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Design of an electric vehicle for people with handicap

Diseño de un vehículo eléctrico para personas con discapacidad motora

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Abstract

This article deals with the development of the detailed conceptual design of an electric vehicle, with the main objective of facilitating the transfer of people with mobility problems, and this avoid dependence on someone else to help them move safely; This is aimed at meeting the needs of a growing population with Handicap. An alternative solution is proposed for the transfer-based design methodology, which addresses each of the established requirements. The result of this work, after having evaluated the technical and financial analysis, is an alternative for the functional design of the electric vehicle, which will be used in the facilities of the Polytechnic University of Guanajuato (UPGTO) facilitating the mobility of people who require.

Conceptual, Mobility, Methodology

Resumen

Este artículo trata sobre el desarrollo del diseño conceptual detallado de un vehículo eléctrico, con el objetivo principal de facilitar el traslado de personas con problemas de movilidad, y con esto evitar la dependencia de otra persona para ayudarlas a moverse con seguridad; esto tiene como objetivo satisfacer las necesidades de una creciente población con discapacidades. Se propone una solución alternativa para la metodología de diseño por transferencia, que aborda cada uno de los requisitos establecidos. El resultado de este trabajo, luego de haber evaluado el análisis técnico y financiero, es una alternativa para el diseño funcional del vehículo eléctrico, que será utilizada en las instalaciones de la Universidad Politécnica de Guanajuato (UPGTO) facilitando la movilidad de las personas que lo requieran.

Conceptual, Movilidad, Metodología

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Introduction

Currently, electric vehicles are a very good alternative to address different problems due to the advantages they provide. In the case of the Polytechnic University of Guanajuato (UPG), with its own development proposal for an electric vehicle as shown in Figure 1 and 2, is to provide a mobility option between the facilities for people with some kind of disability, since it is worth mentioning that the routes could be significantly larger as shown in Figure 3 and Table 1. Another important objective is to promote internal work with students and teachers for the development of the electric vehicle proposal.

Figure 1 Rendering of the proposed electric vehicle near the main entrance of the Polytechnic University of Guanajuato
Own Authorship

Figure 2 Rendering of the proposed electric vehicle near the LT3 laboratories of the Polytechnic University of Guanajuato
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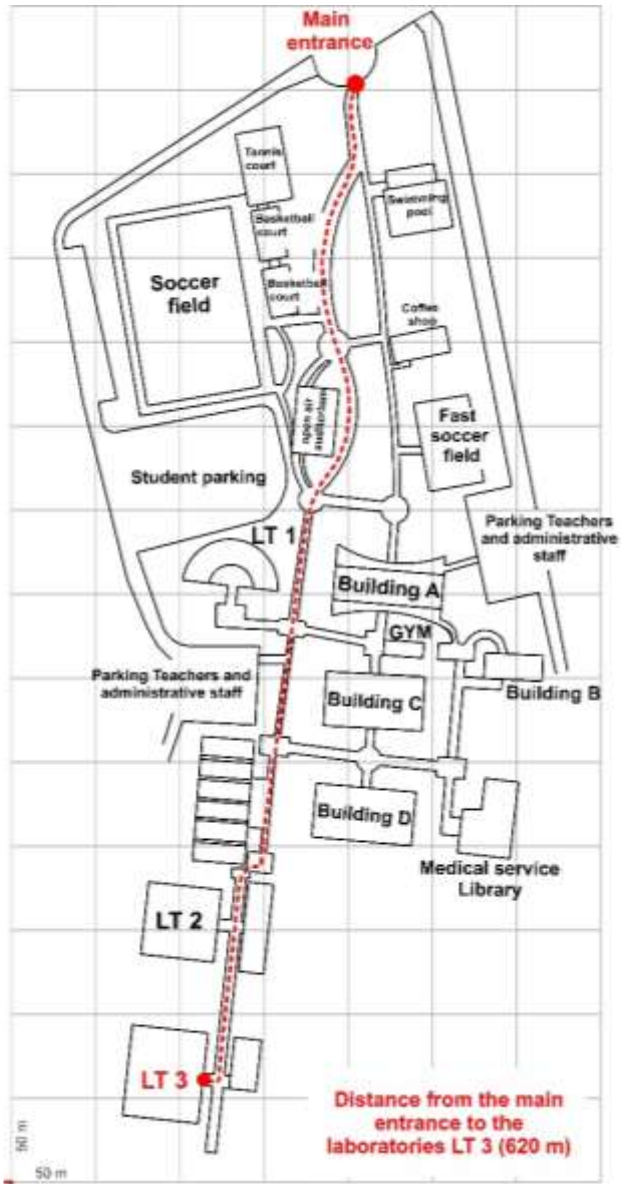

