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RESEARCH ARTICLE

Concept development and rula analyis of a virtual prototype wheelchair for physically challenged persons

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ABSTRACT

A wheelchair is one of the common internal locomotive vehicles used by handicap or sick people who are limited in their functions, such as it needs human force to move it and carry the person from a bed to a wheelchair. This study aims to design and develop a wheel chair using concept generation, concept design, and selection of a concept using different selection methods. Various designs of different parts in a wheelchair have been generated and suitable designs are combined to generate concepts. The Pugh chart and weighted decision matrix have been used to select the best concept based on the criteria. The selected concept has been modeled and analyzed using CATIA RULA module. Human comfort has been analyzed using RULA analysis. It was identified that current virtual prototype developed is safe and comfortable for the caretaker and patient.

Keywords: Conceptual design, Morphological chart, Pugh chart, RULA analysis

1. INTRODUCTION

Product development focuses on current and market opportunities by evolving customer requirements. The process model is the central component of the product model. The product development has different phases.

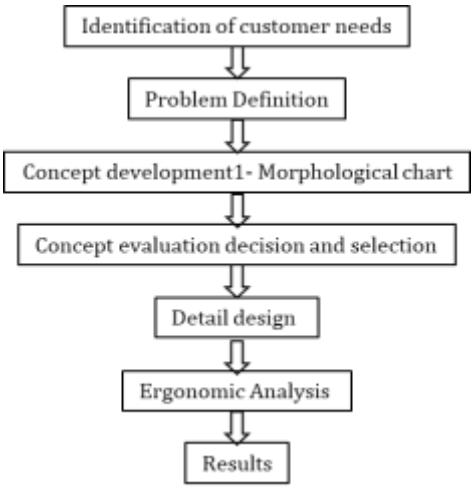

Figure 1. Detailed methodology

The first phase identification of customer needs truly indicates the customer problems; it can be identified in several ways like conducting focus group, survey. Focus group is a method employed to identify the needs of selective number of physically challenged person's. A group of ten physically challenged persons and their responses to the facilitator questions on the proposed problem is recorded. The next phase is problem definition; the detailed statement of the problem is developed. The concept development is used to generate a concept for the problem and the concepts were evaluated using a Pugh chart and weighted decision matrix. The final concept is generated based on the score. Detailed design and virtual prototype development for RULA analysis is proposed for caretaker and patient safety. Jyoti Pragyan Satpathy [1] analyzed and developed a prototype of a motorized wheelchair based on market survey, customer requirements. The project starts with initial research, literature review, and background study. The next phase is concept generation with outlining specifications and a rough sketch. The next phase is design, modeled by using CATIA. The fourth phase is the detailed design phase and the final phase is prototyping and tests the model. Arunachalam et al [2] identified a customer product like a bicycle and developed different concepts using the concept generation method and evaluated the concepts using Pugh chart and numerical scoring methods. Ashby method was selected for material selection. This study checked the human comfort like knee

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clearance, hand reach, foot reach of the bicycle, and FEA analysis under static and dynamic loading for safety. Sreerag et al [3] reported the various issues of mobility equipment and introduced a better design for helping disabled peoples. The wheelchair facilitated the patients and provides equipment for hospitals. Various research methods about hospital mobility aids and data have been collected. QFD was generated and the main priority was given to mechanism, safety, ergonomics, and functionality. Kedar Sukerkar [4] identified the issues faced by the manufacturers and researchers for the wheelchair. One of the major issues is cost versus accuracy. Smart wheelchair for all types of disability is still not available and it should have the ability to monitor the patient conditions. It can be easily used indoor, but for outdoors it needs supervision. Smart wheelchairs have a great scope in the field of robotics and sensors will lead to success. Anjeneyulu & Purushotham [5] understood the issues of disabled people and paid more attention. The stair climbing wheel can work in three modes: stair-climbing mode, powered wheelchair mode, and manual mode. The walking mechanism was first designed, as well as theoretical design and calculation was formulated for the structure and dimensions. The seat backrest adjustment and locking system were installed to make the product safer. Finally, stress analysis, material selection, and animation were made the wheelchair works in a different situation.

