

# Applying of a design methodology for a new mobility product

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**Abstract.** Product innovation involves an understanding of technology through the introduction of a product that is new or has significantly improved characteristics and intended uses with the purpose of upgrading or even changing, in this case, the mobility landscape. Although product development is creative in upgrading components, the implementation requires a systematic approach to guide the processes that must be taken into account and applied to achieve the implementation of a new product to market. To be successful it is important that the needs, preferences and limitations, be taken into consideration. In this paper, an optimized methodology for developing a new product is proposed starting from the existing ones. By investigating the current concepts of solutions to improve the ability to move physically, it is attempted to propose a typology to address the mobility problem. On a basic manual wheelchair, a system will be attached to ensure overcoming the obstacles and to guarantee the ability to negotiate effectively.

## 1 Introduction

The wheelchair has become today indispensable for people experiencing various locomotor disabilities. Fortunately, technological progress has managed to significantly improve the life of people with mobility issues, giving them freedom of movement increasingly higher. The widespread use of various types of wheelchairs is currently known including holding eye-level discussions with people by balancing on two wheels, going up and down steep ramps, traversing outdoor surfaces, climbing curbs and stairs. However, there are still limitations for indoor purposes due to small and confined spaces. There are many studies conducted in areas related to climbing mechanisms and hence, a number of stair climbing mechanisms have been developed for wheelchairs.

Quaglia [1] analyzed aspects of developing a wheelchair for climbing stairs, which can move in various environments that can go over obstacles. The framework consists of a chassis built with two motorized units, support for two electric motors, two wheels and a battery triple. The seat has a tubular structure consisting of a frame and a pivoting wheel. Linkage mechanism is responsible for the relative movement between the frame and the seat during operation and is driven by a motor connected to a lead screw mechanism.

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Lawn [2] proposed a mechanism that is based on the use of four wheels, where the rear wheels are driven independently and the front wheels are free wheel. Also the influence of external factors was evaluated by analyzing the recent advances in mobility assistive devices available for obstacles.

Yuan and Hirose [3] proposed a product with two pairs of parallel wheels that are used to perform stair-climbing motion, with the tire diameter smaller compared to the step height.

Suryawanshi [4] proposes a conceptual design of a transfer mechanism in a wheelchair that assists the disabled person to move easily onto the bed and back again.

Yoneda [5] proposed a deformable track considering the fundamental track based problem, respectively that of the high pressure exerted on the stair edges. The vehicle can easily climb stairs by using two active arms positioned front. A wheelchair with pure leg locomotion has a high climbing capability, but it requires a complex structure for both the control and actuation systems [6].

The stability is a critical aspect when a mobility product is developed, and in this case the seat oscillates due to leg movement during both stair-climbing and flat ground motion, thus causing an unpleasant sensation for the user.

## 2 Design process

A design process applies to systems, assemblies and components and is used for new or innovative products and for making changes to existing products. Even if a product is developed or just modified, there are stages that need to be covered for all projects [7, 8].

Wheelchair users are confronted with the problem of limited mobility because the design of wheelchairs is not sufficiently addressed by changing the use environments.

Ease of handling is essential for the users with mobility issues, disabled or elderly and will be the important point for acceptability.

The aspect of maximizing autonomy will be a motivation behind this mechanism, which reduces the need to rely on external assistance or special equipment.

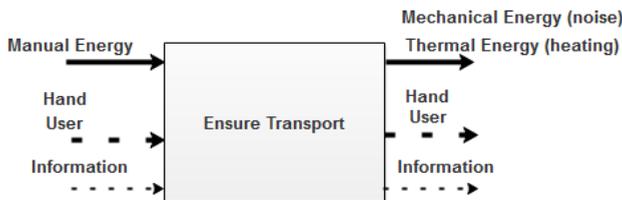
The next goal is to achieve a mechanism that does not exceed the physical dimensions of the existing technology. This is achieved in a basic design, but some dimensions of the prototype may be due to the use of mechanical components that are not available on an appropriate scale.

