SHOPPING ASSISTANT SYSTEM USING MULTI-ATTRIBUTE UTILITY THEORY (MAUT)

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STATEMENT OF ORIGINALITY

I hereby certify that the work embodied in this thesis is the result of original research and has not been submitted for a higher degree to any other University or Institution.

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Date Aye Myint Khine

ABSTRACT

With the widespread use of the Internet, electronic commerce (e-commerce) becomes very popular and one of the most important fields. In today's fast-changing era, it is extremely important to be able to respond to the needs of customers or buyers in the most effective and timely manner. So, most business websites make it easy to help both the customer needs and business requirements. This system is implemented as a shopping assistant system for searching laptop computers matched with user preferences in a variety of several alternatives from seventeen computer shops. An attractive theoretical additive utility function of Multi-Attribute Utility Theory (MAUT) is used in order to evaluate which laptop(s) performs best match with user preferences.

Key words: e-commerce, user preferences, MAUT

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CHAPTER 1
INTRODUCTION

Nowadays, most of the business companies use Internet to expand their markets because the Internet gives them the opportunities to face the world and get more benefits, such as increasing their consumers and becoming famous and known to partners as well as other companies worldwide. Traditional menu-driven navigation and key word search do not allow users to describe their intentions precisely. The distinction between the physical world and the virtual world that will be blurred as electronic presence for people, places and things becomes commonplace. Accessing the virtual world from a desktop or laptop computer will partially give away to access via a variety of mobile technologies. User context and preferences are vital considerations for delivery of electronic content, services and support. The distributed nature of the virtual world requires software to operate in a heterogeneous and dynamic environment composed of many components that must communicate with one another. In recent years, electronic commerce or e-commerce, the activity of buying or selling of products over the Internet becomes very popular. Moreover, e-commerce has changed the way companies distribute their products and services to consumers. Consumers can buy personal computers, television sets and books from an online store through the Internet. One of the popular examples of e-commerce is online shopping that is the action or activity of buying goods or services online. Online shopping has grown in popularity over the years because people find it convenient and easy to buy various items comfortably from their office or home and eliminates the need to wait in long lines or search from store to store for a particular item. In shopping assistant systems, the buyers give their product preferences through product attributes. Based on this, the shopping assistant systems suggest the best products to the buyers. The proposed system will be developed for searching relevant products based on users' desired product characteristics and displaying the best match product(s) to the users by comparing product information using Multi-Attribute Utility Theory (MAUT).

1.1 Objectives of the Thesis

The major objectives of the thesis are as follows:

- To help users in searching required product information
- To provide the search of relevant products by giving user preferences through product attributes
- To implement the shopping assistant system that reduces users' effort and searching time required to get the desired products

1.2 Related Work

Agent-Based Model for Shopping Assistant System was described in 2009. Their system proposed shopping assistant agents as sale representatives for both shoppers and stores to negotiate for desired products based on shopper preferences. The main agent used in their system was buyer agent in order to help customers or buyers in finding the products as they desire. Buyer agent will communicate with other seller agents to complete the product selection phase [15]. The other author also implemented the Agent-Based Online Shopping Assistant System as a shopping assistant system using multi-agent technology. In buying products with multiple attributes and multiple prices, the users might have difficulty in finding the right product they want within their budget. Their shopping assistant system can find the set of relevant items within the buyers' budget [3]. By using online shopping system over the Internet, users can save their time and effort. So, this thesis presents the shopping assistant system for both customers and shops by using effective Multi-Attribute Utility Theory (MAUT).

1.3 Organization of the Thesis

The thesis is composed of five chapters. The structure of the thesis is as follows.

Chapter 1 is the introduction to the system and describes objectives, related work and organization of the thesis.

Chapter 2 discusses the background theory of the system.

Chapter 3 presents one of the Multiple Criteria Decision Making methods (MCDM), Multi-Attribute Utility Theory (MAUT) in detail.

Chapter 4 describes the design and the implementation of the proposed system.

Chapter 5 concludes with the advantages, limitations and further extension of the system.

CHAPTER 2
BACKGROUND THEORY OF THE SYSTEM

E-commerce has emerged as an important information technology tool to business. Many companies and organizations have been using e-commerce as a useful, helpful, and necessary trading tool in their daily business processes. Due to the huge amount of information available on the Internet such that the difficulty to search all shopping websites and compare their prices and services, the consumers experience hard time in finding products or services they want. E-commerce provides a lot of benefits to the online customers that they can buy so many products from many online stores without any effort and they can just pick whatever they want from products posted online. Therefore, shopping through online stores is gaining popularity and acceptance among customers.

2.1 Different E-commerce Business Models

There are different business models in e-commerce. Some of the most popular business models are as follows:

- **Business to Business (B2B):** B2B is when businesses sell to other businesses. This is typical of stationery stores who sell office equipment in bulk to businesses. Normally B2B companies provide a discounted rate per unit if customers buy in bulk which it is great motivation for offices.
- **Business to Consumer (B2C):** B2C is the most commonly thought of business model where merchants sell to consumers who buy a small amount of product. A familiar example of the B2C model would be supermarkets where consumers buy their shopping weekly but they wouldn't normally bulk buy anything.
- **Consumer to Consumer (C2C):** C2C is a relatively new business model where consumers who previously bought something seek to resell this item to another consumer. Through marketplaces like eBay and Craigslist, this can be easy and quite lucrative for selling items.

2.2 Examples of E-commerce

There are many examples in e-commerce. Some of the most commonly used examples are described below:

- **Online Shopping:** Buying and selling goods on the Internet is one of the most popular examples of e-commerce. Sellers create storefronts that are the online equivalents of retail outlets. Buyers browse and purchase products with mouse clicks. Though Amazon.com is not the pioneer of online shopping, it is arguably the most famous online shopping destination.
- **Electronic Payment:** When buying goods online, there needs to be a mechanism to pay online too. That is where payment processors and payment gateways come into the picture. Electronic payment reduces the inefficiency associated with writing and mailing checks. It also does away with many of the safety issues that arise due to payment made in currency notes.
- **Online Auction:** When thinking online auction like eBay, physical auction predates online auction, but the Internet made auction accessible to a large number of buyers and sellers. Online auction is an efficient mechanism for price discovery. Many buyers find the auction shopping mechanism much interesting than regular store front shopping.
- **Internet Banking:** Today it is possible to perform the entire gamut of banking operations without visiting a physical bank branch. Interfacing of websites with bank accounts and by extension credit cards is the biggest driver of e-commerce.
- **Online Ticketing:** Air tickets, movie tickets, train tickets, play tickets, tickets to sporting events and just about any kind of tickets can be booked online. Online ticketing does away with the need to queue up at ticket counters.

2.3 Online Shopping

One of the examples of e-commerce, online shopping is the process of buying goods and services from merchants over the Internet. Since the emergence of the World Wide Web, merchants have sought to sell their products to people who spend

time online. Shoppers can visit web stores from the comfort of their homes and shop as they sit in front of the computers. Consumers can buy a huge variety of items from online stores, and just about anything can be purchased from companies that provide their products online. Books, clothing, household appliances, toys, hardware, software, and health insurance are just some of the hundreds of products that consumers can buy from an online store. Many people choose to shop online because of the convenience. Online shopping also involves searching for items online via web searches and by conducting online research. With online shopping, customers purchase items from anywhere in the world via a digital platform. Online shopping is also great for those who want to avoid stores and long line ups and for those who are too busy to shop in traditional brick and mortar retail stores.

2.4 History of Online Shopping

Before the World Wide Web was created, Michael Aldrich developed a system called Redifon's Office Revolution in March 1980, connecting sales companies, suppliers, and customers together. Companies were able to order supplies from suppliers and sell products to customers electronically, utilizing videotext technology. It is considered as a major predecessor and influence on the development of online shopping.

In 1994, several years after the launching of the World Wide Web, online transaction systems including banking and shopping, started emerging. The first shopping transactions were completed through Internet Shopping Network in 1994, beginning the online shopping boom. Amazon.com and eBay launched their websites in 1995, offering online shopping options for customers.

Many of the first online shopping websites utilized Intershop Online, an online shopping software system, developed in 1995 by Intershop Communications AG. The Intershop Online software allowed businesses to more easily add online shopping capabilities, or e-commerce, on their website, with secure transactions for their customers.

2.5 Shopping Assistant

Shopping assistant is the process of serving customers or buyers. The capabilities of shopping assistant include: (1) helping the buyers decide what product to buy, e.g., by listing what products of certain type are available, (2) finding the specifications and reviews of them, (3) making recommendations and (4) comparison shopping to find the best price for the desired product.

2.6 Characteristics of Shopping Assistant

To reduce the users' effort of shopping around online stores, the system should possess the following characteristics.

- **Autonomy:** In order to reduce for eliminating user intervention during purchasing activity, the system should have autonomous transaction facilities. It executes all the required activities of shopping for the user, generates the shopping list and gathers product information from multiple stores on the Internet.
- **User Adaptability:** User preference is changing all the time. The system should reflect the up-to-date preferences of the users in an adaptation mechanism.
- **Multiple Store Server Access:** The users require product information on several stores, and place orders after comparing it. This shopping system gathers item information from several stores and compares the learned facts with multiple product characteristics based on user preferences of each item.

2.7 Features of Shopping Assistant

This is the central entity responsible for all kinds of information retrieval tasks on the Internet. Shopping assistant interacts with different other assistants and entities to retrieve information from different online stores. Some of the main features of shopping assistant are described as follows;

- **Specification of Items:** Shoppers begin by indicating at least the general category of merchandise they are interested in. These goals may be refined as the task progresses. Shopping needs to enable the specification of goals at various degrees of specificity. Before shoppers can make a selection, they need to become educated about what is available. The proposed system can

aid by presenting various classes of offerings, reviews, demonstrations, etc. Physical shopping can augment this by providing shoppers with a tour of the locally available offerings. As shoppers learn what is available and examine the offerings their preferences evolve, the system needs to enable shoppers to refine their preferences over time.

- **Product Comparison:** As shoppers begin to understand what they want and what is available, they typically compile a list of candidates that will be considered more carefully. The system should support the construction and maintenance of such lists and facilitate the comparison of candidates within the list according to various criteria.
- **Task Automation:** The system needs not be restricted to providing the shopper with information. Ideally the system should negotiate prices and service options with retailers. Naturally, the shopping assistant system should facilitate the transaction itself and it should be able to be used as a channel through which product service can be delivered.

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CHAPTER 3
MULTI-ATTRIBUTE UTILITY THEORY (MAUT)

Decision Making is the process of choosing the best option matched with decision maker from all of the flexible alternatives. There are different decision making methods. Some commonly used methods are:

- Multiple Criteria Decision Making (MCDM) Methods
- Paired Comparison Methods

3.1 Multiple Criteria Decision Making (MCDM)

Multiple Criteria Decision Making (MCDM) is the set of methods that evaluate multiple conflicting criteria in decision making. Cost or price is one of the main conflicting criteria. Some measure of quality is another criterion that is in conflict with the cost or price. There are many MCDM methods. Some widely used methods are:

- MAUT (Multi-Attribute Utility Theory)
- Simple Multi-Attribute Rating Technique (SMART)
- Weighted Sum Model (WSM)

In this system, MAUT is used to evaluate the best match product(s) based on users' request because it produces the product(s) with lower price and higher quality.

3.2 Multi-Attribute Utility Theory (MAUT)

Multi-Attribute Utility Theory (MAUT) is a normative method for the evaluation of items involving multiple competing attributes. MAUT is one of the Multiple Criteria Decision Making (MCDM) methods. It was introduced by Fishbum (1965, 1970), Keeney (1969, 1971, 1973) and Raiffa (1969) who proposed a decision making technique designed for taking decisions under risk. It is a decision-making method used when the decision maker has to take multiple objectives into account. It is also an evaluation method used by many systems for evaluating the interests and preferences of the users and supporting them in configuring the desired product(s). MAUT evaluates not just one user's but several users' preferences and it computes the degree of interest (or utility) of the products regarding the user preferences. It allows

the decision makers to include any kind of attribute in the target system and to express their preferences for these attributes

MAUT is especially a structured methodology designed to handle the tradeoffs among incomparable and conflicting multiple objectives, captured by multiple attributes. Example, better performance and lower price of computer. This method is recommended when prospective alternatives must be evaluated to determine which alternative(s) performs best.

The aim of MAUT is to help the decision makers who face very complex problems choosing between the different possible alternatives, taking into account their preferences. MAUT has been widely used in situations where the decision making depends on multiple factors and the utility calculation of decision alternatives is based on multiple attributes. Therefore, MAUT has been extensively used for decision making of economic and financial like the application area of e-commerce.

There are different utility functions in Multi-Attribute Utility Theory (MAUT). But most commonly used MAUT functions are: additive utility function and multiplicative utility function.

