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AN ONTOLOGY-BASED KNOWLEDGE REPRESENTATION USING ANALYTIC HIERARCHY PROCESS FOR ENHANCING SELECTION OF PRODUCT PREFERENCES

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ABSTRACT

Product alternatives, which emerges from large number of websites during searching, accounts for some hesitation experienced by customers in selecting satisfying product. As a result, making useful decision with many trade-off considerations becomes a major cause of such problem. Several approaches have been employed for product selection such as, fuzzy logic, Neuro-fuzzy, and weighted least square. However, these could not solve the problem of inconsistency and irrelevant judgement that occur in decision making. In this study, Ontology-based Analytic Hierarchy Process (AHP) was used for enhancing selection of product preferences. The model involved three fundamental components: product gathering, selection and decision making. Ontology Web Language (OWL) was utilized to define ontology in expressing product information gathering in a standard and structured manner for the purpose of interoperability while AHP was employed in making optimal choices. The procedure accepts customers' perspectives as inputs which are classified into criteria and sub-criteria. Owl was created to foster customers' interaction and priority estimation tool for AHP in order to generate the consistency ratio of individual judgements. The model was benchmarked with Geometric Mean (GM), Eigenvector (EV), Normalized Column Sum (NCS) Weighted Least Square (WLS) and Fuzzy Preference Programming (FPP). First and second order total deviations and violation rate were the performance parameters evaluation with AHP. The results showed that the minimum and maximum units of products are 2,452and 3,574, respectively. These implied that the proposed model was consistent, relevant and reflected a non-violation of judgment in selection of product preferences.

Keywords: Analytic Hierarchy Process, Product Selection Preferences, Ontology, Knowledge Representation and E-Commerce.

BACKGROUND

The rapid advancement of business-to-consumer (B2C) e-commerce models bring customers not only the convenience in transaction but also various products and services alternatives for making favourite choices. The increase in alternatives provided by the large number of websites have made selection of satisfying products a hesitating process for customers. Product selection with many trades off considerations is the major cause of such a hesitation. Acquiring products information and getting the right optimal product is therefore a concern. Thus, helping customers with mechanisms to choose the right alternative becomes necessary and critical. To solve the problem, merchants and e-commerce companies will require an intelligent decision-making process (Kabir and Sumi, 2010).

One of the major important issues for most companies is how to increase customer satisfaction by improving quality, price, availability of goods and services, customer service, etc. (Barajas and Agard, 2011). According to Jamali (2007), there is a very strong relationship between quality and the level of customer satisfaction. Customer satisfaction depends on many variables and increases with the degree by which the delivered products meet the customer's preferences. Merchants have to assist customers in selectingspecific products from among those available to satisfy their needs and wants (Kabir and Sumi, 2010; Lamaakchaoui *et al.*, 2015). Several approaches have been employed for product selection, such as, fuzzy logic, Neuro-fuzzy, product development and weighted least square. However, these methods could not solve the problem of inconsistency and irrelevant judgement experience during selection (Kamal and Sa'Ed, 2006; Marini *et al.*, 2016).

This paper presents a new model based on ontology and Analytic Hierarchy Process (AHP) for product preference selection. Web ontology has been recommended for specification conceptualisation of product selection because it allows organisation of concept by category, accessibility as well as figuring out what it means to be in the real world. Ontology enables reuse of domain knowledge from the operational knowledge to provide formal analysis of terms in order to facilitate interoperability among the terms, attributes, relationships, meaning and sequence of interactions involved between various components of products and domain. It promotes efficient data exchange across different platforms (Carbo and Fernandez, 2002; Mabotuwana and Warren, 2009; Matsokis and Kiritsis, 2010; Ruiz-Martínez *et al.*, 2012).

In another perspective, AHP, a multi-criteria decision making technique, is used for multi-criteria assessment of selections of products while shopping online (Wasielewska *et al.*, 2012). AHP was used in selecting among similar large number of products according to the customer's requirement (Khondoker *et al.*, 2010). It is a method that allows selection of one or more decision alternatives among several decision alternatives where choosing of products are done according to certain criteria which are weighed and ranked in order to decide the criteria that best derived customers' need (Hsu *et al.*, 2010; Lamaakchaoui *et al.*, 2015).

The work proposed product selection model in order to enhanced consumer's preferences during purchase decision by conducting ontological aggregation with Analytic Hierarchy Process (AHP). There are three fundamental components, namely, product gathering, selection and decision making. Evaluation were done based on certain criteria selected by customers' during transaction such as product features, this is, specification, brand, colour, price and discount, etc.

RELATED WORK

Recent studies on product preferences selection have realized some improvements in achieving customers' satisfaction. However, the problem of inconsistency in individual still remains at stake. Among those researches includes that of Matsokis and Kiritsis (2010) developed a product data and Knowledge Management Semantic Object Model (KMSOM) for an ontology-based Product Lifecycle Management (PLM), by implementing ontology advantages and features into the model. Moreover, they focused on closed-loop PLM model. Their model facilitated several of the Ontology Web Language and Development (OWL-DL) capabilities, while maintaining previously achieved characteristics approach. However, there is need to increase data integration and complicated rules for expressivity and also to compare the efficiency of ontology with ordinary system.

A hybrid method based on enhanced fuzzy multi-criteria collaborative filtering in collaboration with demographic information and item-based ontological semantic filtering approach for customers' recommendation purposes was proposed by Kermany and Alizadeh (2017). An adaptive neuro-fuzzy inference system was used to discover the relationship between each criterion and the overall rating. A fusion of fuzzy cosine and Jacquard similarities was further adopted to calculate the total similarity between customers with respect to the effect of co-rated item set cardinality on the reliability of similarity measures. Gradient Decent Algorithm was used to ensure a minimum prediction error.

