An Ergonomic Design of Light Rail Transit (LRT) in the Philippines for Persons with Special Needs

Ma. Janice J. Gumasing, Marion Ollie V. Zerrudo and Josephine D. German
School of Industrial Engineering and Engineering Management
Mapua University
mjjgumasing@mapua.edu.ph, marionzerrudo@yahoo.com, jdgerman@mapua.edu.ph

Abstract

The need to improve the quality of transportation for persons with mobility impairment and persons with special needs is a concern, which needs attention. Public trains are highly used mode of transportation in the Philippines. According to the 2003-2012 transportation statistics, the Light Rail Transit (LRT) transports over 170 million people, of which the train carts are designed only for passengers in healthy state, defying the benefits of public transportation particularly for persons with special needs (PSN) such as physically disabled, senior citizens, pregnant women, and passengers with babies or children. The PSN represents more than 1.57 percent of LRT's passenger population. Previous researches have focused on the design of public transport for the general public and only a limited amount of research had focused on the design of public transport for persons with special needs. That being so, the researchers aimed to ergonomically design the LRT carts for persons with mobility impairment or special needs such as disabled, elderly, persons carrying children and pregnant women that is fit for use for Filipino commuters. The study covered and mainly focused on designing LRT carts including door, seats, aisles, handrails and other features that require mobility aid such as wheelchairs, crutches and canes. In the ergonomic design of LRT carts, factors such as safety, accessibility and comfortability of passengers were considered. The researchers have conducted review of related literature, direct observation, surveys, actual measurements and statistical analyses in order to describe factually and accurately the current design of train carts in the Philippines. And through application of ergonomic principles and anthropometry, the researchers have improved the current design of LRT carts with the consideration of the issues of the commuters with mobility impairment and special needs.

Keywords

ergonomic design, LRT cart, persons with special needs, mobility impairment

I. Introduction

Public transportation improves quality of life in communities across the country by providing safe, efficient, and economical service. Not only does public transit benefit the people who use it, it also benefits society as a whole (Public Transportation Fact Book, 2008). The public transport system of the Philippines consists of roads, water, air and rail transport; and the Light Rail Transit (LRT) is one of the railway systems in the country. The line is operated by the LRT Authority that carries about 579,000 passengers each day (National Statistics Coordination Board, 2009). The rail transport system enhances personal opportunities, saves money, foster livable communities, provides economic opportunities, creates community benefits and offers mobility for seniors and mobility impaired persons (Benefits of Public Transportation, 2009).

Mobility impairment is a condition which prevents a person from performing physical or mental functions that a normal person can do. This can be caused by a number of factors such as disease, accident, congenital disorder and other needs such as the elderly, persons carrying children and pregnant women. These are called persons with special

needs. These persons experienced difficulties in using public transportation without special equipment or assistance such as wheelchair, crutches, walker and other device that aids mobility.

An article from American Association of People with Disabilities (AAPD) stated that transportation and mobility play key roles in the struggle for civil rights and equal opportunity in the disability community. A mobility management program should be implemented to allow people with disability to have an affordable and reliable use of all types of transportation to meet the needs of individuals with disabilities.

Similarly, in a study done by Cavinato & Cuckovick (1992), stated that in order to fulfill the needs of people with disabilities, the transport infrastructure and mobility factor for the disable has to be assessed and improved. A study by Broome (2009) has discussed that the current conventional urban transport system could not deliver efficient service for the people with disabilities and thus, limitation still exist.

Therefore, this evidently shows the need to improve the quality of transportation for persons with special needs (Zhou, 2012 and Wretstrand, 2009). Prior researches have focused on the design of public transport for the general public and only a limited amount of research had focused on the design of public transport for persons with special needs. That being so, the researchers aimed to ergonomically design the LRT carts for persons with mobility impairment or special needs such as disabled, elderly, persons carrying children and pregnant women that is fit for use for Filipino commuters. The study covered and mainly focused on designing LRT carts that require mobility aid such as wheelchairs, crutches and canes. In the ergonomic design of LRT cart for persons with special needs, factors such as safety, accessibility and comfortability of passengers are considered.