3.2.1 Additive Utility Function

In additive utility function of MAUT, the overall utility of an alternative is calculated by the weighted sums of its measures (i.e. evaluation criteria). It is described by the following equation:

$$U(x_1, \dots, x_n) = \sum_{i=1}^{n} k_i U_i(x_i) \qquad 3.1$$

Where,

$U(x_1,\dots,x_n)$ = the overall utility score of each alternative

$U_i(x_i)$ = the utility function of the ith attribute

k_i = the weight of the ith attribute

$0 \leq U(x_1,\dots,x_n), U_i(x_i) \leq 1$

$k_1 + \dots + k_n = 1$

3.2.2 Multiplicative Utility Function

In multiplicative utility function of MAUT, the overall utility of an alternative is achieved by multiplication of the utility factors for all attributes. It is described by the following equation:

$$U(x_1, \dots, x_n) = I^{-1}\left\{\prod_{i=1}^{n}[1 + I\,k_i U_i(x_i)] - 1\right\} \quad 3.2$$

Where,

$U(x_1,\dots,x_n)$ = the overall utility score of each alternative

$U_i(x_i)$ = the utility function of the ith attribute

k_i = the weight of the ith attribute

I = a scaling constant

$0 \leq U(x_1,\dots,x_n)$, $U_i(x_i) \leq 1$

If $k_1 + \dots + k_n < 1$ then $I > 0$ If $k_1 + \dots + k_n > 1$ then $-1 < I < 0$

Among these functions, additive utility function will be used to find the best match with user requirements in this system because it ignores attribute interaction which is a situation in two or more attributes that act upon one another.

3.3 Processes of Multi-Attribute Utility Theory (MAUT)

The processes of Multi-Attribute Utility Theory involve five stages. The processes are described as follows.

- Identify the attributes, which collectively describe the overall utility of all relevant decision options.
- Identify the alternatives or options to calculate.
- Weight the attributes in terms of their importance.
- Transform the attribute scores, measured in different units, into commensurate (similar measurable standard) units.
- Define aggregate utility function, which combines the transformed scores and weights to measure the overall utility of each option.

3.4 Goals of MAUT

The basic goal of MAUT is to substitute information with an arbitrary measure called utilities and it evaluates the best match product(s) by normalized utility functions for attributes and by weights for expressing the relative importance of attributes. And, the basic of MAUT is the use of utility functions. Through the use of utility functions, the MAUT method converts numerical attribute scales to utility unit scales. MAUT relies on the assumptions that the decision maker is rational (for example, preferring more utility to less utility). Moreover, the decision maker also has perfect knowledge and is consistent in his or her judgments. The goal of the decision makers in this process is to maximize utility score because the alternative with the highest utility score should be the best choice. That is the fundamental principle upon which utility theory is based. So, utility functions of MAUT are computationally very attractive because they provide easy and fast ways to extract the preferences of the decision makers.

CHAPTER 4
SYSTEM DESIGN AND IMPLEMENTATION

This system is an implementation of shopping assistant system for buying laptop computers. There are nine attributes specified in this system. They are Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price and Brand. But eight attributes except Brand are used in calculation. In order to find the user desired laptop, the proposed system develops seventeen computer shops, ADT, ASIA TECH, CHAN MYAY, CITICOM, EASTERN, IDEALINK, KING EMPIRE, KING POWER, KSW, KMD, LIFE MARK, MEDIA LINK, RIT, TECHNOLAND, THA PYAY PWINT, TOP POWER AND UNIQUE. In this system, the users have to provide their desired characteristics (preferences) to the system. Then the list of relevant products based on user preferences are displayed to the users. Among them, the best match product(s) are evaluated using Multi-Attribute Utility Theory (MAUT). Therefore, the users can reduce searching time for shop by shop and save effort to find the right product. The overall architecture of the proposed shopping assistant system is described in Figure 4.1.

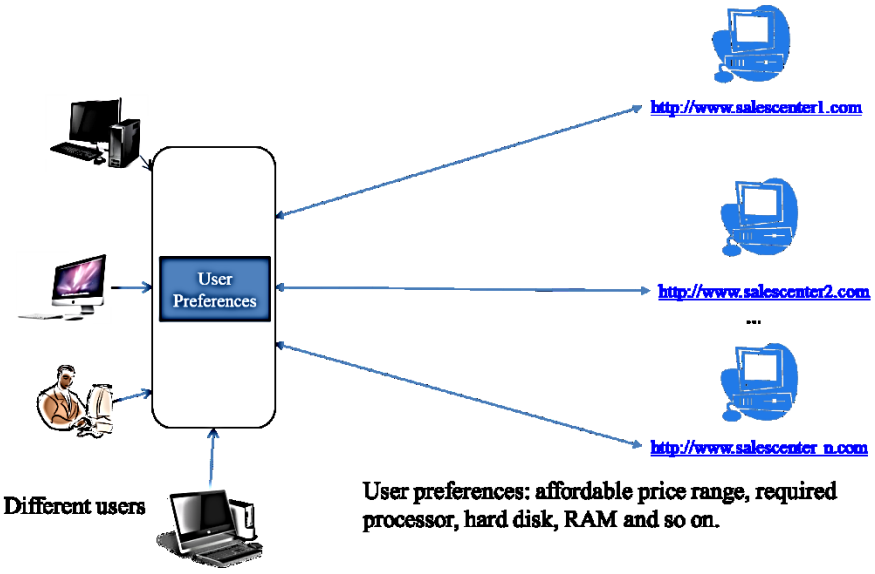


Figure 4.1 Overview Architecture of the System

4.1 Process Flow of the System

The proposed system provides searching and retrieving laptop computers based on user preferences and consists of the following processes. The users have to enter the laptop attributes (user preferences) to the system. The system surfs around the seventeen computer shops. When it gets the relevant laptops with user desired characteristics from the shops, compares the laptop information using MAUT in order to determine which laptop(s) is best match with user preferences. Finally, the best match laptop(s) is displayed to the users. The process flow of the system is described in Figure 4.2.

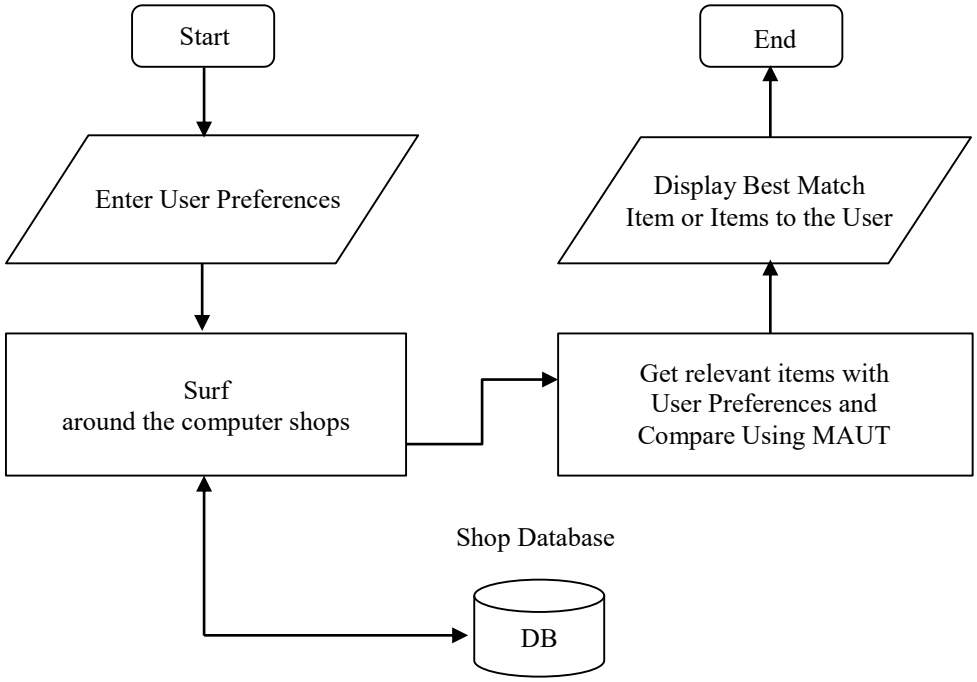


Figure 4.2 Process Flow of the System

4.2 System Implementation and User Interface

There are four main menu links in this system. They are Home page menu link, About page menu link, Shop List page menu link and Search page menu link. When clicking each menu link, the respective page will appear.

4.2.1 Home Page of the System

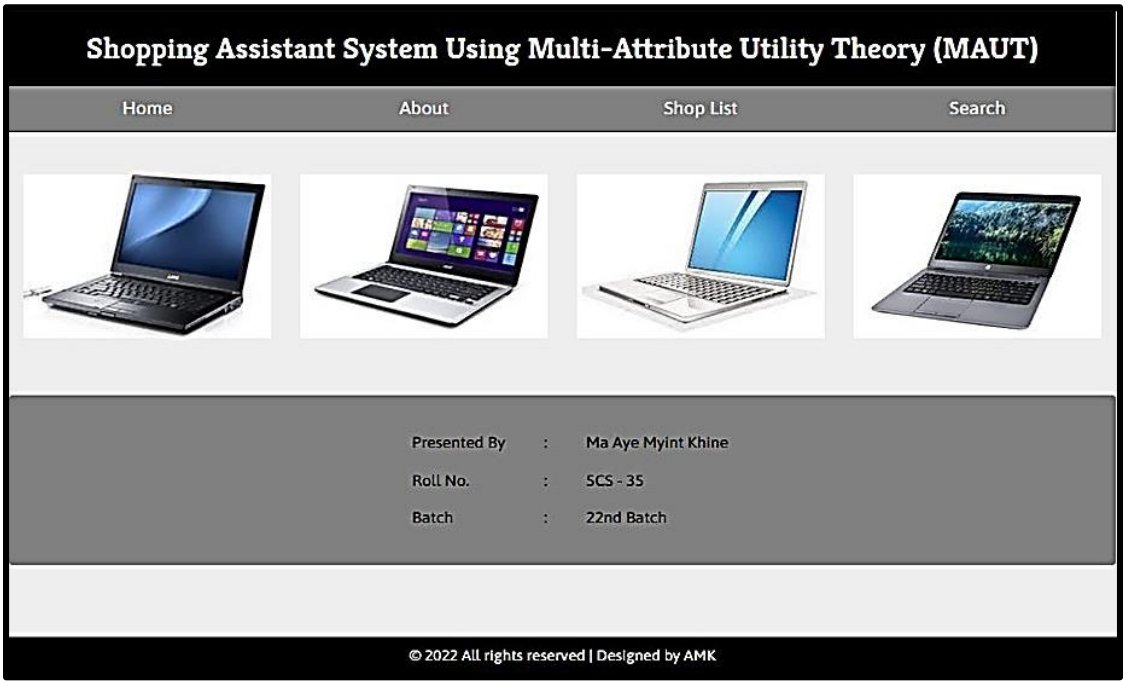


Figure 4.3 Home Page of the System

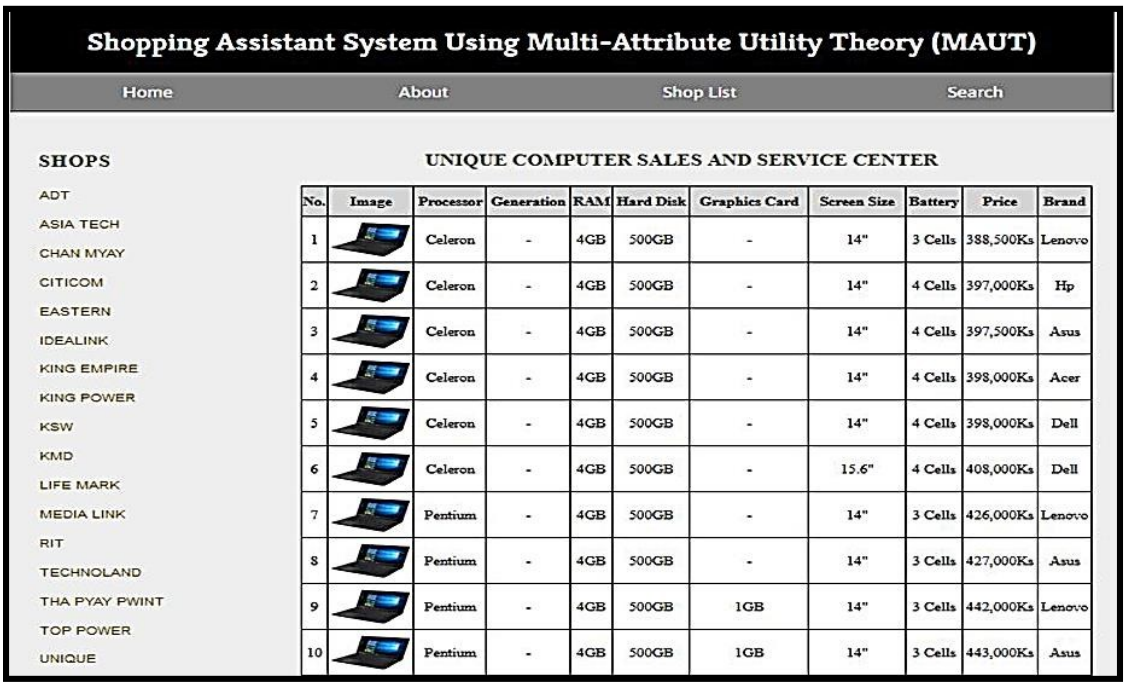
When clicking "Home" page menu Link, "Home" page of the system will appear as shown in Figure 4.3.

4.2.2 About Page of the System

Figure 4.4 About Page of the System

Figure 4.4 is "About" page of the system. This page presents about the system that uses nine attributes and seventeen computer shops for searching the laptops that the users want.

