\ \ldots,\ 5$
$=\{3,5\}$

4) Calculating the concordance and discordance matrix.

a. Calculating the concordance matrix.

Calculated by showing the number of weights included in the concordance set

$$c_{kl} = \sum_{j \in c_{kl}} w_j$$

$$C = \begin{bmatrix} - & c_{12} & c_{13} & \dots & c_{1n} \\ c_{21} & - & c_{23} & \dots & c_{2n} \\ \dots & & & & \\ c_{m1} & c_{m2} & c_{m3} & \dots & - \end{bmatrix}$$

Example of concordance matrix calculation

$c_{12} = w_1 + w_2 + w_3 + w_4 + w_5$
= 5 + 3 + 4 + 4 + 2 = 18

$c_{13} = w_2 + w_3 + w_4 + w_5$
= 3 + 4 + 4 + 2 = 13

$c_{21} = w_5$
= 2

$c_{23} = w_3 + w_4 + w_5$
= 4 + 4 + 2 = 10

$c_{31} = w_1 + w_2$
= 5 + 3 = 8

$c_{32} = w_1 + w_2 + w_4$
= 5 + 3 + 4 = 12

Concordance matrix result :

$$\begin{bmatrix} - & 18 & 13 \\ 2 & - & 10 \\ 8 & 12 & - \end{bmatrix}$$

b. Calculating discordance matrix

This stage is done by dividing the maximum difference in the criteria included in the discordance subset by the maximum difference in the values of all the existing criteria

$$d_{kl} = \frac{max\ \{|v_{kj} - v_{lj}\}_{j \in D_{kl}}}{max\ \{|v_{kj} - v_{lj}\}_{\forall_j}}$$

$$D = \begin{bmatrix} - & d_{12} & d_{13} & & d_{1n} \\ d_{21} & - & d_{23} & \dots & d_{2n} \\ \dots & & & & \\ d_{m1} & d_{m2} & d_{m3} & \dots & - \end{bmatrix}$$

Example of discordance matrix calculation

$$\begin{bmatrix} 2{,}8285 & 1{,}8741 & 2{,}9816 & 2{,}9104 & 1{,}2792 \\ 2{,}1215 & 1{,}4055 & 2{,}3852 & 1{,}9404 & 1{,}2792 \\ 3{,}5366 & 1{,}8741 & 1{,}1924 & 1{,}9404 & 0.8528 \end{bmatrix}$$

$$d_{12} = \frac{max\ \{|v_{1j} - v_{2j}\}_{j \in D_{12}}}{max\ \{|v_{1j} - v_{2j}\}_{\forall_j}}$$

$$= \frac{max\{0\}}{max\{|2{,}8285 - \ ,1215|;|1{,}8741 - 1{,}4055|;|2{,}9816 - 2{,}3852|;|2{,}9104 - 1{,}9404|;|1{,}2792 - 1{,}2792|\}}$$

$$= \frac{max\{0\}}{max\{0{,}7070;0{,}4686;0{,}5964;0{,}9700;0\}} = 0$$

$$d_{13} = \frac{max\ \{|v_{1j} - v_{3j}\}_{j \in D_{13}}}{max\ \{|v_{1j} - v_{3j}\}_{\forall_j}}$$

$$= \frac{max\{2{,}8285 - 3{,}5355\}}{max\{|2{,}8285 - 3{,}5355|;|1{,}8741 - 1{,}8741|;|2{,}9816 - 1{,}1924|;|2{,}9104 - 1{,}9404|;|1{,}2792 - 0{,}8528|\}}$$

$$= \frac{max\{0{,}7070\}}{max\{0{,}7070;0;1{,}7892;0{,}9701;0{,}4264\}} = 0{,}3951$$

Discordance matrix result :

$$\begin{bmatrix} - & 0 & 0{,}3951 \\ 1 & - & 1 \\ 1 & 1 & - \end{bmatrix}$$

5) Calculating the dominant concordance and discordance matrix

a. Calculating the dominant concordance matrix

The dominant concordance matrix is constructed using threshold. The process is to compare each element value of the concordance matrix with the threshold value

$$c_{kl} \geq \underline{c}$$

With threshold value($\underline{c}$)

$$\underline{c} = \frac{\sum_{k=1}^{m} \sum_{l=1}^{m} c_{kl}}{m(m-1)}$$

Then, the value of the matrix F can be calculated

$$f_{kl} = \begin{cases} 1\,,\ if\ c_{kl} \geq \underline{c} \\ 0,\ if\ c_{kl} < \underline{c} \end{cases}$$