2. Methodology

In pursuing and coming up with a result, the study followed a framework that is shown in Figure 1 which provided this paper a structure and a guideline to come up and to have a clear idea on how the output design was constructed.

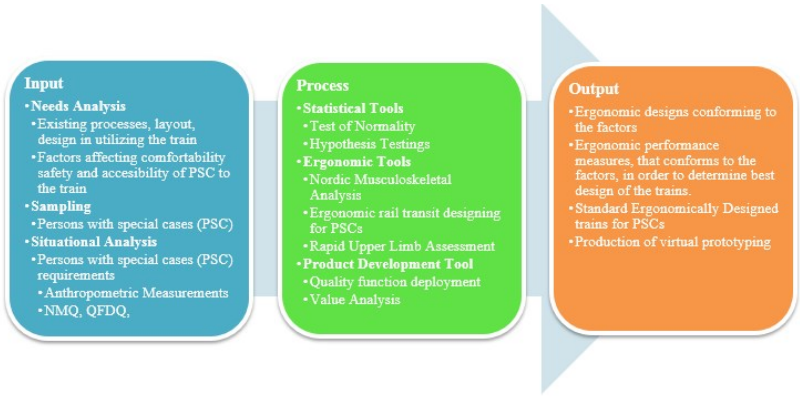

Figure 1. Conceptual Framework

2.1. Data Collection

The researchers have conducted review of related literature, direct observation, surveys, interviews and actual measurements of LRT cart dimensions in order to describe factually and accurately the current design of LRT carts in the Philippines. The researchers were able to identify factors that will be considered in the design of ergonomic train carts in the Philippines such as anthropometric measurements of subjects, body posture of subjects, and actual dimensions of LRT carts. Data were collected by manually measuring the dimensions of the carts that will be incorporated for the proposed design. Along with the measurement of mobility aids and anthropometrics, persons with special needs were treated separately due to their independent demand and measurements. Moreover, body posture of the subjects assessed are boarding and alighting postures since these postures are the most crucial for the persons with mobility impairment. The researcher also conducted an assessment on the current design of the LRT carts in order to determine the specific areas in the cart that will require modifications like height, width, and the like. The gathered

results and measurements had shown the gap from the current measurements to the ideal and user-demanded specifics and had become the basis for formulation and design of the proposed improvement prototype intended for utilization for the persons with special needs.

2.2. Data Analysis

Factors obtained from data gathering procedure were recorded, described, interpreted and analyzed. Statistical analyses and treatments such as sample sizing, hypothesis testing and test for normality were also conducted in order to systematically and statistically investigate and explain the nature of relationship between factors considered in the study. The researchers obtained data from 3 different generation of LRT carts, and in order to test whether the dimensions gathered from the 3 carts are significantly different, analysis of variance was used. The researchers also evaluated the current posture of subjects in riding the LRT through ergonomic tool such as Rapid Upper Limb Assessment (RULA) and determine the discomfort experienced by the subjects using Nordic Musculoskeletal Disorder Questionnaire (NMDQ). This tool estimates the risk of musculoskeletal disorders based on the posture of the subjects. In addition to this, the researchers also performed Importance-Satisfaction Gap Analysis to determine the importance of the design attributes of the LRT carts to the users. And finally, in order to come up with an ergonomic design of LRT carts for persons with special needs, the researchers made use of design tools such as product design and development, prototype making, value analysis, Kepner-Tregoe technique, and Quality Functions Deployment (QFD) tool.

3. Results and Discussion

3.1. Result of RULA and NMDQ

In order to validate if the existing design of train carts is not ergonomically designed and fit for Filipino commuters with special needs, the researchers used RULA and NMDQ tools. Based on the results of RULA, the current body postures of elderly pose moderate risks for musculoskeletal disorders and further investigation and change is recommended while current body posture for disabled and persons with children pose high risk and requires change immediately. The result is presented in the figures below.