Figure 3 Layout of the Polytechnic University of Guanajuato with example of longer route
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	Origin	Destination	Approximate distance (meters)
1	Main entrance	Laboratories LT3	620
2	Main entrance	Laboratories LT2	530
3	Main entrance	Laboratories LT1	410
4	Main entrance	Medical service/library	560
5	Main entrance	Educational building D	480
6	Main entrance	Educational building C	480
7	Main entrance	Educational building A	410
8	LT3 Laboratories	Medical service/library	360

Table 1 Examples of tours at the Polytechnic University of Guanajuato
Own Authorship

Electric vehicles use an electric motor for traction and chemical batteries, fuel cells, ultracapacitors and/or flywheels for their corresponding power sources. The electric vehicle (EV) has many advantages over the conventional internal combustion engine vehicle, such as no emissions, high efficiency, oil independence, and quiet and smooth operation. The modern EV is specially designed, based on original body and frame designs. This meets the unique structural requirements of electric vehicles and makes use of the increased flexibility of electric propulsion. The modern electric powertrain is conceptually illustrated in Figure 4.

The powertrain consists of three main subsystems: electric motor drive, power supply and auxiliary. The electric drive subsystem consists of the vehicle controller, electronic power converter, electric motor, mechanical transmission, and drive wheels. The power supply subsystem includes the power source, power management unit and power replenishment unit. The auxiliary subsystem consists of the power steering unit, the heating system control unit and the auxiliary supply unit. Based on control inputs from the accelerator and brake pedals, the vehicle controller provides appropriate control signals to the electronic power converter, which functions to regulate the power flow between the electric motor and the power source [1].

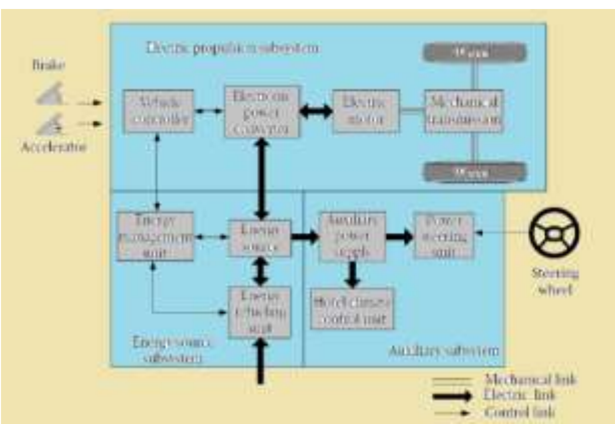

Figure 4 General configuration of an electric vehicle. Ehsani et. al, 2010, p. 106.

The driving performance of a vehicle is generally evaluated by its acceleration time, top speed, and ability to climb inclined planes. In electric vehicle powertrain design, the motor power rating and appropriate driving parameters are the main considerations to meet the performance specification.

The design of all these parameters mainly depends on the speed-power characteristics of the traction motor [1]. In 2014, there were approximately 120 million inhabitants in Mexico, 61.5 are women and 58.5 are men, based on the results of the National Survey of Demographic Dynamics 2014 (ENADID). Of every 10 residents in the country, 5 are under 30 years old, 4 are between 30 and 59 and 1 is 60 years old or older. Among those under 30, the proportion of men is slightly higher than that of women, although the country's population pyramid shows that, starting at age 20, the proportion of the female population exceeds the male population. The prevalence of disability in Mexico for 2014 is 6%, according to data from ENADID 2014.

This means that 7.1 million inhabitants of the country are unable or have great difficulty performing any of the eight activities evaluated: walking, climbing or climbing down with legs; seeing (even if wearing glasses); moving or using their arms or hands; learning, remembering or concentrating; hearing (even if using hearing aids); bathing, dressing or eating; speaking or communicating; and emotional or mental problems.

