Development of a grip and support system for public transport

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Desarrollo de sistema de agarre y sujeción para transporte público

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INFORMACIÓN DEL ARTÍCULO

Historia del artículo:
Enviado: 04/03/2019
Recibido: 10/04/2019
Aceptado: 28/05/2019

Keywords:
Orthostatic Position
Public Transport Service
Support
Grip
Safety

Palabras clave:
Posición ortostática
Servicio de transporte público
Soporte
Agarre
Seguridad

ABSTRACT

It is given that in Bogotá public transport system moves approximately 29.18 % of the population, it is essential to ensure that the features of the service provision are the most appropriate for its users; for example, the support bars inside the vehicle are not at an adequate height according to the physical characteristics of the users, generating risks within the vehicles. Due to this failure has not been resolved in its entirety by the service provider is important to implement a method that allows adequate grip to the fasteners, considering this, the project aims to develop a system of grip and support that reduces the risks of physical damage to the user during his trip. This system will allow users who are in the orthostatic position (standing) to anchor themselves in a simple way of the elements incorporated in the vehicle. The development process was carried out using a combination of the Ulrich and Schnarch methodologies.

RESUMEN

Dado que el sistema de transporte público de Bogotá mueve aproximadamente al 29.18 % de la población, es esencial asegurar que las características de la prestación del servicio sean lo más apropiadas para sus usuarios; por ejemplo, las barras de sujeción dentro del vehículo no se encuentran a una altura adecuada de acuerdo con las características físicas de los usuarios, generando riesgos dentro de los vehículos. Debido a que esta falencia no ha sido solucionada en su totalidad por el proveedor del servicio es importante implementar un método que permita el agarre adecuado a los elementos de sujeción, considerando esto, el proyecto tiene como objetivo desarrollar un sistema de agarre y soporte que reduzca los riesgos de daño físico para el usuario durante su viaje. Este sistema permitirá a los usuarios que se encuentren en posición ortostática (de pie) anclarse ellos mismos de una manera simple de los elementos incorporados en el vehículo. El proceso de desarrollo se realizó empleando una combinación de las metodologías de Ulrich y Schnarch.

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Citar este artículo como: J. C. Conto-Campis, J. M. Ortiz-Guzmán, I. A. Castiblanco-Jiménez and J. E. Ortiz-Guzmán, "Development of a grip and support system for public transport", Visión electrónica, algo más que un estado sólido, vol. 13, no. 2, p.p. 247-253 july-december 2019, https://doi.org/10.14483/22484728.15159

1. Introduction

Public transport has become an index of progress and modernity in cities, since development, not only on a large scale, but also an effective planning of this service, can be the difference between a modern city and a developing city. Such is the importance of this type of transport that even international organizations such as the World Health Organization (WHO) have addressed this issue and everything that surrounds it in order to ensure that this service is appropriate. This organization published a global report, the first major report on this issue jointly published by the WHO and the World Bank, which also highlights the concern of both agencies about the fact that unsafe transit systems are seriously damaging public health and global development, [1].

In general terms, these services in developing countries are considered from a different approach to the global one. Since according to [2], the approaches and establishments of these public service systems in underdeveloped countries showed different characteristics and standards due to the marked differences in implementation. This fact is confirmed by the social, political, and economic characteristics of these countries. Considering the accelerated growth that these means of transport have had in the countries, within this classification and despite existing certain standard parameters in the provision of the service related to travel time, it is important to understand that in countries with these characteristics the choice of mode of transport made by the passenger depends on several other factors different from travel time [3]. All these additional factors that users bear in mind to choose the best transport option become important elements within the establishment of such a service, as it must be designed in a way that meets users' requirements. This explains why certain components of the service must be redesigned around the creation of a mutual benefit relationship between service providers and users, [3].

One of the most relevant problems on the issue of accessibility is the human approach to the service, by receiving such a large number of people per day with such diverse characteristics, it is difficult to implement a system that offers the same characteristics to all its consumers, which makes it difficult to ensure that users have the minimum space, safety, and comfort conditions required to commute when the system is saturated. This is why there is a need to guarantee some of the elements named by the authors, such as service availability, reliability, comfort, cleanliness, security, information, customer service, and environmental impact, [4]. Thus, in order to avoid real risks such as muscle injuries, fractures, etc., this article will discuss the development of a grip and personal support system that provides users with greater safety and stability during the use of the current public transport service.

The document is structured as follows: the methodological steps taken as a guide are chosen; these are: identification of the client needs through qualitative and quantitative methods, creativity process, generation and selection of concepts, then the results obtained so far are described, since the prototype is still in development, and finally the conclusions are established.