POSTURE A
Final Upper Arm Score = +3 + 1 *(shoulder is raised)*
= 4
Final Lower Arm Score = +2 + 1 *(arm out to side of body)*
= 3
Final Wrist Score = +3+ 1 *(wrist is bent from midline)*
= 4
Wrist Twist Score = +1 *(twisted mainly in mid-range)*
= *1*

POSTURE B
Final Neck Score = 1*(neck is twisted)*
Final Trunk Score = 1*(well supported while seated)*
Final Leg Score = 1*(leg and feet supported and balanced)*

FINAL SCORE: 5 = Requires change in the near future

Figure 2. Result of RULA for Elderly Population

POSTURE A
Final Upper Arm Score = +2 + 1 *(shoulder is raised)*
= 3
Final Lower Arm Score = +2 + 1 *(arm is working across body midline)*
= 3
Final Wrist Score = +3 +1 *(wrist is bent from midline)*
= 4
Wrist Twist Score = +2 *(twist or near end of twisting range)*
= *2*

POSTURE B
Final Neck Score = 1 *(neck is twisted)*
Final Trunk Score = 1 *(well supported while seated)*
Final Leg Score = 1 *(leg and feet supported and balanced)*

FINAL SCORE: 7 = Requires immediate change

Figure 3. Result of RULA for Person with Children Population

Figure 4. Result of RULA for Disabled Population

Similarly, the result of the NMDQ also indicated that users in the existing design of train carts experience pain and discomfort in the following body parts: lower back, shoulders, hips, knees, elbows and wrists. This only proves that the existing design of train cart in the Philippines needs improvement and redesign that will specifically cater the commuters with special needs. The result is shown in Table 1 below.

Table 1. Result of NMDQ

BODY PART	OCCURENCES	PREVALENCE
Lower Back	289	90%
Shoulders	254	79%
Hips/Thighs	212	66%
Knees	186	58%
Elbows	165	52%
Wrist/Hands	148	46%
Upper Back	92	29%
Neck	86	27%
Ankles/Feet	73	23%

3.2. Result of Statistical Analyses

In order to assess the statistical difference in cart measurements among the three (3) generations of LRT carts that will be considered in the study, hypothesis testing and analysis of variance (ANOVA) were employed. Train cart measurements such as: overall cart width, overall cart height, overall cart depth, cart seat height, cart seat depth, cart seat width, backrest height, overhead handrail height, aisle width, door clearance and step height are obtained for further assessment and analysis. Based on the result of ANOVA (using p value of 0.05), it was determined that there is no significant difference in cart measurements among the three generations of LRT carts. Therefore, the researchers will use the data gathered from the average measurements of 3 generation of carts in comparison to the anthropometric measurements of the subjects that will be considered in the study. The result is shown in the Table 2 below.

Table 2. Result of ANOVA

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit

Between Groups	22.42	2	11.21	0.01	0.99	3.4
Within Groups	20775	24	865.65			
Total	20798	26				

The researchers also gathered data on anthropometric measurements of the subjects clustered under each condition such as: disabled, elderly, persons with children and pregnant. After which, normality testing was employed in order to validate if the data gathered are normally distributed and sufficient to be used in the study. The result is shown in the Figure 5 below.

