DECISION SUPPORT SYSTEM FOR SELECTION USING ANALYTICAL NETWORK PROCESS

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ABSTRACT

Decision support system is a type of information system whose principal objective is to support a human decision maker during the process of arriving at a decision. Decision-making problem is the process of finding the best option from all the flexible alternatives. Multi-Criteria Decision-Making (MCDM) is selection of the best action from a set of alternatives, each of which is evaluated against multiple, and often conflicting criteria. There are many MCDM methods such as Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Multi-Attribute Utility Theory (MAUT), Weighted Sum Model (WSM) and so on.

Among other MCDM approaches, ANP has been coming into applications in relevant areas three years ago. ANP has been applied in a variety of areas as a useful and practical multi-criteria decision problem. In real life problems that involve dependence and feedback, ANP is an effective tool for decision-making. There are dependence and feedback among elements and alternatives in many real world cases. Feedback enables to factor the future into present to determine how to attain a desired future. Decision-making with feedback and dependence improves the priorities derived from judgments and make prediction more accurate.

In this thesis, ANP model is used to make decision for finding laptop and also considered dependence and feedback among decision criteria such as processor, processor speed, hard disk, memory, battery, operating system, price, weight, dimension, color and warranty. This system is implemented as a web-based decision support system. It also provides the user to browse the detail information of laptop. Moreover, user can get decision for finding the suitable laptop, by using this web-based decision support system. This system is implemented with PHP language and MySQL is used for data storage.

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CHAPTER 1

INTRODUCTION

Decision Support Systems (DSS) are a type of interactive information system whose principle objective is to support a human decision maker during the process of arriving at a decision. DSS have evolved over the past four decades from theoretical concepts into real world computerized applications. Decision-making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker. DSS is also a specific class of computerized information system that supports business and organizational decision-making activities.

This system functions as web-based decision support system with analytical network process model to find appropriate laptop information. This selection is the one that have to be decided by the clients. In order to ensure that the system can be completed successfully, the client must select the appropriate criteria (e.g. cost, technical features, physical appearance etc.). In reality, this system needs a holistic approach in which all criteria and alternatives involved are connected in a network system that accepts various dependencies. Several decision problems cannot be hierarchically structured because they involve the interactions and dependencies in higher/lower level elements.

The Analytic Network Process (ANP) involves dependence and feedback. It allows for more complex interrelationship among decision elements. The ANP is a Multi-Criteria Decision-Making (MCDM) methodology aimed at setting priorities of alternatives or selecting the best alternatives. Feedback improves the priorities derived judgment and makes the prediction more accurate.

In this thesis, ANP helps to figure out the best outcome which features that the consumer need and how to find the laptop that really desire. In order to select a number of laptops to meet the individual basic requirement, the following criteria are established: technical features, physical appearance, cost, and after sales service. Furthermore, this is a web based decision support system that supports the consumer to choose the appropriate laptop brand.

The objective of the thesis is to apply ANP for decision-making in laptop selection process. Furthermore, the thesis has developed a decision support model for laptop selection in order to find the appropriate laptop with user selection criteria as user preference criteria. The ANP that was developed by Thomas Saaty [11] does not depend upon linear top-to-bottom form of hierarchy but looks like a network with the ability to consider feedback and to connect clusters of elements.

1.1Case Study

Having laptops and using them is to make human life easier as it is light and portable. The mobility of laptop enhances its wide usage. Laptops have become the fundamental needs for most of the people especially officers and students because it is very useful for business as well as in personal use. There are variety of laptops in the market nowadays. Therefore, the customers want to know how to use new updated laptops. Laptop is one of the electronic devices for different types of customers that applied various kinds of domains. They utilize it to obtain notes, books, internet access, communication, entertainment, business and other purposes. They need to consider multiple factors or decision criteria before selecting the most suitable laptop. ANP model is a technique that deals with MCDM problem. ANP is a decision-making tool used in complex problems and it involves all kinds of relationship, dependence and feedback in the model and draws a systematical figure of the system. ANP model can help to select the best appropriate alternative based on the preference of the decision makers.

In this study, Laptop models are selected as decision alternatives. The decision criteria are price, warranty, weight, dimension, color, processor, processor speed, hard disk, memory, battery and operating system. ANP model is widely used in determining the ranking or priority of decision alternatives and decision criteria. For collecting data, survey method is used in this study because this study mainly focuses on the customer's choices or priority.

The process of ANP consists of four major steps. In the first step, the laptop selection problem is decomposed into a rational system like a network. The structure can be attained by incorporating the opinion of decision makers through brainstorming or other appropriate methods. For the proposed laptop selection model, overall eleven criteria are determined under the four main criteria clusters: cost, after sales services, physical appearance, technical features. The eleven criteria are processor, processor speed, hard disk, memory, battery, operating system, price, weight, dimension, color and warranty.

As the second step, ANP decision elements at each cluster are pairwise compared with respect to their importance near their control criterion. Moreover, the clusters are also compared pairwise with respect to their contribution to the goal. In pair-wise comparisons, a ratio scale of 1-9 is used to compare any two elements or clusters and three step procedure is used to calculate the priority in pairwise comparison. In this step, user has to input preference how much more important for each cluster in laptop selection to be weighted the priorities in decision for their different purposes.

The next step is supermatrix formation (unweighted, weighted and limit). The original unweighted supermatrix of column eigenvectors obtained from pairwise comparison matrices of elements of laptop models. The weighted supermatrix obtained from the unweight supermatrix components have been multiplied by cluster weight calculated in step2. The Limit matrix of the laptop selection is founded by multiplying supermatrix by itself. Each row contains the same value and provides the final priorities or weights for the alternatives and criteria of laptop selection program.

The last step is the selection of best laptop alternatives. This step has to evaluate each laptop so as to select the most appropriate one to support final decision-making. The criterion to make this selection is the weights of laptops that can be taken from the limit matrix. The limiting priorities of the laptop alternatives can be obtained. The highest ranking of laptop model is selected because it has more priorities than others.

In this study, ANP technique is used for laptop selection in multi-criteria decision-making situation. The ANP is highly recommended because ANP allows the interdependent and feedbacks influences specified in the model. This laptop selection system helps the user can choose the suitable laptop model when she/he needs to make decision.

1.2 Objectives of the Thesis

The objectives of the thesis are as follows:

- To study a useful and simple method to deal with decision making problems.
- To understand the basic structure of ANP technique that consists of an influence network of clusters and nodes contained within the clusters.
- To implement decision support system using different criteria with interdependencies and feedbacks among them.

- To identify and evaluate the factors impact on laptop purchase decisions of the consumers.

1.3 Overview of the Thesis

In this thesis, ANP model is used to select the best outcome which features that the user needs. When the user chooses desired criteria such as brand, price then the system will display the available laptop lists according to the user input. This system is intended to help the user as a decision maker to find the suitable laptops for their preferences. By using this system, the user can choose the suitable laptop brand when she/he needs to make decision. Therefore, a good decision-making method of the suitable laptop selection is necessary. This laptop selection system implements with eleven criteria: processor, processor speed, hard disk, memory, battery, operating system, price, weight, dimension, color and warranty and dynamically calculates maximum two hundred alternatives without worrying about the volume of the matrix may be large and the performance of the system will degrade.

There are four general steps in ANP based multi-criteria decision-making process, including model construction; paired comparisons between each two clusters or nodes; supermatrix calculation based on results from paired comparisons; and selection of the best alternatives. The final ranking result depends on the priority of each laptop model.

1.4 Organization of the Thesis

There are five chapters in this thesis. Chapter 1 firstly presents introduction, case study, objectives of the thesis and overview of the thesis. Chapter 2 discusses decision support systems and analytic network process theory concepts. Chapter 3 explains the step by step process of the Analytic Network Process (ANP) for the proposed system. Chapter 4 describes design and implementation of the proposed system. Chapter 5 presents conclusion, advantages, limitation and further extension of the system.

CHAPTER 2
THEORY BACKGROUND

2.1 Decision Support Systems

Decision support systems (DSS) are interactive, computer-based systems that aid users in judgment and choice activities. They provide data storage and retrieval but enhance the traditional information access and retrieval functions with support for model building and model-based reasoning. They support framing, modeling, and problem solving.

Typical application areas of DSS are management and planning in business, health care, the military, and any area in which management will encounter complex decision situations. DSS are typically used for strategic and tactical decisions faced by upper-level management decisions with a reasonably low frequency and high potential consequences in which the time taken for thinking through and modeling the problem pays off generously in the long run [8].

There are three fundamental components of DSS. They are:

- Database management system (DBMS). A DBMS serves as a data bank for the DSS. It stores large quantities of data that are relevant to the class of problems for which the DSS has been designed and provides logical data structures (as opposed to the physical data structures) with which the users interact. A DBMS separates the users from the physical aspects of the database structure and processing. It should also be capable of informing the user of the types of data that are available and how to gain access to them.
- Model-base management system (MBMS). The role of MBMS is analogous to that of a DBMS. Its primary function is providing independence between specific models that are used in a DSS from the applications that use them. The purpose of an MBMS is to transform data from the DBMS into information that is useful in decision-making. Since many problems that the user of a DSS will cope with may be unstructured, the MBMS should also be capable of assisting the user in model building.
- Dialog generation and management system (DGMS). The main product of an interaction with a DSS is insight. As their users are often managers who are not computer-trained, DSS needs to be equipped with intuitive and easy-to-use

interfaces. These interfaces not only aid in model building, but also support in interaction with the model, such as gaining insight and recommendations from it. The primary responsibility of a DGMS is to enhance the ability of the system user to utilize and benefit from the DSS.

2.1.1 The Features of Decision Support System

Decision Support Systems (DSS) have several features to offer in the general information system environment of an organization. Specifically, DSS can [16]

- Support decision-making in ill-structured situations when, precisely owing to the lack of structure, problems do not lend themselves to full computerization. Yet the decision makers do require computer assistance for access to and processing of voluminous amounts of data.
- Help to rapidly obtain quantitative results needed to reach a decision. A model for the structured part of the problem can be constructed rather quickly, and it can be flexibly deployed with data as needed during the decision-making process.
- Operate in the ad hoc mode to suit the current needs of the user, as opposed to operating on a pre-established schedule, as management reporting system do.
- Support easy modification of models, which increases the organizations responsiveness to the changing environment both within the firm and in the outside world.
- Foster high-quality decision-making by encouraging decisions based on the integration of available information and human judgment. DSSs give decision makers a degree of confidence in their decisions unavailable to a person who is wholly dependent on his or her judgment.
- Facilitate the implementation of decisions, which frequently cut across departmental boundaries. By creating and exercising common models, decision makers in the involved organization units develop common assumptions and, in general, learn to communicate at a deeper level.
- Support group decision-making, particularly through group DSS (GDSS).
- Be user-friendly, a principal feature of a well-designed DSS. User-friendliness can make computer-supported problem solving attractive to individuals at all levels of and organization. The user can work with the system in the style that

best serves him or her. This helps managers, professionals, and other knowledge workers to perform better. It also enriches their jobs, particularly at the operational level.

- Give managers the opportunity to gain a better understanding of their business by developing and working with models.

2.1.2 The Benefits of Decision Support System

The benefits of the decision support system are as follows: [17]

- Improves personal efficiency
- Speed up the process of decision-making
- Increases organizational control
- Encourages exploration and discovery on the part of the decision maker
- Speeds up problem solving in an organization
- Facilitates interpersonal communication
- Promotes learning or training
- Generates new evidence in support of a decision
- Creates a competitive advantage over competition
- Reveals new approaches to thinking about the problem space
- Helps automate managerial processes

2.1.3 The Purpose of Decision Support System

The purpose of a decision support system is to support managerial decision-making. This support may come about indirectly through staff operation of DSS or as a result of hands-on use by management. The developed DSS may require a new organization unit with a position within the organization's structure and submit them to the administrative control of management. The actual operation of a DSS may require skills that are not possessed by many managers. In these cases, an intermediary may operate the system for the user. DSS also supports the manager in the decision-making process by supplying needed information [7].

2.1.4 The Effects of Using a Decision Support System

A decision support system has great impact on the profits of the company. It forces the management to rationalize the depreciation, inventory and inflation policies. It wants the management against impending crises and problems in the company. It specially helps in the following areas [13]:

- The management knows exactly how much credit it could take, for how long and in which interest rate. It has been proven that without proper feedback, managers tend to fake too much credit and burden the cash flow of their companies.
- A decision support allows for careful financial planning and tax planning. Profits go up, non-cash outlays are controlled, tax liabilities are minimized and cash flows are maintained positive throughout.
- As a result of all the above effects, the value of the company grows and its shares appreciate.
- The decision system is an integral part of financial management. It is completely compatible with western accounting methods and derives all the data that it needs from information extant in the company.
- The establishment of a decision system does not hinder the functioning of the company and in any way and does not interfere with the authority and functioning of the financial department.

2.1.5 User Interfaces to Decision Support System

While the quality and reliability of modeling tools and the internal architecture of DSSs are important, the most crucial aspect of DSSs is their user interface. Systems with user interfaces that are cumbersome unclear or that require unusual skills are rarely useful and accepted in practice. The most important result of a session with a DSS is insight into the decision problem. In addition, when the system is based on normative principles, it can play a tutoring role; one might hope that users will learn the domain model and how to reason with it over time and improve their own thinking. A good user interface to DSSs should support model construction and model analysis, reasoning about the problem structure in addition to numerical calculations and both choice and optimization of decision variables. [8]

2.2 Decision-Making

A pioneer in the development of human decision-making models and the foundation for human decision-making models are considered and established by Herbert Alexander Simon [3]. His basic model depicts human decision-making as a three-stage process. [4] These stages are:

- **Intelligence.** The identification of a problem that requires a decision and the collection of information relevant to the decision;
- **Design.** Creating, developing and analyzing alternatives course of action; and
- **Choice.** Selecting a course of action from those available.

2.2.1 Decision-Making Steps

There are decision-making steps [9]. They are:

- The first step - Outline your goal and outcome. This will enable decision makers to see exactly what they are trying to accomplish and keep them on a specific path.
- The second step - Gather data. This will help decision makers have actual evidence to help them come up with a solution.
- The third step - Brainstorm to develop alternatives. Coming up with more than one solution able you to see which one can actually work.
- The fourth step - List pros and cons of each alternative. With the list of pros and cons, you can eliminate the solutions that have more cons than pros, making your decision easier.
- The fifth step - Make the decision. Once you analyze each solution, you should pick the one that has many pros (or the pros that are most significant), and is a solution that everyone can agree with.
- The sixth step - Immediately take action. Once the decision is picked, you should implement it right away.
- The seventh step - Learn from, and reflect on the decision-making. This step allows you to see what you did right and wrong when coming up, and putting the decision to use.