A New Product Development (NPD) was also developed for selecting specific products. AHP was used to define the weights of customer's needs with the description of NPD of a typical impulse buying. The approach focused on evaluating the compatibility of weight vectors among different subsets of respondents and filtered according to their consistency level. AHP best practices suggest that low-consistency respondents should be considered untrustworthy. The work was aimed at analysing a critical way to exclude non-consistent respondents in market analysis (Battistoni *et al.*, 2013). Kamal and Sa'Ed (2006) recognised that product developers made many decisions during the early stages of product development which had a profound impact on the final cost of the product. A concept evaluation and selection methodology capable of capturing the fuzziness and vagueness impeded in concept evaluation was used. It integrated the weighted concept selection matrix with AHP within a fuzzy environment. The criteria were prioritized and assigned fuzzy weights according to their importance with respect to the nature of the product and based on the capabilities of the manufacturing company. However, the great majority of respondents showed an unacceptable value for the consistency index.

Another multi-criteria AHP-based decision technique on product prioritization and selection was also analysed. The process involves evaluating alternative solutions against multiple criteria to select the best options. AHP principles and techniques was applied in decision-making to choose the best product from several options (Christopher and John, 2014). It allowed the use of qualitative as well as quantitative criteria in evaluation. The customer chose the product in the given alternatives through pair wise comparison method. The work recommended that AHP was capable to address prioritization problem to make better decisions.

A recommender systems to assist customers find products and services of interest was also proposed recently. The argument was that having purchased one product, it was likely that the customer may look for complementary products to the bought one. AHP was used to assist customers find the best complementary products. The selection of the best products was done according to certain criteria, which were evaluated and ranked in order to determine the criteria that drives one customer to cross sell. The work recommended that further research should focus on other criteria that drive customers' decision of choosing among different complementary products alternatives (Lamaakchaoui *et al.*, 2015).

Marini *et al.* (2016) proposed Product Development (PD) model that consisted of several activities such as conceptual design stage, which is the most crucial stage in developing a new product. It covered Quality Function Deployment (QFD), Multi Criteria Decision Making (MCDM) including Analytical Network Process (ANP) and Analytical Hierarchy Process (AHP). Tooling medium was used for material selection and design concept. Incorrect design concept and material selection in conceptual stage led to product failure and increase the cost. It was recommended that the conceptual design stage is properly executed, important parameters such as the time and cost can be minimized. The quality of the product also had a tremendous improvement.

THE PROPOSED ONTOLOGY-BASED ANALYTIC HIERARCHY PROCESS FOR PRODUCT PREFERENCES

The proposed ontology-based AHP involves product gathering, selection and decision making. The approach takes into consideration all the elements like price, colour, quality, delivery time, payment method, warrantee, discount and maker needed for effective and reliable product decision making in order to satisfy product selection requirement. Two existing models, namely, Kabir and Sumi (2010) and Christopher and John (2014) were adopted and improved to suite selection criteria for developing ontology and AHP. The improved ontology-based AHP for product preferences' selection is presented in Figure 1.

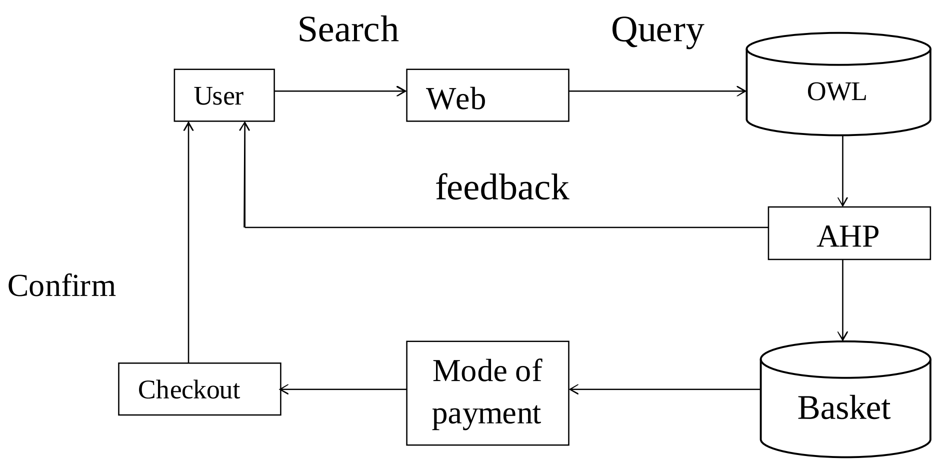


Figure 1: Ontology based-AHP-based Product Selection

In Figure 1, a user searched through the internet in order to select the product of choice from different web sites. During the process of searching, the Web Ontology Language (OWL) was been queried. Data stored in the OWL was expressed in a structured and standard manner for the purpose of interoperability. The system provided customers with an opportunity to interact with the AHP through the use of web browser. The AHP process assisted customers to gather information from merchants and recommend an optimal one according to customer preferences. Feedback was sent back to the customer for acceptance. If not acceptable, the search process begins again until the customer was satisfied with the suggestion. Once the customer gets his choice, transaction continued and the products were added to the e-shopping basket. Payment mode were selected after which all transaction made would be displayed on the checkout for customer to view before finalizing the transaction. In addition, confirmation of purchase were sent to the customer.