Rajasekar et al [6] designed a manually operated wheel chair that can travel on both plain terrains and staircases also. At the time of climbing, one wheel will be in contact with the ground and another wheel will be in contact with the stair. The cost of the stair climbing wheelchair and the normal wheel chair was high when compared to the designed wheel chair. Thus, can be best suited for middle class people. S Chatterjee and S Roy [7] developed a low cost mixed control wheel chair controlled by joystick or Voice. Mixed control wheelchair is presented for paralyzed and elderly people.MCW is the main control to provide appropriate actions. Sree Amrutha Valli Kuppa et al [8] proposed a wheel chair for specially disabled for daily usage. The joystick module, blue tooth module, voice control and android app knowledge helped the handicapped people perform the day to day activities unaccompanied by anyone.

2. PROBLEM DEFINITION

The literature survey showed that wheel chair design for the disabled person lifting from bed and moving to washroom is not addressed. The wheelchair is available in the market, which is limited in its function. The available wheelchair is not easily foldable, tough to remove the seats and backrest. A caretaker is needed to take the disabled people from bed to wheelchair. The disabled person couldn't use the wheelchair while moving to the washroom. This leads to the requirement of designing a product which is easily foldable, adjustable seat and backrest and also easily carry the disabled people from bed.

3. CONCEPTUAL DESIGN

Conceptual design is the early stage of the design phase and comes out with several concepts and it is immediately followed by the schematic design phase. It also involves an understanding of people's needs.

3.1. Concept Generation

The concept development phase moves into the concept generation. The main aim of this phase is to generate several concepts based on components used in Wheelchair.

The morphological chart is one of the tools used for concept generation. After the concept development, the component for each concept was selected. Different concepts have been generated from the morphological chart as shown in Figure 2.

The morphological charts are developed based on the below points.

1. For each component in the wheel chair a number of solutions is listed.

2. Repeat the same for all the components proposed to be used in the wheel chair.

3. Mark the solutions for each concept and draw the combinations.

Based on the above three steps, various concepts have been evolved from the morphological chart are shown in Figures 3 – 6.

Components	Datum	1	2	3	4
Seat	0	Square	Rectangle	Half round	Ellipsoidal
Wheel	0	Stair climbing wheel	Single wheel	6 wheels roller moving wheel	4 wheels roller moving wheel
Arm rest	0	"T" shape	"L" shape	"J" shape	"U" shape
Back rest	0	Square	Trapezoidal	Round	Ellipsoidal
Lock	0	Strap	Lifting type hook	Lifting type hook	Lifting type hook
Foot Rest	0	Foldable foot rest	Rectangular in shape	Rectangular in shape	Foldable foot rest
Back legs of wheelchair	0	"H" shape	"L" shape	"L" shape	Circular rod