Other objective is a design based on the use of relatively low components. The aspect of maximizing the operating range is inherently related to the weight of the equipment, and the addition of functionality, increasing the charging of the power supply which also reduces the operating range compared to a standard motor.

## 3 Design methodology

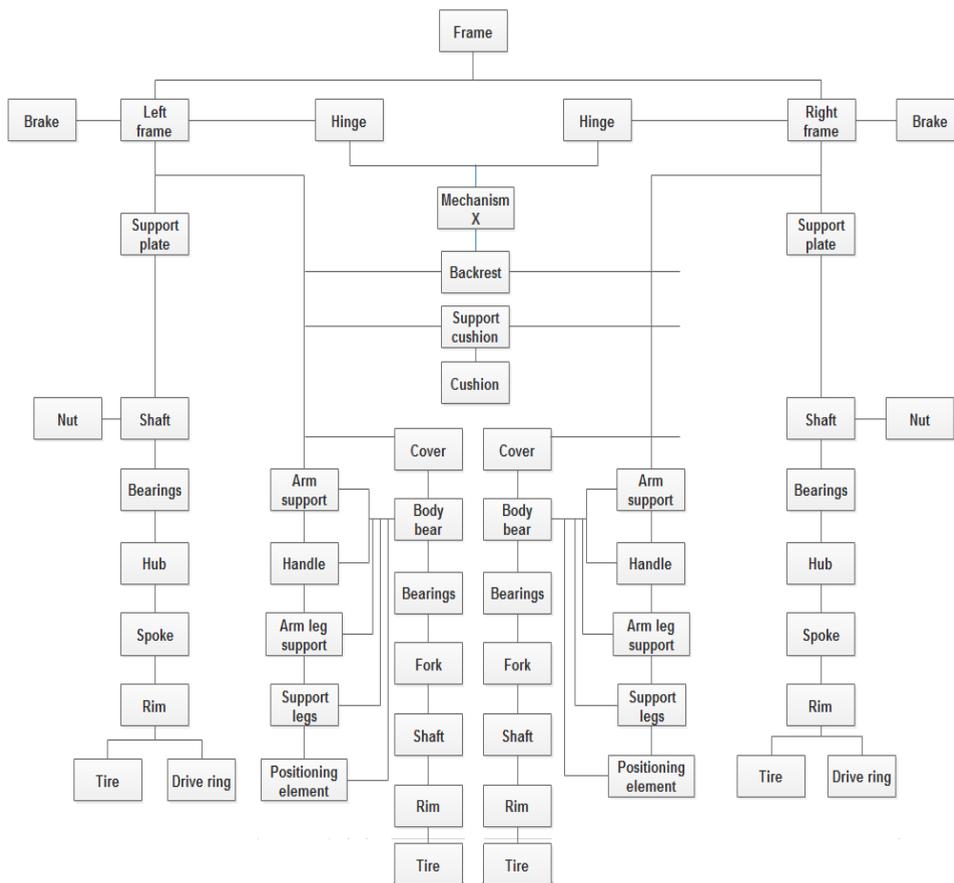
In engineering design, all products have some rightful reason behind their existence: the product functions [9, 10]. A very important early stage in the design process is the conceptual design stage, during which an initial design solution to the design problem is devised to fulfill the required functions [9].

A technical system can be originally modeled as a "black box" with inputs of energy, material, signal and system outputs. The technical system therefore presupposes a functional relationship between inputs and outputs and the black box is the wheelchair's overall function, shown in the following Figure 1.



**Fig. 1.** Black box of the product.

Using physical decomposition as in Figure 2, the product can be decomposed into subassemblies, components, and then the product structure is developed.