Example of the calculation of the dominant concordance matrix

$$\underline{c} = \frac{\sum_{k=1}^{m} \sum_{l=1}^{m} c_{kl}}{m(m-1)}$$
$$= \frac{18 + 13 + 2 + 10 + 8 + 12}{3(3-1)} = \frac{63}{6} = 10{,}5$$

The elements of the F matrix are defined as follows:

$$f_{kl} = \begin{cases} 1\ ,\ if\ c_{kl} \geq \underline{c} \\ 0,\ if\ c_{kl} < \underline{c} \end{cases}$$

Concordane Matrix :

$$\begin{bmatrix} - & 18 & 13 \\ 2 & - & 10 \\ 8 & 12 & - \end{bmatrix}$$

Concordance Dominant Matrix will be :

$$F = \begin{bmatrix} - & 1 & 1 \\ 0 & - & 0 \\ 0 & 1 & - \end{bmatrix}$$

b. Calculating the dominant matrix DISCORDANCE
Matrix G is the dominant discordence matrix.

$$\underline{d} = \frac{\sum_{k=1}^{n}\sum_{l=1}^{n} d_{kl}}{m*(m-1)}$$

With matrix elements determined by:

$$g_{kl} = \begin{cases} 1\ ,\ if\ d_{kl} \geq \underline{d} \\ 0,\ if\ d_{kl} < \underline{d} \end{cases}$$

An example of calculating the DISCORDANCE dominant matrix

$$\underline{d} = \frac{\sum_{k=1}^{m}\sum_{l=1}^{m} d_{kl}}{m(m-1)}$$

$$= \frac{0 + 0{,}3951 + 1 + 1 + 1 + 1}{3(3-1)} = \frac{4{,}3951}{6} = 0{,}7325$$

The elements of the G matrix are defined as follows:

$$g_{kl} = \begin{cases} 1\ ,\ if\ d_{kl} \geq \underline{d} \\ 0,\ if\ d_{kl} < \underline{d} \end{cases}$$

Discordance Matrix

$$\begin{bmatrix} - & 0 & 0{,}3951 \\ 1 & - & 1 \\ 1 & 1 & - \end{bmatrix}$$

So, the discordance dominant matrix :

$$G = \begin{bmatrix} - & 0 & 0 \\ 1 & - & 1 \\ 1 & 1 & - \end{bmatrix}$$

6) Determine the aggregate dominant matrix

The matrix E is obtained from the product of the elements of the matrix F with the elements of the matrix G

$$e_{kl} = f_{kl} \; x \; g_{kl}$$

7) Elimination of Less Favorable Alternatives

At this stage, a process of multiplying the dominant concordance and discordance matrices will be carried out. Thus, the best alternative is the alternative that dominates the other alternatives.

C. Case Study Problem Solving with ELECTREE

Case Study 1: Understanding the ELECTRE method

Objectives: Students understand the problems to be solved using the ELECTRE method

Solution Steps :

1. From the case study in the ELECTRE Handout/Material. Implement it in excel formulas!
2. Consider the following questions:
   There are 3 types of alternative determinants of cancer cells in the human body, namely: p53 inactivation, activation Rb, c-myc activation. Based on these alternatives, there are criteria derived from the

mutated gene, namely p53 protein expression(in%), Rb expression(in%), c-myc expression(in%).

Table 35. Comparison Matrix (ELECTREE TASK)

Alternative	Criteria		
	C1	C2	C3
A1	5	4	5
A2	4	5	4
A3	2	3	3

The weight of the criteria is (3,3,4)

3. Mention the step-by-step solution to problem no. 2 with the ELECTRE method using a flowchart to determine the concordance and discordance matrix!
4. Count using the ELECTRE method for question no. 2 to determine the best alternative!

