IMPROVING PRODUCT CLASSIFICATION THROUGH PRODUCT FAMILY SEGREGATION

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ABSTRACT

Information sources are invaluable when taking decisions in Product design especially at the front end of the design process. Product families if properly classified, the connectivity of product form and interaction of the features assist the designer in taking good decisions. This paper addresses product classification from the design perspective with respect to Product family as reflected by the product's presence in the market. Ten different models for a product (Wheelchair) was randomly selected and recorded. The choice of the product has no specific implication other than to demonstrate the practicability of this approach. TRIZ principles were employed to perform a 3-level component segregation on each model. A matrix is thereafter drawn for the product family. The models are recorded on the horizontal axis of the matrix while their corresponding features are recorded on the vertical axis. The frequencies of the models and corresponding features are noted on the right hand side of the table. The frequencies were then taken through cluster analysis using the dendrogram on SPSS 20. The result shows the features categorized into three groups which reveals the commonality and association of the features that are *Basic, Performance or Luxury* according to customers' satisfaction. This approach also shows a quick method that can ease product design decision making because it is systematic and can be used to dissect and analyze products within a product family. This approach can lead to functional analysis, product design specification preparation and product development.

Keywords: product classification, product family, design, matrix method, TRIZ inventive principles, product development.

1. INTRODUCTION

The designer is usually faced with multi-dimensional challenges as to what to design - from the broad terms of what product to design and what family that product should belong, to the minutest details as this could affect product niches, patent clashes, customer behavior etc. Information sourcing is indispensable whenever decisions are to be made either in design or other spheres of life. This is more important at the front-end of the design process because this is where information is collected and collated into a core that guides the remaining part of the design process. Chandresegaran, [1] opine that decisions made on front end design of any product strongly influences the overall success or otherwise of that product especially in terms of energy, costs, and sustainability.

The customer purchase decision process varies with the type of product being considered. Complex and expensive products are likely to involve greater buyer deliberation [2]. Customer behavior or satisfaction still dominates the focus for product design as 'the customer is considered the king'. This situation still makes designers increase their focus and subsequently decisions on the satisfaction of the customer. Although, some authors have argued that "the customer don't know what they want in future"[3], involving the customer on design process is still the focus of business organizations including the design community because of the designers' belief that customers are sources for ideas [4]. Some authors suggest that the continued existence of poor valued or failed products in the market resulting from the deficit in decision supporting techniques is still a burden on resources and investments [5, 6].

Classification of products helps designers work faster with a defined scope and target audience. Product designers are increasingly being pressured to advance ideas and tools that can fast track product design processes [1] and deliver to the market, as the shorter the time between nursing an idea and bringing it to the market is increasingly found to be a competitive tool in a "Customer centric market" [7]. Research in design for Product planning requires improvement for standardization and adaptation that the global businesses need [8].

Krishna [9] posits that there is still lack of reliable methodologies that can viably support the recognition of real aspects of value which fit in to the hidden consumers' and stakeholders' needs. This lack of reliable methodology creates a gap for integration of efficiency associated issues with product platforms that connect market benefits with high product variety. This connotes that models or methods that have the capability to represent the dynamic progression of customer needs are still lacking [10]; this is in line with Thevenot [11], that the approach required should be consistent, systematic capable of dissecting and analyzing product families. Yang [12] agrees with the above positions and added that product designers need information on critical product form features. For example, if a model is available to show the difference features in product families over time, based on products in the market, this can demonstrate the progression of customer behavioral dynamics. Suffice to note that classification of products, consideration of product families, determination of critical product features, as important as it is to product success and survival is still a challenge.

This work therefore presents to the designer an improved method of product family dissection, analyses and product form features' classification that identifies the Basic or critical features, the Performance or not so critical features and the Excitement or luxury features, that is quick, easy to use, consistent and also recognizes the customer. This approach can also ease standardization and identification for commonality of products. More so, the authors of this work posit that this approach enhances direction and decision making for the designer on what a product in a product family should have and at what category when the customer is seen to appreciate products from three angles: the basic, the performance and the luxury. The approach also shows a clear hierarchical ranking of features in a product family.