4.2.3 Shop List Page of the System



No.	Image	Processor	Generation	RAM	Hard Disk	Graphics Card	Screen Size	Battery	Price	Brand
1		Celeron	-	4GB	500GB	-	14"	3 Cells	388,500Ks	Lenovo
2		Celeron	-	4GB	500GB	-	14"	4 Cells	397,000Ks	Hp
3		Celeron	-	4GB	500GB	-	14"	4 Cells	397,500Ks	Asus
4		Celeron	-	4GB	500GB	-	14"	4 Cells	398,000Ks	Acer
5		Celeron	-	4GB	500GB	-	14"	4 Cells	398,000Ks	Dell
6		Celeron	-	4GB	500GB	-	15.6"	4 Cells	408,000Ks	Dell
7		Pentium	-	4GB	500GB	-	14"	3 Cells	426,000Ks	Lenovo
8		Pentium	-	4GB	500GB	-	14"	3 Cells	427,000Ks	Asus
9		Pentium	-	4GB	500GB	1GB	14"	3 Cells	442,000Ks	Lenovo
10		Pentium	-	4GB	500GB	1GB	14"	3 Cells	443,000Ks	Asus

Figure 4.5 Product List of UNIQUE Computer Shop

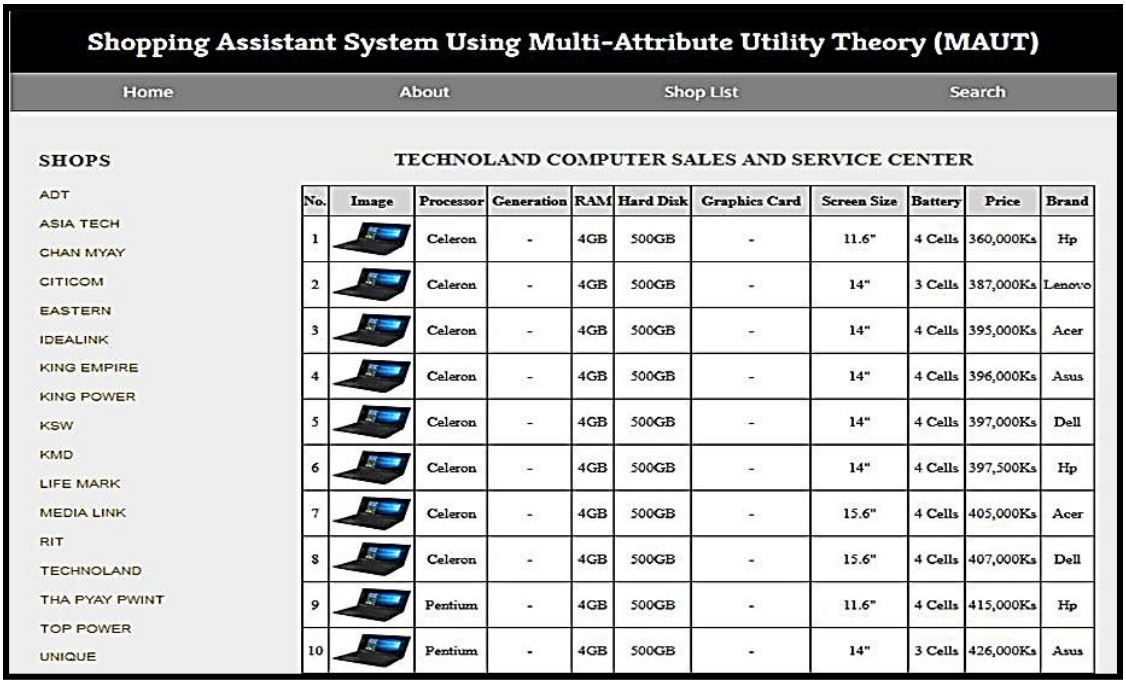


Figure 4.6 Product List of TECHNOLAND Computer Shop

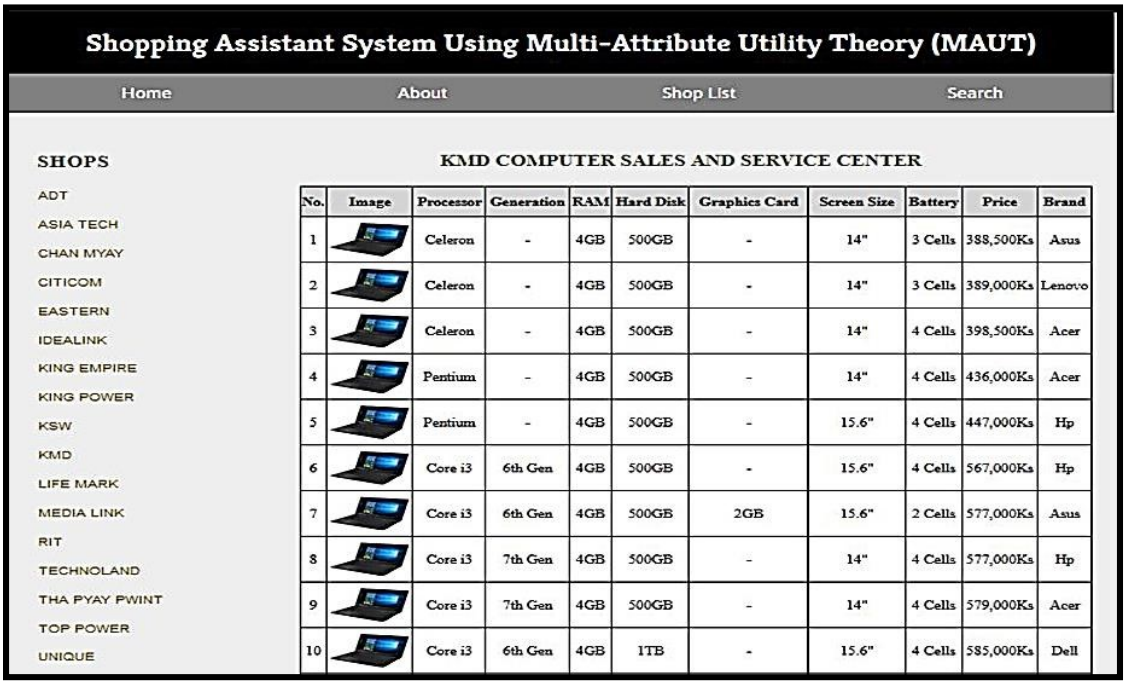


Figure 4.7 Product List of KMD Computer Shop

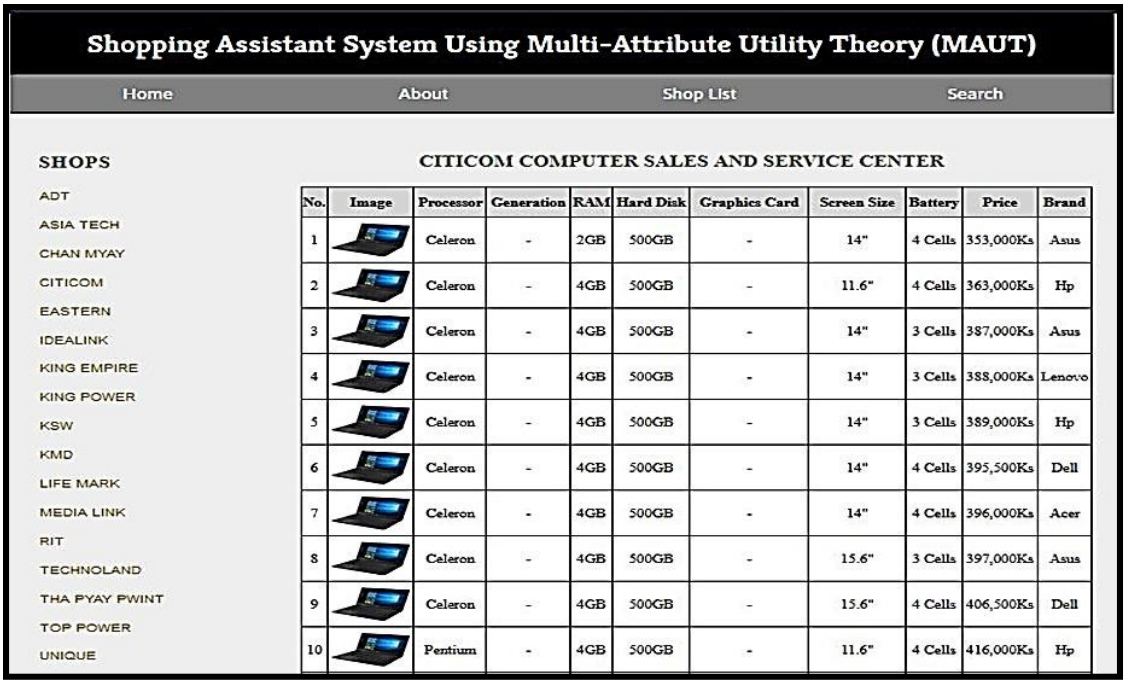


Figure 4.8 Product List of CITICOM Computer Shop

In "Shop List" page, the product lists of seventeen computer shops are displayed. Among these shops, the lists of four computer shops such as UNIQUE, TECHNOLAND, KMD AND CITICOM are shown in Figure 4.5, Figure 4.6, Figure 4.7 and Figure 4.8.

4.2.4 Search Page of the System

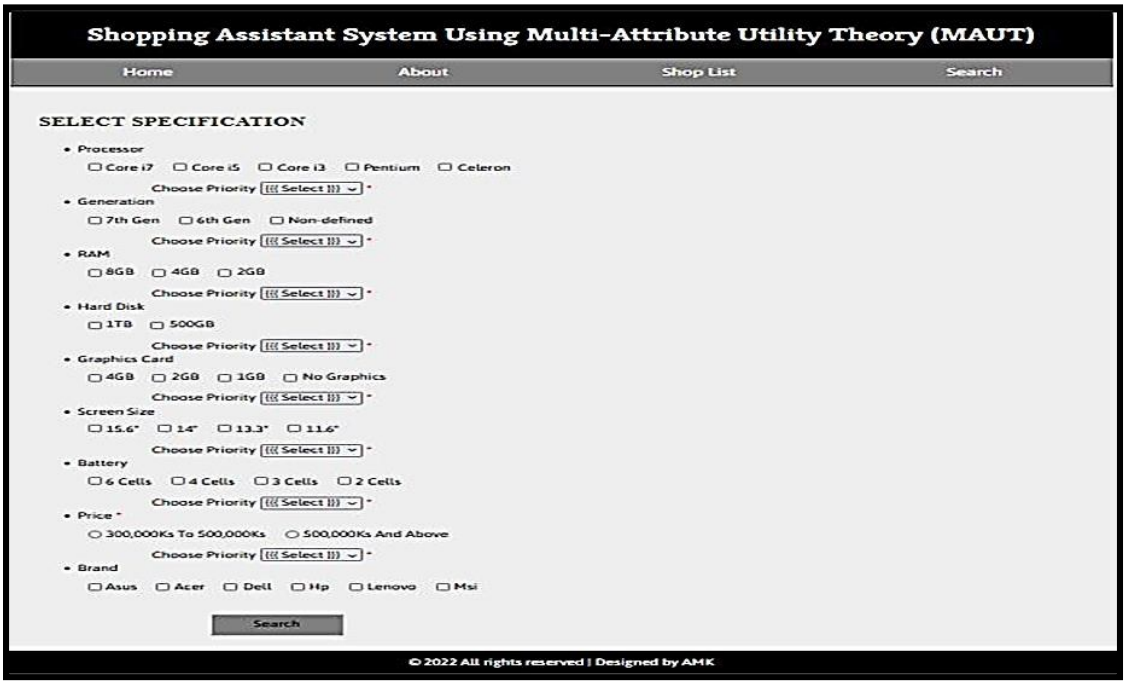


Figure 4.9 User Preferences Entry of the System

When clicking "Search" page menu link, user preferences entry form will appear as shown in Figure (4.9). The users have to provide their preferences as illustrated in Figure (4.10) and Figure (4.17) and click the "Search" button. Then, the list of relevant products will be described. Among these products, best match product(s) will be evaluated using MAUT. Figure (4.11) and Figure (4.18) show result data list of relevant products and best match product(s).

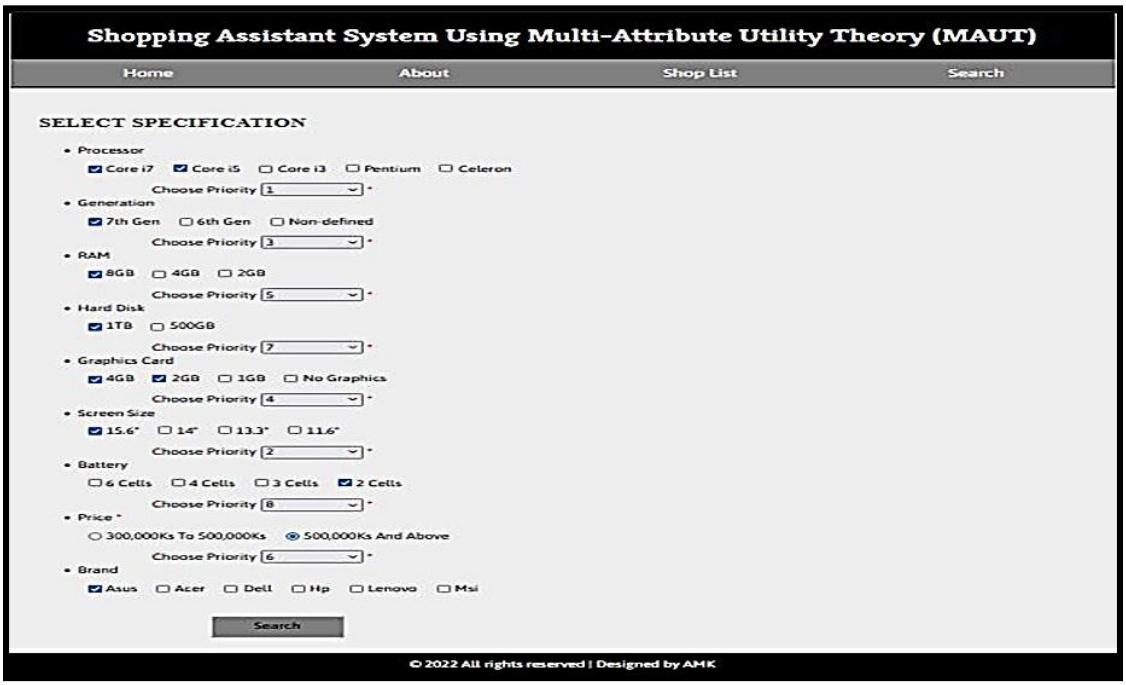


Figure 4.10 User Preferences Entry (by choosing Processor as 1st Priority)

Figure 4.10 is the user preferences entry form that Processor is chosen as first priority and the remaining attributes such as Generation, RAM etc. are chosen by their desired priority.