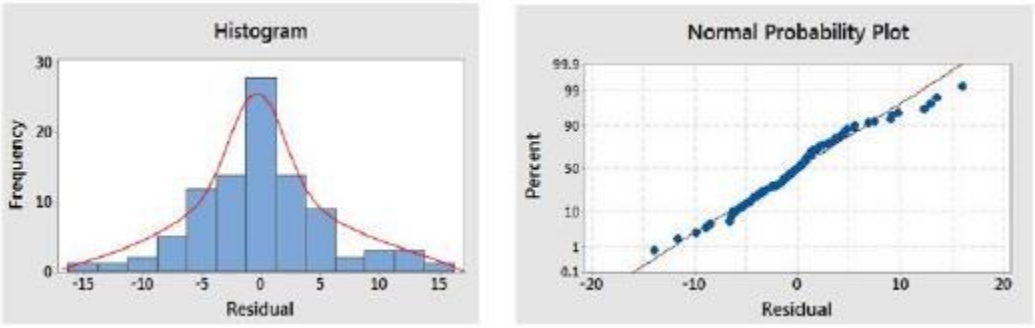

Figure 5. Normal Distribution and Probability Plot for Anthropometric Data

3.2. Result of Anthropometric Measurement

The proposed dimensions for ergonomic design of train carts for persons with special needs were established using the principles of anthropometry. Table 3 below shows the proposed cart specifications based on the anthropometric data of the subjects clustered under each condition: disabled, elderly, persons with children and pregnant.

Table 3. Result of Anthropometric Measurement

Important train elements	**Current train elements**	**Anthropometric Element**	**Cluster**	**Percentile**	**Gender**	**Anthropometric Measurement (in)**
Entrance/Exit	Entrance width	Wheelchair width				64
	Entrance Height	Stature	Person with children	95th	M	70
	Step Height	Step Height	Elderly	5th	F	14.58
Handrails for standing and for sitting	Handle bar height (standing)	Functional Overhead Reach(standing)	Pregnant	5th	F	84.44
	Handle bar height (sitting)	Functional Overhead Reach (sitting)	Disabled	5th	F	43.96
	Handle grip	Functional Forward Reach	Elderly	5th	F	17.38
Priority Seats	Seat height	popliteal height	Elderly	5th	F	10.34
	Seat width	Elbow to elbow breadth	Pregnant	95th	F	26.14
	seat depth	Buttock popliteal depth	Elderly	5th	F	11.93

	backrest height	Shoulder height – buttock popliteal depth – popliteal height	Elderly	5th	F	25.04
Bell pushes	Non existing	functional overhead reach (sitting)	Disabled	5th	F	43.96
		functional forward reach	Elderly	5th	F	17.38

Furthermore, the proposed anthropometric measurements obtained from the subjects were statistically compared to the existing measurement of the train carts using T-Test. The result proved that the proposed measurement is significantly different from the existing measurement of train carts. Thus, the proposed measurement will serve as the basis for the researchers in developing an ergonomic design of train carts.

Table 4. Result of T-Test

Important modified train elements	**Current train elements**	**Anthropometric measurements (inches)**	**Current Train dimension (inches)**
Entrance/Exit	Entrance width	64	58
	Entrance Height	69.96	80
	Step Height	14.58	17.2
Handrails for standing and for sitting	Handle bar height (standing)	68.23	84.4
	Handle height (sitting)	33.96	64.5
	Handle grip	17.38	16
Priority Seats	Seat height	10.34	19.5
	Seat width	26.14	13.7
	seat depth	11.93	17
	backrest height	25.04	19.4
Bell pushes	n/a	17.38	0

3.3. Development of Ergonomic Design of Train Carts

In order to develop an ergonomic design of train carts, the researchers made use of Importance-Satisfaction Analysis and Quality Function Deployment tools. These allow the researchers to better understand important criteria and technical attributes that have to be prioritized in the design aligned with the user demands. The results showed that criteria that must be prioritized in the design are: accessibility (40%), comfortability (30%), safety (20) and aesthetics (10%). The figures below show the proposed train specifications and layout based on the analysis through virtual prototyping.