TRIZ inventive principles are used in this work. TRIZ is a Russian acronym for Theory of Inventive Problem Solving founded by Greenrich Atlshuler (1926-1998). TRIZ is the result of assessment for several product patents with cognizance for the recurrent strengths of the winners and the common mistakes of the losers [13]. TRIZ has 40 inventive principles as guides for inventions. These include: segmentation, trimming, contradiction, functional analysis etc. [14]. Product placement in the market could also be done using the S-curve Analysis in TRIZ [15].

The remaining part of this paper is divided into: Literature review which combines design issues and product classification, research method which shows the framework and the verification for the approach presented, Results, discussions and conclusion.

2. DESIGN ISSUES

Design is a process that includes product form, function and performance. Design is a mental process beyond sketches and drawings that show the visible records that people see. Designers determine specific ways to solving product development challenges [16]. Popovic [17] Opined that design expertise depends on the level of knowledge possessed and the ability to create, extract, analyses and apply that knowledge. Following Charnley [18], this paper agrees that product design is a systematic translation of a function to a feasible real/physical feature, though it could be argued that the definition of product design may be domain dependent [18]. Crilly [19] opine that a product form is determined by its functions but a function usually depends on a feature to transfer energy, material or information between objects that follows a logical pattern [20]. Product design involves highly complex activities that is often not well defined [1]. The authors agree with Ullman and Miaskiewicz [20, 21] that current design processes are yet to be handled properly to keep pace with the ever increasing challenges that product designers have to deal with daily. However, Ullman [20] opined that it is good practice to recognize that great efforts are involved in the development of existing products whether these efforts are clearly seen or hidden. Design requires innovation and sustainability [18].

Innovation in product design can evolve from different sources [22]. Product Innovation is done to improve product acceptance, chances of survival, profit and sustainability. Companies who want to make radical innovations have to face severe hurdles in evaluating several aspects with respect to the lifecycle of new products because, at the very beginning of the design process, project teams own limited and unreliable information about product performances, customers' positive impact value and outcome of product commercial success [10].

Pugh [23] presented a 6-step model for product design referred to as the "Total Design" guide with each considered important in whatever the design domain is: i. Market/Need, ii. Design Specification, iii. Concept Design, iv. Detail Design, v. Manufacturing and vi. Sell. Emphasis is laid on the front end design process as that serves as the core that guides the entire design process. The front end of the design process refers to the stages between the need/market and the product design specifications. Ullman [24] presented the design process in five major steps: identification of needs, planning for the design process, develop engineering specification, develop concepts and develop products. The basic difference between Ullman [24] approach and Pugh [23] is the specific indication of planning as part of the design process model by Ullman.

2.1. Product classification

Some authors have made some findings on product classification. Sousa [25] found that Product classification could be done depending on what the product is, the purpose of classification and how the perspective of the product influences the product development decisions. Four major groups are listed: Marketing, Organisation, Engineering Design and operations management. Korgaonkar [26] found that One way to classify Products is to put the products in two broad categories: Consumer products and services and Business products and services. Products could also be classified in line with available information: Information gotten before the purchase of a product or after purchase and the experience of a product or even products that there was no prior information to evaluate either before first purchase or thereafter. It was also reported in this work that product classification could be done according to Search Experience Credence (SEC), where risk perceptions for a product is influenced by information provided on risk and behavior towards that product. Costa [27] mentioned that Product Classification could depend on grouping items according to pre-defined criteria by emphasizing their common and different attributes. Meyer [28] reports that with respect to intelligent products, a more comprehensive classification is required that analyzes different information architectures in all aspects depending on the kind of Intelligent Products and parts of the product lifecycle is being considered. Product classification is also reported to be done according to Customer satisfaction. The work of Noriaki Kano who

VOL. 9, NO. 5, MAY 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

developed a features model for customer satisfaction has been referred to by quite a number of authors [20, 29, 30]. The model has three lines: Basic, performance and excitement features. The *Basic* features are explained as those features that are assumed to be present and not usually asked for by the customer. The *Performance* features are those that are considered to show an advantage over the *Basic* and the customer usually requests for these features to be sure they are there. The third category refers to products with *Excitement* features those that the customers may not have thought of but will be excited to see such features in the product.