**Fig. 2.** Physical decomposition of the wheelchair.

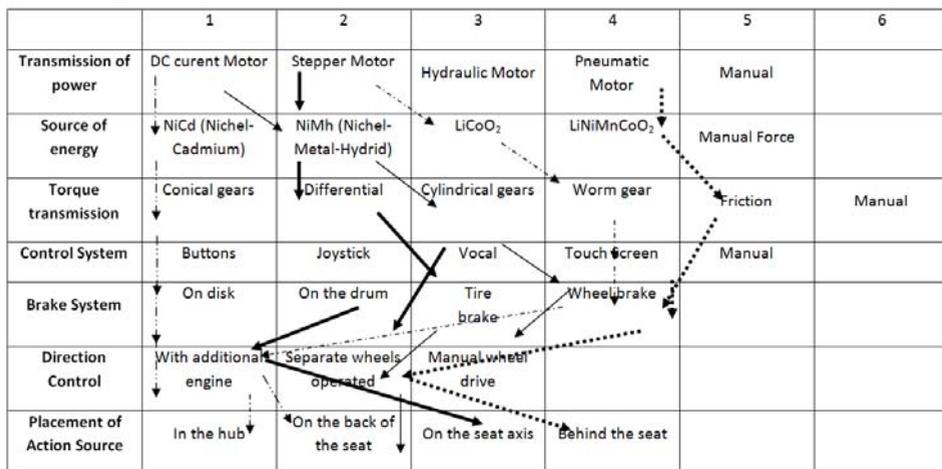
Functional decomposition finds critical product features and attributes that describe functions with input and output flows defined as material, information, and energy.

The structured method for decomposing the functions of a product is hierarchized as follows and presented in the following Table 1, [11]: identifies the components of the product and their functions; describes the interaction between component functions; clarifies the best solution to meet the customer's need by describing the function of the product or component, uses functional descriptions for generating and selecting sets of technology components that meet basic functional requirements.

**Table 1.** Analysis of component – function.

Nr.	Component	Function	Observation
1.	Push handle	Allows a back-up aid to the seat	Extension of the top of the frame
2.	Back of the back	Supports the user's back	Suspension between the vertical components of the seat
3.	Support arms	Supports the arms	They can be rotated during the transfer without having to be removed
4.	Wheel rim	Ensures the surface on which the tire is mounted	It is connected to the spindle through the spoke
5.	Spokes	Connect the tire and the rim to the axle	Represents the suspension system
6.	Hub	Connect spoke and rim	The central component of the wheel
7.	Unlocking Axis	Allows the wheel to disconnect quickly and easily from the frame	-
8.	Plate	Connect the wheel to the frame via the spindle	It is adjustable and allows to extend the wheel base
9.	Seat frame	Supports seat and wheels	Increases the stability of the wheelchair or reduces travel time
10.	Brakes	Allow the wheels to be locked, preventing unwanted movement	Rigid and tubular structure
11.	Framework	-	Extends from frame to wheel and uses a locking system
12.	Lock lever	Ensures the legs during transfer	-
13.	Cover of the casing	Protects the bearings	It is located so that it is easily accessible
14.	Casting plate	Connect the tubular casing to the tubular frame	Allows lubrication of bearings inside the casing
15.	Housing	Increases the maneuverability of the seat	-
16.	Cushion	Allows the dispersion and absorption of the force between the user's body and the settlement surface	Fixed on a tubular extension of the frame
17.	Pillow holder	Allows the seat to gather	It contains ball bearings and forms a swivel joint that can rotate 360 degrees
18.	Hinge X	Ensures expansion from the frame to the cross members of a foldable frame	-

Decomposition of the problem allows finding technical solutions for complex design problems by taking into account simpler subproblems. Design can focus on critical subproblems, others are postponed. The main function of the wheelchair, to transport the user, was divided into five primary subfunctions: facilitates movement, ensures energy, supports user, changes direction, provides support. These functions were then further divided until the description was detailed enough to describe a specific mechanism as shown in Figure 3.