2.2.2 Various Models of Decision-Making

Various views and theories of decision-making may be found in the literature. The following list of views, supporting theories and models are based upon categorizations provided by Keen and Scott Morton (1978), Huber (1981), and Das and Teng (1999). They are [9]:

- The rational model
- The model of bounded rationality
- The increment list view
- The organizational procedures view
- The political view
- The garbage can model
- The individual differences perspective
- Naturalistic decision-making
- The multiple perspectives approach

2.3 Multi-Criteria Decision-Making

Multi-Criteria Decision-Making (MCDM) consists of constructing a global preference relation for a set of alternatives evaluated using several criteria. It selects the best actions from a set of alternatives, each of which is evaluated against multiple, and often conflicting criteria. It consists of two related paradigms:

- Multi Attribute Decision-Making (MADM): these problems are assumed to have a predetermined, limited number of decision alternatives.
- Multi Objective Decision-Making (MODM): the decision alternatives are not given. Instead the set of decision alternatives is explicitly defined by constraints using multiple objective programming. The number of potential decision alternatives may be large [4].

  MCDM problem has four elements. They are:

- Goal – define as the association of a criteria with a target.
- Objectives – represent direction of improvement of a criterion.
- Criteria – defines as a decision's maker values related to reality.
- Alternative – are the methods which change the preliminary condition into preferred condition.

2.3.1 Steps of Multi-Criteria Decision-Making to Solve the Problem

Multi-Criteria Decision-Making (MCDM) has eight-steps to solve the problem. They are [5]:

1. Establish the decision context, the decision objectives (goal) and identify the decision makers.
2. Identify the alternatives.
3. Identify the criteria that are relevant to the decision problem.
4. For each of the criteria, assign scores to measure the performance of the alternatives against each of these and construct an evaluation matrix.
5. Standardize the raw scores to generate a priority scores matrix or decision table.
6. Determine a weight for each criterion to reflect how important it is to the overall decision.
7. Use aggregation functions to compute an overall assessment measure for each decision alternatives by combining the weights and priority scores.
8. Perform a sensitivity to assess the robustness of the preference ranking to changes in the criteria scores and the assigned weights.

2.3.2 Multi-Criteria Decision-Making Methods

There are many Multi-Criteria Decision Analysis (MCDA) or MCDM methods in use today. Some of the MCDA/MCDM methods are [4]:

- Aggregated Indices Randomization Method (AIRM)
    - AIRM is a modification of a well-known aggregated indices method, targeting complex objects subjected to multi-criteria estimation under uncertainty. The main advantage of AIRM over other variants of aggregated indices methods is its ability to cope with poor-quality input information.
- Analytic Hierarchy Process (AHP)
    - AHP is a multi-criteria decision-making technique that can help express the general decision operation by decomposing a complicated problem into a multilevel hierarchical structure of objective, criteria and alternatives.
- Analytic Network Process (ANP)
    - ANP provides a general framework to deal with decisions without

making assumptions about the independence of higher level elements from lower level elements and about the independence of and element within a level. Influence is the central concept in the ANP.

- Data Envelopment Analysis (DEA)
    - DEA is used to provide policy makers of any country with a model to aid in prioritizing actions to improve the safety of their respective roadways in the most efficient ways possible. DEA capable of handling multiple inputs and outputs; efficiency can be analyzed and quantified. The disadvantage of DEA is that it does not deal with imprecise data; assumes that all input and output are exactly known. DEA has been used in economics, medicine, utilities, road, safety, agriculture, retail and business problems.
- Dominance-Based Rough Set Approach (DRSA)
    - DRSA is an extension is an extension of multi-criteria decision analysis (MCDA). The main change compared to the classical rough sets is the substitution for the indiscernibility relation by a dominance relation, which permits one to deal with inconsistencies typical to consideration of criteria and preference-ordered decision classes.
- ELECTRE (Outranking)
    - ELECTRE is and outranking method based on concordance analysis. Its major advantage is that it considers uncertainty and vagueness. One disadvantage is that its process and outcomes can be hard to explain in layman's terms. Further, due to the way preferences are incorporated, the lowest performances under certain criteria are not displayed. ELECTRE has been used in energy, economies, environmental, water management, and transportation problems.
- The Evidential Reasoning Approach (ER)
    - ER is a generic evidence-base multi-criteria decision analysis (MCDA) approach for dealing with problems having both quantitative and qualitative criteria under various uncertainties including ignorance and randomness. It has been used to support various decision analysis, assessment and evaluation activities such as environmental impact assessment and organizational self-assessment based on a range of

quality models.

- Goal programming (GP)
    - GP is a pragmatic programming method that is able to choose from an infinite number of alternatives. One of its advantages is that it has the capacity to handle large-scale problems. Its ability to produce infinite alternatives provides a significant advantage over so weight coefficients.
- Grey Relational Analysis (GRA)
    - GRA is also called Deng's Grey Incidence Analysis model. It is one of the most widely used models of Grey system theory. GRA uses a specific concept of information. It defines situations with no information as black, and those with perfect information as white. However, neither of these idealized situations ever occurs in real world problems. In fact, situations between these extremes are described as being grey, hazy or fuzzy.
- Inner Product of Vectors (IPV)
    - In Euclidean geometry, the dot product of the Cartesian coordinates of two vectors is widely used and often called inner product (or rarely projection product). Algebraically, the dot product is the sum of the products of the corresponding entries of the two sequences of numbers.
- Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH)
    - MACBETH permits the evaluation of options against multiple criteria. The key distinction between MACBETH and other multi-criteria decision analysis (MCDA) methods is that it needs only qualitative judgements about the difference of attractiveness between two elements at a time, in order to generate numerical scores for the options in each criterion and to weight the criteria. The seven MACBETH semantic categories are: no, very weak, weak, moderate, strong, very strong, and extreme difference of attractiveness.
- Disaggregation-Aggregation Approaches (Utility Additive Method (UTA), UTAII, Utilities Additives Discriminates (UTADIS) method)
    - The aggregation-disaggregation approaches as an important field of multi-criteria decision-aid systems aim to infer global preference models

from preference structures, as directly expressed by one or more decision-makers. UTA methods are regression-based approaches that have been developed as an alternative to multiattribute utility theory (MAUT). UTA methods use linear programming techniques for finding additive utility functions that best explain stated preferences. The shape of the utility functions is determined automatically while overfitting is prevented by balancing the model error with model simplicity.

- Multi-Attribute Global Inference of Quality (MAGIQ)
  - MAGIQ is a multi-criteria decision analysis technique. MAGIQ is based on a hierarchical decomposition of comparison attributes and rating assignment using rank order. The MAGIQ technique is used to assign a single, overall measure of quality to each member of a set of systems where each system has an arbitrary number of comparison attributes. The MAGIQ technique has features similar to the analytical hierarchy process (AHP) and the simple multi-attribute rating technique exploiting ranks (SMARTER) technique.
- Multi-Attribute Utility Theory (MAUT)
  - MAUT is essentially an extension of Multi-Attribute Value Theory (MAVT) and is a more rigorous methodology for how to incorporate risk preferences and uncertainty into multi-criteria decision support methods. MAUT takes uncertainty into account and can incorporate preferences. One disadvantage is that it needs a lot of input and preferences need to precise. MAUT has been used in economics, finance, energy and agriculture.
- Multi-Attribute Value Theory (MAVT)
  - MAVT is a foundational idea in multi-criteria decision analysis. Applications of MAVT seek to describe a decision maker's value function over two or more objectives and associated criteria.
- New Approach to Appraisal (NATA)
  - NATA was the name given to a multi-criteria decision framework used to apply transport projects and proposals in the United Kingdom. NATA was built on the well-established cost-benefit analysis and environmental impact assessment techniques (such as those contained

in the Highways Agency's Design Manual for Roads and Bridges (DMRB)) for assessing transport projects and proposals.

- Nonstructural Fuzzy Decision Support System (NSFDSS)
    - The Non-structural fuzzy decision support system (NSFDSS) is applied to facilitate the decision-making process for these multi-objective problems. Modified NSFDSS is presented that is suitable for the appraisal of complex construction problems, which allows assessment based on a pair-wise comparison of alternatives using semantic operators, even under the condition that insufficient precise information is available.
- Potentially All Pairwise Ran Kings of all possible Alternatives (PAPRIKA)
    - PAPRIKA is a method for multi-criteria decision-making (MCDM). The PAPRIKA method is based on users expressing their preferences with respect to the relative importance of the criteria or attributes of interest for the decision or choice at hand by pairwise comparing (ranking) alternatives. In MCDM applications, PAPRIKA is used by decision makers to determine weights on the criteria for the decision being made, representing their relative importance. Depending on the application, these weights are used to rank, prioritize or choose between alternatives.
- PROMETHEE (Outranking)
    - The PROMETHEE method is one of the most frequently used methods of multi-criteria decisions based on mutual comparison of each alternative pair with respect to each of the selected criteria. These methods require very clear additional information that is easily obtained and understood by both decision makers and analysts. PROMETHEE methods had been widely used in various others fields including the Information Security for its mathematical properties and friendless of use.
- Superiority and Inferiority Ranking method (SIR method)
    - SIR is a multi-criterion decision-making model (**MCDA**) which can handle real data and provides six different preference structures for the system user. It also incorporates outranking rationale to deal with the

'poor' true-criteria preference structure which appears in selecting proper equipment. The superiority and inferiority scores are produced through the generalized criteria. The SIR method can also analyze different criteria without compiling them into a small scale as GAs.

- Value Analysis (VA)
  - VA can be defined as a process of systematic review that is applied to existing product designs in order to compare the function of the product required by a customer to meet requirements at the lowest cost consistent with the specified performance and reliability needed. VA has been used in capital goods, raw and semi-processed material, printing and stationery items.
- Value Engineering (VE)
  - VE is a systematic method to improve the "value" of goods or products and services by using an examination of function. Value is the ratio of function to cost. Value can therefore be manipulated by either improving the function or reducing the cost. It is a primary tenet of value engineering that basic functions be preserved and not be reduced as a consequence of pursuing value improvements.
- Weighted Product Model (WPM)
  - WPM is a popular multi-criteria decision analysis (MCDA) method. It is similar to Weighted Sum Model (WSM). The main difference is that instead of addition in the main mathematical operation now there is multiplication.
- Weighted Sum Model (WSM)
  - In decision theory, WSM is the best known and simplest multi-criteria decision analysis (MCDA)/ multi-criteria decision-making (MCDM) for evaluating a number of alternatives in terms of a number of decision criteria.

2.4 Analytical Network Process (ANP)

Among many MCDM approaches, the ANP has been coming into applications in relevant areas in the past three years. [18]

ANP is a generalization of the Analytic Hierarchy Process (AHP), by considering the dependence between the elements of the hierarchy. Many decision problems cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements in a hierarchy on lower-level elements. Therefore, ANP is represented by a network, rather than a hierarchy. [2]

The feedback structure does not have the top-to-bottom form of a hierarchy but looks more like a network, with cycles connecting its components of elements, which we can no longer call levels, and with loops that connect a component to itself. It also has sources and sinks. A source node is an origin of paths of influence (importance) and never a destination of such paths. A sink node is a destination of paths of influence and never an origin of such paths. A full network can include source nodes; intermediate nodes that fall on paths from source nodes, lie on cycles, or fall on paths to sink nodes; and finally sink nodes. Some networks can contain only source and sink nodes. Still others can include only source and cycle nodes or cycle and sink nodes or only cycle nodes. A network has a cluster of elements, with the elements in one cluster being connected to elements in another cluster (outer dependence) or the same cluster (inner dependence).

A decision problem involving feedback arises often in practice. It can take on the form of any of the networks just described. The challenge is to determine the priorities of the elements in the network and in particular the alternatives of the decision and even more to justify the validity of the outcome. Because feedback involves cycles, and cycling is an infinite process, the operations needed to derive the priorities become more demanding than has been familiar with hierarchies. How a Hierarchy compares to a Network is shown in Figure 2.1[5].

In the ANP, one often needs to prioritize the influence of the components themselves on each other component to which the elements belong. This influence is assessed through paired comparisons with respect to a control criterion.

The priority of each component is used to weight the priorities of all the elements in that component. The reason for doing this is to enable us to perform feedback multiplication of priorities by other priorities in a cycle, an infinite number of times. The process would not converge unless the resulting matrix of priorities is column stochastic.

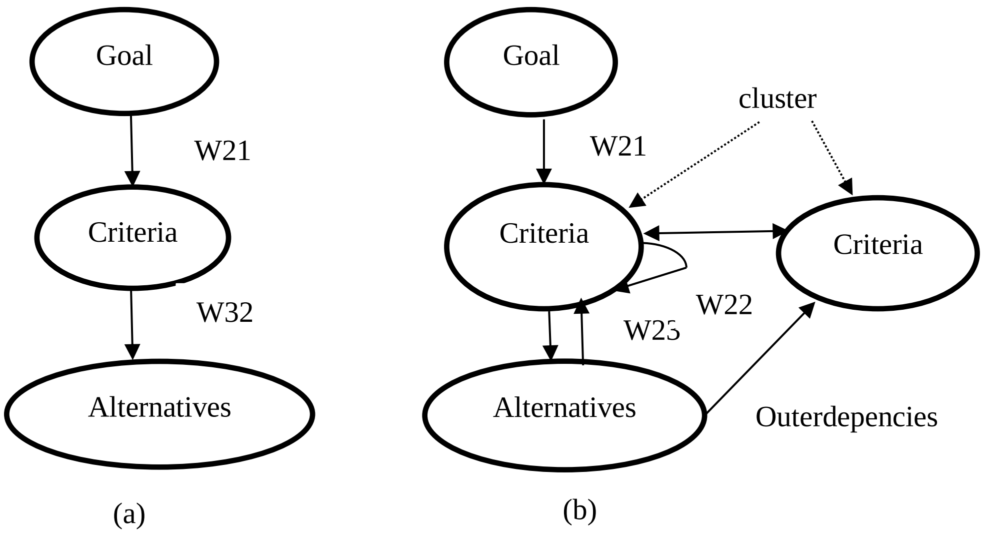


Figure 2.1 Structural Differences between a Hierarchy and a Network
(a) a Hierarchy (b) a Network

ANP is composed of four general steps:

1. Model Construction and Problem Structuring
    - A clear statement of the problem should be prepared and the problem is decomposed into a rational system like a network. The structure can be attained by incorporating the opinion of decision makers through brainstorming or other appropriate methods (Meade and Sarkis, 1998).
2. Pairwise Comparisons Matrices and Priority Vectors
    - Performing pairwise comparisons on the elements of the model.
3. Supermatrix Formation
    - Generating unweighted supermatrix by putting the relative importance weights (eigenvectors), calculated from pairwise comparison matrices, within the supermatrix.
    - Generating the weighted supermatrix by weighting the blocks of the unweighted supermatrix, by the corresponding priorities of the clusters so that it can be column stochastic.
    - Generating the limit supermatrix by raising the weighted supermatrix to the power 2^k+1, where k denotes an arbitrary large number, until the weights converge and stays constant.
4. Selection of Best Alternatives
    - The priority weights of alternatives can be found in the column of alternatives in limit supermatrix. if a supermatrix only comprises

components that are interrelated, additional calculation must be made to obtain the overall priorities of the alternatives. The alternative with the largest overall priority should be the one selected.