Question :

1. What is the difference between concordance and discordance matrices?
2. Write down the results of each step of the excel calculation on the page below!
3. What is the result of the DSS calculation using the ELECTRE method in the above case?

CHAPTER 6
TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION

A. Definition

Yoon and Hwang introduced the TOPSIS approach in 1981 as one of the multi-criteria decision-making strategies. This method is extensively used for making decisions using many or more criteria.

Yoon and Hwang first presented TOPSIS, a multi-criteria decision-making system, in 1981. TOPSIS, according to Hwang and Zeleny (Kusumadewi et al., 2006), is based on the idea that the best-chosen alternative not only has the shortest distance from the positive ideal solution, but also has the longest distance from the negative ideal solution from a geometric standpoint, as measured by the Euclidean distance.

The positive ideal solution is the total of all possible best values for each attribute, whereas the negative ideal solution is the sum of all possible worst values for each attribute (Meliana, 2011). TOPSIS considers both the distance to the perfect solution and the distance to the ideal solution while considering relative proximity to the ideal solution. A different priority arrangement can be obtained based on the comparison of relative distances.

The positive ideal solution is defined as the total of all possible best values for each attribute, whereas the negative ideal solution is defined as the sum of all possible worst values for each attribute (Meliana, 2011). TOPSIS takes into consideration both the distance to the ideal solution and the ideal solution itself, considering relative proximity to the ideal solution. An alternative priority arrangement can be obtained based on the comparison of relative distances.

B. TOPSIS Method Stages

The stages in the TOPSIS method are as follows:

1. Create a normalized decision matrix

2. Create a weighted normalized decision matrix
3. Determine the positive ideal solution matrix and the negative ideal solution matrix
4. Determine the distance between the value of each alternative and the positive and negative ideal solution matrix
5. Determine the preference value for each alternative
6. Normalized Decision Matrix (R)
7. TOPSIS requires performance ranking of each alternative Ai on each normalized C_j criteria, namely:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^{2}{}_{ij}}}$$

with i=1,2,...,m; the value of m indicates the number of alternatives being evaluated, and the value of X_{ij} indicates the value of the i-th alternative fit rating to the j-th criterion. In this case :

Weighted Normalized Decision Matrix (Y)

$$y_{ij} = w_{j} . r_{ij}$$

The value of each normalized data (R) is then multiplied by the weight (W) to obtain a weighted normalized decision matrix (Y).

Where w_j is a positive rank for the benefit attribute, and a negative value for the cost attribute. The value of wj shows the weight value of the jth criterion C.

Positive (A+) and Negative (A-) Ideal Solution Matrix

The positive ideal solution A+ and the negative ideal solution A- can be determined based on the normalized weight ranking (y_{ij}).

Positive Ideal Solution A+
The equation used to determine the positive ideal solution is:

$$A^+ = \{(\max y_{ij} \mid j \in J), (\min y_{ij} \mid \in J'), i = 1,2,3, \dots, m\}$$

Or it can be stated more simply as follows:

$$A^+ = ({y_1}^+, {y_2}^+, {y_3}^+, \dots, {y_n}^+)$$

Negative Ideal Solution A-
The equation used to determine the positive ideal solution is:

$$A^- = \{(\min y_{ij} \mid j \in J), (\max y_{ij} \mid \in J'), i = 1,2,3, \dots, m\}$$

This equation can also be written as follows:

$$A^- = ({y_1}^-, {y_2}^-, {y_3}^-, \dots, {y_n}^-)$$

Information :
J = set of benefit criteria
J' = set of cost criteria
y_{ij} = elements of the weighted normalized decision matrix Y
$y^+_j = \max_i\{y_{ij}\}$; if j is a benefit criteria
$y^+_j = \min_i\{y_{ij}\}$; if j is a cost criteria
$y^-_j = \min_i\{y_{ij}\}$; if j is a benefit criteria
$y^-_j = \max_i\{y_{ij}\}$; if j is a cost criteria
j = 1, 2, 3, . . . , n