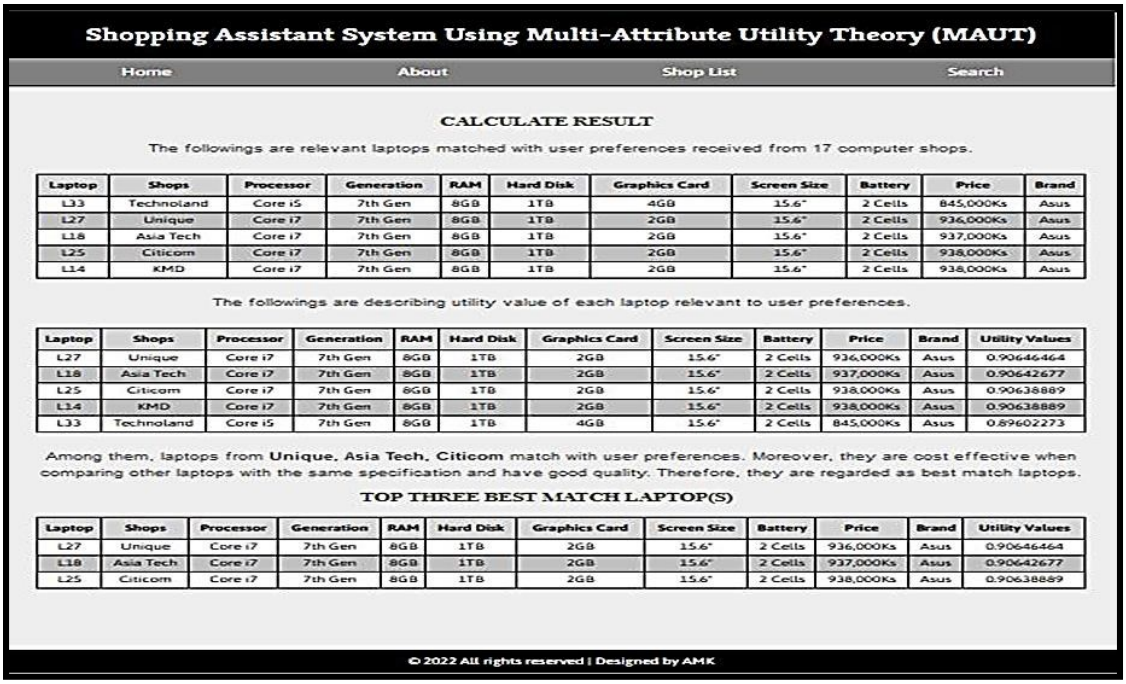


Figure 4.11 Result Data (by choosing Processor as 1st Priority)

Figure 4.11 is the result data list of relevant products and best match product(s) that Processor is chosen as first priority and the remaining attributes such as Generation, RAM etc. are chosen by their desired priority.

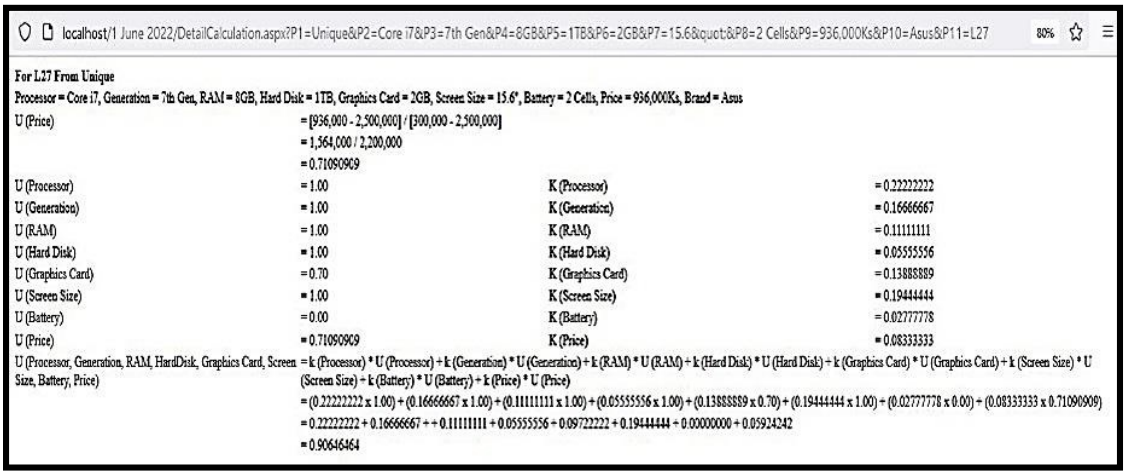
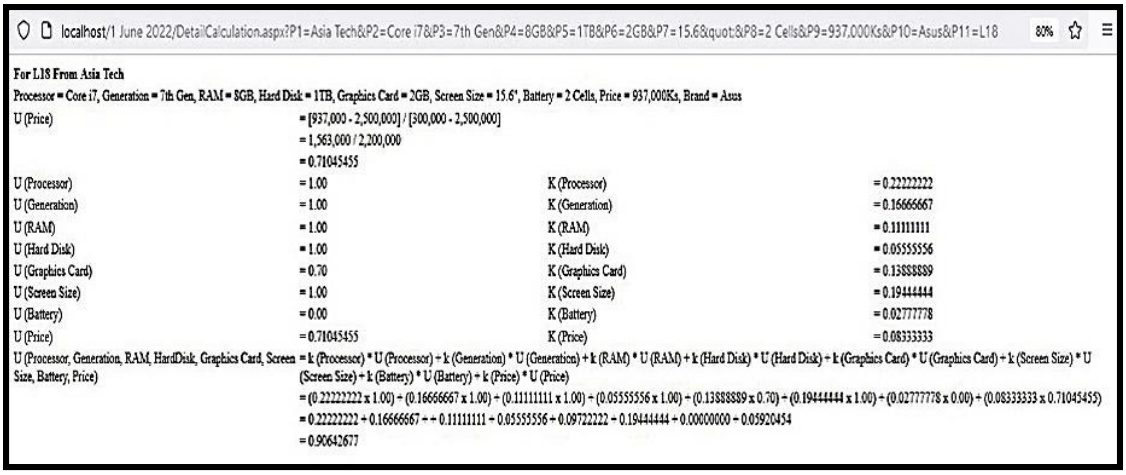


Figure 4.12 Calculation of Utility Value for 1st Best Match Laptop (by choosing Processor as 1st Priority)



localhost/1 June 2022/DetailCalculation.aspx?P1=Asia Tech&P2=Core i7&P3=7th Gen&P4=8GB&P5=1TB&P6=2GB&P7=15.6"&P8=2 Cells&P9=937,000Ks&P10=Asus&P11=L18 80%

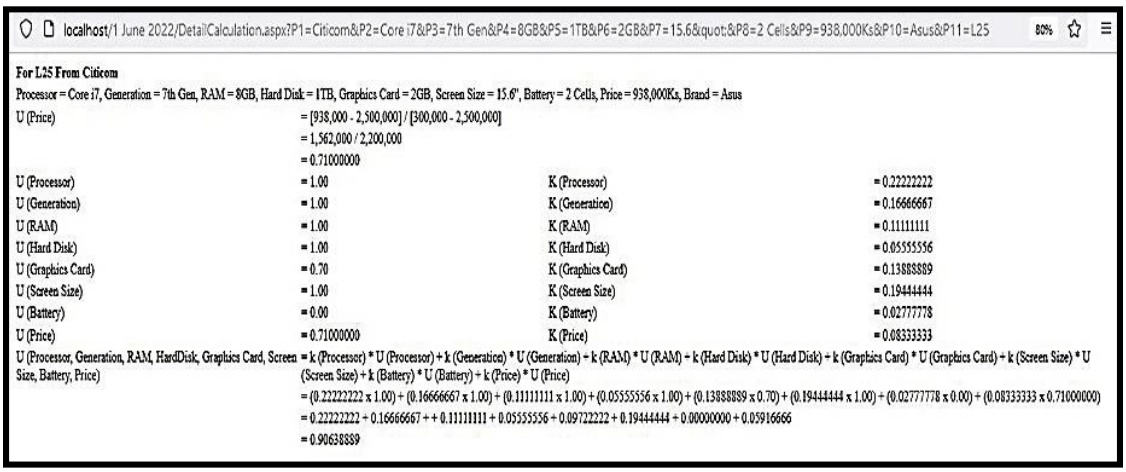
For L18 From Asia Tech

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6", Battery = 2 Cells, Price = 937,000Ks, Brand = Asus

U (Price)	= [937,000 - 2,500,000] / [300,000 - 2,500,000] = 1,563,000 / 2,200,000 = 0.71045455		
U (Processor)	= 1.00	K (Processor)	= 0.22222222
U (Generation)	= 1.00	K (Generation)	= 0.16666667
U (RAM)	= 1.00	K (RAM)	= 0.11111111
U (Hard Disk)	= 1.00	K (Hard Disk)	= 0.05555556
U (Graphics Card)	= 0.70	K (Graphics Card)	= 0.13888889
U (Screen Size)	= 1.00	K (Screen Size)	= 0.19444444
U (Battery)	= 0.00	K (Battery)	= 0.02777778
U (Price)	= 0.71045455	K (Price)	= 0.08333333
U (Processor, Generation, RAM, HardDisk, Graphics Card, Screen Size, Battery, Price)	= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price) = (0.22222222 x 1.00) + (0.16666667 x 1.00) + (0.11111111 x 1.00) + (0.05555556 x 1.00) + (0.13888889 x 0.70) + (0.19444444 x 1.00) + (0.02777778 x 0.00) + (0.08333333 x 0.71045455) = 0.22222222 + 0.16666667 + + 0.11111111 + 0.05555556 + 0.09722222 + 0.19444444 + 0.00000000 + 0.05920454 = 0.90642677		

Figure 4.13 Calculation of Utility Value for 2nd Best Match Laptop

(by choosing Processor as 1st Priority)



localhost/1 June 2022/DetailCalculation.aspx?P1=Citicom&P2=Core i7&P3=7th Gen&P4=8GB&P5=1TB&P6=2GB&P7=15.6"&P8=2 Cells&P9=938,000Ks&P10=Asus&P11=L25 80%

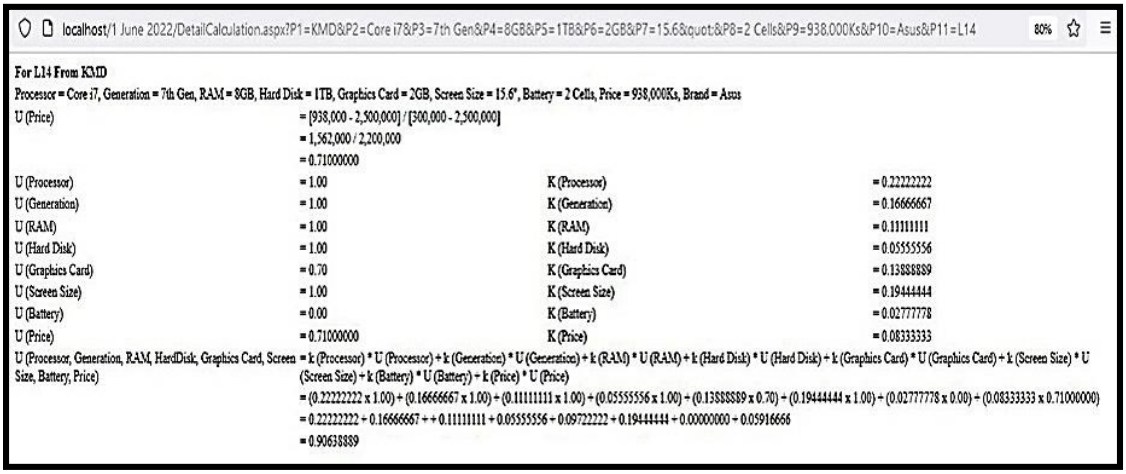
For L25 From Citicom

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6", Battery = 2 Cells, Price = 938,000Ks, Brand = Asus