And it is these people who face multiple obstacles (WHO, 2014) to enjoy "all the rights established by the Mexican legal system, without distinction of ethnicity, nationality, gender, age, social, economic or health status, religion, opinions. marital status, sexual preferences, pregnancy, political identity, language, migratory status or any other characteristic of the human condition or that undermines their dignity" (DOF, 2011: 2) [2].

To meet the needs of the population with disabilities, there are different vehicle designs in the market that are generally customized designs and are expensive; on the other hand, modifications have also been made in public transportation and even in private vehicles to facilitate access, ascent and descent, such as the implementation of ramps. In some way, these modifications contribute a considerable percentage in favor of the quality of life of people with disabilities. Based on the above, speaking of the lack of functional, economical and accessible means of transportation for this sector of the population, it is especially important to consider the needs of these people to design an electric vehicle that can cover all their needs.

As is the purpose of the proposal that the authors present in this article to create this functional, economical and adapted to the needs of people with disabilities vehicle. To achieve this, engineering design methodologies and CAD platforms are used. The main objective is the development of a virtual prototype of an electric vehicle to be used in the facilities of the Polytechnic University of Guanajuato (UPGTO), consisting of the following stages: conceptual design and CAD / CAM / CAE analysis.

Development of electric vehicle

Adequate transportation facilities, as well as spaces designed for people with disabilities are currently quite limited, this is mainly due to the cost of investment required to carry them out. According to INEGI studies, people with disabilities have low income in terms of labor activity [2]. Therefore, the methodology for the development of an electric vehicle is proposed, starting from the conceptual design based on the descriptive engineering method as the first stage, which describes the process from the identification of transportation needs in people with disabilities. In this area, the objective of this work is to design, through the engineering method, an electric vehicle, manually operated for the transportation of people with disabilities on their own.

Scientific methodology and stages of the project

The development of the electric vehicle design was based on the methodology of Pahl & Beitz [3] (see Figure 5), which is based on the type of descriptive methods and design processes.

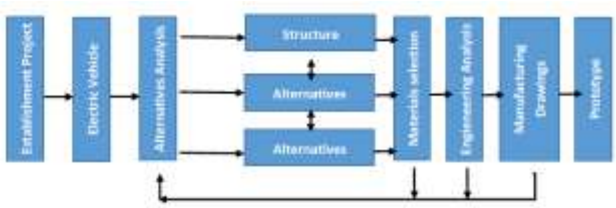

Figure 5 Descriptive design methodology
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The diagram shows the joint function of the design methods with the methodology used (see figure 6).

Where a main problem can be divided into secondary problems to generate secondary solutions and combine them in the main solution.

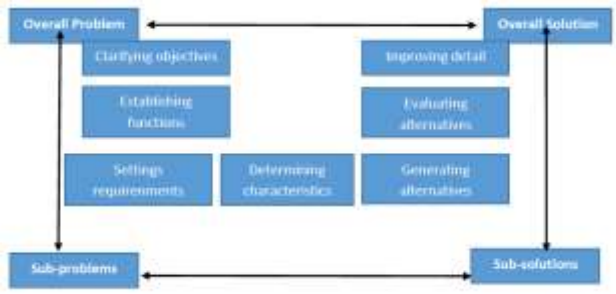

Figure 6 Integration methods
Source: Adapted from "Design methods. Strategies for product design", (Cross, N.,2010), p. 56.

Method: objective tree

The objective tree method offers a useful and complete format to address the problem, this method shows the general objectives and the means to achieve them. The following diagram (see figure 7) shows the different objectives of electric vehicle design related to the hierarchical pattern.

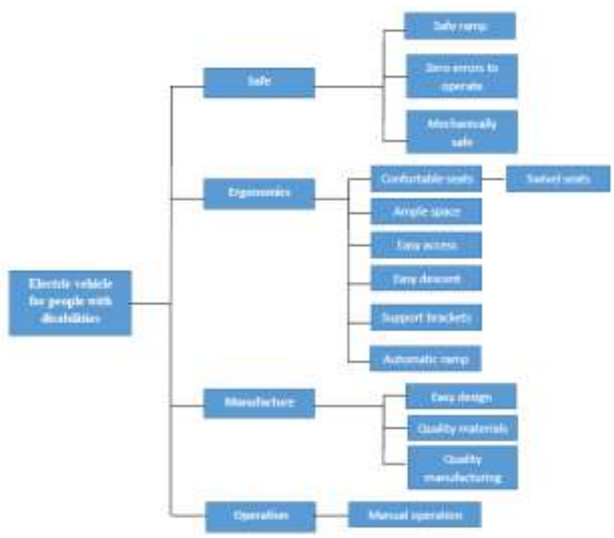

Figure 7 Objectives Tree Method
Source: Adapted from "Design methods. Strategies for product design", (Cross, N., 2010), p. 68.