2. Background

The new tendency to focus on the client has led several authors to try to define standards in order to quantitatively and qualitatively analyze the key factors to establish a successful public transport program that customers have redefined, the search for standardization leads to analyze the client from several approaches. One of the determining factors is ergonomics, understood as *the study of the adaptation of machines, furniture, and utensils to the person who frequently uses them, to achieve greater comfort and efficiency* [5]; it is the key to ensure a principle that define as comfort, understanding that, given the nature of public transportation systems, it is necessary to redefine this term if it is to be applied to the service, [3].

Ergonomics offers statistical data in which certain basic conditions in the position of the human body define what it is to be in a comfortable stance. These data, once collected, are of great importance in the search for this comfort that authors have previously defined; as [6] suggest, it is necessary to identify these conditions so that they can be assured to the user to make the service every time more accessible. These suggestions, along with the WHO report, show the need to create a control process that allows reducing the real risks which users experience daily, such as muscle injuries, fractures, among others.

This was the case of Bogotá, Colombia, a city in which, after having a transport system with several suppliers, all these services were unified in an integrated system, where the service operator was able to establish and standardize a manual in which we try to explain the minimum requirements with the intent to achieve the best possible service, [2]. This operation manual seeks to organize the mass transport system, to plan it, to exercise control over its operation, and to determine the

factors of the operation. Likewise, another purpose is to integrate, evaluate, and monitor the operation [7]; within it, there are guidelines not only in the field of customer service but also for ergonomic specifications for the fleet's inner space layouts. The establishment of these standard spaces opened the accessibility debate by noting that *2.358.665* users occupy the system daily, [8].

Since approximately *1.595.199* (DANE, 2017) people, within a range of stature between 1,40 m and 1,65 m, enter the system per day, there is a need to guarantee some of the elements named by the authors such as service availability, reliability, comfort, cleanliness, security, information, customer service, and environmental impact, [4].

3. Method

From the elements identified in the previous section, and using tools such as Voice of Customer (*VOC*), there are enough tools to develop a product that aims to improve the usage conditions of these services by the population who are within the stature range defined by this investigation, which for this case would be between 1,40 m and 1,65 m.

However, after carrying out the literature review of the methodologies proposed by several authors regarding the development of a new product, it was determined that the most pertinent step was to establish a methodology that would bring together the basic concepts of product development process proposed by Ulrich and Eppinger [9] and the marketing-oriented approach proposed by Schnarch Kirberg [9].

Therefore, it was necessary to define which stages of concept development proposed by [9] were relevant, given the nature of the project; consequently, the following were considered:

- **Identify the needs of the client:** Data were collected from 68 people (obtained through a simple sampling), through specific questions, which were interpreted, hierarchized in terms of client needs and the relative importance of each one of these; however, the team found it difficult to ask questions that would give a quantitative result of the level of stability felt by users inside the vehicle. For the quantitative study of the perception of stability of users of public transport service, the analysis of heart rate variability (HRV) was used, an indicator that reflects the activation level of the sympathetic nervous system (SNS) or parasympathetic nervous system (PNS) depending on the environmental conditions surrounding the users (strong braking, sudden changes of direction, many people inside the bus, etc.) For the analysis of the results, the principle was that the predominance in the discharge of the SNS corresponds to greater physical or psychological stress (instability), while a predominance of the PNS or a decrease in the SNS express feelings of comfort or tranquility (stability).

- **Execute creativity process:** The four stages proposed by Schnarch [9] were carried out for the process of generating ideas: preparation, incubation, lighting, and verification to obtain ideas that meet the needs identified in the previous stage.

- **Generate product concepts:** A clarification of the general problem was made by decomposing it into sub-problems, to subsequently carry out an external and internal search for solutions. Finally, solutions were selectively linked through a classification tree and a combination table.

- **Select product concept(s):** The concepts obtained in the previous stage regarding client's needs were evaluated, through two processes called filtering and evaluation of concepts, to select a concept or a combination of several for development.

The aforementioned methodology was complemented through the use of support material from several authors or theories that are relevant to the project, among which the following stand out: APQP, design thinking, market research, and prototyping, [10].