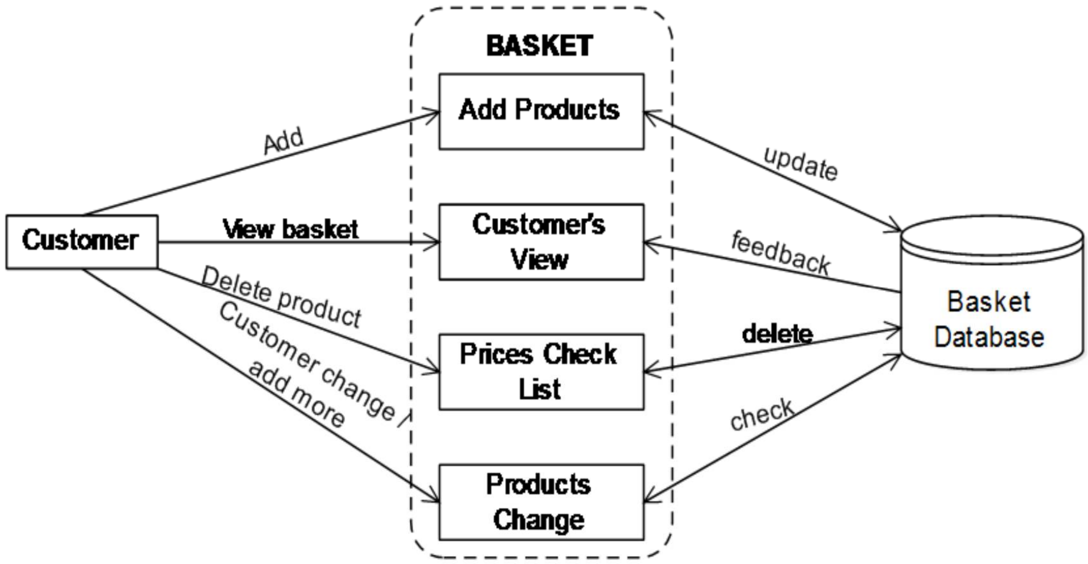


Figure 2: The E-Shopping Basket

Figure 2 presents a description of the ontological e-shopping basket. The e-shopping basket enables customers who intend to purchase specific products from any e-commerce website to select items and add the list of items in accumulations as it emerges. An automatic and dynamic item of products list will be produced for easy purchase.

Selection of Product through Web Ontology Language (OWL)

In this work, an ontology simply embodies some sort of general views with respect to product selection. These views were conceived as a set of concepts such as entities, attributes, processes, definitions and interrelationship, referred to as conceptualisation of ideas. The method used for developing the ontology was Methontology, which enables the construction of ontology at the knowledge level from the scratch. Eleven developmental stages were used in developing the proposed ontology. Table 1 describes the glossary of the product ontology.

Table 1: The Glossary of Terms of Product Ontology

Preferences	Synonyms	Acronyms	Description	Type
Purchase details	Order	--	Goods ordered by customer	Concept
Purchase date	Date	--	Date ordered for goods	Instance
Products	Goods	--	Items purchased by customer	Concept
Specification	Requirement	--	Description or specification of goods	Instance
Price	Sale details	--	Cost of the goods or product	Instance
Rate	--		Price per product	Instance
Quantity	Number of item	--	Quantity of goods to purchase	Instance
Manufacture date	Date	--	Date the product was manufactured	Instance
Basket	Cart	--	Carrying or keep product	Instance
Check out	--	--	Display of product added to basket	Instance
ATM card	Credit card Debit card	--	Type of payment	Instance
Delivery mode	FEDEX DHL	--	Means of delivery	Instance
Acknowledgement	Remark	--	Receipt of payment and supply of goods	Concept
Phone (SMS)	--	--	Receipt of payment and supply of goods can be received through mobile phone	Instance

The first task involves the glossary of terms shown in Table 1. It includes all the relevant terms of the domain such as concepts, instances, attributes that represents concept properties, relations between concepts, their natural language descriptions, and their synonyms and acronyms. The second task is the concept taxonomies, which describe the subclass-of, discount-decomposition, exhaustive-decomposition and partition. The third task involves the conceptualization process of an ad hoc binary relation diagrams used to establish relationships between contents of the same concept taxonomy. Figure 3 presents a fragment of the ad hoc binary relation of the product selection. The relation connect the root concepts, namely, customer, merchant, product and payment mode.