U (Price)	= [938,000 - 2,500,000] / [300,000 - 2,500,000] = 1,562,000 / 2,200,000 = 0.71000000		
U (Processor)	= 1.00	K (Processor)	= 0.22222222
U (Generation)	= 1.00	K (Generation)	= 0.16666667
U (RAM)	= 1.00	K (RAM)	= 0.11111111
U (Hard Disk)	= 1.00	K (Hard Disk)	= 0.05555556
U (Graphics Card)	= 0.70	K (Graphics Card)	= 0.13888889
U (Screen Size)	= 1.00	K (Screen Size)	= 0.19444444
U (Battery)	= 0.00	K (Battery)	= 0.02777778
U (Price)	= 0.71000000	K (Price)	= 0.08333333
U (Processor, Generation, RAM, HardDisk, Graphics Card, Screen Size, Battery, Price)	= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price) = (0.22222222 x 1.00) + (0.16666667 x 1.00) + (0.11111111 x 1.00) + (0.05555556 x 1.00) + (0.13888889 x 0.70) + (0.19444444 x 1.00) + (0.02777778 x 0.00) + (0.08333333 x 0.71000000) = 0.22222222 + 0.16666667 + + 0.11111111 + 0.05555556 + 0.09722222 + 0.19444444 + 0.00000000 + 0.05916666 = 0.90638889		

Figure 4.14 Calculation of Utility Value for 3rd Best Match Laptop

(by choosing Processor as 1st Priority)



localhost/1 June 2022/DetailCalculation.aspx?P1=KMD&P2=Core i7&P3=7th Gen&P4=8GB&P5=1TB&P6=2GB&P7=15.6"&P8=2 Cells&P9=938,000Ks&P10=Asus&P11=L14 80%

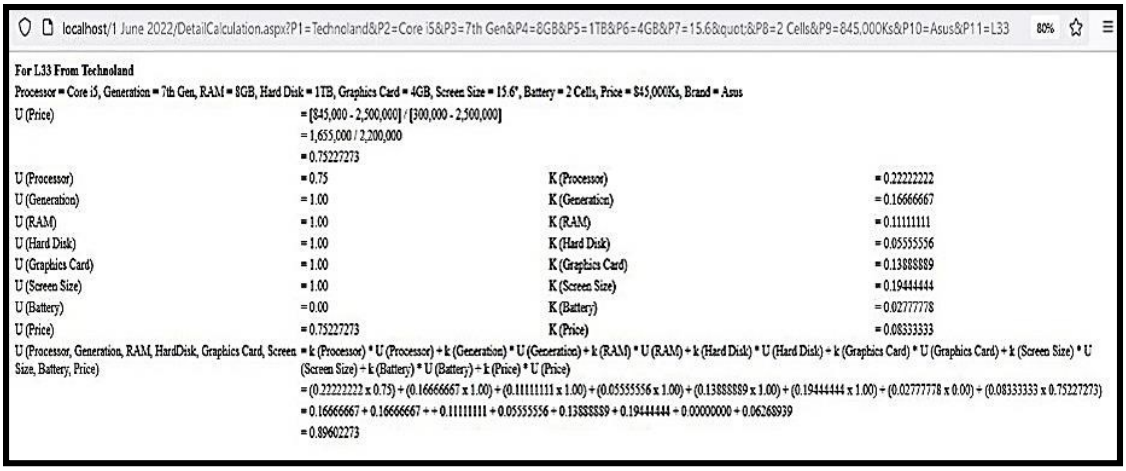
For L14 From KMD

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6", Battery = 2 Cells, Price = 938,000Ks, Brand = Asus

U (Price)	= [938,000 - 2,500,000] / [300,000 - 2,500,000] = 1,562,000 / 2,200,000 = 0.71000000		
U (Processor)	= 1.00	K (Processor)	= 0.22222222
U (Generation)	= 1.00	K (Generation)	= 0.16666667
U (RAM)	= 1.00	K (RAM)	= 0.11111111
U (Hard Disk)	= 1.00	K (Hard Disk)	= 0.05555556
U (Graphics Card)	= 0.70	K (Graphics Card)	= 0.13888889
U (Screen Size)	= 1.00	K (Screen Size)	= 0.19444444
U (Battery)	= 0.00	K (Battery)	= 0.02777778
U (Price)	= 0.71000000	K (Price)	= 0.08333333
U (Processor, Generation, RAM, HardDisk, Graphics Card, Screen Size, Battery, Price)	= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price) = (0.22222222 x 1.00) + (0.16666667 x 1.00) + (0.11111111 x 1.00) + (0.05555556 x 1.00) + (0.13888889 x 0.70) + (0.19444444 x 1.00) + (0.02777778 x 0.00) + (0.08333333 x 0.71000000) = 0.22222222 + 0.16666667 + + 0.11111111 + 0.05555556 + 0.09722222 + 0.19444444 + 0.00000000 + 0.05916666 = 0.90638889		

Figure 4.15 Calculation of Utility Value for 4th Best Match Laptop

(by choosing Processor as 1st Priority)



localhost/1 June 2022/DetailCalculation.aspx?P1=Technoland&P2=Core i5&P3=7th Gen&P4=8GB&P5=1TB&P6=4GB&P7=15.6"&P8=2 Cells&P9=845,000Ks&P10=Asus&P11=L33 80%

For L33 From Technoland

Processor = Core i5, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 4GB, Screen Size = 15.6", Battery = 2 Cells, Price = 845,000Ks, Brand = Asus

U (Price)	= [845,000 - 2,500,000] / [300,000 - 2,500,000] = 1,655,000 / 2,200,000 = 0.75227273		
U (Processor)	= 0.75	K (Processor)	= 0.22222222
U (Generation)	= 1.00	K (Generation)	= 0.16666667
U (RAM)	= 1.00	K (RAM)	= 0.11111111
U (Hard Disk)	= 1.00	K (Hard Disk)	= 0.05555556
U (Graphics Card)	= 1.00	K (Graphics Card)	= 0.13888889
U (Screen Size)	= 1.00	K (Screen Size)	= 0.19444444
U (Battery)	= 0.00	K (Battery)	= 0.02777778
U (Price)	= 0.75227273	K (Price)	= 0.08333333
U (Processor, Generation, RAM, HardDisk, Graphics Card, Screen Size, Battery, Price)	= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price) = (0.22222222 x 0.75) + (0.16666667 x 1.00) + (0.11111111 x 1.00) + (0.05555556 x 1.00) + (0.13888889 x 1.00) + (0.19444444 x 1.00) + (0.02777778 x 0.00) + (0.08333333 x 0.75227273) = 0.16666667 + 0.16666667 + + 0.11111111 + 0.05555556 + 0.13888889 + 0.19444444 + 0.00000000 + 0.06268939 = 0.89602273		

Figure 4.16 Calculation of Utility Value for 5th Best Match Laptop (by choosing Processor as 1st Priority)

Figure (4.12), Figure (4.13), Figure (4.14), Figure (4.15) and Figure (4.16) present detailed calculation of each laptop received from each computer shop that Processor is chosen as first priority and the remaining attributes such as Generation, RAM etc. are chosen by their desired priority.

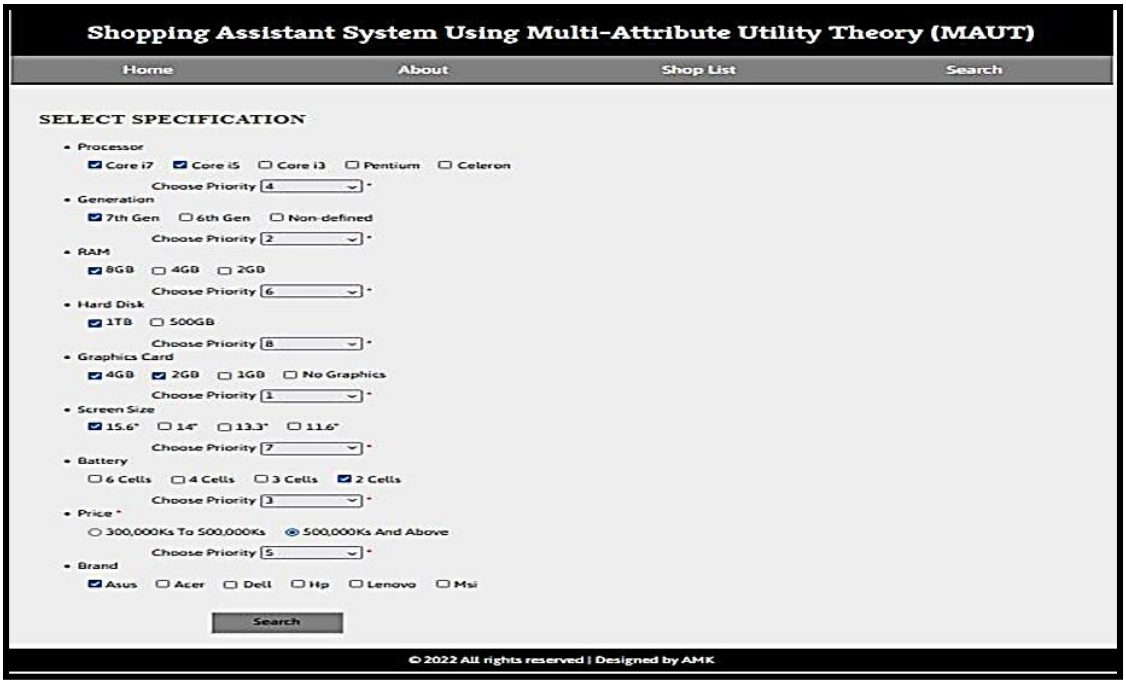


Figure 4.17 User Preferences Entry (by choosing Graphics Card as 1st Priority)

Figure 4.17 is the user preferences entry form that Graphics Card is chosen as first priority and the remaining attributes such as Generation, RAM etc. are chosen by their desired priority.

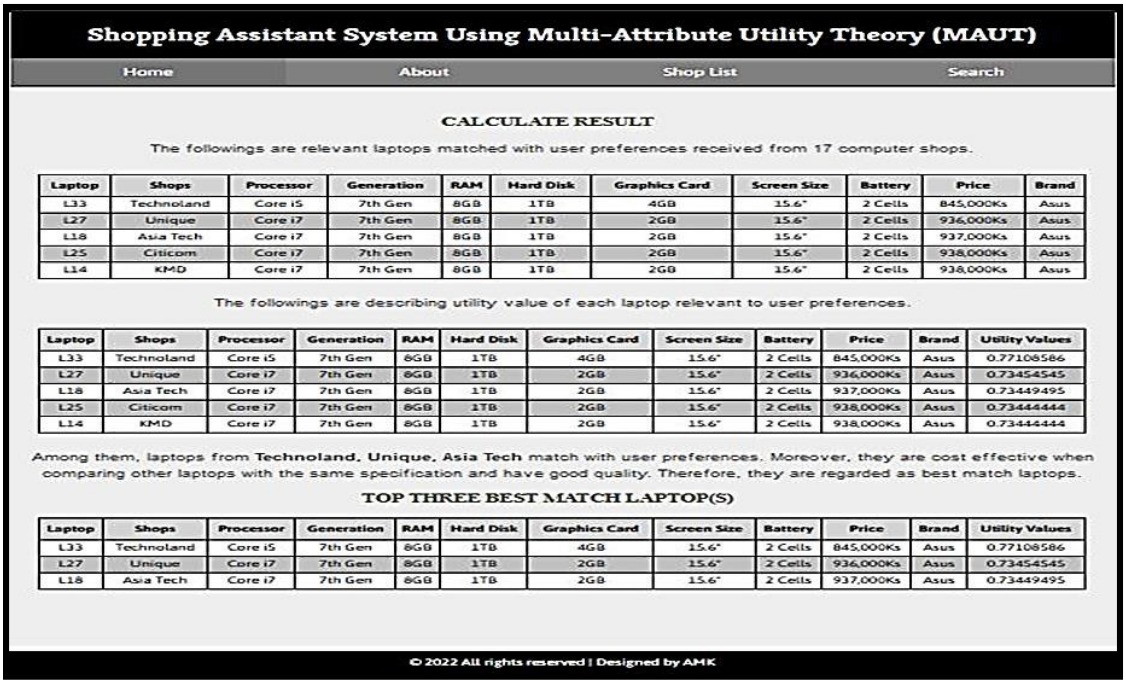


Figure 4.18 Result Data (by choosing Graphics Card as 1st Priority)

Figure 4.18 is the result data list of relevant products and best match product(s) that Graphics Card is chosen as first priority and the remaining attributes such as Generation, RAM etc. are chosen by their desired priority.