2.5 Fundamental Ideas of Analytical Network Process

The fundamental ideas of Analytical Network Process (ANP) are:

- ANP is built on the widely used Analytical Hierarchy Process (AHP).
- ANP allows for interdependency; therefore, ANP goes beyond AHP.
- ANP deals with dependence within a set of elements (inner dependence) and among different sets of elements (outer dependence).
- In the looser network structure of the ANP, any problem may be represented without concern for which criteria come first and which come next, as would be the case in a hierarchy.
- ANP is a non-linear structure that deals with sources, cycles, and sinks having a hierarchy of linear form with goals in the top level and the alternatives in the bottom level.
- ANP portrays a real-world representation of the problem under consideration by prioritizing not only the elements but also the groups or clusters of elements, as is often necessary.
- ANP utilizes the idea of a control hierarchy or a control network in dealing with different criteria, eventually leading to the analysis of benefits, opportunities, costs, and risks. [12]

2.6 Calculation Steps of Analytic Network Process

The ANP represents a decision-making problem as a network of criteria and alternatives (all called elements), grouped into clusters. All the elements in the network can be related in any possible way, i.e. a network can incorporate feedback and interdependence relationships within and between clusters. This provides a more realistic modeling of complex settings. The influence of the elements in the network on other elements in that network can be represented in a supermatrix. This new concept consists of a two-dimensional element-by-element matrix which adjusts the relative importance weights in individual pairwise comparison matrices to build a new overall supermatrix with the eigenvectors of the adjusted relative importance weights. [10]

There are four major steps in ANP based multi-criteria decision-making process. They are:

1. Model for ANP Network Structure
2. Pairwise Comparisons Matrices and Priority Vectors
3. Supermatrix Formation
4. Selection of Best Alternatives

Step 1: Model for ANP Network Structure

The problem should be stated clearly and decomposed into a rational system, such as a network. First, the structure of the decision-making issue must be defined through the recognition of its main objective. Such objective must be later divided into groups ("clusters"), constituted by various elements ("nodes"), and alternatives or options where to choose.

Secondly, the relationships between the different parts of the network must be identified. Each element can be a "source", that is an origin of path influence, or a "sink", that is a destination of paths influences. The elements in a component may influence other elements in the same component (inner dependence) and those in other components (outer dependence) with respect to each of several properties. Feedback Network Structure is shown in Figure 2.2 [2].

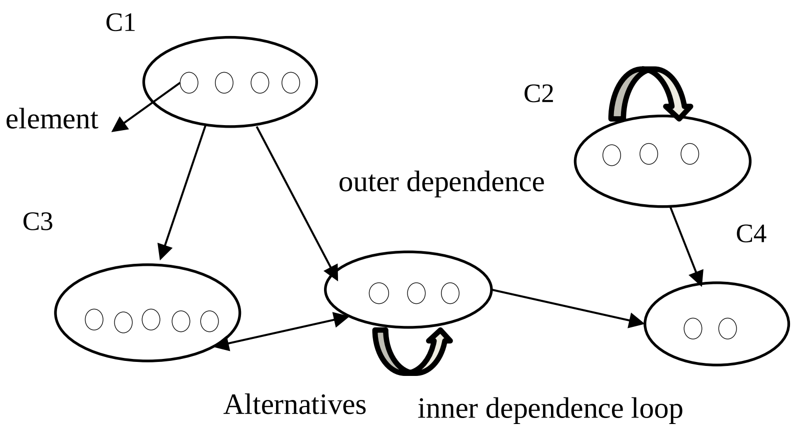


Figure 2.2 Feedback Network

Step 2: Pairwise Comparisons Matrices and Priority Vectors

In ANP, decision elements at each component are compared pairwise with respect to their importance for their control criterion, and the components themselves are also compared pairwise with respect to their contribution to the goal.

Two kinds of pairwise comparison questions encountered in the ANP:

- "of the sub-elements, which one influences the parent element more and how much more?"
- "of the dependent factors, which one influnces the common factor more and how much more?"

Decision makers are asked to respond to a series of pairwise comparisons of two elements or two components in terms of how they contribute to their particular upper-level criterion. In addition, if there are interdependencies among elements of a component, pairwise comparisons are also created. An eigenvector can be obtained for each element to show the influence of other elements on it. [15] In pairwise comparisons, a ratio scale of 1-9 is used to compare any two elements is shown in Table 2.1.

Table 2.1 Fundamental scale of ANP

Intensity of Importance	Definition	Explanation
1	Equal Importance	The two elements contribute equally to the objective.
3	Moderate Importance	Experience and judgment slightly favor one element over another.
5	Strong Importance	Experience and judgment strongly favor one element over another.
7	Very Strong Importance	An element is favored very importance strongly over another.
9	Extreme Importance	The evidence favoring one element over another is of the highest possible order of affirmation.
2,4,6,8	Even Number values are intermediate values.	

A reciprocal value is assigned to the inverse comparison; that is, $a_{ij}=1/a_{ji}$, where a_{ij} (a_{ji}) denotes the importance of the i^{th} (j^{th}) element. In this stage, the following three-step procedure is used to synthesize priorities [14].

1. Sum the values in each column of the pairwise comparison matrix.
2. Divide each element in a column by the sum of its respective column. The resultant matrix is referred to as the normalized pairwise comparison matrix.

3. Sum the elements in each row of the normalized pairwise comparison matrix, and divide the sum by the *n* elements in the row. These final numbers provide an estimate of the relative priorities for the elements being compared with respect to their upper-level criterion. Priority vectors must be derived for all comparison matrices.

Step 3: Supermatrix Formation (Unweighted Supermatrix, Weighted Supermatrix and Limit Supermatrix)

This step aims to form a synthesized supermatrix to allow for the resolution of the effects of the interdependences that exists between the elements (nodes and clusters) of the ANP model.

To obtain global priorities in a system with interdependent influences, the local priority vectors are entered in the appropriate columns of a matrix known as a supermatrix. Each element is represented at one row and one respective column.

A supermatrix is actually a partitioned matrix, where each matrix segment represents a relationship between two nodes (components or clusters) in a system. The computed eigenvector of the sub-elements with respect to their parent element is placed to the column representing the parent element and the rows representing the sub-elements.

In order to obtain useful information for the laptop ranking, the calculation of supermatrix is to be conducted following three sub-steps, which transform an initial supermatrix (Unweighted) to a weighted supermatrix, and then to a synthesized (Limit) supermatrix.

The original **Unweighted Supermatrix** of column eigenvectors obtained from pairwise comparison matrices of elements. **Weighted Supermatrix** in which the unweighted supermatrix components have been multiplied by cluster weights. This renders the weighted supermatrix column stochastic (each of its columns adds to one).The **Limit Supermatrix** obtained by raising the weighted supermatrix to large powers in order to have the converged or stable values. [6]

Step 4 - Selection of Best Alternatives

This step aims to evaluate each alternative so as to select the most appropriate one to support final decision-making. The criterion to make this selection is the weights of alternatives that can be taken from the synthesized (Limit) supermatrix.

2.7 Benefits of Analytic Network Process

The Analytical Network Process (ANP) is a generalization of Analytical Hierarchy Process (AHP). While the AHP method is a decision-making framework using a unidirectional hierarchy relationship among decision levels, ANP allows for more complex interrelationships among the decision levels and criteria. In AHP, the top element of the hierarchy is typically the overall goal for the decision model. The hierarchy decomposes the general to more specific attributes until a level of manageable decision criteria is achieved. The ANP does not require this strict hierarchical structure; it allows factors to control and be controlled by the varying levels or clusters of criteria. Some controlling factors are also present at the same level. This interdependency among factors and their levels is defined as a system with feedback approach.

The AHP does not contain feedback loops among the factors that can adjust weightings and lessen the possibility of the reverse ranking phenomenon. The relative importance or the strength of the impacts on a given element is measured on a ratio scale similar to AHP. ANP allows for complex interrelationships among decision levels and criteria. The ANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominated or being dominated, directly or indirectly. The ANP approach is also capable of handling interdependent relationships among the elements by obtaining the composite weights through the development of a supermatrix [1].

The benefits of ANP are:

- The alternatives depend on the criteria as in a hierarchy but may also depend on each other.
- The criteria themselves can depend on the alternatives and on each other as well.
- Feedback improves the priorities derived from judgments and makes prediction much more accurate.
- The power ANP lies in its use of ratio scales to capture all kinds of interactions and make accurate predictions, and, even further, to make better decisions.
- It has proven itself to be a success when expert knowledge is used with it to predict sports outcomes, economic turns, business, and social and political decision outcomes.
- Decisions with the ANP should be more stable because one can consider their effect on and survival in the face of other influences.

2.8 Weak Points of Analytic Network Process

There are some weak points of Analytical Network Process (ANP) are:

- Explanation of concept and process to management extremely challenging
- Requires a specific software to calculate results
- Verification of result due to feedback loops and interrelationships impossible
- Complex for an implementation as a standard tool for practical decision-making

CHAPTER 3

THE PROPOSED SYSTEM

The proposed system considers the best selection laptop when user needs to make decision for getting laptop according to their requirements. In this system, the decision criteria are processor, processor speed, hard disk, memory, battery, operating system, price, warranty, weight, dimension and color. The alternatives are laptops (Laptop1, Laptop2, Laptop3, Laptop4, Laptop5). When the user input preferences, the system generates the suitable laptop that is calculated by laptop selection model.

3.1 Model for Laptop Selection

The first step is to construct a feedback decision network for Laptop selection model. A network has cluster of elements, with the elements in one cluster being connected to elements in same clusters (inner dependence) or another cluster (outer dependence). All the elements in the clusters are connected to the alternatives. Elements are also known as the decision criteria. The cluster and the elements considered in this laptop selection model are described in Figure 3.1.

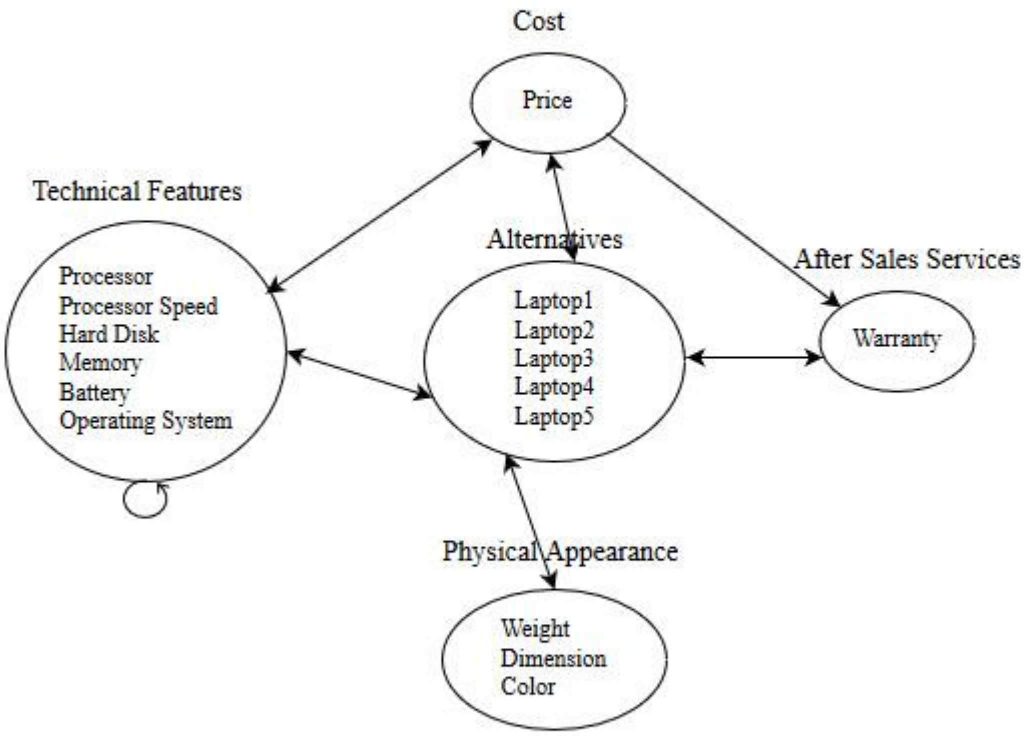


Figure 3.1 ANP Network Structure for Laptop Selection

Laptop selection model used five clusters and eleven criteria (processor, processor speed, hard disk, memory, battery, operating system, weight, dimension, color, price, warranty).

1. Cost cluster consists of price.
2. After Sales Services cluster consists of warranty.
3. Physical Appearance cluster consists of weight, dimension and color.
4. Technical Features cluster consists of processor, processor speed, hard disk, memory, battery, motherboard and operating system.
5. Alternatives cluster consists of Laptop series.

The arrow from the Cost cluster to After Sales Services means that the elements of After Sale Services cluster influence the elements of the Cost cluster. There is an inner loop in Technical Features cluster because the elements are dependent on each other. As in Figure 3.1, not only does the importance of the decision criteria determines the importance of the laptops as in hierarchy, but also the importance of the alternatives themselves determines the importance of the criteria.

