Title:
Ergonomics Product Development of Over Bed Table for Bedridden Patients

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Abstract:
Over bed tables are used worldwide to help disable or injured patience but the most of the available products does not meet the basic standards of ergonomics. Nowadays when designing a human control product, the ergonomic standards should be satisfied to make a product which will not harm the user. This study was conducted to develop a new ergonomic over bed table for patients which will be useful to get a better recovery and which will be helpful for users as the way they expect. This paper presents a methodology to develop a new type of over bed table for bedridden patients. The objective of the research is to design and produce a new type of over bed table for helping disable or injured patients. Most of the available products are not considered ergonomics factors. In this approach, Quality Function Development (QFD) technique is considered with ergonomics factors and developed to satisfy the quality of products and ergonomics standards which will not harm the user. A virtual ergonomic analysis has been performed in Jack SIEMEN® using the constructed virtual human models with anthropometric data. Details of the research activities, development of QFD and ergonomics analysis are mainly discussed in this paper.

Keywords:
Quality Function Deployment (QFD), Conceptual Design, Ergonomics Analysis and Simulation, Design for Manufacturing (DFM)

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Introduction:
The over bed tables are widely used in majority of hospitals around the world. Those are used to help disable or injured patience but the most of the available products does not meet the basic standards of ergonomics. We can see human operators facing long term problems such as repetitive task injuries after being engaged in operating certain machinery. Therefore, the main aim of ergonomics is to help these operators or users by producing products which fit their capabilities so that none of the users will face any injuries when using them. In order to fit the job according to the person, measurements (Anthropometry) relevant to the human body are very important. Therefore, when designing a product, according to the capabilities and limitations of the user, ergonomists mainly consider anthropometry so that the product can be designed without any flaws using the correct materials, dimensions, shape, weight and so on. The objective of ergonomics is to achieve the best possible match between a product and its users in the context of the work task to be performed. Human factors are involved in several steps of product life (design, manufacture, etc) and the capability to keep them into account effectively is a key point for a winning product on the market. Therefore, many researchers have been focusing on the ergonomic factors of hospital bed, computer desk and mobile workstation for healthcare [2] [4] [7] [8] [10]. Ergonomics design and maintenance operation through virtual human models are studied in [3] [9]

Fig.1 shows a flow chart for ergonomics product development of over bed table. In this paper our approach will be discussed how we develop a methodology using QFD, CAD and Virtual Ergonomic Analysis tools. This methodology can be applied for other products. This paper is organized as follows: Introduction, Development of the Quality Function Deployment (QFD) and Virtual Ergonomics Analysis and Conclusion.

Development of the Quality Function Deployment (QFD) and ERGONOMICS Analysis:

QFD is a tool for improving the development cycle and manufacturing products that better match customer needs [1]. QFD accomplishes these goals through the use of a design tool that is known as "House of Quality" (HOQ). Author applied QFD in the new product development for Scooter [6]

Concept Generation

Several ideas were converted into sketch (drawing) in order have a rough idea as to how the model should be built. Before coming up with a final conceptual model, all these drawings were analyzed so that the pros and cons of these sketches could be identified before coming up with the preliminary design models. Basic Functions such as high adjustability, portability, ergonomic factors, drawer, movability, simplicity, tilting table top are attached to the concept of new prototype. Some of the conceptual designs are shown in Fig. 2.

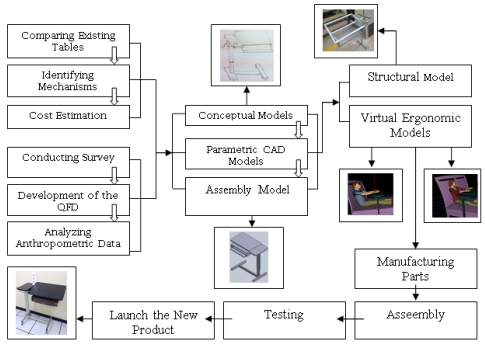
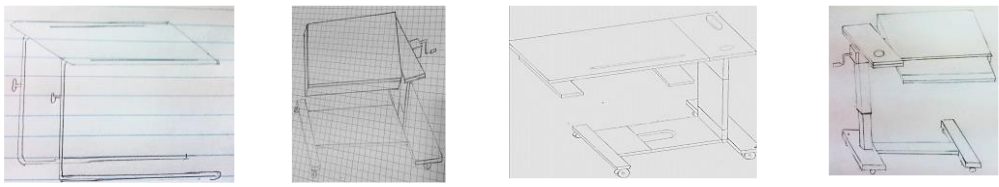


Fig. 1: A Flow Chart for Ergonomics Product Development of Over Bed Table.