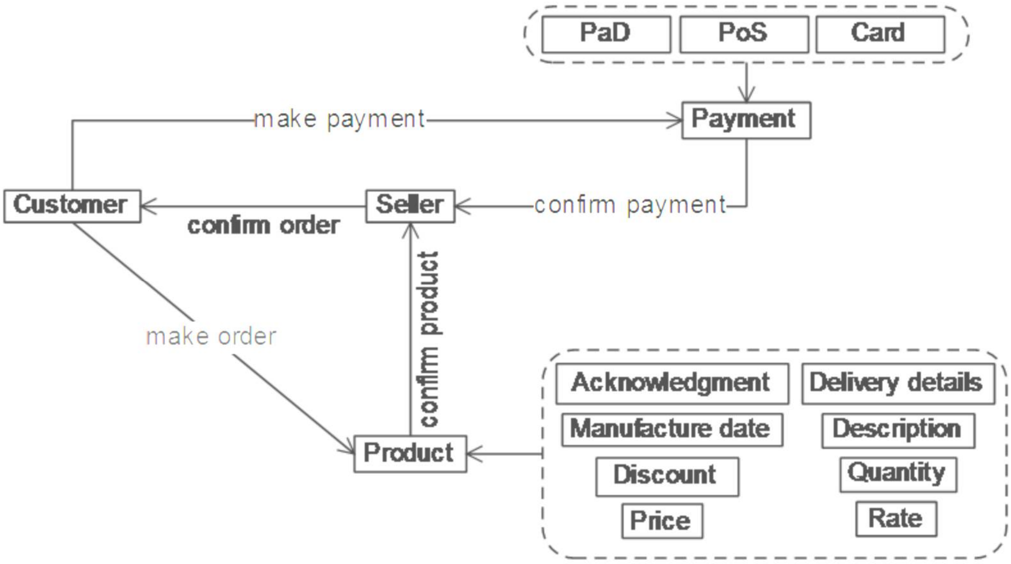


Figure 3: Ad hoc Binary Relation of the Proposed Product Ontology

Task four represents the concept dictionary, which specifies the properties and relations that describes each concept of the taxonomy in a concept dictionary. It defines the attribute of each concept as sub-class, type-of and means-of. Task five represents ad hoc binary. The ad hoc binary describes all the ad hoc binary included in the concept dictionary. The ad hoc of the ontology shows details of processes involved, such as supply of product to customer. Task six is the instance attribute in detail, which describes all the instance attributes already included in the concept dictionary by means of an instance attribute table. Instance attribute are those attributes whose value(s) may be different for each instance of the concept. For each instance attribute, the following field must be specified as: its name, the concept it belongs to, value type, measurement unit, precision and range of values, minimum and maximum cardinality, instance attributes, class attributes and constants used to infer values of the attribute. Task seven is the class attribute in detail and each row of the class attribute contains a detailed description of the class attribute. Class attribute are neither inherited by the subclasses nor by the instances. Task eight consists of constants defined in the glossary of terms. For each constant, the following were specified: name, value type, measurement unit for numerical constants, and the attributes that can be inferred using the constant.

Tasknine establishes the formal axioms identified in the ontology and describe them precisely. For each formal axiom definition, the following information must be specified, name, description, the logical expression that formally describes the axiom using first order logic, the concepts, attribute and ad hoc relations to which the axiom refers, and the variable used. Tasktenare therules which are needed in the ontology. Taskelevenrepresents the instances after creating the conceptual model.

Product Selection with Analytic Hierarchy Process

The data were derived by using a set of pairwise comparisons from individual judgement. These comparisons are used to obtain the weights according to the importance of the criteria, and the relative performance measures of the alternatives pertaining to each individual decision criterion (Triantaphyllou and Mann, 1995).

Four steps are considered to measure the AHP, namely, construction of structural hierarchy, construction of comparative judgments or pair-wise comparison matrices, weight determination through normalization procedure, and synthesis of weight and consistency test (Alam *et al.,* 2012; Cay and Mevlut, 2013). A complex buying decision were decomposed into a structural hierarchy from the goal at the topmost level in the hierarchy to the various criteria and sub-criteria and to the very lowest level in descending order shown in Figure 4.

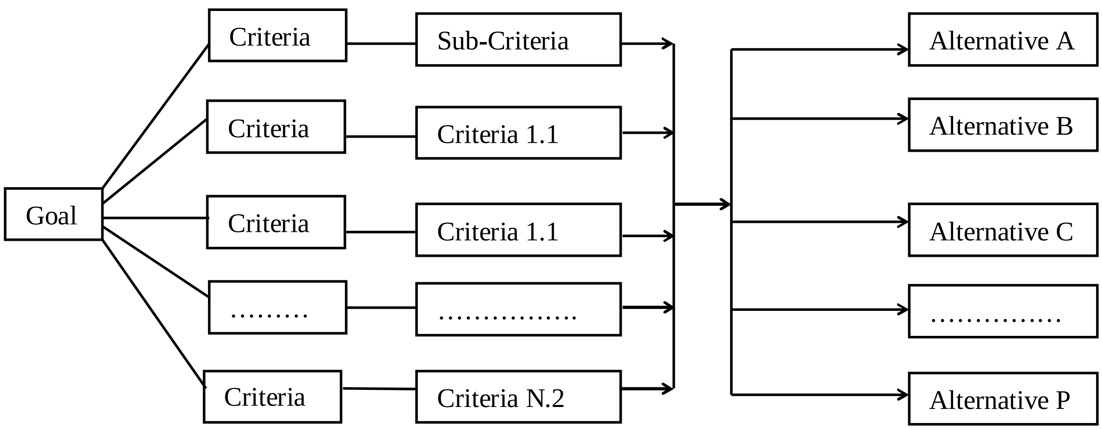


Figure 4: AHP Structure

The alternatives were set at the very last level in the hierarchy as represented in Figure 4. Once the hierarchy was constructed, we determined the priorities of the variables at each level of buying by constructing a set of comparison matrices of all the variables in relation to each other. The pair-wise correlation outlines how a variable X is more essential than variable Z. These consistent inclinations were measured utilizing a pair-wise comparison evaluation scaling of a random index (RI) from point one to nine. The set of alternative matrix b_{ij} is represented in Eq. (1) as

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{13} & \cdots & \cdots & b_{1n} \\ b_{21} & b_{22} & b_{23} & \cdots & \cdots & b_{2n} \\ b_{31} & b_{32} & b_{33} & \cdots & \cdots & b_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ b_{n1} & b_{n2} & b_{n3} & \cdots & \cdots & b_{nn} \end{bmatrix} \quad (1)$$

where $B = b_{ij}, b_{ij} > 0 \; and \frac{1}{b_{ji}} = b_{ij}[b_{ij}], where, i, j = 1,2,3, \ldots, n. \; if, b_{ij} = 1 \; then, i = j,$ and $if, b_{ij} = \frac{1}{b_{ji}} \; then, i \neq j$. If " n " numbers were given for pair-wise comparison, the process in Eq. (1) was analysed to determine the weights of criteria with $B = n \times n$ and n represents the comparison number of variables, " B " represent the alternatives in $b_{11} - b_{1n}$, and others were the pair-wise alternatives. The value of the variables that are related to the diagonal of the matrix is equal to 1, such that $b_{ij} = 1$. The preference was assumed as a reciprocal where $b_{ij} = \frac{1}{b_{ji}}$ for, $i \neq j$. For example, if i^{th} variable is *Y* times more favourable than the j^{th} variable, then $B_{ij} = y$, at this point it was assumed that j^{th} variable(s) is $1/y$, as important between i^{th} variable $b_{ji} = \frac{1}{y}$ and $b_{ji} = \frac{1}{b_{ji}}$. A bi-way random index of 1-9 extreme important 9 to equal 1 of Random index (*RI*) values as appeared in (Saaty, 2008) was used for comparison so as to know the degree of importance of the variables.