4. Results

Identify the needs of the client: The interpretation of the results of the specific questions asked revealed a series of needs that were required to rank and establish the relative importance of each of them, resulting in the following outstanding needs, which were transformed into indicators that facilitated the recognition of certain elements that allowed evaluating performance (Table 1). As the objective of the project is to provide a solution to a problem, the name of the product has not been chosen, therefore from now on the product will be referred as "X"

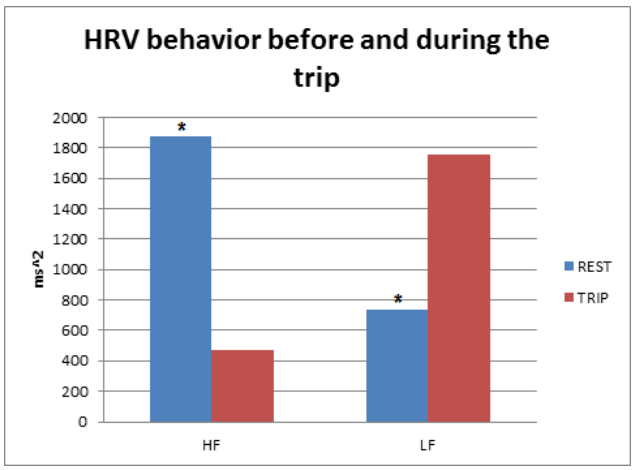
Table 1: Outstanding needs and their respective conversion to indicator.

NEED	INDICATOR
X reduces the risk of fractures, hand-related injuries, and spinal injuries, among others, during the commute.	Ergonomics
X provides a standard method for attaining the horizontal clamping bars.	Reach
X generates stability during the journey inside the vehicle.	Holding
X works even if there is congestion inside the vehicle.	Grip
X provides a single fastening element that replaces other methods (traditional or non-traditional).	Comfort

Source: own.

Regarding the quantitative study of the perception of stability from users by studying the physiological behavior through HRV analysis, the results showed that a trip of 30 minutes in the integrated transport system does modify HRV behavior compared to the resting values for each person ($p < 0{,}05$). In addition, observationally, it was found that there are alterations in HRV record in relation to events occurred during the trip, such as heavy braking, sudden changes in direction, many people inside the bus, etc. (Figure 1).

Figure 1: Behavior of the HRV before and during the course.

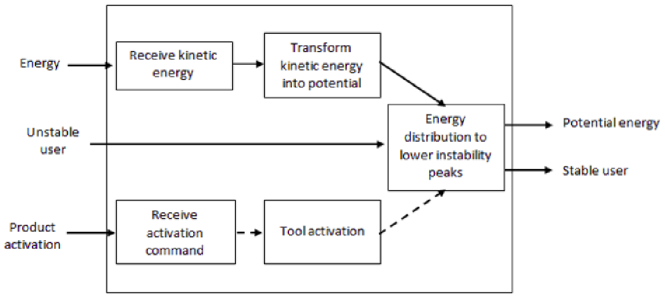


Source: own.

$*: p < 0,05$ regarding resting values
HF: High frequency (parasympathetic tone).
LF: Low frequency (sympathetic tone).

Generate product concepts: The problem was clarified by performing a functional decomposition by means of a block diagram as shown below (Figure 2):

Figure 2: Functional decomposition by means of block diagram.



Source: own.

The functional decomposition facilitated the decomposition into sub-problems which allowed to solve more specific problems and thus give solution to the general. Then, through an internal and external search, a large number of solutions were obtained for these sub-problems, which were synthesized by classification trees in order to facilitate their comparison and elimination. Finally, the combination table was continued with the objective of generating concepts that approximate the final product as shown in Table 2.

Table 2: Table of combination of solutions to sub-problems.

Receive external energy	Transform kinetic energy into potential	Receive activation command	Activate
Air compression	Belts	Digital	Apply activation energy
Solar panel	Busbars	Manual	Manual
Translational	Safety hooks		
Rotational	Springs		
Electric socket	Pulley		
Battery	Platforms		

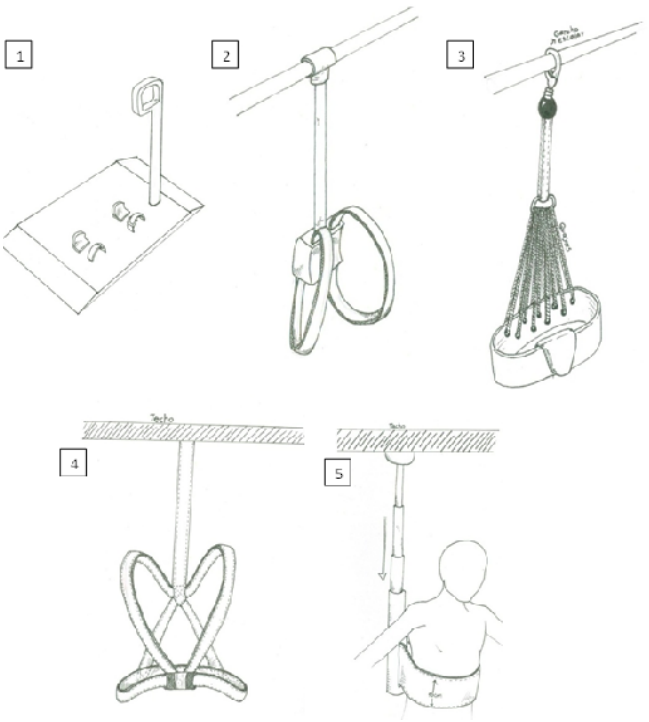
Source: own.