(a) (b) (c) (d)

Fig. 2: Conceptual Models: (a) Concept 1, (b) Concept 2, (c) Concept 3, and (d) Concept 4.

A Survey

In attempting to meet the patients need, a survey was conducted with a purpose of making statistical analysis about the population, and the outcome of survey depends on how analytical ability of survey. For data collection a sample size was calculated mainly. It was divided into two main categories: Probability samples and non-probability samples. Probability sampling is a method that sub-populations within a general population are recognized and included in the sample selected in a balanced way. The main purpose of carrying out this survey is to identify the major problems that users face with the existing products in the market. The survey questions were mainly focus on understanding the customer needs and difficulties which they are facing during the use of current tables in the market. Survey results are shown in Fig. 3.

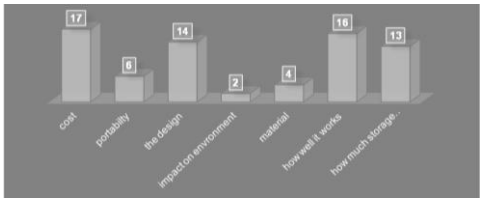


Fig. 3: Survey results.

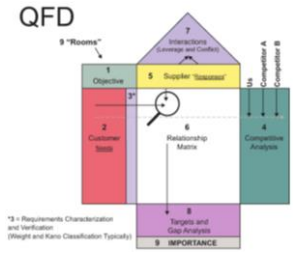


Fig. 4: Basic structure of QFD [11].

A development of QFD

The basic structure of a Quality Function Deployment is shown in Fig. 4. Customer requirements were identified through the survey that was carried out in the hospital together with 20 patients those who use over bed tables and the hospital staff which had quite a good knowledge about this product. Therefore, the customer importance factor was tabulated by the grading's that were given by the customers with regard to each requirement. For an example if we consider the first customer requirement which is the Design, this was included in our survey. All the customers that were involved in the survey were asked to give a grading about this factor (A grading from 1-5). After that all the 20 surveys were summed up and the average importance factor was obtained for each factor. The factors that were obtained are shown in Fig. 5.

The next step was to run the competitive analysis. This was done again by the help of customers (hospital staff). The analysis was done by comparing the conceptual model together with the model which was available in the hospital. Questions were asked orally from the hospital staff to compare our conceptual model along with the existing model in the hospital and were asked to grade both the products. After interview process, an average value for each customer requirement was tabulated by taking the average and the two models were compared.

Fig. 6 depicts the competitive analysis of the table along with the existing table in the hospital. According to the customers, the conceptual model was ahead of the existing table in most of the aspects except or a few. Grading's that were tabulated for the table are depicted in squares while the hospital table is shown using triangles.

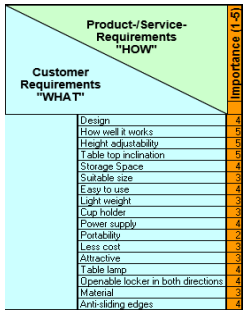


Fig. 5: Customer requirements.

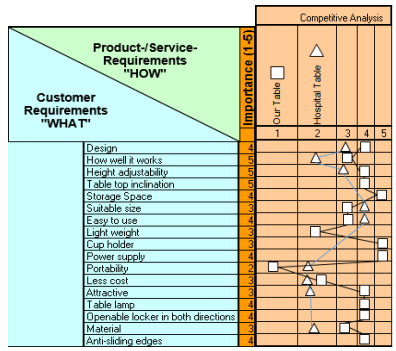


Fig. 6: Competitive analysis.

After executing the competitive analysis, technical requirements were taken into consideration. These requirements are also known as the supplier responses. This was mainly due to the reason that in order to build a product of high quality, there should be a proper understanding as to what sort of

relationship exist in between technical requirements and customer requirements. These technical requirements were the most important factors that were needed to consider when coming up with the final design. Basic requirements of the model were multi-functionality, safe when using, stability, convenient for the user, ergonomic, strength, durability and reliability.

Fig. 7: Technical requirements.