Analysis functions

The function of the analysis method provides the means to consider the essential tasks and the level at which the problem should be addressed. The following diagram (see Figure 8) shows the essential functions that must be fulfilled by the product design, regardless of the physical components that may be used. The level of the problem was decided by setting boundaries around a consistent subset of functions.

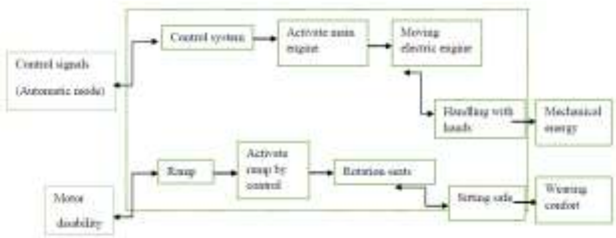

Figure 8 Functional analysis (transparent box)
Source: Adapted from "Design methods. Strategies for product design", (Cross, N., 2010), p. 82

Requirement sheets

Generally, design problems are always set within certain limits according to certain requirements. Some of the most important product, machinery and device limits are cost, size or weight of a machine, performance, legal or safety requirements, among others. The purpose of the method for establishing design requirements is to make an accurate specification of the performance required in a design solution. Table 2 shows the requirements and collection specifications of the proposed electric vehicle.

Requirements	W o D
1. Ergonomics - Ample interior space. - Comfortable seats. - People must get into the car without assistance. - Support brackets.	 **W** **W** **D** **D**
2. Operability features - Automatic ramp. - Space for one person with a wheelchair. - Stability.	 **W** **W** **W**
3. Control system - Short response when the ramp is activated.	 **W**
4. Mode of operation - Manual	 **W**
5. Power generation - Electric motor.	 **D**
6. Power transmission - Electrical.	 **W**
8. Working conditions - Frequent use. - Reliability.	 **D** **W**
9. Weight - Maximum net weight 500 kg. - Load capacity 300 kg.	 **D** **W**
10. Dimensions - 1500 x 2600 x 1700	 **W**
11. Maintenance - Minimal. - Commercial parts.	 **D** **W**

Table 2 Requirement sheets
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Generation of alternatives: Brainstorming

The diagrams of the given proposals are made to reach a precise point about the scope of each of these evaluations. The three options (see figure 9) are constituted by an electric vehicle structure for people with disabilities, whose elements are configured in such a way that the proposals are: a) the first option shows a small vehicle with automatic ramp, rotation seats and ample interior space to facilitate access for people in wheelchairs; b) the second option is a jeep type van with rear compartment; and c) the third option, describes a vehicle with a rear ramp, a support in the canopy to facilitate access for people in wheelchairs.

Figure 9 Design of alternatives
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Technical and economic evaluation of proposals

The proposals are submitted to a technical and economic evaluation respectively (see tables 3 and 4). To make this possible, the different points of comparison, where each proposal is assigned a value (1 to 10), depending on how the proposal complies with the point in question, being 1 poor and 10 excellent indicator, likewise, the market study is assigned according to the scope of the project. This weighting is known as the influence factor, with 1 being important, 2 very important and 3 essential.

			Score (Pi)			
	Evaluation of alternatives	**Weighting (Wi)**	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Ideal option**
1	Operation	3	9	8	8	10
2	Manufacturing	3	9	7	8	10
3	Materials	2	8	7	8	10
4	Maintenance	2	8	7	7	10
5	Manufacturing	1	8	7	8	10
	TOTAL =Σ (Wi X Pi)		94	80	86	110
	Economic Coefficient = Total Score / Perfect Score		0.854545455	0.727272727	0.781818181	