3.2 Pairwise Comparisons

In ANP, decision elements at each component are pairwise compared with respect to their importance control criterion. In addition, if there are interdependencies or relationships among elements of a component, pairwise comparisons also need to be formed and an eigenvector can be attained for each element to show the influence of other elements on it. This step aims to perform pairwise comparisons among the clusters, as well as pairwise comparisons between criteria in Laptop selection model, as they are interdependent on each other. The ANP algorithm for calculating priority values is as shown in Figure 3.2.

3.2.1 Cluster Pairwise Comparisons

For **cluster pairwise comparisons**, the clusters themselves are also compared pairwise with respect to their contribution to the goal. In laptop selection model, the comparison among the five considered clusters from the point of view, respectively, of alternatives, Technical Features, physical appearance, After Sales Services and cost are shown from Table 3.1 to Table 3.5.

Algorithm: ANP Algorithm for Calculating Priority Values

```
function eignenVector (priority)
    column_result = array ();
    row_result = array ();
    for i from 0 to priority
    do
        column_total ← 0; //set 0 into column total
        for j from 0 to priority[i]
        do
              column_total ← priority[j][i] + column_total;
       enddo
       column_result[i] ← column_total;
   enddo
    for i from 0 to priority
    do
        row_total ← 0;
        for j from 0 to priority[i]
        do
            if column_result[j]! =0 then
                row_total+= priority[i][j]/column_result[j];
            else
                 row_total+=0;
        enddo
         row_total= row_total /count(priority[i]);
         row_result[i]=number_format(row_total,5);
  enddo
endfunction
```

Figure 3.2 ANP Algorithm for Calculating Priority Values

In this step, decision makers are asked to respond to a series of pairwise comparisons of two clusters in terms of how they contribute to their particular upper-level criterion in laptop selection.

So, user can choose preferences how much more important for each cluster in laptop selection to be weighted the priorities in decision and the relative weighted values are shown in Table 3.1, where a score of 1 represents equal importance between the two clusters and a score 9 indicates the extreme importance of one cluster in laptop selection model. The priority of each comparison cluster is obtained by using the three-step procedure as discussed in step2 pairwise comparison of section 2.6.

Table 3.1 Relative importance of all clusters with respect to Alternatives

Score	Technical Features	Physical Appearance	Cost	After Sales Services	Priority
Technical Features	1	9	9	9	0.75000
Physical Appearance	0.1111	1	1	1	0.08333
Cost	0.1111	1	1	1	0.08333
After Sales Services	0.1111	1	1	1	0.08333

In Table 3.2, to compare alternatives, Technical Features and After Sales Services clusters with respect to Cost cluster, where a score of 1 represents equal importance for all clusters according to user preference.

Table 3.2 Relative importance of all clusters with respect to Cost

Score	Alternatives	After Sales Services	Technical Features	Priority
Alternatives	1	1	1	0.50000
After Sales Services	1	1	1	0.50000
Technical Features	1	1	1	0.50000

In Laptop selection model, After Sales Services cluster and Physical Appearance cluster which are only influence to alternatives cluster. So, there is no cluster to compare with alternatives cluster. Table 3.3 and Table 3.4.

Table 3.3 Relative importance of all clusters with respect to After Sales Services

Score	Alternatives	Priority
Alternatives	1	1.00000

Table 3.4 Relative importance of all clusters with respect to Physical Appearance

Score	Alternatives	Priority
Alternatives	1	1.00000

In Table 3.5, it is possible to ask: "From the point of view of the Technical Features, is it more important to respect the relation with the alternatives or Cost?" The relative weighted values of user preference with respect to admission are shown in Table 3.5, where a score of 1 represents equal importance between the alternative cluster and technical features cluster.

Table 3.5 Relative importance of all clusters with respect to Technical Features

Score	Alternatives	Cost	Priority
Alternatives	1	1	0.50000
Cost	1	1	0.50000

The final priority vectors that result from the five clusters comparison matrixes in laptop selection model determine the columns of the matrix containing the cluster weights is shown in Table 3.6. The cluster weights in cluster priority matrix is used to generate the weighted matrix in supermatrix formation step.

Table 3.6 Cluster's priority matrix

Score	Alternatives	Technical Features	Physical Appearance	Cost	After Sales Services
Alternatives	0	0.50000	1	0.50000	1
Technical Features	0.75000	0	0	0.50000	0
Physical Appearance	0.08333	0	0	0	0
Cost	0.08333	0.50000	0	0	0
After Sales Services	0.08333	0	0	0.50000	0

3.2.2 Element Pairwise Comparisons

For element-pair comparisons, decision criteria at each cluster are compared pair-wised with respect to their importance towards their control criterion. In order to compare the elements of the cluster, the system performs pairwise comparisons for each element to get local priorities**.**

Laptops are compared with respect to the eleven criteria in laptop selection model. To show elements pairwise comparison, tables 3.7 from 3.17 illustrate the comparisons of alternatives with respect to each criterion. The 2nd, 3rd, 4th, 5th and 6th

columns represent the normalized criteria of each alternative. The priority criteria of each alternative are included in the last columns of the tables which give idea about their importance with respect to each criterion.

For 1st criterion, the operating system score of each laptop is shown in Table 3.7. The score of operating system is defined as the following.

if (OS==License) {value=7}

else if (OS==No License) {value=3}

For example, to compare Laptop1 and Laptop2 with respect to operating system. According to operating system range defined by the system, the value of 1 means that the operating system of Laptop1 and Laptop2 are equal. Table 3.7 shows the priority with respect to operating system.

Table 3.7 Pairwise comparison matrix for Operating System

	Laptop1	**Laptop2**	**Laptop3**	**Laptop4**	**Laptop5**	**Priority**
Laptop1	1	1	0.14286	0.14286	0.14286	0.04348
Laptop2	1	1	0.14286	0.14286	0.14286	0.04348
Laptop3	7	7	1	1	1	0.30435
Laptop4	7	7	1	1	1	0.30435
Laptop5	7	7	1	1	1	0.30435

For 2nd criterion, the score of Weight criterion is defined as following.

if (Weight<=2.0) {value=7}

else if (Weight>2.0 && Weight<=2.5) {value=5}

else if (Weight>2.5) {value=3}

The priority of weight criterion is shown in Table 3.8.

Table 3.8 Pairwise comparison matrix for Weight

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	1	1	5	1	0.23810
Laptop2	1	1	1	5	1	0.23810
Laptop3	1	1	1	5	1	0.23810
Laptop4	0.20000	0.20000	0.20000	1	0.20000	0.04762
Laptop5	1	1	1	5	1	0.23810

For 3rd criterion, the normalized weight of Dimension criterion is defined as following.

if (Dimension>=15) {value=5}

else if (Dimension >=14 && Dimension <15) {value=3}

else if (Dimension <14) {value=1}

The priority of dimension criterion is shown in Table 3.9.

Table 3.9 Pairwise comparison matrix for Dimension

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	0.20000	0.20000	1	1	0.07692
Laptop2	5	1	1	5	5	0.38462
Laptop3	5	1	1	5	5	0.38462
Laptop4	1	0.20000	0.20000	1	1	0.07692
Laptop5	1	0.20000	0.20000	1	1	0.07692

For 4th criterion, the score of Color criterion is defined as following.

if (Color == white) {value=1}

else if (Color == black) {value=1}

else {value=1}

The priority of color criterion is shown in Table 3.10.

Table 3.10 Pairwise comparison matrix for Color

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	1	1	1	1	0.20000
Laptop2	1	1	1	1	1	0.20000
Laptop3	1	1	1	1	1	0.20000
Laptop4	1	1	1	1	1	0.20000
Laptop5	1	1	1	1	1	0.20000

For 5th criterion, the score of Battery criterion is defined as the following.

if (Battery == 6-Cells) {value=7}

else if (Battery == 4-Cells) {value=5}

else {value=3}

The priority of battery criterion is shown in Table 3.11.

Table 3.11 Pairwise comparison matrix for Battery

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	1	5	5	5	0.38462
Laptop2	1	1	5	5	5	0.38462
Laptop3	0.20000	0.20000	1	1	1	0.07692
Laptop4	0.20000	0.20000	1	1	1	0.07692
Laptop5	0.20000	0.20000	1	1	1	0.07692

For 6th criterion, the score of Memory criterion is defined as the following.

If (Memory>=2 && Memory<4) {value=3}

If (Memory>=4 && Memory<8) {value=5}

If (Memory >=8) {value=7}

The priority of memory criterion is shown in Table 3.12.

Table 3.12 Pairwise comparison matrix for Memory

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	7	7	7	1	0.41176
Laptop2	0.14286	1	1	1	0.14286	0.05882
Laptop3	0.14286	1	1	1	0.14286	0.05882
Laptop4	0.14286	1	1	1	0.14286	0.05882
Laptop5	1	7	7	7	1	0.41176

For 7th criterion, the value of Hard disk criterion is defined as the following.

if (Hard disk == 128 GB) {value=1}
else if (Hard disk == 256 GB) {value=3}
else if (Hard disk == 500 GB) {value=5}
else if (Hard disk == 1 TB) {value=7}
else if (Hard disk == 2 TB) {value=9}

The priority of hard disk criterion is shown in Table 3.13.

Table 3.13 Pairwise comparison matrix for Hard disk

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	1	7	7	1	0.30435
Laptop2	1	1	7	7	1	0.30435
Laptop3	0.14286	0.14286	1	1	0.14286	0.04348
Laptop4	0.14286	0.14286	1	1	0.14286	0.04348
Laptop5	1	1	7	7	1	0.30435

For 8th criterion, the score of Processor Speed is defined using the following rule.

if (Processor Speed <= 1.0 GHz) {value=1}
else if (Processor Speed <= 2.0 GHz) {value=3}
else (Processor Speed > 2.0 GHz) {value=5}

The priority of processor speed criterion is shown in Table 3.14.

Table 3.14 Pairwise comparison matrix for Processor Speed

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	0.20000	0.20000	0.20000	1	0.05882
Laptop2	5	1	1	1	5	0.29412
Laptop3	5	1	1	1	5	0.29412
Laptop4	5	1	1	1	5	0.29412
Laptop5	1	0.20000	0.20000	0.20000	1	0.05882

For 9th criterion, the score of Processor criterion is defined using the following rule.

if (Processor =="Intel Core i7”) {value=9}
else if (Processor =="Intel Core i5”) {value=7}
else if (Processor ==Intel Core i3”) {value=5}
else {value=3}

The priority of processor is shown in Table 3.15.

Table 3.15 Pairwise comparison matrix for Processor

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	1	9	9	9	0.39153
Laptop2	1	1	9	9	9	0.39153
Laptop3	0.11111	0.11111	1	0.20000	0.14286	0.02851
Laptop4	0.11111	0.11111	5	1	0.14286	0.06042
Laptop5	0.11111	0.11111	7	7	1	0.12801

For 10th criterion, the score of Warranty is defined using the following rule.

if (Warranty >=2) {value=5}

else if (Warranty <2 && Warranty >=1) {value=3}

else if (Warranty < 1) {value=1}

The priority of warranty is shown in Table 3.16.

Table 3.16 Pairwise comparison matrix for Warranty

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	1	5	5	5	0.38462
Laptop2	1	1	5	5	5	0.38462
Laptop3	0.20000	0.20000	1	1	1	0.07692
Laptop4	0.20000	0.20000	1	1	1	0.07692
Laptop5	0.20000	0.20000	1	1	1	0.07692

For 11th criterion, the Price criterion score is defined as the following.

if (Price <= 300) {value=9}

else if (Price > 300 && Price <= 500) {value=7}

else if (Price >500 && Price <= 700} {value=5}

else if (Price > 700} {value=3}

The priority of price criterion is described in Table 3.17.

Table 3.17 Pairwise comparison matrix for Price

	Laptop1	Laptop2	Laptop3	Laptop4	Laptop5	Priority
Laptop1	1	5	0.14286	0.11111	1	0.07714
Laptop2	0.20000	1	0.14286	0.11111	0.20000	0.02993
Laptop3	7	7	1	0.11111	7	0.24026
Laptop4	9	9	9	1	9	0.57553
Laptop5	1	5	0.14286	0.11111	1	0.07714

3.3 Supermatrix formation (Unweighted Supermatrix, Weighted Supermatrix and Limit Supermatrix)

The original unweighted supermatrix of column eigenvectors obtained from pairwise comparison matrices of elements. The priorities of elements are arranged both vertically and horizontally according to clusters. The ANP algorithm for calculating unweighted matrix is shown in Figure 3.3.

Algorithm: ANP Algorithm for calculating Unweighted Supermatrix

```
function get_cluster_matrix (A, B: matrix): matrix
 n ← number of rows of matrix A;
        for i from 0 to n
        do
              column_total <- 0; //set 0 into column total
              m ← number of columns of each row;
              for j from 0 to m
              do
                     column_total ← A[i][j] + column_total;
                     enddo
              column_result[i] ← column_total;
        enddo
 for i from 0 to n
       do
              row_total ← 0;
              for j from 0 to m
              do
                     row_total ← row_total + (A[i][j] /column_result[j]);
                     enddo
              cluster_matrix[i] ← row_total / m;
       enddo
 endfunction
```

Figure 3.3 ANP Algorithm for Calculating Unweighted Supermatrix

The Unweighted Supermatrix results are as shown in Table 3.18. Where 1 = Laptop1, 2 = Laptop2, 3 = Laptop3, 4 = Laptop4, 5 = Laptop5, 6 = Price, 7 = Warranty, 8 = Processor, 9 = Processor Speed, 10 = Hard disk, 11 = Memory, 12 = Battery, 13 = Operating System, 14 = Weight, 15 = Dimension, 16 = Color.

1	0.00000	0.00000	0.00000	0.00000	0.00000	0.07714	0.38462	0.39153	0.05882	0.30435	0.41176	0.38462	0.04348	0.23810	0.07692	0.20000
2	0.00000	0.00000	0.00000	0.00000	0.00000	0.02993	0.38462	0.39153	0.29412	0.30435	0.05882	0.38462	0.04348	0.23810	0.38462	0.20000
3	0.00000	0.00000	0.00000	0.00000	0.00000	0.24026	0.07692	0.02851	0.29412	0.04348	0.05882	0.07692	0.30435	0.23810	0.38462	0.20000
4	0.00000	0.00000	0.00000	0.00000	0.00000	0.57553	0.07692	0.06042	0.29412	0.04348	0.05882	0.07692	0.30435	0.04762	0.07692	0.20000
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.07714	0.07692	0.12801	0.05882	0.30435	0.41176	0.07692	0.30435	0.23810	0.07692	0.20000
6	0.63636	0.09091	0.09091	0.09091	0.09091	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
7	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
8	0.63636	0.09091	0.09091	0.09091	0.09091	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
9	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
11	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
12	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
13	0.30159	0.30159	0.02742	0.30159	0.06780	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
14	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
15	0.52670	0.08629	0.21443	0.08629	0.08629	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
16	0.52670	0.08629	0.21443	0.08629	0.08629	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table 3.18 Unweighted supermatrix

The ANP algorithm for calculating Weighted Matrix is as shown in figure 3.4.