We determined the weights of the criteria and that of the alternatives from the pair-wise comparison matrices by dividing each value of the column j by the total value of column j. This resulted in a total value of the columns in the matrix to be 1 to achieve a normalization of the pair-wise comparison (Cay & Mevlut, 2013). This is represented in Eq. (2) as

$$Bw = \begin{bmatrix} \frac{b_{11}}{\sum b_{i1}} & \frac{b_{12}}{\sum b_{i2}} & \frac{b_{13}}{\sum b_{i3}} & \cdots & \cdots & \frac{b_{1n}}{\sum b_{in}} \\ \frac{b_{21}}{\sum b_{i1}} & \frac{b_{22}}{\sum b_{i2}} & \frac{b_{23}}{\sum b_{i3}} & \cdots & \cdots & \frac{b_{2n}}{\sum b_{in}} \\ \frac{b_{31}}{\sum b_{i1}} & \frac{b_{32}}{\sum b_{i2}} & \frac{b_{33}}{\sum b_{i3}} & \cdots & \cdots & \frac{b_{3n}}{\sum b_{in}} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{b_{n1}}{\sum b_{i1}} & \frac{b_{n2}}{\sum b_{i2}} & \frac{b_{n3}}{\sum b_{i3}} & \cdots & \cdots & \frac{b_{nn}}{\sum b_{in}} \end{bmatrix}. \qquad (2)$$

In addition, we obtained a global weights of the alternatives through synthesis of the local weights. The eigenvector of matrix *B* was determined by calculating C_i as the average values in the row i, and Bw matrix was calculated for the column vector C where C_i value indicates the relative degree of importance as explained in Eq. (3).

$$C = \begin{bmatrix} C_1 \\ C_2 \\ C_3 \\ \vdots \\ \vdots \\ \vdots \\ C_n \end{bmatrix} = \begin{bmatrix} \frac{\frac{b_{11}}{\sum b_{i1}}}{n} + & \frac{\frac{b_{12}}{\sum b_{i2}}}{n} + & \frac{\frac{b_{13}}{\sum b_{i3}}}{n} + & \cdots & \cdots & + \frac{\frac{b_{1n}}{\sum b_{in}}}{n} \\ \frac{\frac{b_{21}}{\sum b_{i1}}}{n} + & \frac{\frac{b_{22}}{\sum b_{i2}}}{n} + & \frac{\frac{b_{23}}{\sum b_{i3}}}{n} + & \cdots & \cdots & + \frac{\frac{b_{2n}}{\sum b_{in}}}{n} \\ \frac{\frac{b_{31}}{\sum b_{i1}}}{n} + & \frac{\frac{b_{32}}{\sum b_{i2}}}{n} + & \frac{\frac{b_{33}}{\sum b_{i3}}}{n} + & \cdots & \cdots & + \frac{\frac{b_{3n}}{\sum b_{in}}}{n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\frac{b_{n1}}{\sum b_{i1}}}{n} + & \frac{\frac{b_{n2}}{\sum b_{i2}}}{n} + & \frac{\frac{b_{n3}}{\sum b_{i3}}}{n} + & \cdots & \cdots & + \frac{\frac{b_{nn}}{\sum b_{in}}}{n} \end{bmatrix} \qquad (3)$$

The consistency of the weight values C_i was controlled by calculating the consistency vector $B \times C$ Matrix. Following this, y_i was calculated by multiplying B and $C(B \times C)$ in order to attain the best approximation to the eigenvector in Eq. (4).

$$B \times C = \begin{bmatrix} b_{11} & b_{12} & b_{13} & \cdots & \cdots & b_{1n} \\ b_{21} & b_{22} & b_{23} & \cdots & \cdots & b_{2n} \\ b_{31} & b_{32} & b_{33} & \cdots & \cdots & b_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ b_{n1} & b_{n2} & b_{n3} & \cdots & \cdots & b_{nn} \end{bmatrix} \times \begin{bmatrix} C_1 \\ C_2 \\ C_3 \\ \vdots \\ C_n \end{bmatrix} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ \vdots \\ y_n \end{bmatrix} \quad (4)$$

Hence, the estimation of the eigenvalue λ_{max} of the pair-wise comparison matrix was calculated in Eq. (5). Also, the approximation to the consistency index CI was calculated as illustrated in Eq. (6). The consistency judgment for appropriate value of n by CR was checked in order to guarantee the consistency of the pair-wise comparison matrix as

$$\lambda_{max} = \sum_{i=1}^{n} \frac{y_1}{C_1} \text{ and} \quad (5)$$

$$CI = \frac{\lambda_{max} - n}{n-1}, \quad (6)$$

with consistency ratio

$$CR = \frac{CI}{RI}. \quad (7)$$

The range of random index (RI) represents the length of the sequence (0.00, 0.00, 0.58, 0.09, 1.12, 1.24, 1.32, 1.41, 1.45, 1.49), and RI values for different numbers of n varies from 1 to 10. Note that, if $CR \leq 0.10$, then the degree of consistency is satisfactory, however, if $CR > 0.10$ then this indicates a serious inconsistencies.