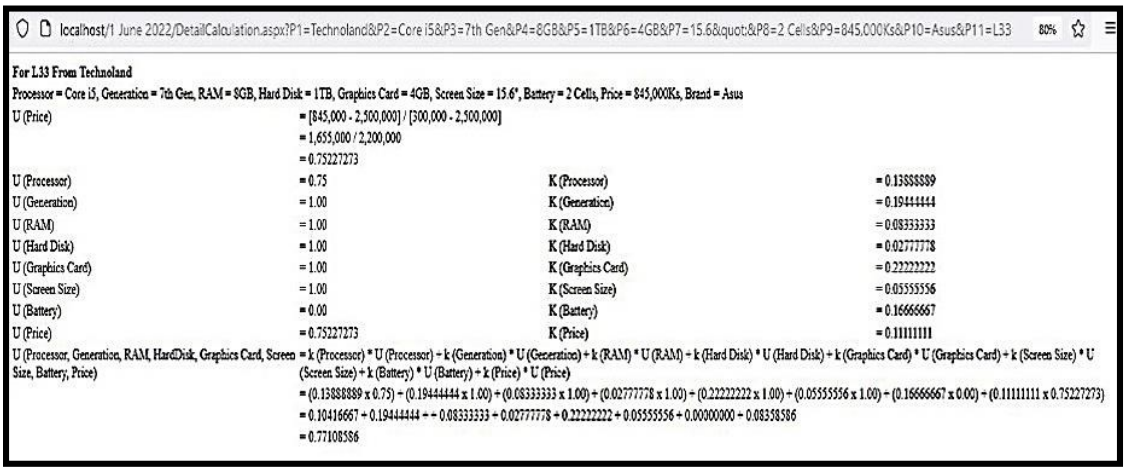


Figure 4.19 Calculation of Utility Value for 1st Best Match Laptop (by choosing Graphics Card as 1st Priority)

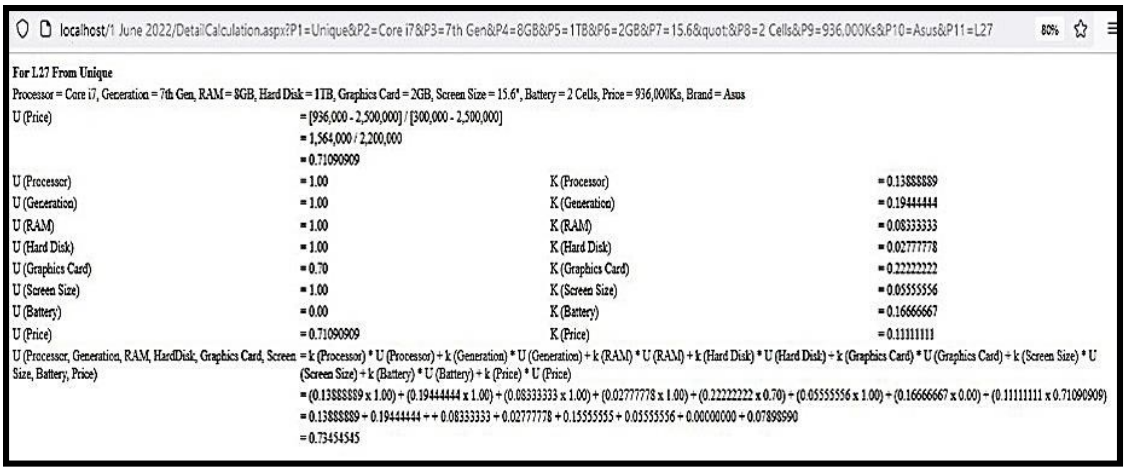
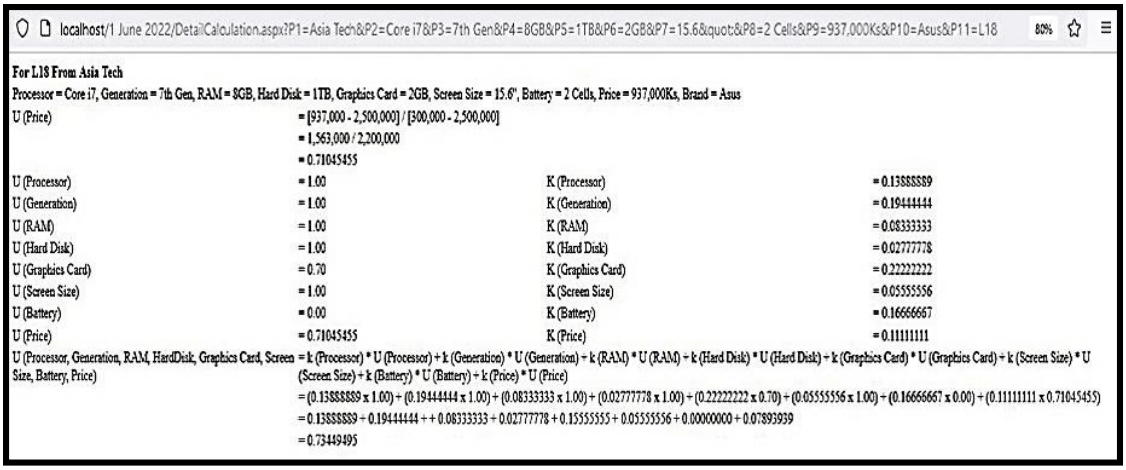


Figure 4.20 Calculation of Utility Value for 2nd Best Match Laptop (by choosing Graphics Card as 1st Priority)



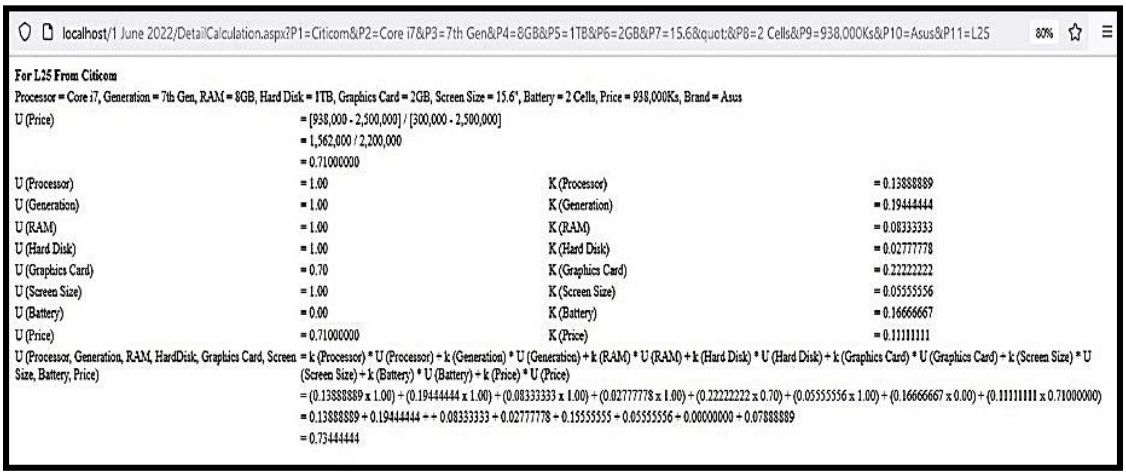
localhost/1 June 2022/DetailCalculation.aspx?P1=Asia Tech&P2=Core i7&P3=7th Gen&P4=8GB&P5=1TB&P6=2GB&P7=15.6"&P8=2 Cells&P9=937,000Ks&P10=Asus&P11=L18 80%

For L18 From Asia Tech

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6", Battery = 2 Cells, Price = 937,000Ks, Brand = Asus

U (Price)	= [937,000 - 2,500,000] / [300,000 - 2,500,000] = 1,563,000 / 2,200,000 = 0.71045455		
U (Processor)	= 1.00	K (Processor)	= 0.13888889
U (Generation)	= 1.00	K (Generation)	= 0.19444444
U (RAM)	= 1.00	K (RAM)	= 0.08333333
U (Hard Disk)	= 1.00	K (Hard Disk)	= 0.02777778
U (Graphics Card)	= 0.70	K (Graphics Card)	= 0.22222222
U (Screen Size)	= 1.00	K (Screen Size)	= 0.05555556
U (Battery)	= 0.00	K (Battery)	= 0.16666667
U (Price)	= 0.71045455	K (Price)	= 0.11111111
U (Processor, Generation, RAM, HardDisk, Graphics Card, Screen Size, Battery, Price)	= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price) = (0.13888889 x 1.00) + (0.19444444 x 1.00) + (0.08333333 x 1.00) + (0.02777778 x 1.00) + (0.22222222 x 0.70) + (0.05555556 x 1.00) + (0.16666667 x 0.00) + (0.11111111 x 0.71045455) = 0.13888889 + 0.19444444 + + 0.08333333 + 0.02777778 + 0.15555555 + 0.05555556 + 0.00000000 + 0.07893939 = 0.73449495		

Figure 4.21 Calculation of Utility Value for 3rd Best Match Laptop (by choosing Graphics Card as 1st Priority)



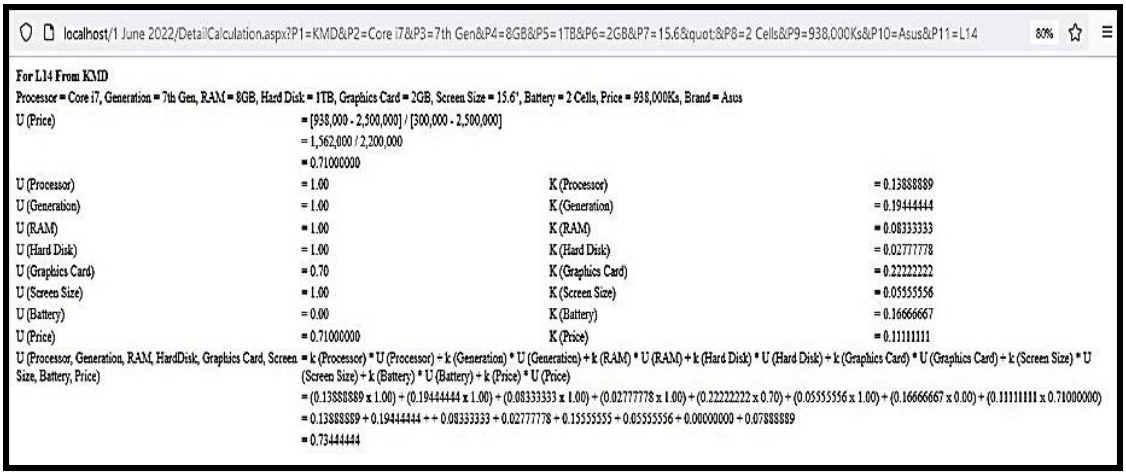
localhost/1 June 2022/DetailCalculation.aspx?P1=Citicom&P2=Core i7&P3=7th Gen&P4=8GB&P5=1TB&P6=2GB&P7=15.6"&P8=2 Cells&P9=938,000Ks&P10=Asus&P11=L25 80%

For L25 From Citicom

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6", Battery = 2 Cells, Price = 938,000Ks, Brand = Asus

U (Price)	= [938,000 - 2,500,000] / [300,000 - 2,500,000] = 1,562,000 / 2,200,000 = 0.71000000		
U (Processor)	= 1.00	K (Processor)	= 0.13888889
U (Generation)	= 1.00	K (Generation)	= 0.19444444
U (RAM)	= 1.00	K (RAM)	= 0.08333333
U (Hard Disk)	= 1.00	K (Hard Disk)	= 0.02777778
U (Graphics Card)	= 0.70	K (Graphics Card)	= 0.22222222
U (Screen Size)	= 1.00	K (Screen Size)	= 0.05555556
U (Battery)	= 0.00	K (Battery)	= 0.16666667
U (Price)	= 0.71000000	K (Price)	= 0.11111111
U (Processor, Generation, RAM, HardDisk, Graphics Card, Screen Size, Battery, Price)	= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price) = (0.13888889 x 1.00) + (0.19444444 x 1.00) + (0.08333333 x 1.00) + (0.02777778 x 1.00) + (0.22222222 x 0.70) + (0.05555556 x 1.00) + (0.16666667 x 0.00) + (0.11111111 x 0.71000000) = 0.13888889 + 0.19444444 + + 0.08333333 + 0.02777778 + 0.15555555 + 0.05555556 + 0.00000000 + 0.07888889 = 0.73444444		

Figure 4.22 Calculation of Utility Value for 4th Best Match Laptop (by choosing Graphics Card as 1st Priority)



localhost/1 June 2022/DetailCalculation.aspx?P1=KMD&P2=Core i7&P3=7th Gen&P4=8GB&P5=1TB&P6=2GB&P7=15.6"&P8=2 Cells&P9=938,000Ks&P10=Asus&P11=L14 80%

For L14 From KMD

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6", Battery = 2 Cells, Price = 938,000Ks, Brand = Asus

U (Price)	= [938,000 - 2,500,000] / [300,000 - 2,500,000] = 1,562,000 / 2,200,000 = 0.71000000		
U (Processor)	= 1.00	K (Processor)	= 0.13888889
U (Generation)	= 1.00	K (Generation)	= 0.19444444
U (RAM)	= 1.00	K (RAM)	= 0.08333333
U (Hard Disk)	= 1.00	K (Hard Disk)	= 0.02777778
U (Graphics Card)	= 0.70	K (Graphics Card)	= 0.22222222
U (Screen Size)	= 1.00	K (Screen Size)	= 0.05555556
U (Battery)	= 0.00	K (Battery)	= 0.16666667
U (Price)	= 0.71000000	K (Price)	= 0.11111111
U (Processor, Generation, RAM, HardDisk, Graphics Card, Screen Size, Battery, Price)	= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price) = (0.13888889 x 1.00) + (0.19444444 x 1.00) + (0.08333333 x 1.00) + (0.02777778 x 1.00) + (0.22222222 x 0.70) + (0.05555556 x 1.00) + (0.16666667 x 0.00) + (0.11111111 x 0.71000000) = 0.13888889 + 0.19444444 + + 0.08333333 + 0.02777778 + 0.15555555 + 0.05555556 + 0.00000000 + 0.07888889 = 0.73444444		

Figure 4.23 Calculation of Utility Value for 5th Best Match Laptop (by choosing Graphics Card as 1st Priority)

Figure (4.19), Figure (4.20), Figure (4.21), Figure (4.22) and Figure (4.23) present detailed calculation of each laptop received from each computer shop that Graphics Card is chosen as first priority and the remaining attributes such as Generation, RAM etc. are chosen by their desired priority.

4.3 Experimental Setting and Results

In Multi-Attribute Utility Theory (MAUT), weight values and utility values of the attributes are needed to define.

4.3.1 Defining Weight Values of the Attributes

Rank Sum Weight Method is used to define the weight value of each attribute.

According to Rank Sum Weight Method,

$$k_i = \frac{2(n + 1 - r_i)}{n(n + 1)} \quad 4.1$$

Where,

k_i = Weight of each attribute

r_i = Rank of each attribute

n = Number of the attributes = 8

The detailed information of the attributes and their types are shown in Table 4.1.