Algorithm: ANP Algorithm for calculating Weighted Supermatrix

```
function get_weighted_matrix (A, B: matrix): matrix
   n ← number of rows of matrix A;
   for i from 0 to n
   do
         m ← number of columns of each row;
         for j from 0 to m
         do
             weighted_matrix[i][j] ← B[i][j] * A [i][j];
         enddo
   enddo
endfunction
```

Figure 3.4 ANP Algorithm for Calculating Weighted Supermatrix

The weighted supermatrix in which the unweighted supermatrix (Table 3.18) have been multiplied by cluster weights (Table 3.6) as shown in Table 3.19. Where 1 = Laptop1, 2 = Laptop2, 3 = Laptop3, 4 = Laptop4, 5 = Laptop5, 6 = Price, 7 = Warranty, 8 = Processor, 9 = Processor Speed, 10 = Hard disk, 11 = Memory, 12 = Battery, 13 = Operating System, 14 = Weight, 15 = Dimension, 16 = Color.

In limit supermatrix, the weighted supermatrix is raised to limiting power to get the global priority vectors. It has same value in each row. The values of this limit matrix are the desired priorities of the elements with respect to the goal as shown in Table 3.20. Where 1 = Laptop1, 2 = Laptop2, 3 = Laptop3, 4 = Laptop4, 5 = Laptop5, 6 = Price, 7 = Warranty, 8 = Processor, 9 = Processor Speed, 10 = Hard disk, 11 = Memory, 12 = Battery, 13 = Operating System, 14 = Weight, 15 = Dimension, 16 = Color.

1	0.00000	0.00000	0.00000	0.00000	0.00000	0.07714	0.38462	0.39153	0.05882	0.30435	0.41176	0.38462	0.04348	0.23810	0.07692	0.20000
2	0.00000	0.00000	0.00000	0.00000	0.00000	0.02993	0.38462	0.39153	0.29412	0.30435	0.05882	0.38462	0.04348	0.23810	0.38462	0.20000
3	0.00000	0.00000	0.00000	0.00000	0.00000	0.24026	0.07692	0.02851	0.29412	0.04348	0.05882	0.07692	0.30435	0.23810	0.38462	0.20000
4	0.00000	0.00000	0.00000	0.00000	0.00000	0.57553	0.07692	0.06042	0.29412	0.04348	0.05882	0.07692	0.30435	0.04762	0.07692	0.20000
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.07714	0.07692	0.12801	0.05882	0.30435	0.41176	0.07692	0.30435	0.23810	0.07692	0.20000
6	0.05303	0.00758	0.00758	0.00758	0.00758	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
7	0.01667	0.01667	0.01667	0.01667	0.01667	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
8	0.47727	0.06818	0.06818	0.06818	0.06818	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
9	0.15000	0.15000	0.15000	0.15000	0.15000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.15000	0.15000	0.15000	0.15000	0.15000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
11	0.15000	0.15000	0.15000	0.15000	0.15000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
12	0.15000	0.15000	0.15000	0.15000	0.15000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
13	0.22619	0.22619	0.02057	0.22619	0.05085	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
14	0.01667	0.01667	0.01667	0.01667	0.01667	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
15	0.04389	0.00719	0.01787	0.00719	0.00719	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
16	0.04389	0.00719	0.01787	0.00719	0.00719	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0000

Table 3.19 Weighted supermatrix

1	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888
2	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978
3	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568
4	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257
5	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668
6	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309
7	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966
8	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999
9	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654
10	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654
11	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654
12	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654
13	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418	2.37312966418
14	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966
15	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951
16	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951	0.26903947951

Table 3.20 Limit supermatrix

The ANP algorithm for calculating limit supermatrix is as shown in figure 3.5.

Algorithm: ANP Algorithm for calculating Limit Supermatrix

```
function matrix_power (A:  matrix, n: int): matrix
      x ← number of rows of A;
      y ← number of columns of each row;
      res ← mkone_matrix (x, y);
      while n > 0
      do
          if n mod 2 = 0 then
              A ← mmult (A);
              n = n/ 2;
          else
              res ← mmult (res, A);
              n--;
          endif;
      enddo
endfunction

function mkone_matrix (rows, cols: int) : matrix
      for i from 0 to rows
      do
             for j from 0 to cols
             do
                  if i= j then
                         mx[i][j] ← 1;
                  end if;
             enddo
      enddo
endfunction

function mmult (A: matrix):  matrix
      n ← number of rows of A;
      m ← number of columns of each row;
      for i from 0 to x
      do
            for j from 0 to y
             do
                    x ← 0;
                    for k from 0 to y
                    do
                          x ← x + A[i][k] * A[k][j];
                    enddo
                    M[i][j] ← x;
             enddo
       enddo
endfunction
```

Figure 3.5 ANP Algorithm for Calculating Limit Supermatrix

3.4 Selection of Best Alternatives

This step aims to evaluate each laptop so as to select the most appropriate one to support final decision-making. The criterion to make this selection is the weights of laptops that can be taken from the limit supermatrix as shown in Table 3.21.

Table 3.21 Priority value for each laptop model

Model	Limit Value	Priority %
1. Laptop1	1.73888852888	26 %
2. Laptop2	1.65429214978	25 %
3. Laptop3	0.950699961568	14 %
4. Laptop4	0.972120453257	15 %
5. Laptop5	1.37771048668	21 %

Finally, user can get best suitable laptop within his/her preference by using Analytic Network Process (ANP). In this example, the final priority of Laptop1 is higher than Laptop2, Laptop3, Laptop4 and ‘Laptop5 as shown in Table 3.22. So, ‘Laptop1’ is the best laptop model for user.

Table 3.22 Laptop ranking result

Ranking No.	Model	Priority %
1	Laptop1	26 %
2	Laptop2	25 %
3	Laptop5	21 %
4	Laptop4	15 %
5	Laptop3	14 %

CHAPTER 4
DESIGN AND SYSTEM IMPLEMENTATION

4.1 System Overview

The proposed system is implemented as a web-based decision support system based on multiple criteria and applied Analytical Network Process (ANP). It can select the best laptop when user needs to make decision based on their requirements for selecting the best laptop. There are two main modules; user module and administrator module.

In user module, any user can use this application. The user can browse not only laptop series but also laptop prices. ANP model is used to select the optimal laptop series. The user input preferences for ANP model, it shows that the system generates the better laptop ranked list that is calculated by laptop selection model. There are four main steps in ANP based on multi-criteria decision-making process. They are model construction, pairwise comparisons, supermatrix formation and selection of best alternatives. For the first step, the decision problem demonstrates a general view of networking that shows the dependencies among the criteria. The problem is divided into eleven criteria such as price, processor, processor speed, hard disk, memory, battery, operating system, price, weight, dimension, color and warranty and maximum two hundred laptop alternatives. The best laptop is selected based on these criteria. For the second step, once the elements and clusters are formulated the interrelationships among them are represented by "Network" of influence. The intensity of preference is assigned using relative weights (fundamental 1-9 scale) between each pair to element or clusters with respect to the controlling elements.

The outcome of step3 is supermatrix formation. There are three supermatrix formation. They are unweighted supermatrix formation, weighted supermatrix formation and limit supermatrix formation. The unweighted supermatrix is constructed from the priorities derived from different pairwise comparisons by arranging both vertically and horizontally according to clusters. The weighted supermatrix is obtained by multiplying the unweight supermatrix by the priority of influence of the component on the left from the cluster matrix (step2). The limit supermatrix is founded by multiplying the weighted supermatrix by itself numerical times. And this multiplication will be stopped when the limit supermatrix appears same value in each row. Each row contains the same value and provides the final priorities or weights for the alternatives and criteria. For the last step, the limiting priorities or weights of the laptop alternatives are appeared. Among them, we choose higher priority than others.

In administrator module, system administrator can manage the laptop list such as inserting new laptops, updating and deleting existing laptop lists.

4.1.1 Detail Design of the System

This proposed system is mainly focused on decision-making to choose appropriate laptop according to user preferences and survey information of each laptop. The user can view details of laptop information. Besides, the user can get by entering their preferences and they can browse which laptop is best for their requirement. The administrator can insert, delete and update the system information. Administrator can add new laptop series of each brand. Because of dynamic web application, user can know what is modified and can view immediately after administrator changes the system information. The flow diagram of the proposed system is shown in Figure 4.1.

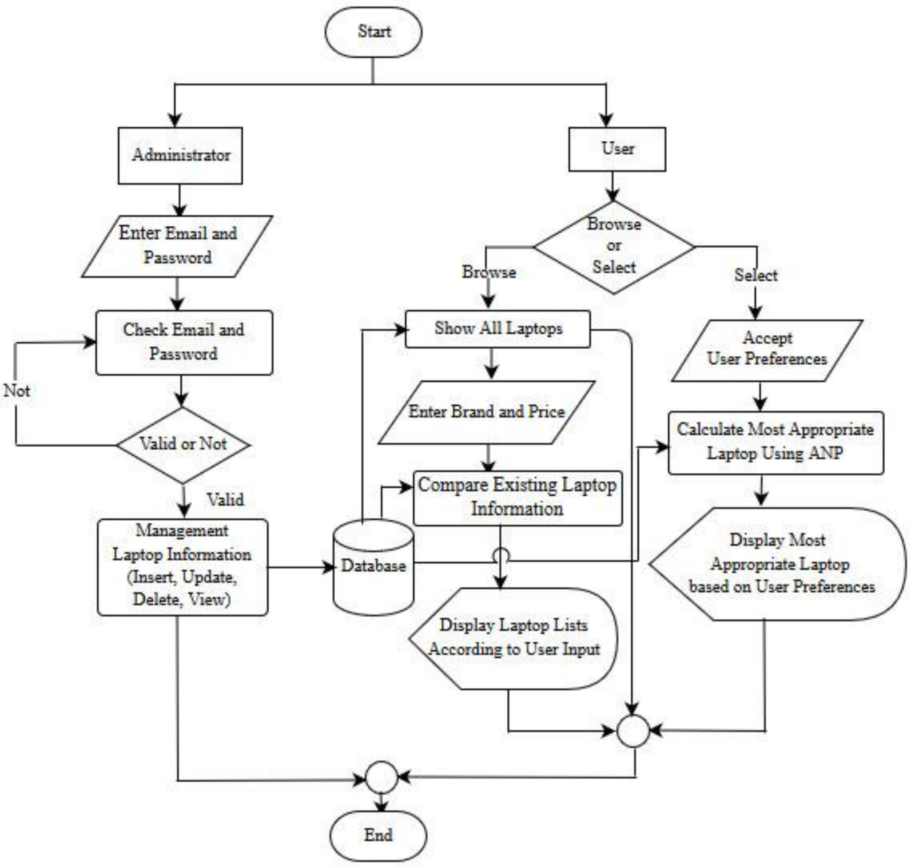


Figure 4.1 Flow Diagram of the Proposed System

4.1.2 Database Design of the System

In this system, there are three tables. They are model_specification table, preferences table and user table. They are shown in Figure 4.2.

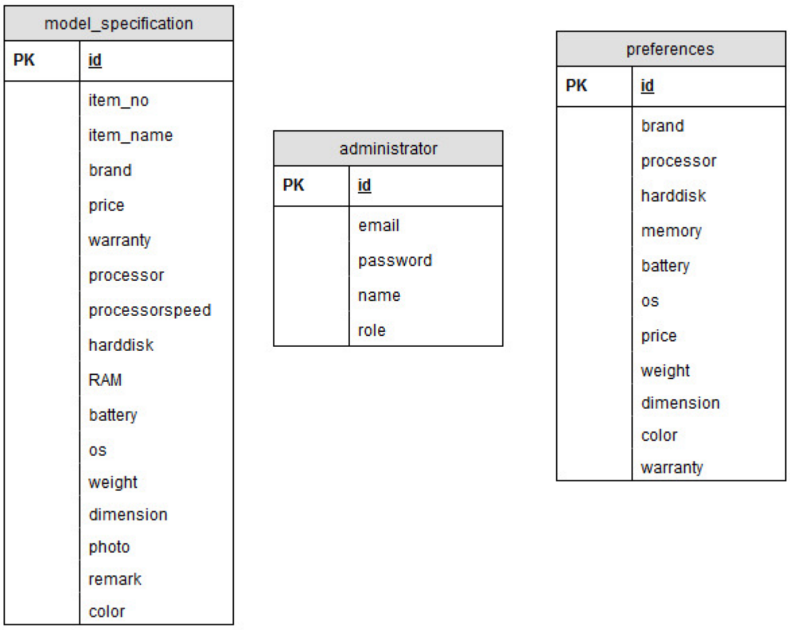


Figure 4.2 Database Design of the System

4.1.3 Class Diagram of the System

In this system, there are three tables used for class diagram. They are administrator table, preferences table and model specification table. Figure 4.3 shows the class diagram of finding the appropriate laptop.

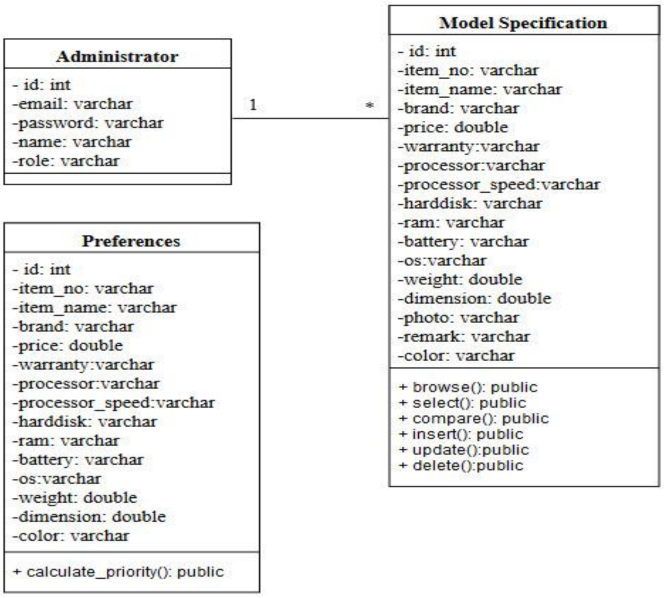


Figure 4.3 Class Diagram of the System

4.2 System Implementation

The system implements for two types of user: admin and user. The user not only can browse the laptop information but also select the preferences to buy the appropriate laptop. The admin can enter the system, by the login process with valid email and password. When the login user is administrator, the system redirects to the admin home page. The administrator manages the laptop information. The detail implementation of the system is described in following section.