Table 3 Economic Evaluation
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			Score (Pi)			
	Evaluation criteria	Weighting (Wi)	Alternative 1	Alternative 2	Alternative 3	Ideal option
1	Security	3	9	8	8	10
2	Easy maninobrability	2	9	6	7	10
3	Maintenance	2	8	8	8	10
4	Manufacturing	2	8	7	8	10
5	Ergonomics	2	8	7	8	10
6	Easy access	3	9	6	8	10
7	Ample space	2	9	7	7	10
8	Load capacity	3	9	8	8	10
9	Energy costs	1	8	7	8	10
10	Accessories	2	8	7	7	10
	TOTAL = Σ (Wi X Pi)		189	157	170	220
	Technical Coefficient = Total score /Perfect score		0.859090909	0.713636363	0.772727272	

Table 4 Technical evaluation
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The best choice is the one that, in addition to having the most appropriate technical and economic factors, must maintain a balance between both aspects. Therefore, the indicated project will be developed based on the first option as shown in the graph (see figure 10).

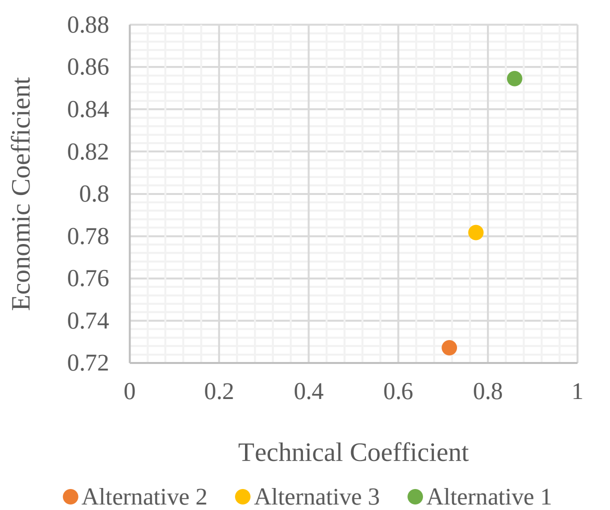

Figure 10 Economic-technical balance
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Results

This article describes the conceptual design of a new electric vehicle to be used by people with motor disabilities (see Figure 9). This development was mainly based on the stages of the engineering process and the engineering design method, such as tree objectives, requirements cards and specifications, functional structure, morphological matrix, conceptual alternatives, decision matrix, optimal design, drawings and manufacturing documentation.

The vehicle has the necessary elements to satisfy the technical and economic requirements of the project compared to the other alternatives. Based on the development of all the above methodologies, a final virtual prototype was obtained, using CAD tools, as shown in Figure 11. The prototype consists of an automatic ramp at the rear of the vehicle that helps people to enter the vehicle with the wheelchair, it also has a seat that can rotate and move forward and backward to facilitate seating and has a manual control to drive more easily also only with the hands.

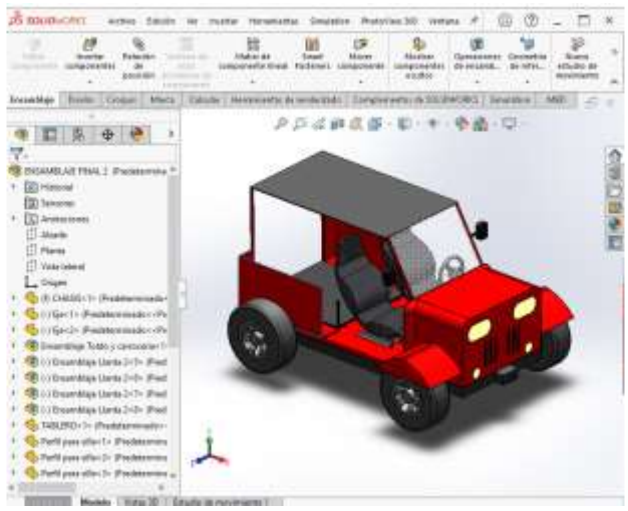

Figure 11 Result: Virtual prototype of the electric vehicle for people with disabilities
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Conclusions

The authors think that it is important to consider the design of this proposal because it will help a lot, that type of person who has motor disabilities, to be in different places without help from anyone. The developed process allowed to obtain a virtual prototype of an electric vehicle that has the requirements to fulfill the objective for which it was designed, as well as the proposed requirements were met.

It was decided to work on this type of vehicle because of the importance and impact it has on people with motor disabilities. As a next stage of the project, we intend to work on the development of a physical prototype that includes manufacturing and assembly, as well as optimizing the integration of the ramp to achieve the main objective and offer functional alternatives.

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