Table 4.1: Defining Attributes and Attribute Types

Attributes	Attribute Types
Processor	Core i7, Core i5, Core i3, Pentium, Celeron
Generation	7th Gen, 6th Gen, Other
RAM	8GB, 4GB, 2GB
Hard Disk	1TB, 500GB
Graphics Card	4GB, 2GB, 1GB, Other
Screen Size	15.6”, 14”, 13.3”, 11.6”
Battery	6 Cells, 4 Cells, 3 Cells, 2 Cells
Price	Numeric Price Value
Brand	Asus, Acer, Dell, Hp, Lenovo, Msi

4.3.2 Defining Utility Values of Each Attribute

The utility values of each attribute are needed to define. Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size and Battery are qualitative attributes. So, the utility value of such each qualitative attribute is defined between 0 and 1. The worst score on each attribute is defined as a utility value of 0, the best score is defined as a utility value of 1 and the remaining scores are defined according to their quality. The predefined utility values of processor used in this system are described in Table 4.2, the utility values of generation are described in Table 4.3, the utility values of RAM are shown in Table 4.4 and so forth. Finally the predefined utility values of Battery are also shown in Table 4.8.

Table 4.2: Defining Utility Values of Processor

Processor	
Attribute Types	**Utility Values**
Core i7	1
Core i5	0.75
Core i3	0.50
Pentium	0.25
Celeron	0

Table 4.3: Defining Utility Values of Generation

Generation	
Attribute Types	**Utility Values**
7th Gen	1
6th Gen	0.5
Other	0

Table 4.4: Defining Utility Values of RAM

RAM	
Attribute Types	**Utility Values**
8GB	1
4GB	0.5
2GB	0

Table 4.5: Defining Utility Values of Hard Disk

Hard Disk	
Attribute Types	**Utility Values**
1TB	1
500GB	0

Table 4.6: Defining Utility Values of Graphics Card

Graphics Card	
Attribute Types	**Utility Values**
4GB	1
2GB	0.70
1GB	0.35
Other	0

Table 4.7: Defining Utility Values of Screen Size

Screen Size	
Attribute Types	**Utility Values**
15.6”	1
14”	0.70
13.3”	0.35
11.6”	0

Table 4.8: Defining Utility Values of Battery

Battery	
Attribute Types	**Utility Values**
6 Cells	1
4 Cells	0.70
3 Cells	0.35
2 Cells	0

4.3.3 Defining Utility Values of Price

The utility values of Price are also needed to define in this system. Since price is a quantitative attribute, the utility value of price can be computed as follow:

$$\mathrm{U(Price)} = \frac{\mathrm{x - Worst}}{\mathrm{Best - Worst}} \qquad 4.2$$

Where,

x = Price defined in each shop

Worst = Maximum price defined in the system,

Best = Minimum price defined in the system

In this system, the maximum price and minimum price are fixed such that the value of Worst as 2,500,000Ks and Best as 300,000Ks. Moreover, the price must be selected in this system because it has a significant effect on the buying behavior of consumers because the higher a product is priced, the fewer units are sold. Additionally, the price of a good is also determined by the point at which supply and demand are equal to each other. Normally, the demand dictates the price. For (purely) inelastic demand, the price is entirely set by demand and price is the dependent variable.

Suppose that user wants the laptop with the following attributes based on the following user preferences:

Processor = Core i7, Core i5, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 4GB, 2GB, Screen Size = 15.6", Battery = 2 Cells, Brand = Asus and Price = 500,000Ks & Above.

There are five relevant laptops that matched with user preferences received from seventeen computer shops and the results sorted by ascending order of price are shown in Table 4.9.

Table 4.9: Relevant Laptops with User Preferences

Laptop	Shops	Processor	Generation	RAM	Hard Disk	Graphics Card	Screen Size	Battery	Price (Ks)	Brand
L33	Technoland	Core i5	7th Gen	8GB	1TB	4GB	15.6"	2 Cells	845,000Ks	Asus
L27	Unique	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	936,000Ks	Asus
L18	Asia Tech	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	937,000Ks	Asus
L25	Citicom	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	938,000Ks	Asus
L14	KMD	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	938,000Ks	Asus

The followings are choosing priority of the attributes for the users who choose Processor as first priority and the remaining attributes such as Generation, RAM etc. as their desired priority.

Choosing Priority of the Attributes

If Priority of Processor => 1, Rank of Processor (or) $r_{Processor}$ => 1

If Priority of Generation => 3, Rank of Generation (or) $r_{Generation}$ => 3

If Priority of RAM => 5, Rank of RAM (or) r_{RAM} => 5

If Priority of Hard Disk => 7, Rank of Hard Disk (or) $r_{Hard\ Disk}$ => 7

If Priority of Graphics Card => 4, Rank of Graphics Card (or) $r_{Graphics}$ => 4

If Priority of Screen Size => 2, Rank of Screen Size (or) $r_{Screen\ Size}$ => 2

If Priority of Battery => 8, Rank of Battery (or) $r_{Battery}$ => 8

If Priority of Price => 6, Rank of Price (or) r_{Price} => 6

The followings are calculating weight values of the attributes for the users who choose Processor as first priority and the remaining attributes such as Generation, RAM etc. as their desired priority.

Calculating Weight Values of the Attributes

Weight of Processor = k (Processor) = 2 (8 + 1 – 1) / 8 (8 + 1) = 0.22222222

Weight of Generation = k (Generation) = 2 (8 + 1 – 3) / 8 (8 + 1) = 0.16666667

Weight of RAM = k (RAM) = 2 (8 + 1 – 5) / 8 (8 + 1) = 0.11111111

Weight of Hard Disk = k (Hard Disk) = 2 (8 + 1 – 7) / 8 (8 + 1) = 0.05555556

Weight of Graphics Card = k (Graphics Card) = 2 (8 + 1 – 4) / 8 (8 + 1)

= 0.13888889

Weight of Screen Size = k (Screen Size) = 2 (8 + 1 – 2) / 8 (8 + 1) = 0.19444444

Weight of Battery = k (Battery) = 2 (8 + 1 – 8) / 8 (8 + 1) = 0.02777778

Weight of Price = k (Price) = 2 (8 + 1 – 6) / 8 (8 + 1) = 0.08333333

The followings are detailed calculation of each laptop received from each shop for the users who choose Processor as first priority and the remaining attributes such as Generation, RAM etc. as their desired priority.

For L33 From Technoland,

Processor = Core i5, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 4GB, Screen Size = 15.6", Battery = 2 Cells, Price = 845,000Ks, Brand = Asus

U(Price)

= [845,000 – 2,500,000] / [300,000 – 2,500,000] = 1,655,000 / 2,200,000

= 0.75227273

U(Processor)	= 0.75	k(Processor)	= 0.22222222
U(Generation)	= 1.00	k(Generation)	= 0.16666667
U(RAM)	= 1.00	k(RAM)	= 0.11111111
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.05555556
U(Graphics Card)	= 1.00	k(Graphics Card)	= 0.13888889
U(Screen Size)	= 1.00	k(Screen Size)	= 0.19444444
U(Battery)	= 0.00	k(Battery)	= 0.02777778
U(Price)	= 0.75227273	k(Price)	= 0.08333333

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.22222222 * 0.75) + (0.16666667 * 1.00) + (0.11111111 * 1.00) + (0.05555556 * 1.00) + (0.13888889 * 1.00) + (0.19444444 * 1.00) + (0.02777778 * 0.00) + (0.08333333 * 0.75227273)

= 0.16666667 + 0.16666667 + 0.11111111 + 0.05555556 + 0.13888889 + 0.19444444 + 0.06268939

= 0.89602273

The overall utility value of laptop number - L33 received from "Technoland" computer shop is 0.89602273.

For L27 From Unique,

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6", Battery = 2 Cells, Price = 936,000Ks, Brand = Asus

U(Price)

= [936,000 – 2,500,000] / [300,000 – 2,500,000] = 1,564,000 / 2,200,000

= 0.71090909

U(Processor)	= 1.00	k(Processor)	= 0.22222222
U(Generation)	= 1.00	k(Generation)	= 0.16666667
U(RAM)	= 1.00	k(RAM)	= 0.11111111
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.05555556
U(Graphics Card)	= 0.70	k(Graphics Card)	= 0.13888889
U(Screen Size)	= 1.00	k(Screen Size)	= 0.19444444
U(Battery)	= 0.00	k(Battery)	= 0.02777778
U(Price)	= 0.71090909	k(Price)	= 0.08333333

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.22222222 * 1.00) + (0.16666667 * 1.00) + (0.11111111 * 1.00) + (0.05555556 * 1.00) + (0.13888889 * 0.70) + (0.19444444 * 1.00) + (0.02777778 * 0.00) + (0.08333333 * 0.71090909)

= 0.22222222 + 0.16666667 + 0.11111111 + 0.05555556 + 0.09722222 + 0.19444444 + 0.05924242

= 0.90646464

The overall utility value of laptop number - L27 received from "Unique" computer shop is 0.90646464.

For L18 From Asia Tech,

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6", Battery = 2 Cells, Price = 937,000Ks, Brand = Asus.

U(Price)

= [937,000 – 2,500,000] / [300,000 – 2,500,000] = 1,563,000 / 2,200,000

= 0.71045455

U(Processor)	= 1.00	k(Processor)	= 0.22222222
U(Generation)	= 1.00	k(Generation)	= 0.16666667
U(RAM)	= 1.00	k(RAM)	= 0.11111111
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.05555556
U(Graphics Card)	= 0.70	k(Graphics Card)	= 0.13888889
U(Screen Size)	= 1.00	k(Screen Size)	= 0.19444444
U(Battery)	= 0.00	k(Battery)	= 0.02777778
U(Price)	= 0.71045455	k(Price)	= 0.08333333

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.22222222 * 1.00) + (0.16666667 * 1.00) + (0.11111111 * 1.00) + (0.05555556 * 1.00) + (0.13888889 * 0.70) + (0.19444444 * 1.00) + (0.02777778 * 0.00) + (0.08333333 * 0.71045455)

= 0.22222222 + 0.16666667 + 0.11111111 + 0.05555556 + 0.09722222 + 0.19444444 + 0.05920454

= 0.90642677

The overall utility value of laptop number - L18 received from "Asia Tech" computer shop is 0.90642677.

For L25 From Citicom,

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6”, Battery = 2 Cells, Price = 938,000Ks, Brand = Asus.

U(Price)

= [938,000 – 2,500,000] / [300,000 – 2,500,000] = 1,562,000 / 2,200,000 = 0.71

U(Processor)	= 1.00	k(Processor)	= 0.22222222
U(Generation)	= 1.00	k(Generation)	= 0.16666667
U(RAM)	= 1.00	k(RAM)	= 0.11111111
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.05555556
U(Graphics Card)	= 0.70	k(Graphics Card)	= 0.13888889
U(Screen Size)	= 1.00	k(Screen Size)	= 0.19444444
U(Battery)	= 0.00	k(Battery)	= 0.02777778
U(Price)	= 0.71	k(Price)	= 0.08333333

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.22222222 * 1.00) + (0.16666667 * 1.00) + (0.11111111 * 1.00) + (0.05555556 * 1.00) + (0.13888889 * 0.70) + (0.19444444 * 1.00) + (0.02777778 * 0.00) + (0.08333333 * 0.71)

= 0.22222222 + 0.16666667 + 0.11111111 + 0.05555556 + 0.09722222 + 0.19444444 + 0.05916666

= 0.90638889

The overall utility value of laptop number - L25 received from "Citicom" computer shop is 0.90638889.

For L14 From KMD,

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6”, Battery = 2 Cells, Price = 938,000Ks, Brand = Asus.

U(Price)

= [938,000 – 2,500,000] / [300,000 – 2,500,000] = 1,562,000 / 2,200,000 = 0.71

U(Processor)	= 1.00	k(Processor)	= 0.22222222
U(Generation)	= 1.00	k(Generation)	= 0.16666667
U(RAM)	= 1.00	k(RAM)	= 0.11111111
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.05555556
U(Graphics Card)	= 0.70	k(Graphics Card)	= 0.13888889
U(Screen Size)	= 1.00	k(Screen Size)	= 0.19444444
U(Battery)	= 0.00	k(Battery)	= 0.02777778

U(Price) = 0.71 k(Price) = 0.08333333

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.22222222 * 1.00) + (0.16666667 * 1.00) + (0.11111111 * 1.00) + (0.05555556 * 1.00) + (0.13888889 * 0.70) + (0.19444444 * 1.00) + (0.02777778 * 0.00) + (0.08333333 * 0.71)

= 0.22222222 + 0.16666667 + 0.11111111 + 0.05555556 + 0.09722222 + 0.19444444 + 0.05916666

= 0.90638889

The overall utility value of laptop number - L14 received from "KMD" computer shop is 0.90638889.

By Calculating MAUT, the utility values of each laptop relevant to the user preferences are sorted by descending order and described in Table 4.10.