Positive/Negative Ideal Solution Distance (D)
Distance between Alternative A_i and Positive Ideal Solution (D+)

$$D_i{}^+ = \sqrt{\sum_{j=1}^{n} ({y_1}^+ - y_{ij})^2}$$

Distance between Alternative A_i and Negative Ideal Solution (D-)

$$D_i^- = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_1^-)^2}$$

Information :
y^+_j = positive ideal solution for the jth attribute
y^-_j = negative ideal solution for the jth attribute
y_{ij} = elements of weighted normalized decision matrix Y

Preference Value (V)
The preference value for each alternative (V_i) is given as:

$$V_i = \frac{D_i^-}{D_i^- + D_i^+}$$

A larger V_i value indicates that alternative A_i is preferred

C. TOPSIS Strength and Weakness

TOPSIS Strength

The notion is straightforward and simple to grasp. The process flow of the TOPSIS approach, which is not overly convoluted, demonstrates its simplicity. because it makes decisions with the use of criteria indicators and alternative factors

Computing is efficient, computational calculations are more efficient and rapid, and it can be used as an alternative performance measure as well as alternative decisions in the form of a simple form of computational output, and it may be employed because of speedier decision-making processes.

Weakness of TOPSIS

There is no priority weight determination, which is the priority calculation against the criteria, which is useful for increasing the validity of the weight value of the criteria calculation. So, for this reason, this method can be combined, for example, with the AHP method to produce maximum output or decisions.

There is no linguistic form for alternative assessment of the criteria. Usually, this linguistic form is interpreted as a fuzzy number. In the absence of a mediator such as a hierarchy, if it is processed independently, then the accuracy of decision-making tends not to produce perfect decisions.

This TOPSIS method can be used in determining the ranking of alternatives by considering the ideal solution to a problem and determining the weight of each criterion. However, it is not good if it is used in obtaining weights that consider the relationship between criteria. Although it can be done by pairwise comparison, it requires more complicated matrices and calculations. Therefore, it is combined with other methods such as the ANP Analytic Network Process to overcome the weighting problem.

In the process that uses the TOPSIS method, the ranking and weighting of the criteria are given a definite value. In fact, in real-life applications, there is often incomplete information, or the required information is not available. An example of the cause of incomplete information is due to human judgments, which are often uncertain and fuzzy and cannot estimate rankings in definite numerical data. This uncertainty is something that cannot be overcome using the TOPSIS method unless further algorithm calculations are carried out in the formulation of the TOPSIS method.

The TOPSIS method determines the solution based on the shortest distance to the ideal solution and the largest distance from the ideal negative solution. However, this method does not consider the relative importance of each of these distances.

In the TOPSIS method, assumptions are often made on the relative importance of each response, and these are used in combination with other methods to resolve these assumptions. An example is using the AHP Analytical Hierarchy Process or ANP Analytic Network Process method to obtain a weighted value that represents the relative importance of each criterion.

In the TOPSIS method, the alternative with the highest ranking is the best solution, but not necessarily the highest ranking is the closest to the ideal solution. So it needs to be calculated again to be sure.

D. Case Study Problem Solving with TOPSIS

Case Study 1 : Understand the TOPSIS method

Objective : Students understand the problem to be solved using the TOPSIS method

Solution Steps:

1) Pay attention to the following questions:
   Class XI students of SMA N 16 Jakarta will move up to class XII and start entering majors which consist of 3 types (IPA, Social Sciences, and Language). By using the help of the DSS, you will find the appropriate major for each student. One of the students who will be used as an example of finding a solution with this DSS is Sandi with 9 existing criteria, namely science specialization, social studies specialization, language specialization, science psychology, social science psychology, language psychology, science report card, social studies report card, and language report card.

2) State the step-by-step solution to problem no. 1 with TOPSIS method!

Questions :

1) Why is it necessary to find the ideal solutions A+ and A-?

2) What happens if we equate the cost criteria with the benefit criteria?

Case Study 2 **:** Looking for the best Alternative Solution with TOPSIS

Objective **:** Students know and are able to calculate using the TOPSIS method

Solution Steps:

1) Pay attention to the questions below:
   a. Based on the questions in experiment 1, it is known that the decision matrix is

Table 36. Comparison Matrix (TOPSIS Task)

Alternative	Criteria								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
LANGUANGE	3	3	4	2	2	4	3	3	5
SCIENCE	4	3	3	3	2	2	5	4	4
SOCIAL	3	4	3	2	3	2	3	5	4
Weight	4	3	3	4	3	3	2	2	3

2) Normalize the weights on the questions above!
3) Perform the calculation of the best alternative using the TOPSIS method according to the stages described previously!