Findings from some works on product classification are presented above. The Kano model in its original form has comparatively wider coverage. It also has a great consideration for the customer but it is quite general and open to a lot of interpretations. The Kano model does not have a quantitative assessment capability and provides limited support in taking decisions on engineering design. Also it can only be applied effectively by experienced designers. On product classification by grouping items, it is argued that whatever criteria or definitions used should be clear, concise and comprehensive with a clear cut hierarchical ranking.

The product designer requires tools, techniques and methods that support engineering design with due consideration for the customer and environment [1]. The required tools should have information on features of a product that are critical and facilitates quick deduction in identifying critical product form features (PFFs) to aid them in producing appealing products [12]. The required tools should assist the designer in quick evaluation and possible changes in features criterion [31]. The required tools should facilitate product design process and quick delivery as the shorter the time between nursing an idea and bringing it to the market is increasingly a competitive tool in a customer centered market [7]. This work therefore focuses on these needs. This work provides the designer with a product classification that identifies critical and the not so critical and luxury product form features that is quick, easy to use and focuses on the customer.

3. METHODOLOGY

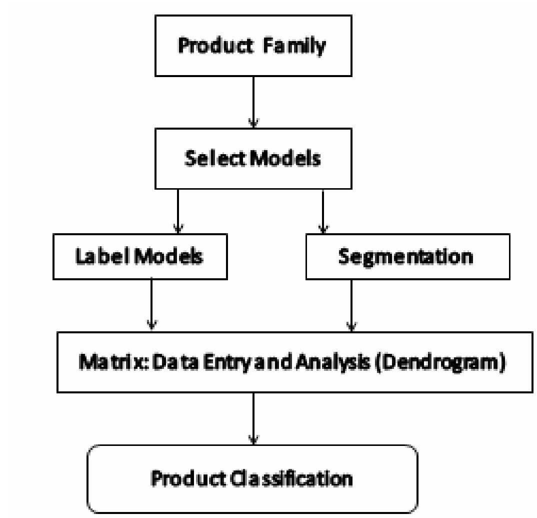

Figure-1. Operational framework.

Figure-1 shows the operational framework followed in developing this approach. A classification approach was developed to classify and dissect the equipment (wheelchair) using the TRIZ inventive principles, Matrix method and cluster analysis method. Cluster analysis techniques sorts different objects into groups by showing the nature of association between them whether it is maximal or minimal [32]. Cluster analysis techniques are widely used and very useful [33, 34].

Ten (10) different models (Appendix A-J) of a selected product family (the wheelchair) were collected at random from the internet for analysis. A sample size of Ten (10) has been used in a previous studies [35, 36]. The ten models are taken through the segmentation principle (principle 1 of the TRIZ inventive principles. See Figure-2). Segmentation principle involves the breaking down of the main equipment into sub-assemblies and/or component parts referred to as features in this work. The segmentation process led to identification of 25 different features The 25 features were noted and recorded in Table-1.

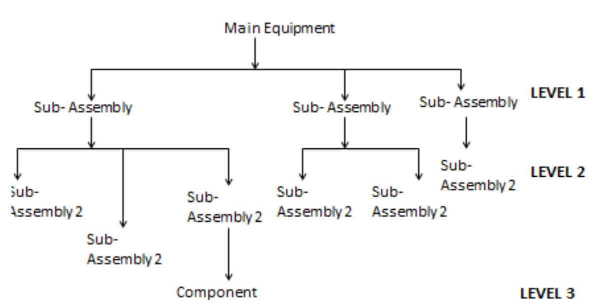

Figure-2. Equipment segmentation (Adapted from Ikovenko, 2012).