Figure 2. Morphological chart

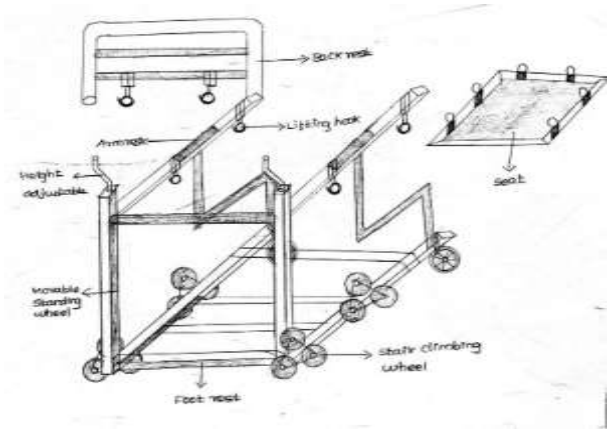

Figure 3. Concept 1 a2-b1-b2-c2-d1-e2-f3-g1

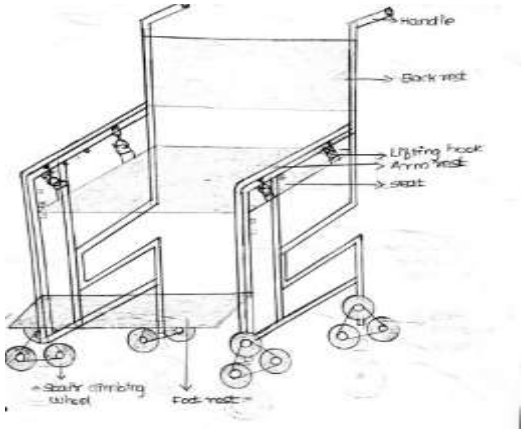

Figure 4. Concept 2 a2-b1-c2-d1-e2-f2-g1

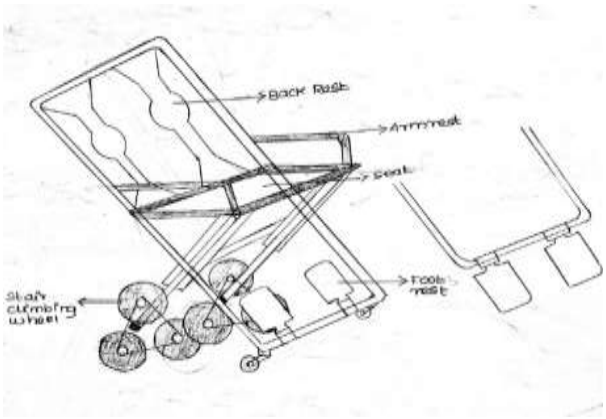

Figure 5. Concept 3 a2-b1-b2-c2-d1-e3-f1-g4

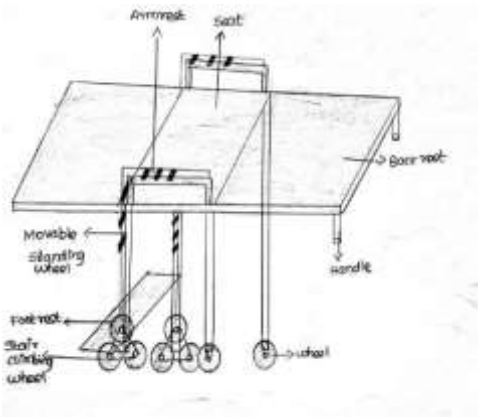

Figure 6. Concept 4 a2-b1-b2-c4-d1-e2-f2-g4

3.2 Concept Evaluation and Selection

The next step of conceptual design is concept evaluation. There are number of methods available to refine the concepts. The Pugh chart and weighted decision matrix are the two methods are used during concept selection. The first step of concept evaluation is to set a criteria's on which the concepts are selected.

3.2.1 Pugh chart

Table 1 shows Pugh chart for the product wheel chair. The criteria are formed based on the features of the product. The concepts are evaluated based on the symbols (-, 0, +) where '-' is worse than datum '0' is same as datum, '+'is better than datum. The criterion is performed better than datum than the concept assigned as '+' sign. If it's performed worse than datum then the concept assigned as'-' sign. If the performance of the criteria is same as the datum then assigned it as '0' sign. The net score for each concept is based on the sign and it decides the concepts going to next level.

Table 1. Pugh concept selection chart

CRITERIA'S	DATUM	CONCEPT 1	CONCEPT2	CONCEPT 3	CONCEPT4
Ability to transfer handicap to bed	0	+	+	0	+
Easily fit to bed	0	+	+	0	+
Backrest adjustability	0	0	0	-	+
Safety handle handicap	0	+	+	0	0
Easy maintenance	0	-	-	+	0
Easy foldability	0	0	-	+	-
Easy use of lifting hooks	0	+	+	-	-
Ability to withstand the force in back legs	0	-	-	0	0
Customize seat design	0	0	0	-	-
Easy detaching of wheels	0	+	+	-	+

Sum +'s	0	5	5	2	4
Sum 0's	0	3	4	4	3
Sum –'s	0	2	3	4	3
Net score	0	3	2	-2	1

3.2.2 Weighted decision matrix

The weighted decision matrix assumes all criteria having the same importance. The weighted scale can be scaled in percentage and the score of each item on a scale is between 1 (poor) to 5 (very good). Finally add up all the weights for each concepts. The highest score was selected for further level. Table 2 shows the weighted decision matrix of wheel chair.

Table 2. Weighted decision matrix

CRITERIA'S	WEIGHTS	CONCEPT 1		CONCEPT 2	
		SCORE	TOTAL	SCORE	TOTAL
Ability to transfer handicap to bed	12%	5	0.6	5	0.6
Easily fit to bed	12%	5	0.6	4	0.48
Backrest adjustability	8%	4	0.32	3	0.24
Safety handle handicap	9%	4	0.36	3	0.27
Easy maintenance	6%	3	0.18	2	0.12
Easy foldability	8%	2	0.16	3	0.24
Easy use of lifting hooks	11%	4	0.44	3	0.33
Ability to withstand the force in back legs	12%	3	0.36	3	0.36
Customize seat design	10%	4	0.4	3	0.3
Easy detaching of wheels	12%	4	0.48	4	0.48
Total	**100%**		**3.9**		**3.42**

4. EMBODIMENT DESIGN

Embodiment design is a part of design process and it has various stages to carryout ideas. The stages are CAD model human comfort, check, two-handed chart. All the stages are mentioned below.