Questions **:**

1) Does the DSS for the selection of majors at the high school level have a cost criterion? If the answer is yes, please state what the criteria are!
2) Which criterion has the greatest priority in determining the chosen alternative?

3) Mention the ranking of alternative calculations based on the calculation of the TOPSIS method for the case study above!

CHAPTER 7
SIMPLE MULTI-ATTRIBUTE RATING TECHNIQUE

A. Definition

Edward created the multi-attribute decision-making technique known as SMART (Simple Multi Attribute Rating Technique) in 1971. (Filho 2005). Initially, the goal of this strategy was to make it simple to use the MAUT (Multi-Attribute Utility Theory) method. Failures in this approach have been discovered throughout time and have been addressed (Edwards and Barron, 1994), who developed the SMARTS and SMARTER methodologies, offering two distinct ways to address these flaws (Filho, 2005).

A development of the SMART (Simple Multi-Attribute Rating Technique) approach is the SMART (Simple Multi-Attribute Rating Technique Exploiting Rank) method. In 1977, the SMART approach was given that moniker. The SMARTS (Simple Multi-Attribute Rating Technique Swing) technique was created from the SMART method, which was later enhanced and adjusted by Edward and Baron in 1994 to become the SMART method (Simple Multi-Attribute Rating Technique). Ranking Method Based on Attributes).

A multi-attribute decision-making technique is called SMART (Simple Multi Attribute Rating Technique). This multiple-attribute decision-making method helps decision-makers select one from several options. Each decision-maker must select a course of action that is consistent with the established goals.

Every alternative has a collection of qualities, each of which has a value. A specific scale is used to average this number. Every characteristic has a weight that indicates how significant it is on a scale, and each attribute also has a weight that indicates how significant it is in relation to other attributes. Each alternative is evaluated using this weighting and ranking to find the optimal one.

The value of each alternative is predicted by SMART using an adaptive linear model. Because of how easily SMART responds to decision makers' needs and how it examines replies, it is more commonly used. This approach offers a deep grasp of the issue and is acceptable to decision-makers because the best analyses are transparent. By using a scale of 0 to 1, SMART weighting makes it simpler to compute and evaluate values for each choice.

B. SMART Method Stages

The SMART paradigm has the following steps, according to Goodwin and Wright (2004) in order according to Figure 12:

Figure 12. SMART Method Stages

1) Define Criteria
   Determine the standards through which decision-making challenges are resolved. For the problem to be solved, information from the decision maker or the competent/authorized party is required to ascertain the criteria used in this decision-making system.

2) Determining Criteria Weight

Each criterion is weighted using a range of 1-100, with the most important criterion receiving the most priority.

3) Normalization of Criteria Weight
   By comparing the value of each criterion's weight with the sum of all the criteria, one may determine how to normalize the weights of each criterion.

4) Provide Parameter Values for Each Criterion
   The criterion value for each of these alternatives can be expressed as either quantitative data (numbers) or qualitative data, depending on the alternative. For instance, it has been proven that the value for the pricing criteria is in quantitative form, whereas the value for the facility criteria can be in qualitative form (very complete, complete, less complete). If the criterion value is qualitative, we must convert it to quantitative data by changing the parameter of the criterion value to, for instance, extremely complete means 3, complete means 2, and incomplete means 1.