From the possible combinations shown in Table 2, the following sketches were made in order to materialize the concepts generated (Figure 3).

Sketch 1: It consists of a long floor platform where the user is held by means of a handle.

Sketch 2: It consists of some handles which the user places as the straps of a suitcase, which are attached to a horizontal bar of the vehicle.

Figure 3: Sketches of the concepts generated from the combination table of solutions to the sub-problems.



Source: own.

Sketch 3: It consists of a system of belts with spokes that meet at a common point that then becomes a belt and holds the user's waist and in turn is subject to a horizontal bar of the vehicle.

Sketch 4: It consists of a belt vest that fits the torso of the person and is attached to the roof of the vehicle by an elastic strap.

Sketch 5: It consists of a retractable rod that attaches to the roof of the bus by means of a magnetic system from which a belt 10 cm wide that surrounds the waist of the person is deployed.

Select product concept(s): The indicators defined in the identification of customer needs were used as criteria for the development of a selection matrix that would allow the calculation of each concept's score. Such matrix is presented below (Table 3).

The handle was then defined as a reference concept since this product was chosen and is considered as the direct competitor and according to this the relative evaluation was indicated in Table 4

Table 3: Concept screening, filtering method that identifies the concepts that best meet the identified needs.

SELECTION CRITERIA	CONCEPTS					
	HANDLES (REF)	1	2	3	4	5
HOLDING	0	-	+	-	+	-
GRIP	0	+	+	0	0	0
REACH	0	+	0	+	+	+
ERGONOMICS	0	0	+	+	+	0
COMFORT	0	+	+	+	+	0
Sum of +	0	3	4	3	4	1
Sum of 0	0	1	1	1	1	3
Sum of -	0	1	0	1	0	1
Score		2	4	2	4	0
Classification		2nd	1st	2nd	1st	3rd
Decision		No	Combine	No	Combine	Review

Source: own.

Table 4: Relative score used in concept scoring [10].

Relative evaluation	Score
Better than the reference	+
Same as the reference	0
Worse than the reference	-

For each selection criterion

Once the classification of each concept is established, this allows, along with the numerical evaluation of each of these, to identify the main concepts for their combination (concepts 2 and 4), allowing a revision of number 5 for the possible union of some of its functions with any of the chosen concepts and discarding concepts 1 and 3.

Once the concept *screening* was completed, a more detailed quantitative analysis of the remaining concepts was continued using a tool called concept scoring, which resulted in **concept 2 as the main** one, discarding 4 and *admitting part of concept 5* to combine it with the one selected as shown in the table below (Table 4):

Table 5: Concept scoring, method that allows to calculate the score of each concept to continue discarding concepts and choose the final one or those that continue to combine.

Selection criteria	Weight (%)	CONCEPTS							
		Handle (Reference)		2		4		5	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Holding	30%	3	0.9	4	1.2	4	1.2	2	0.6
Grip	25%	3	0.75	5	1.25	3	0.75	3	0.75
Reach	20%	3	0.6	3	0.6	4	0.8	4	0.8
Ergonomics	15%	3	0.45	5	0.75	5	0.75	3	0.45
Comfort	10%	3	0.3	4	0.4	4	0.4	3	0.3
Total Score		3		4.2		3.9		2.9	
Range		4		1		2		3	
Continues?		-		Develop		NO		*	
* In this case, part of the concept will be used to combine it with the one that does continue.									

Source: own.

The qualification of each concept was made again comparing it with the chosen reference concept (handle) by means of the following scale:

Table 6: Scale from 1 to 5 used in concept scoring [10].

Relative performance	Score
Much worse than the reference	1
Worse than the reference	2
Same as the reference	3
Better than the reference	4
Much better than the reference	5

For each selection criterion

5. Conclusions

It is concluded that the trip in public transport does generate a sense of instability in people, this is analyzed through quantitative and qualitative methods, which highlights the need to implement additional tools in vehicles that mitigate the sensation of instability the users.

If future studies are required, it is recommended to take into account the possibility that, although there are already general established systems, it is necessary to observe their behavior at specific times or places, since there are unexplored or unresolved points [11].

So far, the project has provided the research team with enough data to continue with the product design process. Validations are currently being made of the beta prototype that has already been developed (a combination of concept 2 and 5 was used), all the final analysis and conclusions about the last stage of the process will be included once the final phases of the product development process are executed.

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