Fig. 7 clearly explains the technical requirements that were considered in the quality function deployment. Next step was to identify the relationship between the customer requirements and technical requirements. This was done by using the technique of relationship matrix. Both customer and technical requirements were analyzed and three values were given for the existing relationships between them. The relationship matrix was very important since it provided us with the necessary information in order to calculate the final absolute importance.

The Fig. 8 shows the relationship matrix that was produced for the over bed table. Different symbols were assigned with different values. For an example the black color circle mentions that there exist a high relationship between that particular customer requirement and the technical requirement. Likewise all the possible relationships between the customer requirements and the technical requirements were identified. The next step was to analyze the direction of improvement of the QFD house as shown in Fig. 9. For an example it's always better to reduce the weight of the product you produce so that the customer can handle it easily. So likewise this enables you to identify as to which of the requirements should be increased and which should be reduced. The main idea of this is to somehow make sure that we finally work towards the direction of improvement of each factor so that it helps the product to be of a better quality at the end.

After that the roof of house of quality (Fig. 10) was drawn in order to identify the positive and negative correlations of the technical requirements. This particular section in the QFD is where the term House of Quality comes from since it makes the QFD look like a house with a roof. Though the correlation matrix consumes a very small amount of space in the House of Quality, this roof does a great help to the design engineers in the next phase of a comprehensive QFD project. A basic analysis was done as to how each of the technical requirements affects each other, whether in a positive manner or a negative manner. The main idea of coming up with the roof is to identify the negative correlations between technical requirements and work to eliminate those physical contradictions.

Next step was to benchmark (Fig. 11) our conceptual model with the existing table in the hospital. After doing the benchmarking, we were able to identify that our product was ahead of the existing table in many ways. Next step was to identify the goals (Fig. 12) of the table with respect to the technical requirements of our product.

Final step was to tabulate the absolute importance for each of the factors. This was done by multiplying the values of the relationship matrix columns by the importance factor and summing it up for each technical requirement. By doing this we were able to identify the most import requirements for the customer and therefore we were able to give the priority to the most important factors so that we could come up with a high-quality product.

Virtual Ergonomics Models and Analysis:

In designing the over bed table anthropometric measurements of Thai population was considered. Using anthropometric data [5] of Thai males and female's dimensions as shown in Tab. 1 was calculated. Different sizes in anthropometry are described with the aid of percentiles. Fig. 14 shows the creation of Thai population using JACK SIEMENS with the data collected. After crating a visual human model, 95th percentile of Thai male and 5th percentile of Thai females was selected in order to analyses for ergonomic factors. After importing the solid works model of the over bed table to the JACK SIEMENS, virtual Thai human was placed and analyzed for ergonomic factors. After making the adjustments forcers was analyzed for bed ridden and seating position for Thai Virtual model using following analysis tools (ForceSolver, Ovako working posture analysis (OWAS) and
Lower back analysis). ForceSolver offers powerful alternative to the traditional method of conducting a static strength or low back assessment. In addition to considering posture, We can define task parameters, such as support forces and standing strategy, in order to predict the maximum acceptable force that a human can exert and also hand forces can be analyzed by assigning positions. This analysis was conducted to 95th Percentile of Thai Male Population for bedridden position and 5th Percentile of Thai Female Population for bedridden position (Fig. 15).

Lower back analysis uses a complex biomechanical low back model to evaluate the spinal forces that act on the lower back under an unlimited number of posture and loading conditions. This analysis was conducted to 95th Percentile of Thai Male Population for bedridden position and 5th Percentile of Thai Female Population for bedridden position (Fig. 16). Ovako working posture analysis (OWAS) evaluates the relative discomfort of a work posture based on the positions and load requirements of the back, arms and legs. OWAS helps determine the urgency of taking corrective measures. This analysis was conducted to 95th Percentile of Thai Male Population for bedridden position and 5th Percentile of Thai Female Population for bedridden position (Fig. 17).

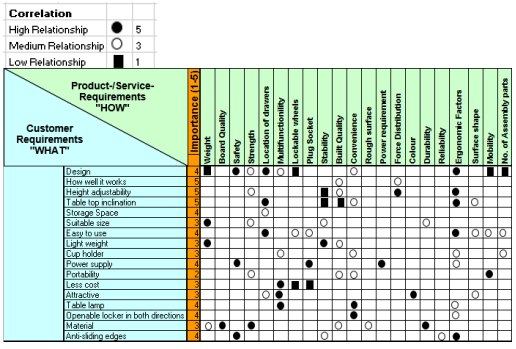


Fig. 8: Relationship matrix.