5) Determine the Utility Value
   By transforming the value of the criteria in each criterion into the value of the standard data criteria, you can calculate the utility value. The nature of the criterion has an impact on its utility value.

$$u_i(a_i) = 100\ \frac{(C_{max} - C_{out\,i})}{(C_{max} - C_{min})}\ \%, \text{ for cost criteria}$$

$$u_i(a_i) = 100\ \frac{(C_{out\,i} - C_{min})}{(C_{max} - C_{min})}\ \%, \text{ for benefit criteria}$$

Information

$u_i(a_i)$: utility value of i-th criterion for i-th alternative
c_{max} : maximum criterion value
c_{min} : minimum criteria value

$c_{out\ i}$: i-th criterion value

6) Determine the final value
   By dividing the result of normalizing the standard data criteria values by the normalized value of the criteria weights, you can get the final value of each.

$$u(a_i) = \sum_{J=1}^{m} w_j u_i\,(a_i), \qquad i = 1,2, \dots m$$

Information:

$u(a_i)$: total value for alternative i
w_j : the value of the weight of the jth criteria that has been normalized
$u_j(a_i)$: utility value of the jth criterion for alternative i

7) Ranking
   The results of the final value calculation are then sorted from the largest to the smallest value, the alternative with the largest final value indicates the best alternative

C. SMART Strength and Weakness

The following are some of the advantages and disadvantages of the SMART method. The strength can be seen from the following points:

As the impact of the number of categories increases, the SMART method is simple to alter (Yeh and Chang 2009). The SMART method evaluates panelist preferences using a ratio scale (Yeh and Chang 2009). SMART is a helpful strategy since it is straightforward, uncomplicated, and time-efficient, all of which are crucial for those who must make decisions (Gu et al. 2012). When using SMART, adding more options is helpful

because it does not affect the decision made based on the initial number of alternatives (Chen and Hou 2004; Panagopoulos et al. 2012). In comparison to other techniques, using SMART in performance measures may be preferable (Gu et al. 2012). Because it analyzes data using a variety of quantitative and qualitative criteria, SMART is particularly well-liked (Chen and Hou 2004). Although SMART has been effectively used to solve MCDM issues, this method falls short when addressing the inherent ignorance of language judgments in decision making (Gu et al. 2012; Chen and Hou 2004). The SMART model's benefit is that it is independent of alternatives (Panagopoulos et al. 2012; Afshar et al. 2011).

While The weakness can be seen from the following points:

Comparisons of an attribute's importance have been underlined as being worthless if they do not also consider the full range of its effects (Von Winterfeldt and Edwards 1986). This technique's disregard for the relationships between parameters is one of its drawbacks (Demirci et al. 2009). The decision value of the initial alternative will not change simply by increasing the number of alternatives considered since alternative ratings are not correlated (Valiris et al. 2005). The SMART technique would be too complicated to implement and maintain due to the numerous qualities (Benzerra et al. 2012).

D. Case Study Problem Solving with SMART

In this sub-chapter, an example of the use of the SMART method will be discussed in a decision support system.

A CCC College wishes to select annual outstanding students who represent the achievements of all students from all majors. Of course, it is not an easy thing to make the selection because it requires high accuracy and fairness in the assessment in accordance with the determining criteria that make a student worthy of being an outstanding student. There are 4 criteria according to the provisions: number of academic achievements, number of non-academic achievements, concern

for the environment, foreign language skills. The settlement is carried out in 7 stages according to the discussion of the steps for calculating decision recommendations using the SMART method.

- Define Criteria, Determining Criteria Weight, and Provide Parameter Values for Each Criterion

Table 37. Table for Define Criteria, Determining Criteria Weight, and Provide Parameter Values for Each Criterion (SMART Method)

Criteria	**Score**	**Weight**
number of academic achievements		25%
>20 certificate	100	
12-20 certificate	75	
5-11 certificate	50	
<5 certificate	0	
number of non-academic achievements		25%
>20 certificate	100	
12-20 certificate	75	
5-11 certificate	50	
<5 certificate	0	
concern for the environment		35%
Very good	100	
Good	80	
Enough	60	
Not enough	30	

Criteria	Score	Weight
Very less	10	
foreign language skills		16%
Very good	100	
Good	80	
Enough	60	
Not enough	30	
Very less	10	

❖ Normalization of Criteria Weight

Table 38. Normalization of Criteria Weight (Smart Method

Criteria	Weight	Normalization
number of academic achievements	25%	0.25
number of non-academic achievements	25%	0.25
concern for the environment	35%	0.35
foreign language skills	15%	0.15

❖ Determine the Utility Value

The following is a table of alternative weights per criterion as a first step in determining the utility value. In this case, we know that all the existing criteria are benefits, so the utility value formula used is the utility value benefit criteria formula.