AHP was used in two areas, namely, the buyer and the merchants. The procedure accepts the buyers' perspectives as inputs based on criteria and sub-criteria towards the specific goal. A method for measuring consistency level by congruence and dissonance based on congruence measure is defined as

$$\Theta_{ij} = \frac{1}{n-2}\sum_{k=1}^{n}\left|\log(a_{ij}) - \log a_{ik}a_{kj}\right| \tag{8}$$

and dissonance as

$$\psi_{ij} = \frac{1}{n-2}\sum_{k=1}^{n} step(-\log a_{ij}\log a_{ik}a_{kj}), \tag{9}$$

where $i \neq k \neq j$. The congruence and dissonance measure in Eqs. (8) and (9) were used together to detect and highlight outlying judgments. An objective function was formulated and minimized for total deviation (TD) between the given judgments a_{ij} and the estimated weights w was analyzed with distance function defined by

$$TD(w) = \sum_{i=1}^{n}\sum_{i=1}^{n}\left(a_{ij} - \frac{w_i}{w_j}\right)^2. \tag{10}$$

In Eq. (10), $\sum w_i = 1$, $w_i > 0 \text{ and } i \in \{1,2,\dots,n\}$. When $a_{ij} > 1$. The estimated priority vector to preserve the preference direction implies $w_i > w_j$. However, when $w_i < w_j$, it means that a priority violation has occurred. To forestall this, a minimization of second-order deviations TD2 given in Eq. (11)

$$TD2(w) = \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n}\left(a_{ik}a_{kj} - \frac{w_i}{w_j}\right)^2, \tag{11}$$

is employed to cater for inconsistency when TD (w) produces solution with higher number of violations (NV) in Eq. (12).

$$minimize[TD(w), TD2(w), NV(w)]^T. \tag{12}$$

IMPLEMENTATION AND RESULT

In order to demonstrate the product selection decision making model, a descriptive shopping from an e-commerce site was considered, which consisted of different products from the e-commerce site. Each product had several alternatives in order to compensate customer's interest. Customer's perspective concerning different products were recorded and analysed. In that regard, the geometric mean was calculated.

The domain ontology was created based on the Owl. Figure 5 shows the Jambalaya representation of relationships among classes and subclasses. In Figure 5, the various classes were made to relate to show the class hierarchy, various sub-class and relations that existed in them. The domain ontology described the properties and relationships among classes and subclasses developed for the products. Classes are represented as nodes while slots were represented as arcs.

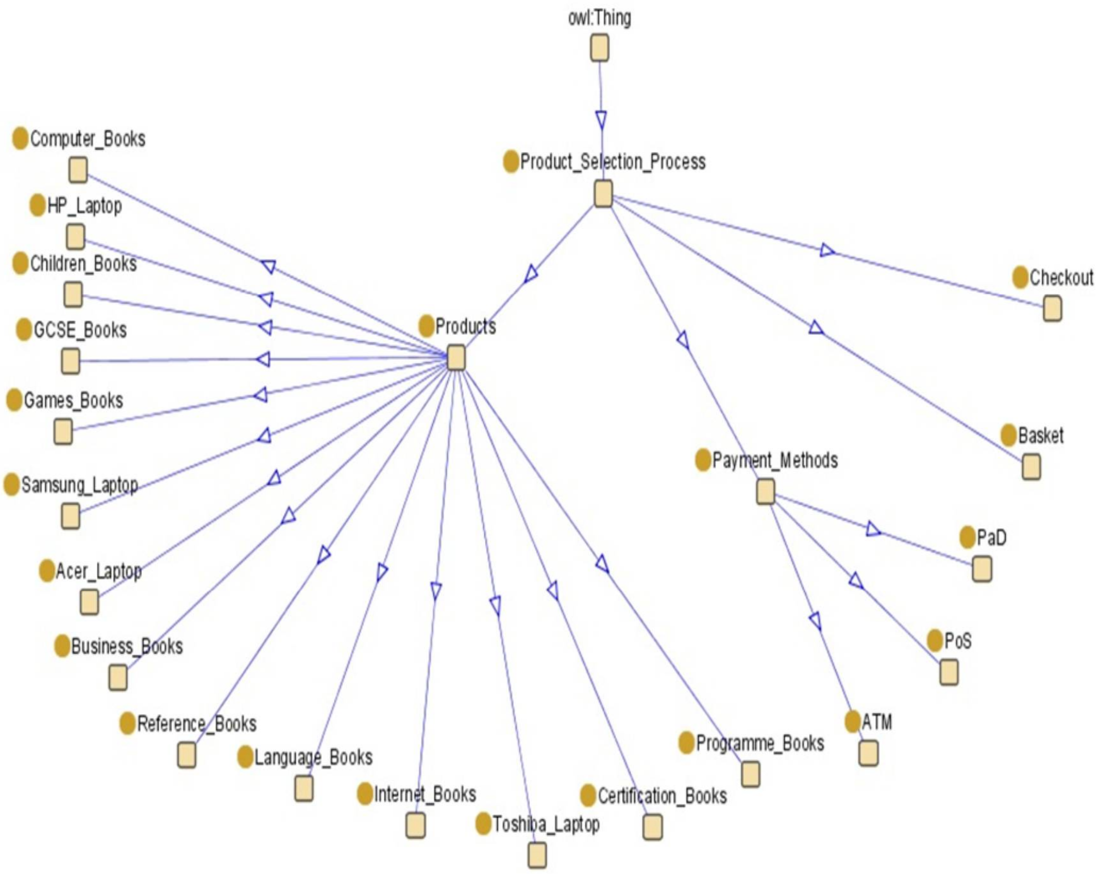
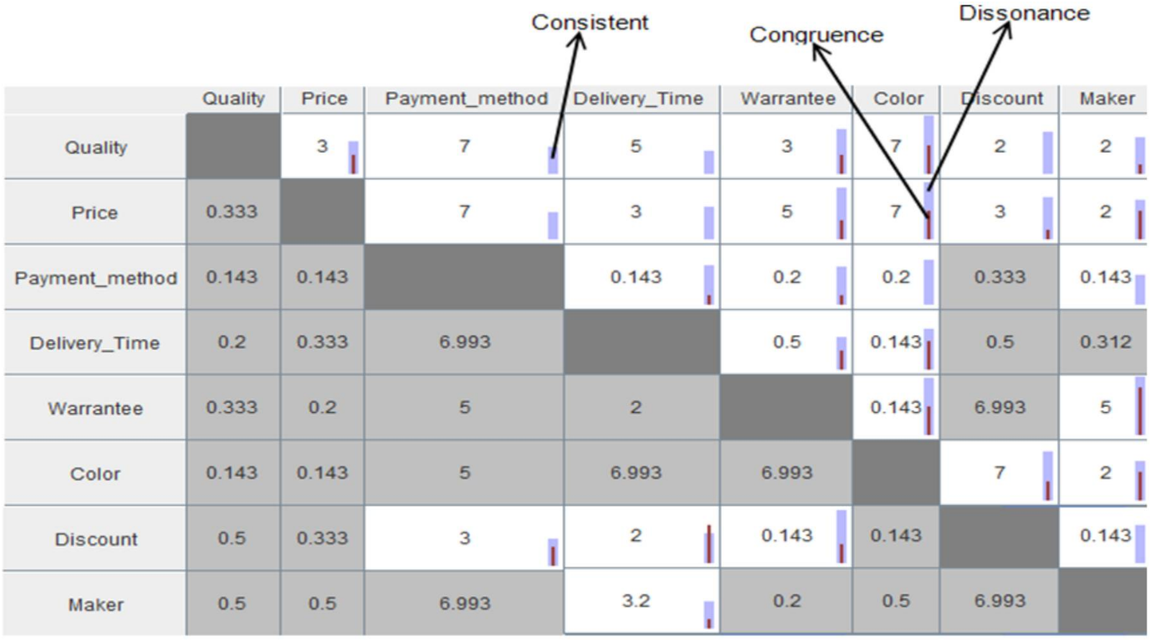