4.2.1 Home Page of the Laptop Selection System

By using the web-based decision support system, user can easily get the decision for selecting the suitable laptop. The Home page of the laptop selection system is shown in Figure 4.4.

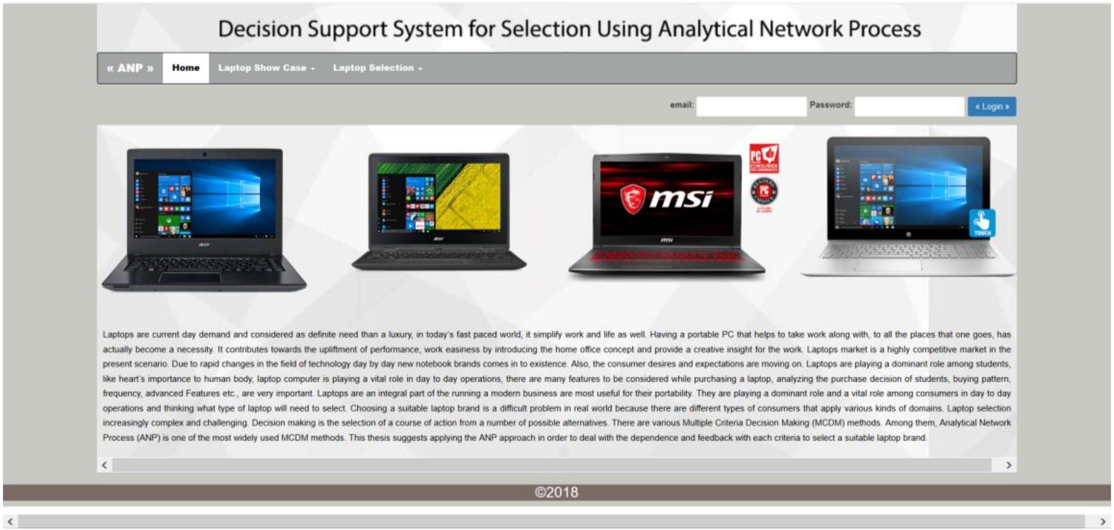


Figure 4.4 Home Page of the Laptop Selection System

4.2.2 User Preference Page

The user can choose preference how much more important for each cluster to be weighted the priorities in decision. In this step, decision makers are asked to respond to a series of pairwise comparisons among the five considered clusters from the point of view, respectively, of alternatives (laptops), technical features, physical appearance, and cost and after sales services.

For example, it is possible to ask: "From the point of view of the alternatives, is it more important to respect the relation with the technical features or physical appearance or cost or after sales services?" as shown in Figure 4.5. In Figure 4.5, the relative weighted values are determined with fundamental scale of the ANP. Where a score of 1 represents equal importance between two clusters and a score 9 indicates the extreme importance. The priority of each comparison cluster is obtained by using the three step procedure mention above step2 pairwise comparison of section 2.6.

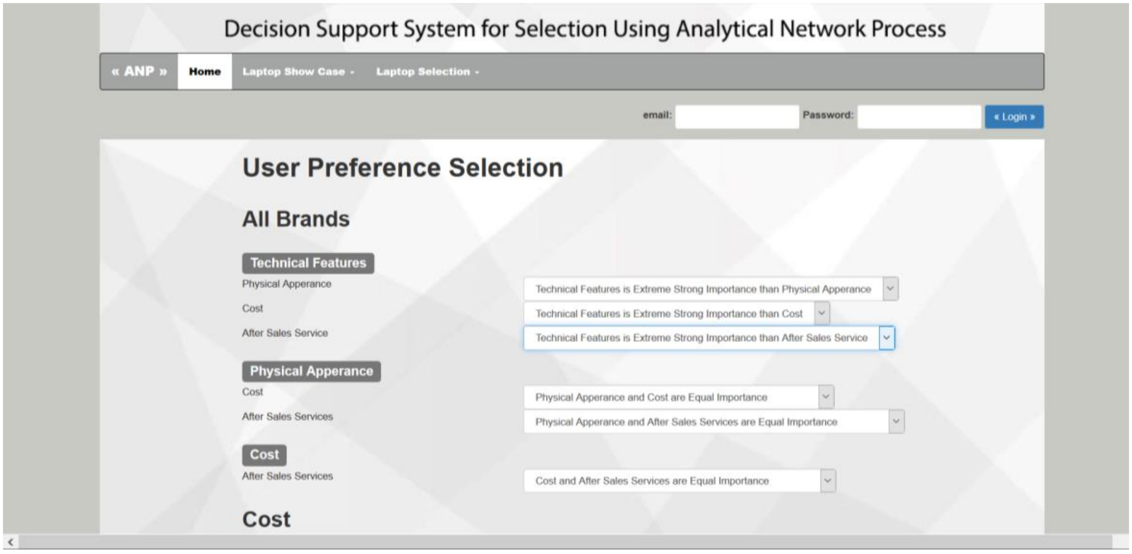
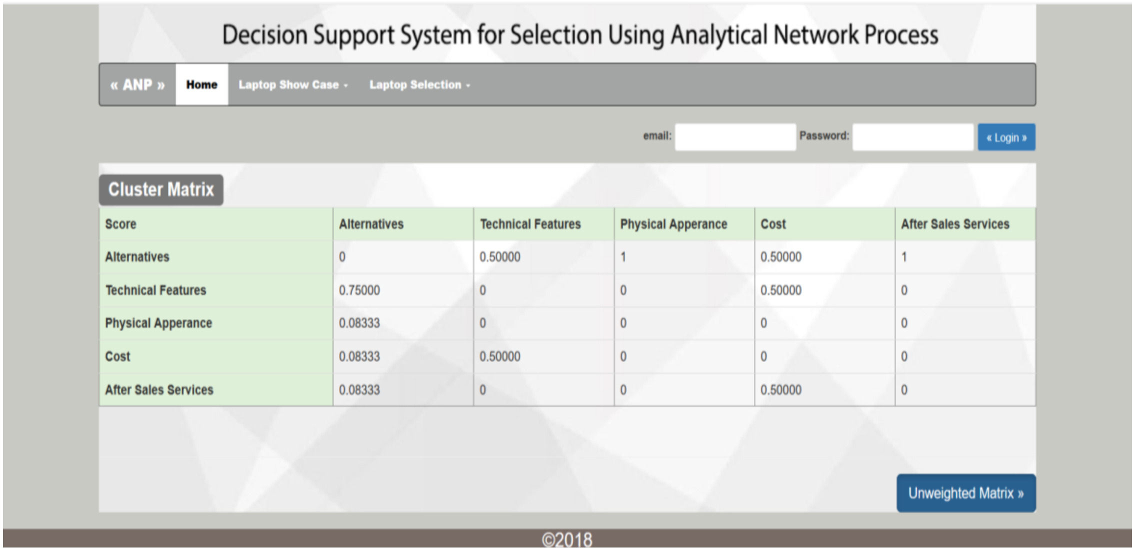


Figure 4.5 User Preference Page

4.2.3 Cluster Comparison Matrix Page

After user chooses preference, the system generate cluster priority matrix that results from the five clusters comparisons matrix as shown in Figure 4.6. The cluster weights in cluster priority matrix are used to generate the weighted supermatrix in supermatrix formation step.

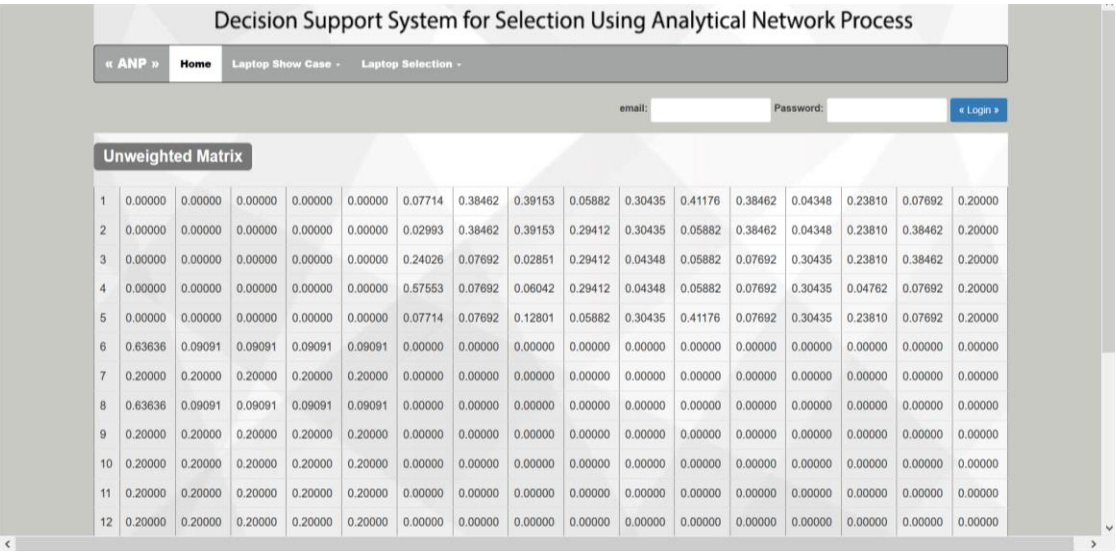


Score	Alternatives	Technical Features	Physical Apperance	Cost	After Sales Services
Alternatives	0	0.50000	1	0.50000	1
Technical Features	0.75000	0	0	0.50000	0
Physical Apperance	0.08333	0	0	0	0
Cost	0.08333	0.50000	0	0	0
After Sales Services	0.08333	0	0	0.50000	0

Figure 4.6 Cluster Comparison Matrix Page

4.2.4 Formation of Unweighted Matrix Page

The final priority vectors that result from different element pairwise comparison matrixes in laptop selection model determined the columns of the unweighted supermatrix. The formation of unweighted matrix page is shown in Figure 4.7.

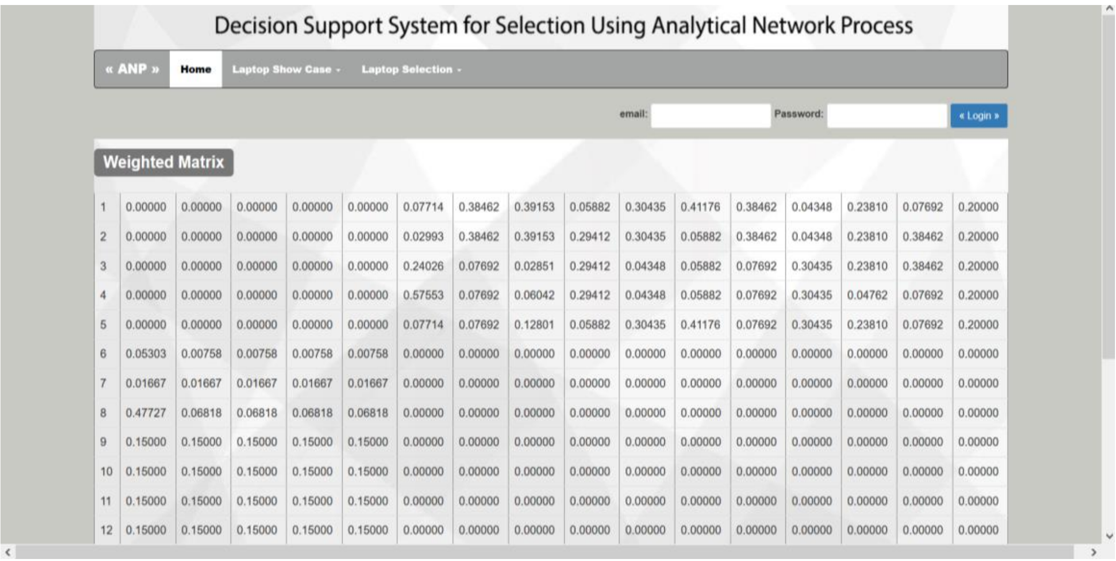


1	0.00000	0.00000	0.00000	0.00000	0.00000	0.07714	0.38462	0.39153	0.05882	0.30435	0.41176	0.38462	0.04348	0.23810	0.07692	0.20000
2	0.00000	0.00000	0.00000	0.00000	0.00000	0.02993	0.38462	0.39153	0.29412	0.30435	0.05882	0.38462	0.04348	0.23810	0.38462	0.20000
3	0.00000	0.00000	0.00000	0.00000	0.00000	0.24026	0.07692	0.02851	0.29412	0.04348	0.05882	0.07692	0.30435	0.23810	0.38462	0.20000
4	0.00000	0.00000	0.00000	0.00000	0.00000	0.57553	0.07692	0.06042	0.29412	0.04348	0.05882	0.07692	0.30435	0.04762	0.07692	0.20000
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.07714	0.07692	0.12801	0.05882	0.30435	0.41176	0.07692	0.30435	0.23810	0.07692	0.20000
6	0.63636	0.09091	0.09091	0.09091	0.09091	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
7	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
8	0.63636	0.09091	0.09091	0.09091	0.09091	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
9	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
11	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
12	0.20000	0.20000	0.20000	0.20000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Figure 4.7 Formation of Unweighted Matrix Page

4.2.5 Formation of Weighted Matrix Page

Weighted supermatrix obtained from the unweighted supermatrix components have been multiplied by cluster weights. The weighted supermatrix is shown in Figure 4.8.