Table 39. Data for Utility Process (SMART Method)

SMART METHOD				
Weight	0,25	0,25	0,35	0,15
Category	Benefit	Benefit	Benefit	Benefit
Alternative	**C1**	**C2**	**C3**	**C4**
A1	50	50	60	10
A2	100	0	30	30
A3	75	75	80	30
A4	0	100	10	60

Then it is calculated, for example, as alternative 1, criteria 1, and alternative 2, criteria 2, as in the calculation below:

$$u_1(a_1) = 100\ \frac{(C_{out\ 1}\ -\ C_{min})}{(C_{max}\ -\ C_{min})}\ \%$$

$$u_1(a_1) = 100\ \frac{(50\ -\ 0)}{(100\ -\ 0)}\ \% = 50\% = 0{,}5$$

$$u_2(a_2) = 100\ \frac{(C_{out\ 2}\ -\ C_{min})}{(C_{max}\ -\ C_{min})}\ \%$$

$$u_2(a_2) = 100\ \frac{(0\ -\ 0)}{(100\ -\ 0)}\ \% = 0\% = 0$$

then if it is calculated as a whole it becomes as follows

Table 40. Utility Value (SMART Method)

UTILITY				
Weight	0,25	0,25	0,35	0,15
Category	Benefit	Benefit	Benefit	Benefit
Alternative	**C1**	**C2**	**C3**	**C4**
A1	0.5	0.5	0.598571429	0.098
A2	1	0	0.298571429	0.298
A3	0.75	0.75	0.798571429	0.298
A4	0	1	0.098571429	0.598

- Determine the final value

Then it is calculated final value, for example, as alternative 1 until and alternative 4, as in the calculation below:

$$u(a_1) = \sum_{J=1}^{m} w_j u_i\,(a_1)$$

$$u(a_1) = (0.25 * 0.5) + (0.25 * 0.5) + (0.35 * 0.59) + (0.15 * 0.09) = (0.4742)$$

then if it is calculated as a whole it becomes as follows

Table 41. Final Value (SMART Method)

Alternative	Final Value
A1	0.4742
A2	0.3992
A3	0.6992
A4	0.3742

❖ Ranking

Based on the final value, sequentially the following results are obtained.

Table 42. Ranking Result (SMART Method)

Alternative	Final Value	Ranking
A3	0.6992	1
A1	0.4742	2
A2	0.3992	3
A4	0.3742	4

And the top order of outstanding students fell to the 3rd student or alternative 3. While the last order fell to the 4th student or alternative 4

Question:

1) How to complete the SMART method's decision recommendations when compared to the SAW method?
2) What are the consequences if the unitally valued segregation is not carried out for benefits and criteria?
3) How can the SMART method's decision recommendations be resolved when compared to the ELECTREE method?

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GLOSARIUM

A

Algorithm

A method or set of guidelines that must be followed while performing calculations or other problem-solving tasks, particularly by a computer.

Alternative

One or more items that having a different potential outcome.

Artificial Intelligence

A system with artificial intelligence has intelligence that may be configured in a scientific environment.

B

Benefit

A benefit or gain resulting from anything.

Business

A person's regular occupation, profession, or trade.

C

Categorical

unambiguously clear and straightforward

Clinical

involving the observation and care of real patients as opposed to theoretical or laboratory research.

Combination

A combining or merging of various elements, wherein each component part is unique from the others.

Comparison

An evaluation of the similarities and differences between two things or individuals.

Components

A component, especially one found in a machine or vehicle, that makes up a bigger total.

Computer Science

The research of computer usage and theory.

Consistency

Conformity in the use of something, usually what is required for the purpose of reason, truth, or justice.

Cost

A sum that must be spent or paid in order to purchase anything.
Criteria

A guideline or benchmark by which something can be assessed or determined.

D

Data Warehouse

Computers. a sizable, central repository for digital data acquired from various organizational units

Database

A thorough compendium of connected data arranged for easy access, typically in a computer.

Decision

The act or process of deciding resolution of a query or doubt by passing judgment:

Diagnostics

Medicine/Medical (used with a singular verb).