Figure 5: Jambalaya Relationships of Classes and Subclasses in Product Selection

Analytic Hierarchy Process Analysis

The product selection decision making model described in section 3 was implemented using PriEsT tool to generate the AHP pairwise comparison matrix, visualizing the level of inconsistency, and the transitive judgment. The congruence and dissonance measurement show the contribution of individual judgments toward the overall inconsistency of the pairwise comparison metric (PCM) which were later used to detect and correct inconsistent judgments. The overall congruence $\psi = 0.083$ while the overall dissonance $\Theta = 0.905$. From Figure 6, eight (8) criteria, namely, Price (P), Quality (Q), Delivery time (Dt), Payment method (Pm), Warrantee (W), Colour (C), Discount (D) and Maker (M)) were compared on the ratio scale. Figure 6 clearly shows the level of inconsistency of each individual judgment by AHP. The congruence and dissonance measures were plotted as bar graphs against their respective judgments. The most consistent, which were set of three judgments were shown in small blue dots on the blamed judgments.



	Quality	Price	Payment_method	Delivery_Time	Warrantee	Color	Discount	Maker
Quality		3	7	5	3	7	2	2
Price	0.333		7	3	5	7	3	2
Payment_method	0.143	0.143		0.143	0.2	0.2	0.333	0.143
Delivery_Time	0.2	0.333	6.993		0.5	0.143	0.5	0.312
Warrantee	0.333	0.2	5	2		0.143	6.993	5
Color	0.143	0.143	5	6.993	6.993		7	2
Discount	0.5	0.333	3	2	0.143	0.143		0.143
Maker	0.5	0.5	6.993	3.2	0.2	0.5	6.993	

Figure 6: Pairwise Comparison Matrix Showing Level of Inconsistency

From the product selection criteria given, each judgment in Figure 7 was shown as a connector between two nodes, while the bolder side of each line describes the dominating node. The preference of quality over Warrantee and that of Warrantee over delivery time suggested that quality should be preferred over delivery time.