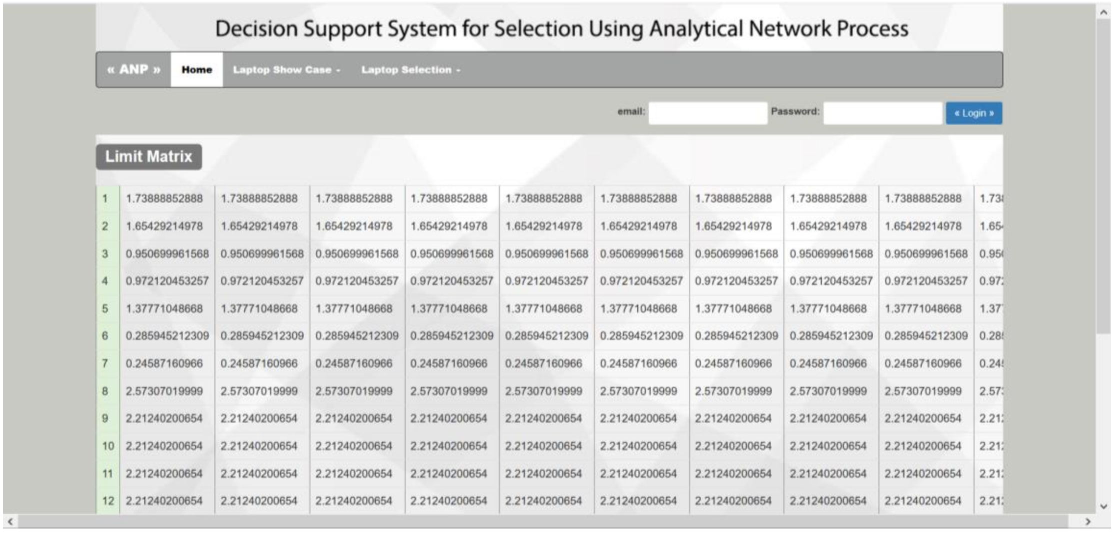


1	0.00000	0.00000	0.00000	0.00000	0.00000	0.07714	0.38462	0.39153	0.05882	0.30435	0.41176	0.38462	0.04348	0.23810	0.07692	0.20000
2	0.00000	0.00000	0.00000	0.00000	0.00000	0.02993	0.38462	0.39153	0.29412	0.30435	0.05882	0.38462	0.04348	0.23810	0.38462	0.20000
3	0.00000	0.00000	0.00000	0.00000	0.00000	0.24026	0.07692	0.02851	0.29412	0.04348	0.05882	0.07692	0.30435	0.23810	0.38462	0.20000
4	0.00000	0.00000	0.00000	0.00000	0.00000	0.57553	0.07692	0.06042	0.29412	0.04348	0.05882	0.07692	0.30435	0.04762	0.07692	0.20000
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.07714	0.07692	0.12801	0.05882	0.30435	0.41176	0.07692	0.30435	0.23810	0.07692	0.20000
6	0.05303	0.00758	0.00758	0.00758	0.00758	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
7	0.01667	0.01667	0.01667	0.01667	0.01667	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
8	0.47727	0.06818	0.06818	0.06818	0.06818	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
9	0.15000	0.15000	0.15000	0.15000	0.15000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.15000	0.15000	0.15000	0.15000	0.15000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
11	0.15000	0.15000	0.15000	0.15000	0.15000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
12	0.15000	0.15000	0.15000	0.15000	0.15000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Figure 4.8 Formation of Weighted Matrix Page

4.2.6 Formation of Limit Matrix Page

The limit supermatrix obtained by raising the weighted supermatrix to large powers in order has the converged or stable values. The formation of the limit supermatrix is shown in Figure 4.9.

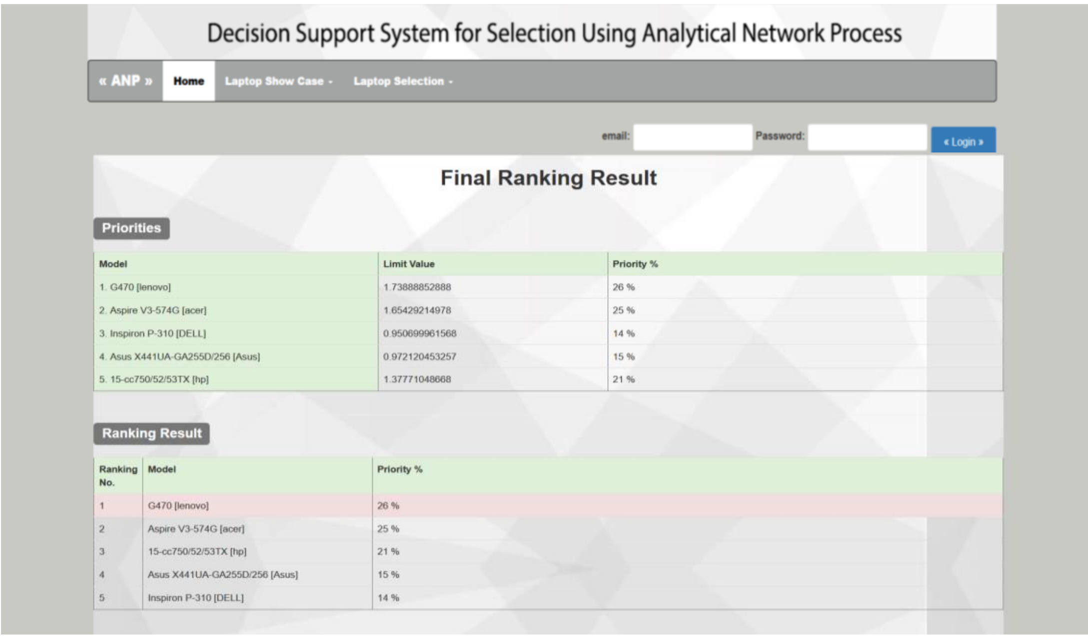


1	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888	1.73888852888
2	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978	1.65429214978
3	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568	0.950699961568
4	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257	0.972120453257
5	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668	1.37771048668
6	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309	0.285945212309
7	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966	0.24587160966
8	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999	2.57307019999
9	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654
10	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654
11	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654
12	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654	2.21240200654

Figure 4.9 Formation of Limit Matrix Page

4.2.7 Final Ranking Result Page

User has to input preference for ANP processing; the system generates the appropriate laptop for each user as shown in Figure 4.10. According to user's preferences, laptop model (G470) is the appropriate laptop among five laptops.



Model	Limit Value	Priority %
1. G470 [lenovo]	1.73888852888	26 %
2. Aspire V3-574G [acer]	1.65429214978	25 %
3. Inspiron P-310 [DELL]	0.950699961568	14 %
4. Asus X441UA-GA255D/256 [Asus]	0.972120453257	15 %
5. 15-cc750/52/53TX [hp]	1.37771048668	21 %

Ranking No.	Model	Priority %
1	G470 [lenovo]	26 %
2	Aspire V3-574G [acer]	25 %
3	15-cc750/52/53TX [hp]	21 %
4	Asus X441UA-GA255D/256 [Asus]	15 %
5	Inspiron P-310 [DELL]	14 %

Figure 4.10 Final Ranking Result Page

4.2.8 Laptop Series According to Selected Brand Page

The user can browse by choosing brand name (Lenovo, Acer, Dell, etc.).Then the system retrieves the laptop series by selected brand as shown in Figure 4.11.

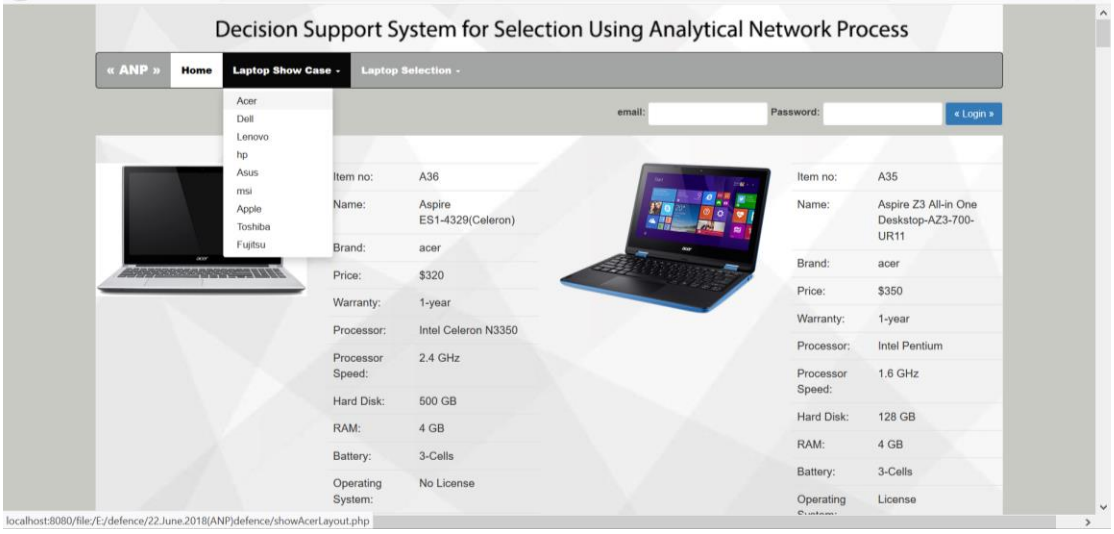


Figure 4.11 Laptop Series According to Selected Brand Page

4.2.9 Price Input Page

The user can view the laptop series by selecting their estimated price as shown in Figure 4.12.

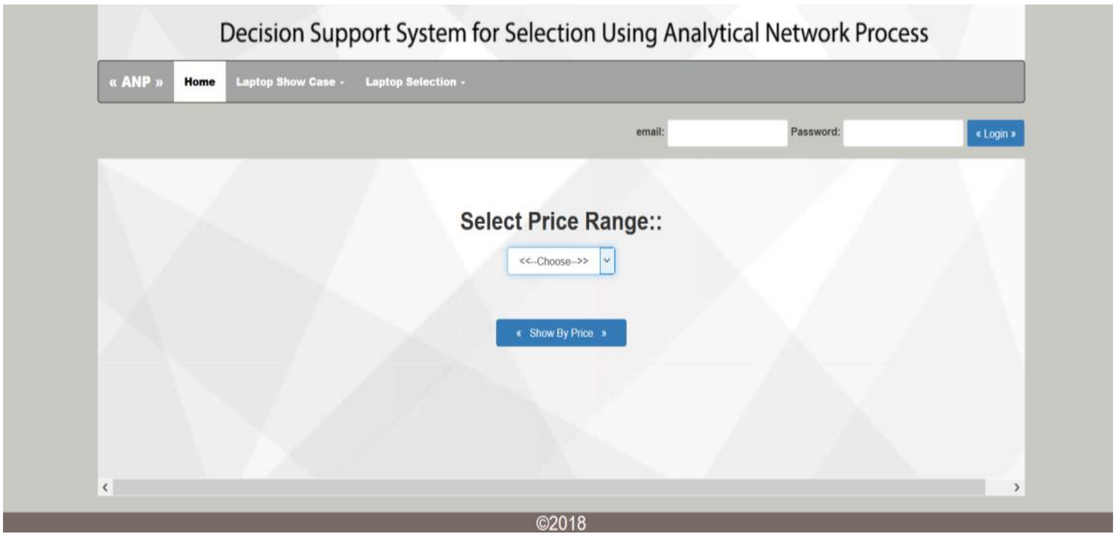


Figure 4.12 Price Input Page

4.2.10 Brand and Price Input Page

The user can also browse the laptop series by selecting brand and their estimated price as shown in Figure 4.13.

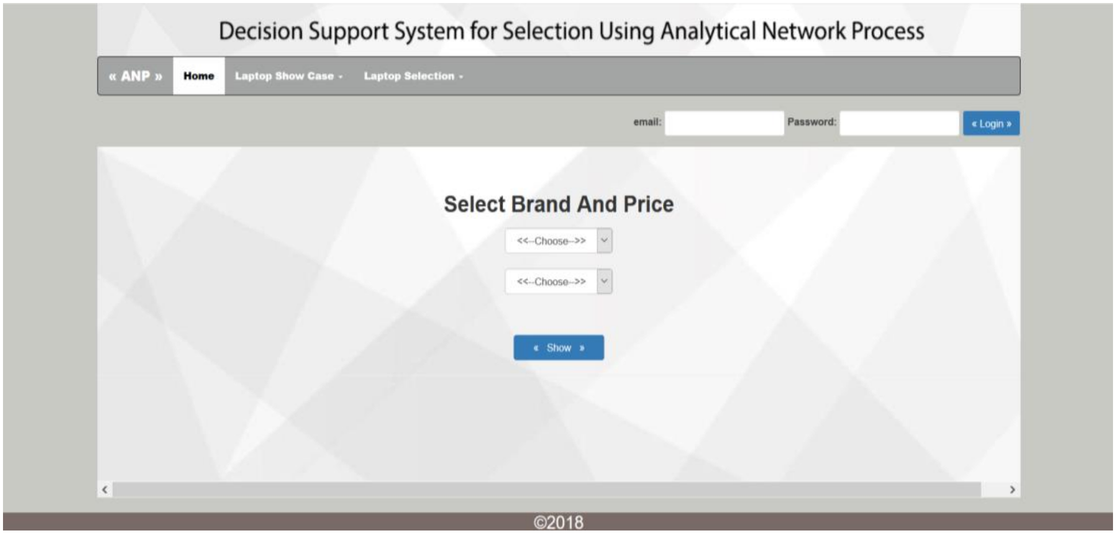


Figure 4.13 Brand and Price Input Page

4.2.11 Detail Selection Page

The user can also view the laptop series by selecting brand, processor, memory, hard disk, display size and their estimated price as shown in Figure 4.14.

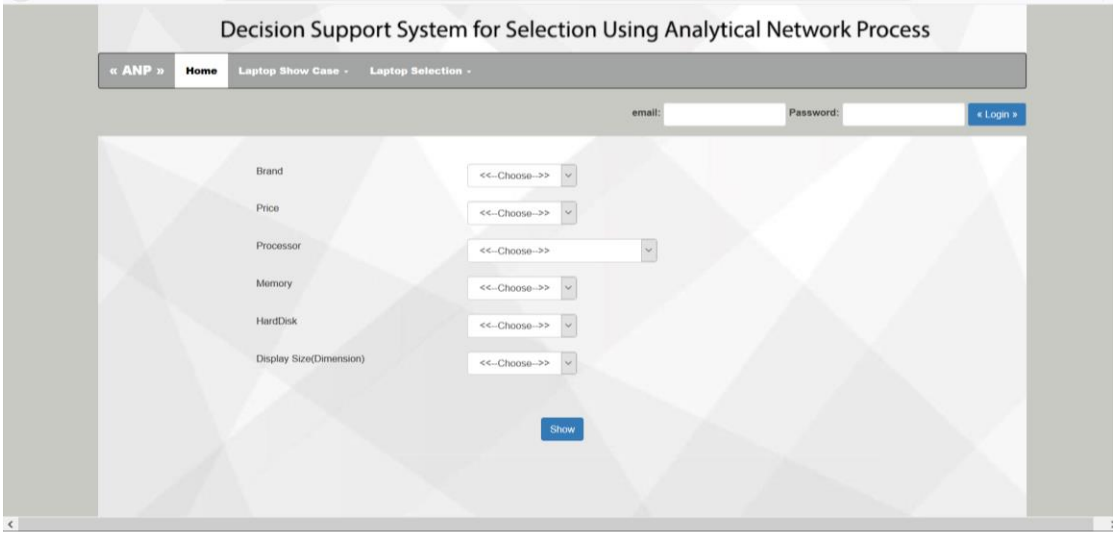


Figure 4.14 Detail Selection Page

4.2.12 Admin Home Page

For administrator, he or she can add, update, and retrieve laptop information. To add or update or retrieve laptop information, he or she needs to login to the system. Admin Home page is shown in Figure 4.15.