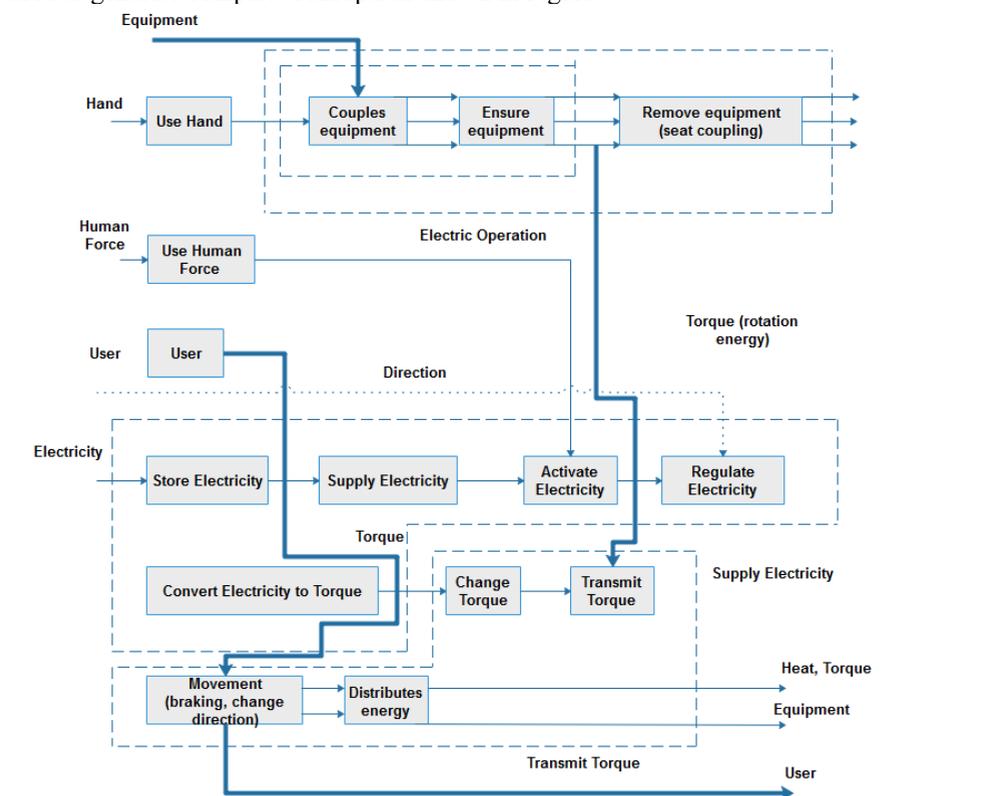


**Fig. 3.** Morphological Chart of the system.

Once the morphological chart has been developed, it is possible to combine individual solutions into effective conceptual projects [12]. This methodology is not a substitute for

creative thinking, but a structured means for developing and documenting design alternatives. The concept selection process is done using the Pugh method [11, 13] where the concepts were narrow down first by concept screening and then by concept scoring. After the best concept is selected, the detailed design and specifications will be defined. The highest score involves the use of the following components, DC motor, LiCoO<sub>2</sub> battery, worm gear, joystick, additional steering control behind the seat, normal wheels, has been adopted.

The functions from the last branch of the diagram were then incorporated into a morphological chart used to brainstorm possible corresponding mechanisms. The morphological chart is organized according to the results of the FAST diagram and was used to generate complete concepts as shown in Figure 4.



**Fig. 4.** Functional Analysis System Technique.

After determining the required functions, methods were brainstormed that could be used to perform each. The functions which primarily describes the structural components of the chair, resulted in numerous solutions. To generate a complete design, one concept from each subfunction category was selected.

## 4 Conclusions

The methodologies used in product development are set to evolve with the maturity in process model. In a methodology for developing a new product, it is essential to have a design procedure where all the activities and stages must be crossed with the purpose to find the best solutions. To ensure the developing of better products, structured and more agile methodologies are needed because of the accelerating appearance of new technologies

and the change and increase of customer demands that create a faster moving framework of product development.

The proposed approach towards an adaptive methodology allows a more dynamic and detailed adaptation to the development context. To allow this break down of the product development methodology, the product is decomposed into modules. The new attachment system proposed will be designed to provide the possibility for a wheelchair user to have a cheap product without permanently altering the existing product, will provide the ability for a wheelchair user to negotiate effectively the interior and exterior, will be able to increase the maneuverability required in the presence of obstacles and provide a sufficient suspension to absorb the shock. The wheelchair user can attach and detach independently the power attachment.

Further work consists in the fact the product will be designed considering the chosen concept and detailed specifications and then tested in a real environment.

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