Table 4.10: Relevant Laptops with Utility Values (Processor as 1st Priority)

Laptop	Shops	Processor	Generation	RAM	Hard Disk	Graphics Card	Screen Size	Battery	Price(Ks)	Brand	Utility Values
L27	Unique	Core i7	7th Gen	8GB	1TB	2GB	15.6”	2 Cells	936,000Ks	Asus	0.90646464
L18	Asia Tech	Core i7	7th Gen	8GB	1TB	2GB	15.6”	2 Cells	937,000Ks	Asus	0.90642677
L25	Citicom	Core i7	7th Gen	8GB	1TB	2GB	15.6”	2 Cells	938,000Ks	Asus	0.90638889
L14	KMD	Core i7	7th Gen	8GB	1TB	2GB	15.6”	2 Cells	938,000Ks	Asus	0.90638889
L33	Technoland	Core i5	7th Gen	8GB	1TB	4GB	15.6”	2 Cells	845,000Ks	Asus	0.89602273

In the proposed system, the top three best match laptops relevant to the user preferences are displayed from seventeen computer shops. Since there can be many best match laptops relevant to the user preferences with the same specification and same price, the top three best match laptops are displayed in this system. These best match laptops are shown in Table 4.11. According to the results in this table, the first best match laptop is from "Unique", the second is from "Asia Tech" and the third best match relevant laptop is from "Cititcom" because because the higher the utility value, the better the best match in MAUT.

Table 4.11: Top Three Best Match Laptop(s) (Processor as 1st Priority)

Laptop	Shops	Processor	Generation	RAM	Hard Disk	Graphics Card	Screen Size	Battery	Price(Ks)	Brand	Utility Values
L27	Unique	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	936,000Ks	Asus	0.90646464
L18	Asia Tech	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	937,000Ks	Asus	0.90642677
L25	Citicom	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	938,000Ks	Asus	0.90638889

The followings are choosing priority of the attributes for the users who choose Graphics Card as first priority and the remaining attributes such as Generation, RAM etc. as their desired priority.

Choosing Priority of the Attributes

If Priority of Processor => 4, Rank of Processor (or) $r_{Processor}$ => 4

If Priority of Generation => 2, Rank of Generation (or) $r_{Generation}$ => 2

If Priority of RAM => 6, Rank of RAM (or) r_{RAM} => 6

If Priority of Hard Disk => 8, Rank of Hard Disk (or) $r_{Hard\ Disk}$ => 8

If Priority of Graphics Card => 1, Rank of Graphics Card (or) $r_{Graphics}$ => 1

If Priority of Screen Size => 7, Rank of Screen Size (or) $r_{Screen\ Size}$ => 7

If Priority of Battery => 3, Rank of Battery (or) $r_{Battery}$ => 3

If Priority of Price => 5, Rank of Price (or) r_{Price} => 5

The followings are calculating weight values of the attributes for the users who choose Graphics Card as first priority and the remaining attributes such as Generation, RAM etc. as their desired priority.

Calculating Weight Values of the Attributes

Weight of Processor = k (Processor) = 2 (8 + 1 – 4) / 8 (8 + 1) = 0.13888889

Weight of Generation = k (Generation) = 2 (8 + 1 – 2) / 8 (8 + 1) = 0.19444444

Weight of RAM = k (RAM) = 2 (8 + 1 – 6) / 8 (8 + 1) = 0.08333333

Weight of Hard Disk = k (Hard Disk) = 2 (8 + 1 – 8) / 8 (8 + 1) = 0.02777778

Weight of Graphics Card = k (Graphics Card) = 2 (8 + 1 – 1) / 8 (8 + 1)

= 0.22222222

Weight of Screen Size = k (Screen Size) = 2 (8 + 1 – 7) / 8 (8 + 1) = 0.05555556

Weight of Battery = k (Battery) = 2 (8 + 1 – 3) / 8 (8 + 1) = 0.16666667

Weight of Price = k (Price) = 2 (8 + 1 – 5) / 8 (8 + 1) = 0.11111111

The followings are detailed calculation of each laptop received from each shop for the users who choose Graphics Card as first priority and the remaining attributes such as Generation, RAM etc. as their desired priority.

For L33 From Technoland,

Processor = Core i5, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 4GB, Screen Size = 15.6”, Battery = 2 Cells, Price = 845,000Ks, Brand = Asus

U(Price)

= [845,000 – 2,500,000] / [300,000 – 2,500,000] = 1,655,000 / 2,200,000

= 0.75227273

U(Processor)	= 0.75	k(Processor)	= 0.13888889
U(Generation)	= 1.00	k(Generation)	= 0.19444444

U(RAM)	= 1.00	k(RAM)	= 0.08333333
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.02777778
U(Graphics Card)	= 1.00	k(Graphics Card)	= 0.22222222
U(Screen Size)	= 1.00	k(Screen Size)	= 0.05555556
U(Battery)	= 0.00	k(Battery)	= 0.16666667
U(Price)	= 0.75227273	k(Price)	= 0.11111111

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.13888889 * 0.75) + (0.19444444 * 1.00) + (0.08333333 * 1.00) + (0.02777778 * 1.00) + (0.22222222 * 1.00) + (0.05555556 * 1.00) + (0.16666667 * 0.00) + (0.11111111 * 0.75227273)

= 0.10416667 + 0.19444444 + 0.08333333 + 0.02777778 + 0.22222222 + 0.05555556 + 0.08358586

= 0.77108586

The overall utility value of laptop number - L33 received from "Technoland" computer shop is 0.77108586.

For L27 From Unique,

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6”, Battery = 2 Cells, Price = 936,000Ks, Brand = Asus.

U(Price)

= [936,000 – 2,500,000] / [300,000 – 2,500,000] = 1,564,000 / 2,200,000

= 0.71090909

U(Processor)	= 1.00	k(Processor)	= 0.13888889
U(Generation)	= 1.00	k(Generation)	= 0.19444444
U(RAM)	= 1.00	k(RAM)	= 0.08333333
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.02777778
U(Graphics Card)	= 0.70	k(Graphics Card)	= 0.22222222
U(Screen Size)	= 1.00	k(Screen Size)	= 0.05555556
U(Battery)	= 0.00	k(Battery)	= 0.16666667
U(Price)	= 0.71090909	k(Price)	= 0.11111111

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.13888889 * 1.00) + (0.19444444 * 1.00) + (0.08333333 * 1.00) + (0.02777778 * 1.00) + (0.22222222 * 0.70) + (0.05555556 * 1.00) + (0.16666667 * 0.00) + (0.11111111 * 0.71090909)

= 0.13888889 + 0.19444444 + 0.08333333 + 0.02777778 + 0.15555555 + 0.05555556 + 0.07898990

= 0.73454545

The overall utility value of laptop number - L27 received from "Unique" computer shop is 0. 73454545.

For L18 From Asia Tech,

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6”, Battery = 2 Cells, Price = 937,000Ks, Brand = Asus.

U(Price)

= [937,000 – 2,500,000] / [300,000 – 2,500,000] = 1,563,000 / 2,200,000

= 0.71045455

U(Processor)	= 1.00	k(Processor)	= 0.13888889
U(Generation)	= 1.00	k(Generation)	= 0.19444444
U(RAM)	= 1.00	k(RAM)	= 0.08333333
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.02777778
U(Graphics Card)	= 0.70	k(Graphics Card)	= 0.22222222
U(Screen Size)	= 1.00	k(Screen Size)	= 0.05555556
U(Battery)	= 0.00	k(Battery)	= 0.16666667
U(Price)	= 0.71045455	k(Price)	= 0.11111111

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.13888889 * 1.00) + (0.19444444 * 1.00) + (0.08333333 * 1.00) + (0.02777778 * 1.00) + (0.22222222 * 0.70) + (0.05555556 * 1.00) + (0.16666667 * 0.00) + (0.11111111 * 0.71045455)

= 0.13888889 + 0.19444444 + 0.08333333 + 0.02777778 + 0.15555555 + 0.05555556 + 0.07893939

= 0.73449494

The overall utility value of laptop number - L18 received from "Asia Tech" computer shop is 0.73449494.

For L25 From Citicom,

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6", Battery = 2 Cells, Price = 938,000Ks, Brand = Asus.

U(Price)

= [938,000 – 2,500,000] / [300,000 – 2,500,000] = 1,562,000 / 2,200,000 = 0.71

U(Processor)	= 1.00	k(Processor)	= 0.13888889
U(Generation)	= 1.00	k(Generation)	= 0.19444444
U(RAM)	= 1.00	k(RAM)	= 0.08333333
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.02777778
U(Graphics Card)	= 0.70	k(Graphics Card)	= 0.22222222
U(Screen Size)	= 1.00	k(Screen Size)	= 0.05555556
U(Battery)	= 0.00	k(Battery)	= 0.16666667
U(Price)	= 0.71	k(Price)	= 0.11111111

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.13888889 * 1.00) + (0.19444444 * 1.00) + (0.08333333 * 1.00) + (0.02777778 * 1.00) + (0.22222222 * 0.70) + (0.05555556 * 1.00) + (0.16666667 * 0.00) + (0.11111111 * 0.71)

= 0.13888889 + 0.19444444 + 0.08333333 + 0.02777778 + 0.15555555 + 0.05555556 + 0.07888889

= 0.73444444

The overall utility value of laptop number - L25 received from "Citicom" computer shop is 0.73444444.

For L14 From KMD,

Processor = Core i7, Generation = 7th Gen, RAM = 8GB, Hard Disk = 1TB, Graphics Card = 2GB, Screen Size = 15.6”, Battery = 2 Cells, Price = 938,000Ks, Brand = Asus.

U(Price)

= [938,000 – 2,500,000] / [300,000 – 2,500,000] = 1,562,000 / 2,200,000 = 0.71

U(Processor)	= 1.00	k(Processor)	= 0.13888889
U(Generation)	= 1.00	k(Generation)	= 0.19444444
U(RAM)	= 1.00	k(RAM)	= 0.08333333
U(Hard Disk)	= 1.00	k(Hard Disk)	= 0.02777778
U(Graphics Card)	= 0.70	k(Graphics Card)	= 0.22222222
U(Screen Size)	= 1.00	k(Screen Size)	= 0.05555556
U(Battery)	= 0.00	k(Battery)	= 0.16666667
U(Price)	= 0.71	k(Price)	= 0.11111111

U (Processor, Generation, RAM, Hard Disk, Graphics Card, Screen Size, Battery, Price)

= k (Processor) * U (Processor) + k (Generation) * U (Generation) + k (RAM) * U (RAM) + k (Hard Disk) * U (Hard Disk) + k (Graphics Card) * U (Graphics Card) + k (Screen Size) * U (Screen Size) + k (Battery) * U (Battery) + k (Price) * U (Price)

= (0.13888889 * 1.00) + (0.19444444 * 1.00) + (0.08333333 * 1.00) + (0.02777778 * 1.00) + (0.22222222 * 0.70) + (0.05555556 * 1.00) + (0.16666667 * 0.00) + (0.11111111 * 0.71)

= 0.13888889 + 0.19444444 + 0.08333333 + 0.02777778 + 0.15555555 + 0.05555556 + 0.07888889

= 0.73444444

The overall utility value of laptop number - L14 received from "KMD" computer shop is 0.73444444.

By Calculating MAUT, the utility values of each laptop relevant to the user preferences are sorted by descending order and described in Table 4.12.

Table 4.12: Relevant Laptops with Utility Values (Graphics Card as 1st Priority)

Laptop	Shops	Processor	Generation	RAM	Hard Disk	Graphics Card	Screen Size	Battery	Price(Ks)	Brand	Utility Values
L33	Technoland	Core i5	7th Gen	8GB	1TB	4GB	15.6"	2 Cells	845,000Ks	Asus	0.77108586
L27	Unique	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	936,000Ks	Asus	0.73454545
L18	Asia Tech	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	937,000Ks	Asus	0.73449494
L25	Citicom	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	938,000Ks	Asus	0.73444444
L14	KMD	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	938,000Ks	Asus	0.73444444

Since there can be many best match laptops relevant to the user preferences with the same specification and same price, the top three best match laptops are displayed in this system. These best match laptops are shown in Table 4.13. According to the results in this table, the first best match laptop is from "Technoland", the second is from "Unique" and the third best match relevant laptop is from "Asia Tech" because the higher the utility value, the better the best match in MAUT.

Table 4.13: Top Three Best Match Laptop(s) (Graphics Card as 1st Priority)

Laptop	Shops	Processor	Generation	RAM	Hard Disk	Graphics Card	Screen Size	Battery	Price(Ks)	Brand	Utility Values
L33	Technoland	Core i5	7th Gen	8GB	1TB	4GB	15.6"	2 Cells	845,000Ks	Asus	0.77108586
L27	Unique	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	936,000Ks	Asus	0.73454545
L18	Asia Tech	Core i7	7th Gen	8GB	1TB	2GB	15.6"	2 Cells	937,000Ks	Asus	0.73449494

CHAPTER 5
CONCLUSION

Considering the multiple attributes of the shopping item and its various parameters, the item information can be described in various ways and the approximate cost of these items can be estimated. The proposed system is implemented as a shopping assistant system for buying laptop computers. The additive utility function of MAUT is used to evaluate the best match product(s) based on user preferences. This system can assist human buyers by searching the products according to their preferences within their budget. By using this, they can save time and effort in searching required product information and are able to choose the best match laptop(s) from the most suitable ones.

5.1 Advantages of the System

The implementation of this system is developed as a shopping assistant for laptops. In buying products with multiple attributes and multiple prices, the users might have difficulty in finding the right product they want within their budget. It greatly reduces the browsing time and searching in the multiple online shops. For a human user, it is difficult to find the right item store by store online. Shopping assistant finds the set of the relevant products so the user can be able to select the most suitable product to buy.

5.2 Limitations and Further Extension

The proposed system has some limitations such that users can only choose predefined preferences for providing their desired products. This system can be extended with Natural Language Processing for understanding user query rather than predefined sets of attributes.

AUTHOR'S PUBLICATION

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