Table-1. Features - models matrix (adapted from Pugh, 1993).

S/No	Models / Features	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H	Model I	Model J	Percentage %
1	Push Handle	√		√					√		√	50
2	Backrest	√	√	√	√		√	√	√	√	√	90
3	Seat	√	√	√	√	√	√	√	√	√	√	100
4	Brake	√	√	√	√	√	√	√	√	√	√	100
5	Push Rim	√		√	√		√		√		√	60
6	Wheels(2)	√	√	√	√	√		√	√	√	√	90
7	Caster wheels(1)							√				10
8	Caster wheels(2)	√	√	√	√				√		√	60
9	Caster wheels(3)									√		10
10	Caster wheels(4)						√			√		20
11	Foot rest	√	√	√	√	√	√	√	√	√		90
12	Arm rest		√	√					√	√	√	50
13	Lights		√									10
14	Automatic		√							√		20
15	Manual Control	√		√	√	√	√	√	√		√	80
16	Shield for Hot Sun										√	10
17	Head rest		√							√		20
18	Bag								√			10
19	Adjustable seat		√			√				√		30
20	Foldable (vertically)		√	√		√					√	40
21	Foldable (Horizontally)	√		√			√			√		40
22	Lap belt						√					10
23	Leg guard	√										10
24	Calf support		√			√	√		√	√		50
25	Frame	√	√	√	√	√	√	√	√	√	√	100

From Table-1 the corresponding frequencies of the features in the models are recorded and analyzed further using the cluster analysis method through SPSS 20. This is done to determine the position of each feature in the product family and how this position is represented with respect to the feature being a *Basic, Performance or Excitement* feature.

4. RESULTS AND DISCUSSIONS

From the dendrogram Figure-3, it is clearly seen that the features have separated into three groups. These groups are referred to as the Basic features group, the Performance features group and the Excitement or Luxury features group. The Basic features are the features that are taken for granted that they exist in every product within a product family and the customer usually don't ask for them. The performance features are a degree higher that the basic because they are features that the customer will demand for and may influence his/her decision to buy that product or not. For the third and final category, which is the excitement features, the features represent added comfort during use. These features may be new to the customer but they are usually more expensive (this is why some authors refer to this features as luxurious) and mainly exciting.

The Basic features as shown above are seven: Big wheels (6), frame (25), seat (3), brakes (4), back rest (2), foot rest (11) and manual (15). For these features there exist an unspoken understanding between the seller and the buyer of what features are supposed to be present in a product. For a customer in this case study, these features are normal to be present in a wheelchair.

The performance features from the results presented above are: Push rim (5), Casters2 (8), Collapsible vertical (20), Collapsible horizontal (21), Arm rest (12), Calf support (24) and Push handle (10). These features enhance the performance of the product. The customer is likely to ask or look for these features. Their presence or absence could affect his buying behavior.

The final category is the Excitement features. From Figure-3 above they are eleven: Lap belt (22), Leg guard (23), Caster1 (7), Sunshield (16), Bag (18), Caster4 (10), Lights (13), Casters3 (9), Automatic (14), Head rest (17) and Seat adjustment (19). For this category of features, they are considered extra - they usually attract additional cost. Sometimes the customer is not expecting these features in a product. In some products this category are exclusive for those who can afford.