4.1 CAD model

Figure 7. RULA analysis

In CAD modeling, the each part of the product were modeled and assembled by using CATIA software

5. RULA ANALYSIS IN CATIA V5.

Rapid Upper Limb Assessment (RULA) is used to analyze the upper extremity ergonomic risk factors. The RULA checks the postural load and bio-mechanical requirements for the neck, trunk, and upper extremities. The RULA assessment sheet is a single page worksheet, used to assess the force, posture, and repetitions of work. In RULA worksheet, section A assesses arms, wrists and section B assess of the neck and trunk. The score for sections A & B is totaled to assess the risk of MSD. RULA analysis by mere observation, the results could slightly vary from person to person.

In Catia V5, the manikin posture is developed at sitting and standing posture .The caretaker is in a stand position and physically challenged in a seated position in the wheel chair. Sitting and standing posture of Manikin is selected by an option in the product. Indian Male Anthropometric dimensions of 5th, 50th, 95th Percentile are utilized in the analysis are shown in table 3.

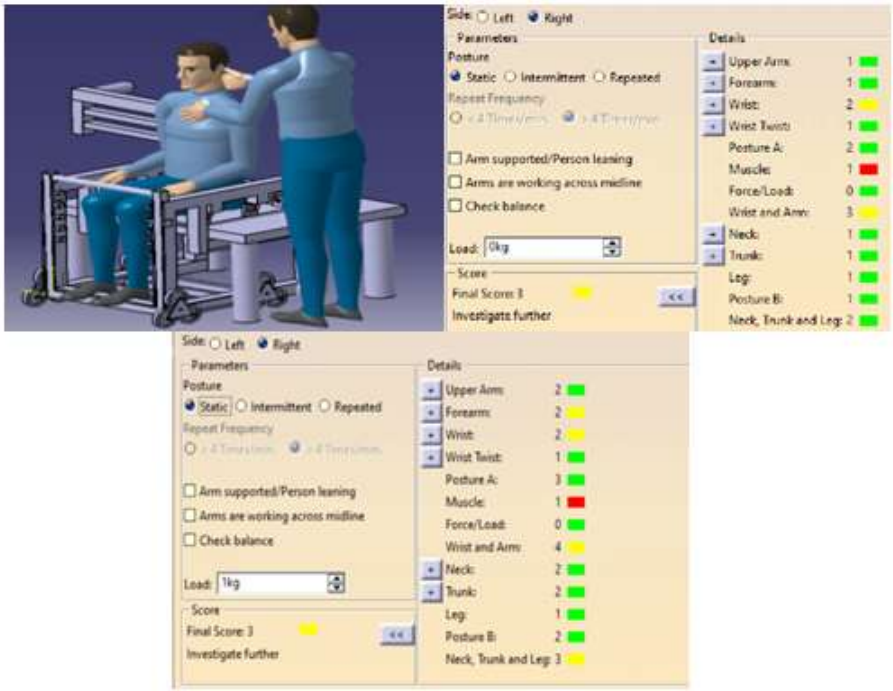

Figure 8. RULA analysis

Table 3. Percentile used

HUMAN COMFORT	INDIAN ANTHROPOMETRIC PERCENTILE USED
Care taker	5^{th}, 50^{th}, 95^{th} p
Handicap	5^{th}, 50^{th}, 95^{th} p

Table 4. RULA score

HUMAN COMFORT	INDIAN ANTHROPOMETRIC 95^{TH}PERCENTILE SCORE	INDIAN ANTHROPOMETRIC 95^{TH} PERCENTILE SCORE	INDIAN ANTHROPOMETRIC 95^{TH}PERCENTILE SCORE
Care taker	3	3	3
Handicap	3	3	3

As the product goes to the next step the RULA tool is used to check the human comfort like care taker and handicap position while using the product. RULA score for the care taker and Handicap are displayed in the table 4.The musculoskeletal disorder risk of 3 is found to be minimum and change of initial design is not required.

6. CONCLUSION

In this paper, a novel design of wheelchair for physically challenged person is discussed. Indian Anthropometric data for Care taker and Handicap for wheelchair using Human Digital Model is deduced. RULA Analysis is conducted to measure discomforts. The virtual prototype checked for caretaker and handicap posture risk indicated a minimum value of 3.It is found to be safe for the caretaker and handicap.

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Conflict of Interest

Author has no conflict of interest.

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