4.2.13 Saving New Laptop Data Page

Administrator can add a new laptop according to each laptop brand as shown in Figure 4.16.

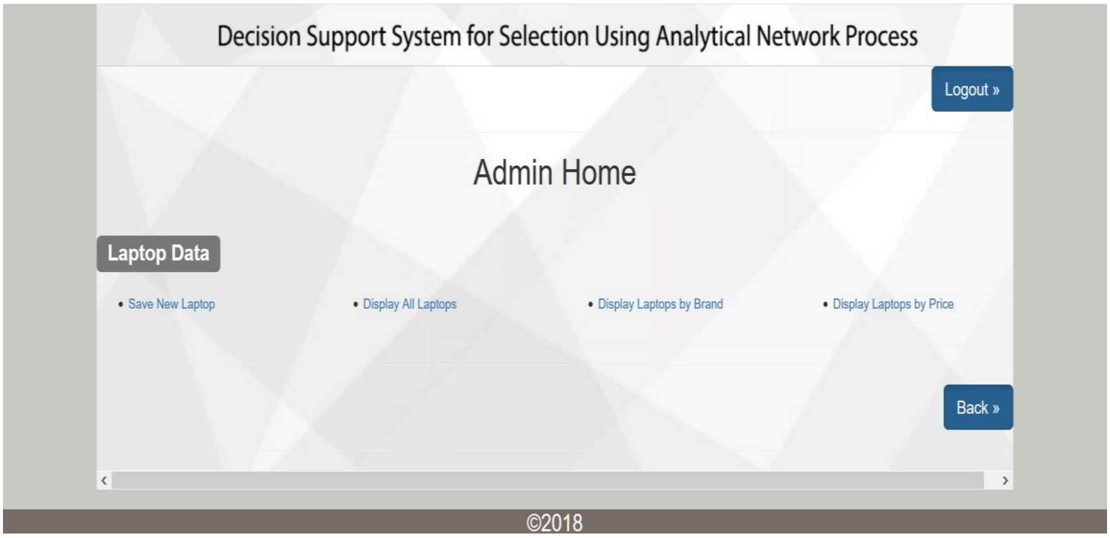


Figure 4.15 Admin Home Page

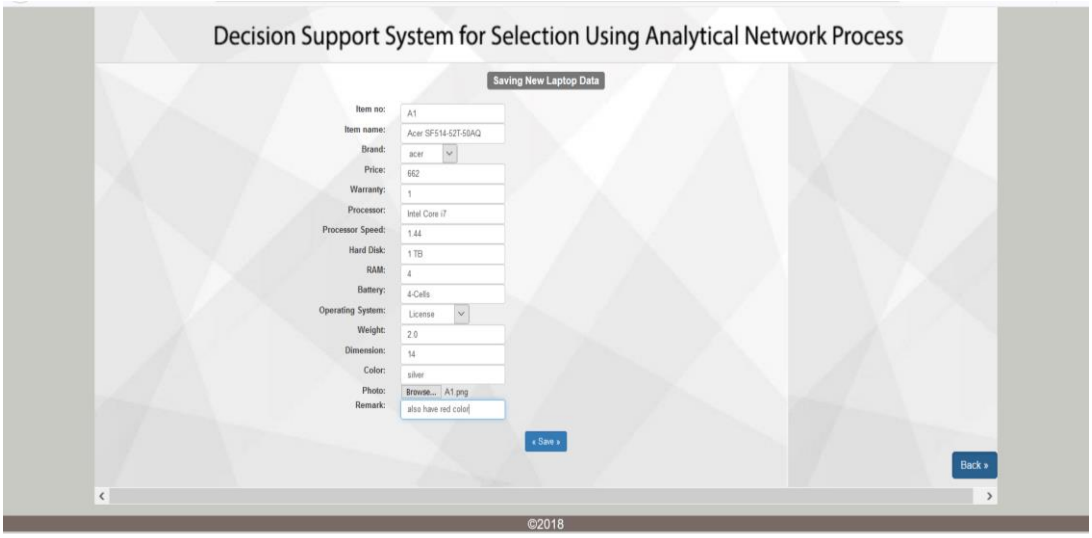


Figure 4.16 Saving New Laptop Data Page

4.2.14 Updating Existing Laptop Data Page

Administrator can update for each laptop as shown in Figure 4.17. In this figure, the administrator edit price.

4.2.15 Select Brand Page

The administrator can select brand to view laptop series. Then the system displays laptops concerned with brand as shown in figure 4.18.

4.2.16 Select Price Range Page

The administrator can view the laptop series by choosing price as shown in Figure 4.19.

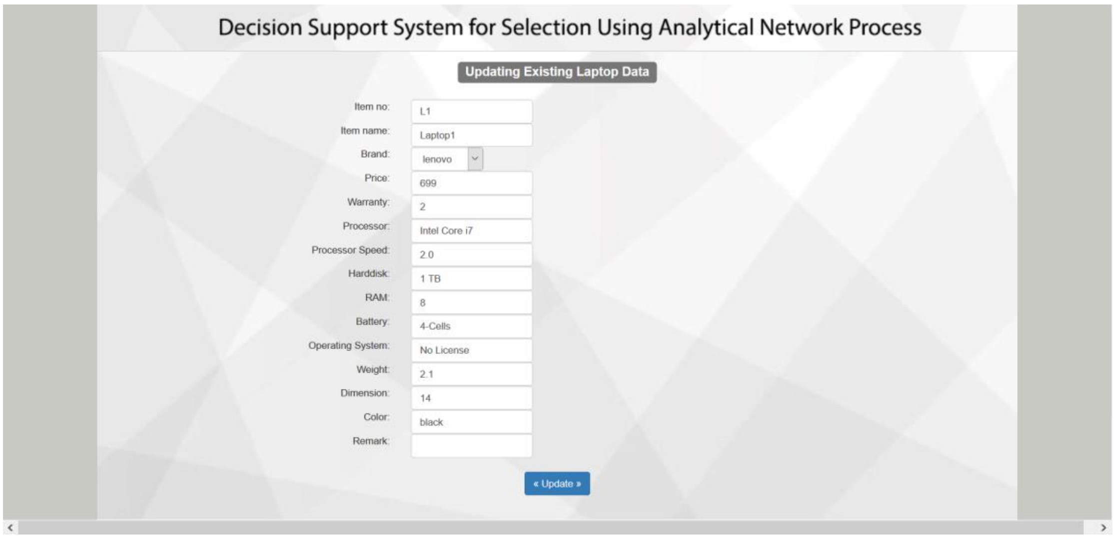


Figure 4.17 Updating Existing Laptop Data Page

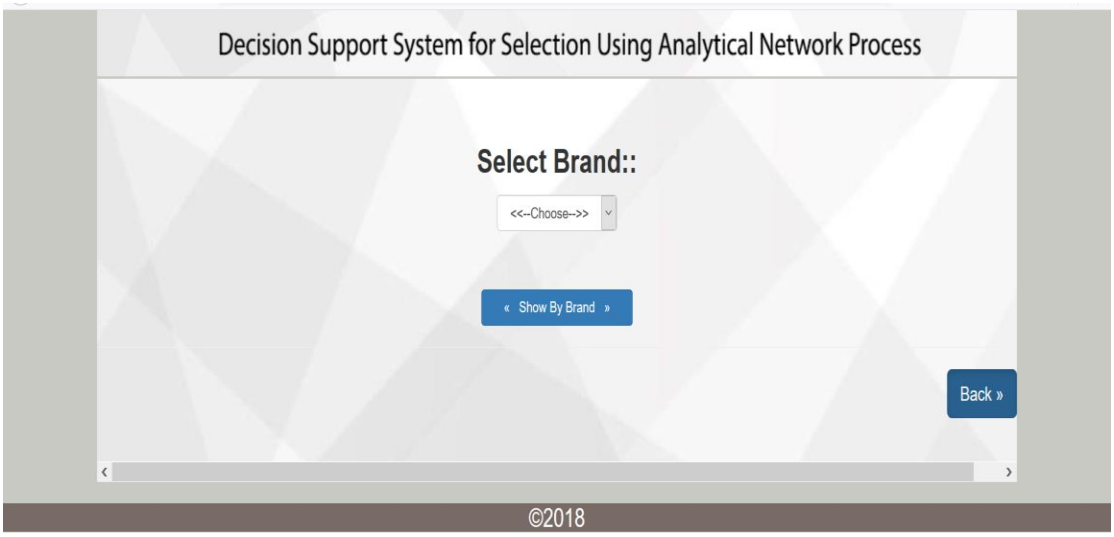


Figure 4.18 Select Brand Page

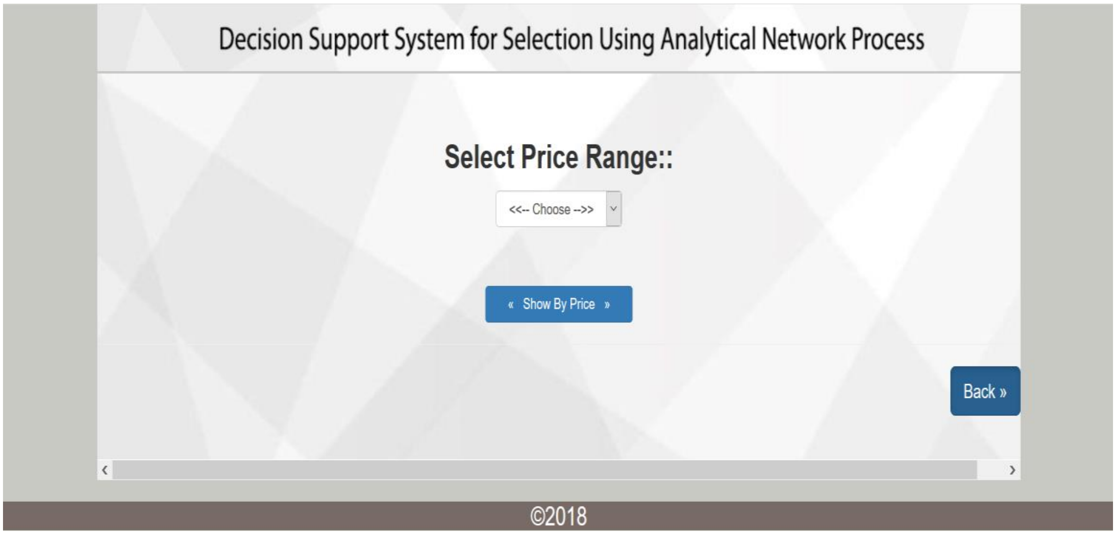


Figure 4.19 Select Price Range Page

CHAPTER 5
CONCLUSION

The Analytical Network Process (ANP) is one of Multi-Criteria Decision-Making (MCDM) methods. ANP method is utilized for the multi-criteria decision-making problems. The ANP feedback method is a networking approach which interchanges hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominated or being dominated, directly or indirectly. ANP organizes not only the importance of the criteria as in a hierarchy but also the importance of the alternatives may have impact on the importance of the criteria.

The ANP is highly recommended because ANP allows the interdependent and feedbacks influences specified in the model. ANP has applied to a large variety of decisions: marketing, political, social, and forecasting and prediction and many others. In this thesis, the ANP is used for selecting a suitable laptop. This is a web-based decision support system that supports the user to choose the appropriate laptop.

The proposed decision support system implements with eleven criteria and maximum two hundred alternatives. It also considers the dependence and feedback among decision criteria. When choosing the criteria for purchasing a laptop, the demandable user's requirements are also identified because users are looking for additional or attractive features. When we asked users for their requirements and purposes to select a portable laptop, we had known the requirements and features that they mostly wanted and used for. Based on their requirements, the criteria are selected and compared. Mostly demandable requirements are given more importance when constructing the comparison matrices. By doing such kind of field work, a huge information and knowledge about the marketing side are also gathered. Finally, this analysis helps the user's requirements for selecting a laptop. By using this system, the user obtains the best laptop which is suitable for him/her. In this system, the user can browse not only laptop series but also laptop prices.

Generally, ANP is a perfect and practical decision method which can be used to evaluate laptop selection model completely and scientifically. ANP is now widely used in decision-making with dependence and feedback.

5.1 Advantages of the System

The power of the ANP lies in its use of ratio scale to capture all kinds of interactions and makes accurate predictions. The proposed system implements with five clusters, eleven criteria and calculates maximum twenty-two alternatives and do calculation time depending on matrix power. So, it does not worry that the volume of matrix will be large and the performance of the system will degrade. Moreover, user can choose preference how much more important for each cluster to be weighted the priorities in decision for their different objectives and purposes. The laptop ranking result depends on each user requirement in cluster pairwise comparison.

5.2 Limitation of the System

The weighting values are based on decision maker's subjective opinion because ANP is dependent on the decision maker. ANP uses matrix in the calculation of pairwise comparisons. So, if there are too many criteria and alternatives, the volume of the matrix may be large and the performance of the system can be degraded. The proposed system implements with eleven criteria and dynamically calculates maximum two hundred alternatives. User is not allowed to choose criteria dynamically by this system.

5.3 Further Extension of the System

This system is developed by using Analytical Network Process (ANP). The system can be expanded with more criteria (e.g. motherboard, free accessories, graphics etc.) and alternatives for laptop selection model in order to meet the user requirements. Besides, the proposed decision support system does not involve any sub-criteria of each criteria. This proposed decision support system can be expanded by adding more criteria and sub-criteria.

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