VOL. 9, NO. 5, MAY 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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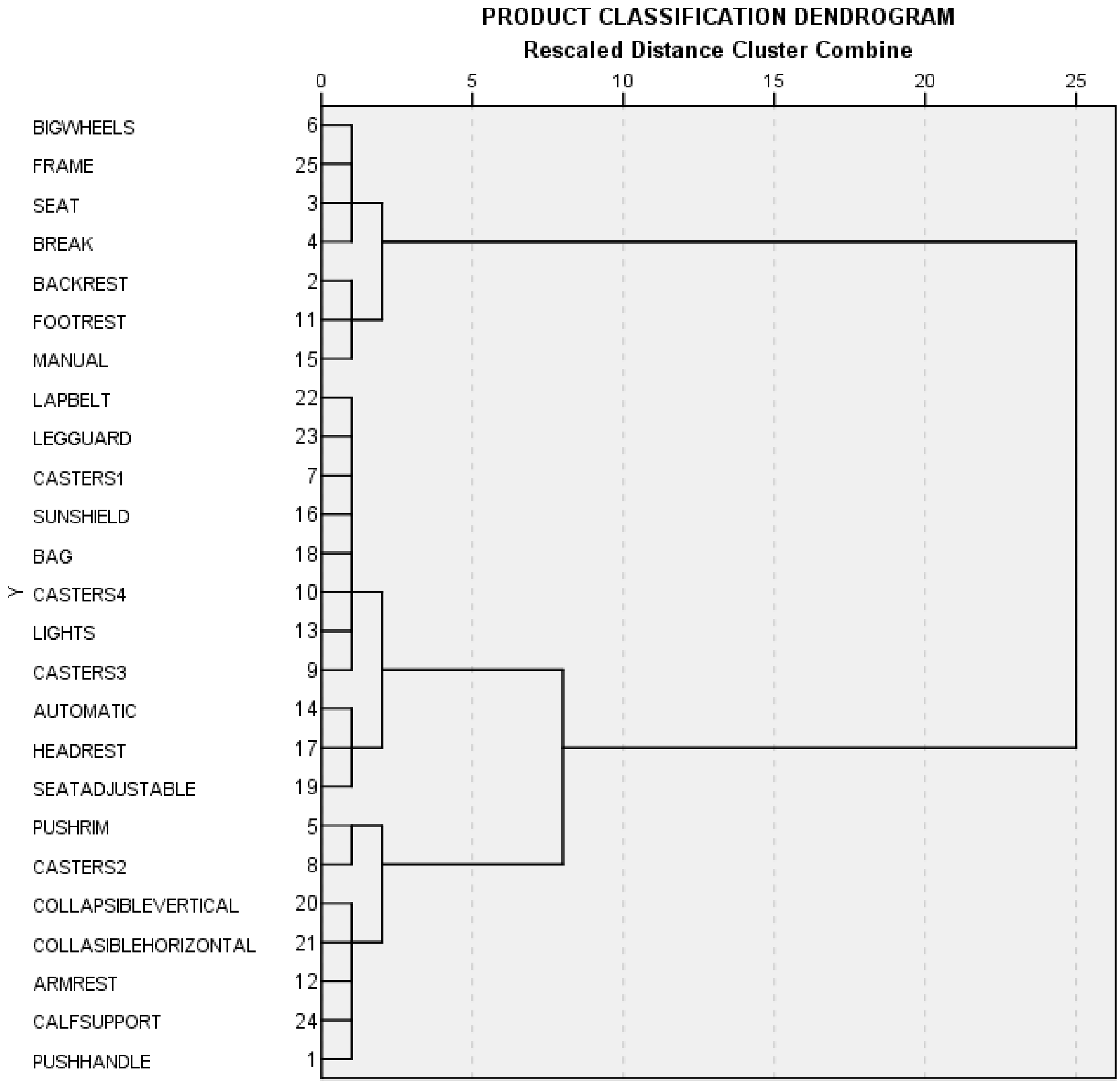

Figure-3. Products Classification Analysis.

5. CONCLUSIONS

In this paper, a product classification approach using Segregation, the matrix method and classification dendrogram methods has been presented. The approach as presented does not only reduce the time used in the decision making on the front end of product design process, it also addresses the challenge of finding a product classification approach that is consistent and systematic that can dissect and analyze product families which is still in great need. The approach presented here enhances direction and decision making for the designer on what a product in a product family should have and at what category when the customer is seen to appreciate products from three angles: the basic, the performance and the excitement. This approach though have some things (classification of features into three) in common with the Kano model, it is different because the producers concern for product features are taken care of through direct critical features identification and analysis. It also dissects the features of products with ease. It could also help in determining where to concentrate for designers who intend to create a unique product. Designers either with long years of experience or new entrants into the design field will find this approach invaluable for product classification. As front end design takes a large chunk of the total time required for product development, any approach like this aimed at reducing the rigor and time required in design terms, which also translate to costs reduction will aid the product development process immensely. This classifications approach can further be explored to address other activities in the design process like components functional analysis, product design specification and can be used to interpret product trends.