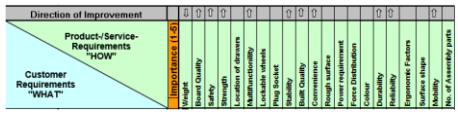


Fig. 9: Direction of improvement.

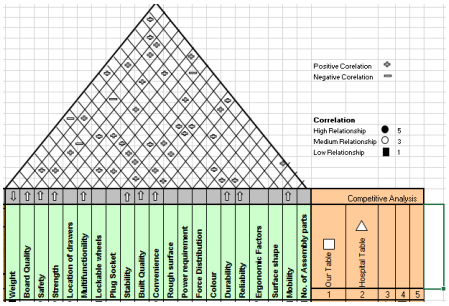


Fig. 10: Roof.

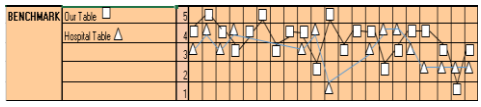


Fig. 11: Benchmarking.

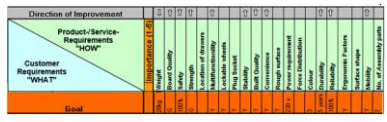


Fig. 12: Goal.

Conclusions:

A methodology has been implemented for ergonomics product development of over bed table for bedridden patients. A prototype was manufactured using the recommendations of QFD and ergonomics considerations using CAD Models and Jack SIEMENS® Ergonomics software. Anthropometric data of southern Thai population was considered since our goal was to produce this table suit to this population. After finalizing the dimensions, ergonomic factors were taken into consideration in order to make sure that the product was ergonomic and safe to be used by any customer. A prototype was made using iron bars and analyses. This was done in order to make sure that final design will not have any errors when tilting, locating the drawer and so on.

Ergonomic Analysis proved that there are no any long-term injuries to the lower back or wrist by using this table. It was proved that using this table is totally safe for any person even with a disability. Ergonomics is an important aspect which should not be neglected when designing a product and from this research study we understood that un-ergonomic product can lead the user to various types of injuries with the long-term use.

Anthropometric factor	**Dimensions (cm)**
Ground to drawer height	
-Maximum	97.5
-Minimum	60
Knee height	43.96
Popliteal height	36.66
Thigh height	7.3
Standing elbow height of 1st percentile Thai female	90.63
Hip height of 1st percentile Thai female	69.76
Hip to shoulder height 1st percentile (Thai female)	20.87
minimum height from ground to table top when tilted	72
The angle of inclination after considering the best ergonomic factors	15degrees
Forward grip reach 1st percentile (Thai female)	62.91
Table max grip reach	35.56

Tab. 1: Calculated dimensions of the over bed table.

Fig. 13: A Skeleton of new design.

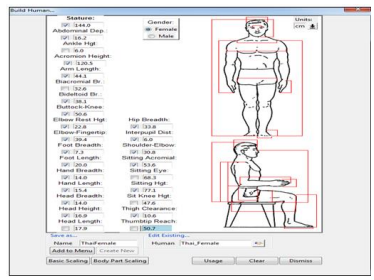


Fig. 14: Thai Population.

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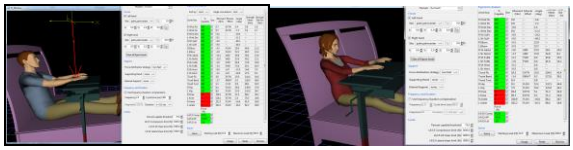

Fig. 15: ForceSolver analysis.

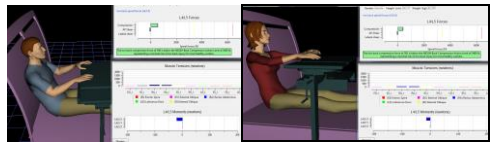

Fig. 16: Lower back analysis.

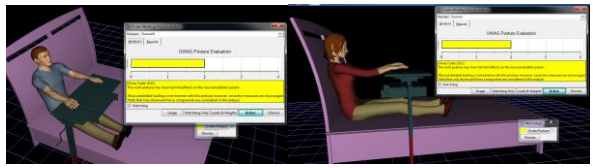

Fig. 17: Ovako Working Posture Analysis.