Distributed

Having or having to do with a single database that is shared across this network, particularly one that incorporates several smaller databases

E

Ecosystem

Any system or network of components that interact and are interconnected, such as in a business
Employee

A person receiving compensation while working for another individual or a company.

Errors

The state of holding an untrue belief
Expert Systems

A computer program that, using the information at hand, provides diagnoses, answers, or solutions by going through steps meant to mimic the methods and knowledge used by experts in each subject.

F

Feasibility

The likelihood, capacity, or potential for something to be done or accomplished (frequently used in an attributional sense)

Fuzzy Logic

A branch of logic created to allow levels of knowledge and reasoning imprecision, exemplified by words like "extremely," "very probably," and "unlikely," to be represented in a way that the data can be processed by computers.

H

Hierarchy
any system of persons or things ranked one above another.
Hospitalizations

I

Information System

a computer system or set of components for collecting, creating, storing, processing, and distributing information, typically including hardware and software, system users, and the data itself:

K

Knowledge

knowledge of facts, truths, or principles, as gleaned from research or study; general erudition

Linguistic

Of or belonging to language

M

Manager

A person who has control or direction of an institution, business, etc., or of a part, division, or phase of it.

Matrix

Something that constitutes the place or point from which something else originates, takes form, or develops

N

Natural Language

A language used as a native tongue by a group of speakers, as Arabic, English, Mandarin, etc.

Neural Networks

Any group of neurons that conduct impulses in a coordinated manner, as the assemblages of brain cells that record a visual stimulus

Normalized

To cause (something previously considered abnormal or unacceptable) to be treated as normal*:*

Numeric
Of or relating to numbers; of the nature of a number.

O

Operation

An act or instance, process, or manner of functioning or operating.
Organization

The state or manner of being organized.

P

Patient

A person who is under medical care or treatment.

Planning

The act or process of planning or plans.

Preference

The favoring of one country or group of countries by granting special advantages over others in international trade.

R

Rank

Several persons forming a separate class in a social hierarchy or in any graded body.

Ratio

The relation between two similar magnitudes with respect to the number of times the first contains the second

Recommendation

Representation in favor of a person or thing.
Records

To set down in writing or the like, as for the purpose of preserving evidence.

Robotics

The use of computer-controlled robots to perform manual tasks, especially on an assembly line.

S

Safety

The state of being safe; freedom from the occurrence or risk of injury, danger, or loss.

Scale

A cause of blindness or ignorance, as regarding the true nature of a person, situation, etc*:*

Semi-Structured

Having and manifesting a clearly defined between structure and unstructured on organization.

Solution

A particular instance or method of solving; an explanation or answer:

Storage

The act of storing; state or fact of being stored

Strategies

The use or an instance of using this science or art.

Support

To bear or hold up (a load, mass, structure, part, etc.); serve as a foundation for

Synthesis

The combining of the constituent elements of separate material or abstract entities into a single or unified entity (opposed to analysis,) the separating of any material or abstract entity into its constituent elements.

System

An assemblage or combination of things or parts forming a complex or unitary whole

T

Tactical

Of or relating to a maneuver or plan of action designed as an expedient toward gaining a desired end or temporary advantage

Transactions

Something that is transacted, especially a business agreement.

U

Unstructured

Lacking a clearly defined structure or organization

User Interface

The interface features through which users interact with the hardware and software of computers and other electronic devices

V

Vector

Such a quantity with the additional requirement that such quantities obey the parallelogram law of addition.

W

Warehousing

An act or instance of a person or company thatwarehouses something.

Weights

The amount or quantity of heaviness or mass; amount a thing weighs

INDEKS

H
Health Service
Hierarchy
Hospitalizations
I
Information System
K
Knowledge
L
Linguistic
M
Manager
Matrix
N
Natural Language
Neural Networks
Normalized
Numeric
O
Operation
Organization
P
Patient
Planning
Preference
R
Rank
Ratio
Recommendation
Records
Robotics
S
Safety
Scale
Semi-Structured
Solution

Storage
Strategies
Support
Synthesis
System

T

Tactical
Transactions

U

Unstructured
User Interface

V

Vector

W

Warehousing
Weights

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Catatan :