REFERENCES

[1] Chandrasegaran S.K., Ramani Karthik., Sriram Ram D., Horváth Imré., Bernard Alain., Harik Ramy F. and Gao Wei. 2013. The evolution, challenges, and future of knowledge representation in product design systems. Computer-Aided Design. 45(2): 204-228.

[2] Kiang M.Y., Ye Qiang, Hao Yuanyuan, Chen Minder. and Li Yijun. 2011. A service-oriented analysis of online product classification methods. Decision Support Systems. 52(1): 28-39.

[3] Eisingerich A.B., Bell S. J. and Tracey P. 2010. How can clusters sustain performance? The role of Network Strenght, network openness and environmental uncertainty. Research Policy. 39(2): 239-253.

[4] Mukhtar M., Ismail Mohamed Nazul. and Yahya Yazrina. 2012. A hierarchical classification of co-creation models and techniques to aid in product or service design. Computers in Industry. 63(4): 289-297.

[5] Appio F.P., Achiche S., McAloone T. and Di Minin A. 2011. Understanding managers decision making process for tools selection in the core front end of innovation. In: International Conference on Engineering Design (ICED11). ICED 11.

[6] Steven G.and Burley J. 1997. 3000 raw ideas=1 commercial success! Research Technology Management. 40(3): 16-27.

[7] Wang L., Shen W., Xie H., Neelamkavil j. and Pardasani A. 2002. Collaborative Conceptual Design-state of the art and future trends. Computer-Aided Design. p.34.

[8] Boztepe S. 2007. Toward a framework of product development for global markets: a user-value-based approach. Design Studies. 28(5): 513-533.

[9] Krisna V. and Ulrich K.T. 2001. Product Development Decisions: A review of the Literature. Management Science. 47(1): 1-21.

[10] Borgianni Y., Cascini Gaetano., Pucillo Francesco. and Rotini Federico. 2013. Supporting product design by anticipating the success chances of new value profiles. Computers in Industry. 64(4): 421-435.

[11] Thevenot H.J. and Simpson Timothy W. 2007. Guidelines to minimize variation when estimating product line commonality through product family dissection. Design Studies. 28(2): 175-194.

[12] Yang C. 2011. A classification-based Kansei engineering system for modeling consumers' affective responses and analyzing product form features. Expert Systems with Applications. 38(9): 11382-11393.

[13] Mahmud J.O., Ismail M. S. Mohd. and Taib J. Mohd. 2012. Engineering Education and Product Design: Nigeria's Challenge. Procedia - Social and Behavioral Sciences. 56(0): 679-684.

[14] Yeoh T.S. 2008. Systematic Innovation in Manufacturing - Introduction to TRIZ, in 2008 Asia Academic Forum. Intel: Taipei, Taiwan.

[15] Ikovenko S. 2011. Inventing the Future with Systematic Innovation, in MyTRIZ Workshop 2011. Gens3 partners Inc.: Uniten, Malaysia.

[16] Pahl G., Beitz W., Feldhusen J. and Grote K. H. 2007. Engineering Design. 3rd Ed. B. Wallace K., L. Springer-Verlag London Limited. p. 617.

[17] Popovic V. 2004. Expertise development in product design-strategic and domain-specific knowledge connections. Design Studies. 25(5): 527-545.

[18] Charnley F., Lemon M. and Evans S. 2011. Exploring the process of whole system design. Design Studies. 32(2): 156-179.

[19] Crilly N., Moultrie J.and Clarkson P. J. 2009. Shaping things: intended consumer response and the other determinants of product form. Design Studies. 30(3): 224-254.