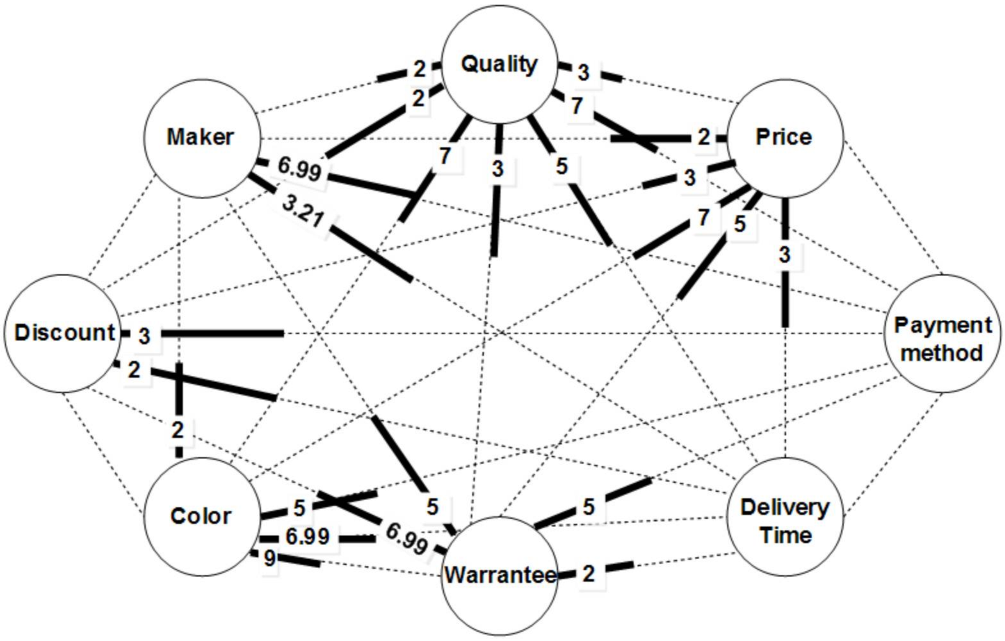


Figure 7: Set of Judgments

Evaluation of APH Judgement

The AHP evaluation was done using Geometric Mean (GM). The priority vectors obtained using GM, EV, NCS, WLS, and FPP were given in Table 2. The ideal ranking possible for this PCM was P-> Q-> Dt-> Pm-> W-> C-> D-> M. However, the ranking order suggested by GM, EV and NCS was P-> M-> Q-> Pm-> Dt-> W-> D-> C. Although, the judgment were found to be transitive. The WLS method has violated the order of preference P-> M-> Q-> Pm-> Dt-> D-> W-> C for one judgment, that is, E against G. FPP method also suggested a different ranking order of P-> M-> Q-> Pm-> Dt-> W-> D-> C with one violated judgment. Figures 8 and 9 showed the capability of PriEsT decision strength as an interactive selection for any non-dominated solution by plotting NV against TD and TD against TD2. Any of the solutions having NV > 0 were considered to be inconsistent or less relevant. The FPP solution generated more violations than GM, EV, NCS and WLS. Figure 8 show a graph of NV against TD. The results showed that the minimum units of products is 2,452 and maximum is 3,574.

Table 2: Elicitation Methods for the Pairwise Comparison Matrix

Method	TD	NV	TD2				vector				
GM	318.439	2	26722.434	0.286	0.229	0.02	0.048	0.107	0.156	0.044	0.109
NCS	318.165	0	27241.967	0.259	0.196	0.018	0.052	0.133	0.172	0.055	0.116
FPP	482.743	4	35358.566	0.149	0.149	0.109	0.11	0.11	0.115	0.109	0.149
WLS	548.438	4	27023.995	0.433	0.244	0.029	0.05	0.058	0.069	0.029	0.088
EV	440.286	0	25351.086	0.288	0.242	0.017	0.039	0.11	0.17	0.041	0.092

GM= Geometric Mean
EV= Eigenvector
NCS= Normalized Column Sum
WLS= Weighted Least Square
FPP= Fuzzy Preference Programming

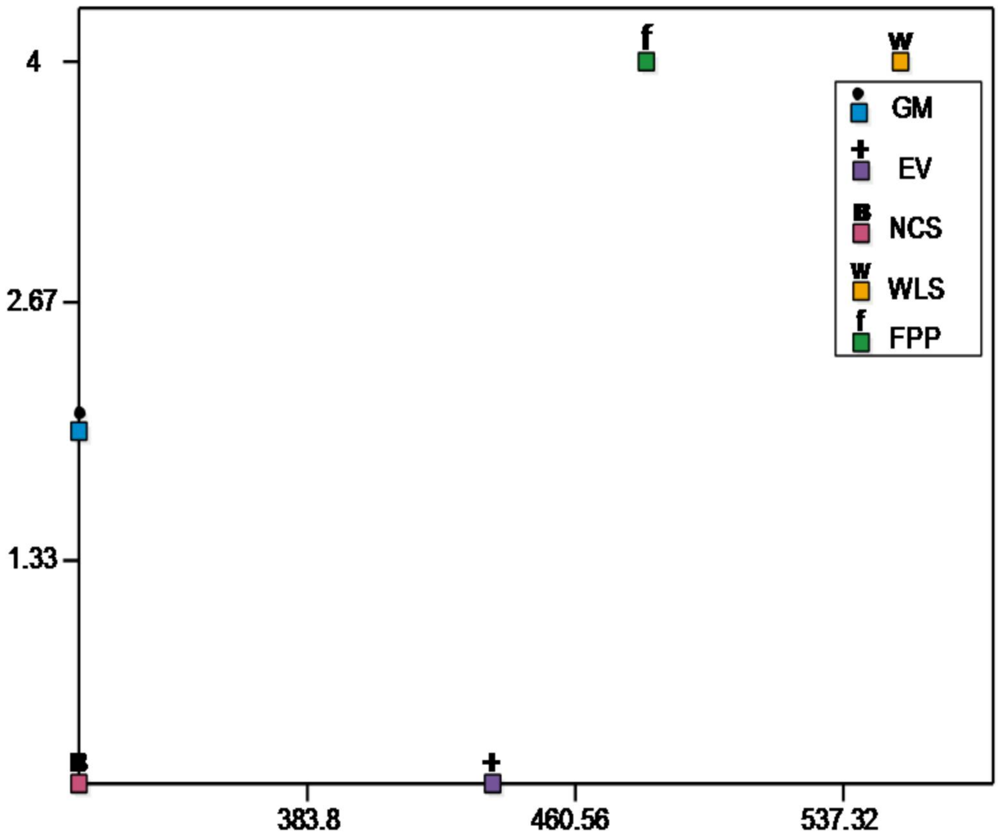


Figure 8: Total Deviation (TD) against Number of Violations (VN)

CONCLUSION

This paper presented a model for selecting product preferences with the aim to assist customers in selecting the best products of choice on the e-commerce website. An Ontology-based Analytic Hierarchy Process was used to provide consumers with the decision support services for selection of product preferences. Ontology was used for describing products and their properties meaningfully, such as, full details about the products, warranty on goods, price, and discount, etc. In addition, AHP was used as requirement in order to select among similar products and services according to the customer's requirements. The proposed intelligent system could help to solve any shopping problem because it offers an adaptive selection and optimal choice of suggestions to the consumers.

The use of the modified AHP was very instrumental and mostly effective in solving problems of complex decision making that involves multi-criteria and alternatives, which was compared to the work of Kabir and Sumi, 2010. The extraordinary function of AHP is in its time utilization, which is reduced compared to other approaches. However, selecting product preferences would be better analysed with other fussy logic combinations to achieve the best outcome with respect to degree of satisfaction and customer retention.

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