[20] Ullman D.G. 2010. The Mechanical Design Process. Fourth Ed. New York: McgrawHill.

[21] Miaskiewicz T. and Kozar K.A. 2011. Personas and User-Centred design: How can personas benefit product design processes. Design studies. 32(5): 417-430.

[22] Rampino L. 2011. The innovation pyramid: A categorization of the innovation phenomenon in the product-design field. International Journal of Design. 5(1): 3-16.

[23] Pugh S. 1993. Total Design: Integrated Methods for Successful Product Engineering. Addison-Willey Publishing Company, Inc.

[24] Ullman D.G. 1997. The Mechanical Design Process. Second ed. McGraw-Hill Companies incorporated.

[25] Sousa I. and Wallace David. 2006. Product classification to support approximate life-cycle assessment of design concepts. Technological Forecasting and Social Change. 73(3): 228-249.

[26] Korgaonkar P., *et al*. 2010. Product classifications, consumer characteristics, and patronage preference for online auction. Journal of Retailing and Consumer Services. 17(4): 270-277.

[27] Costa A.I.A., Dekker M., Beumer R. R., Rombouts F. M. and Jongen W. M. F. 2001. A consumer-oriented classification system for home meal replacements. Food Quality and Preference. 12(4): 229-242.

[28] Meyer G.G., Främling Kary. and Holmström Jan. 2009. Intelligent Products: A survey. Computers in Industry 60(3): 137-148.

[29] Spool J.M. 2011. Understanding the Kano Model-ATool for sophisticated Designers. [Cited 2013 16/08].

[30] Xu Q., *et al*. 2009. An analytical Kano model for customer needs analysis. Design Studies. 30(1): 87-110.

[31] Wei W. and Chang W. 2008. Analytic network process-based model for selecting an optimal product design solution with zero-one goal programming. Journal of Engineering Design. 19(1): 15-44.

[32] Usman D. and Kane I. L. 2012. Prevalence of Infectious Diseases in Katsina State: An insight using Clustering approach. Engineering Science and Technology: An International Journal. 2(6): 1009-1016.

[33] Han J. and Kamber M. 2001. Data Mining Concepts and Techniques. San Francisco: Morgan Kaufmann.

[34] Hartigan J.A. 1972. Direct Clustering of a data matrix. Journal of American Statistical Association. 67: 123-129.

[35] Van der Woude L.H.V., de Groot S. and Janssen T. W. J. 2006. Manual wheelchairs: research and innovation in sports and daily life. Science and Sports. 21(4): 226-235.

[36] Kawamura T. and Murakami T. 2013. Multifunctional control of a two-wheel driven wheelchair considering comfort of a passenger. IEEJ Transactions on Industry Applications. 133(4): 404-413.

APPENDIX
Selected Models

A. ADL W5 SA. Source: http://www.wolturnus.com . Retrieved. 04/08/2012

B. ZK122LGC. Source: http://wwwwheelchairassistance.com.
Retrieved. 04/08/2012

C. Aluminium Travel Wheelchair ATC 19.
Source: http://www.discountmobility.com.
Retrieved. 04/08/2012

VOL. 9, NO. 5, MAY 2014 ISSN 1819-6608
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D. HEROes Zupan. Source: http://www.yankodesign.com.
Retrieved. 04/08/2012

E. Mobi Electric Folding Wheelchair.
Source:
http://www.universaldesignstyle.com.
Retrieved. 04/08/2012

F. Rugby Defensive FS771LQ-32.
Source: http://www.healthcare deep.com.
Retrieved. 04/08/2012

G. Snug Seat Cheetah.
Source:
http://www.homehealthpavilion.com.
Retrieved. 04/08/2012

H. Wheelchair-Bag-Grey.
Source:
http://www.janshop.org.uk.
Retrieved. 04/08/2012

I. GT Electric Wheelchair
Source: http://www.mymobility.com.
Retrieved. 04/08/2013

J. Folding Ultra light Wheelchair
Source: http://www.andreviger.com.
Retrieved. 04/08/2013