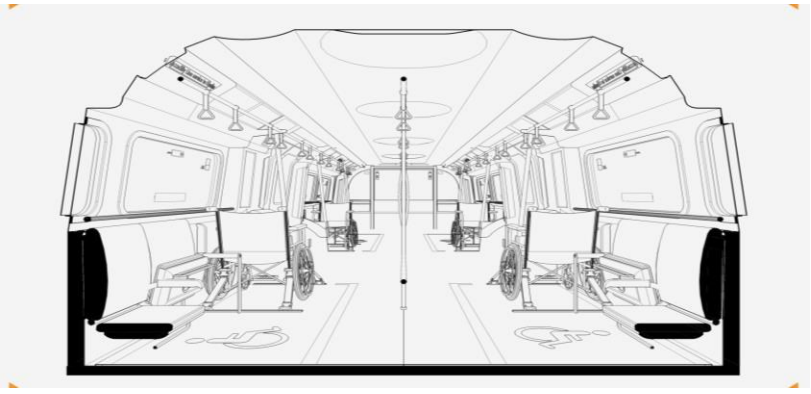

Fig. 6. Proposed Design of Train Cart (Cross Section View)

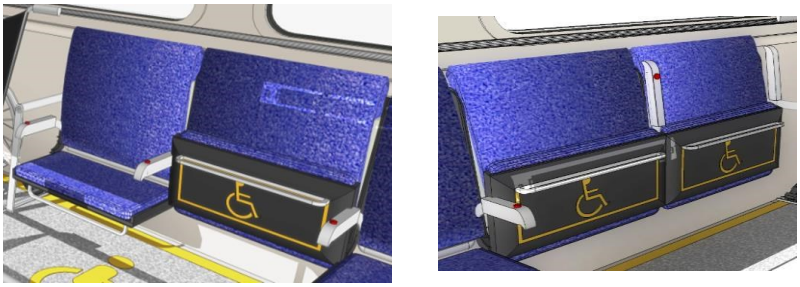

Fig. 7. Virtual Prototype Design of Seat (3D Rendering)

Fig. 8. Virtual Prototype Design of Bell Pushes (3D Rendering)

Fig. 9. Virtual Prototype Design of Handrails (3D Rendering)

Fig. 10. Virtual Prototype Design of Train Cart (3D Rendering)

Fig. 11. Virtual Prototype Design of Train Cart (3D Rendering)

4. Conclusion

The findings of the study have proven that the existing design of train carts in the Philippines is not ergonomically designed and fit for Filipino commuters with special needs. This was proven on the result of the RULA and NMDQ analysis of the researchers. The result revealed that users experienced pain and discomfort in different body parts in riding the LRT, which justified the need to redesign and improve current train carts. In the design of train carts, accessibility, comfortability and safety of users were taken into consideration based on the need and requirements of users obtained from Importance-Satisfaction Gap Analysis and Quality Function Deployment. And finally, by applying the principles of anthropometry, the researchers were able to come up with a proposed design of train carts for persons with special needs such as disabled, elderly, person with children and pregnant. The proposed design aims to cater and support the needs of users with mobility impairment in order to achieve comfort and safety when riding the LRT trains in the Philippines.

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Biographies

Ma. Janice J. Gumasing is an Assistant Professor of School of Industrial Engineering and Engineering Management at Mapua University in Intramuros, Manila, Philippines. She has earned her B.S degree in Industrial Engineering and Masters of Engineering Program major in I.E. from Mapua University, Intramuros, Manila, Philippines. She is a Professional Industrial Engineer (PIE) with over 10 years of experience. She is also a professional consultant of Kaizen Management Systems, Inc. She has taught courses in Ergonomics, Methods Engineering, Simulation, Occupational Safety & Health, Project Management and Computer Integrated Manufacturing. She has done research projects in ergonomics, manufacturing, simulation, safety engineering, continuous improvement and methods engineering. She is a member of Philippine Institute of Industrial Engineers (PIIE) and Philippine Ergonomics Society (PhilErgo).

Josephine D. German is an Assistant Professor of School of Industrial Engineering and Engineering Management at Mapua University in Intramuros, Manila, Philippines. She has earned her B.S degree in Industrial Engineering and Masters of Engineering Program major in I.E. from Mapua University, Intramuros, Manila, Philippines. She is a Professional Industrial Engineer (PIE) with over 10 years of experience. She has taught courses in Methods Engineering, Logistics and Supply Chain Management and Systems Engineering. She has done research projects in logistics and supply chain management, and systems dynamics. She is a member of Philippine Institute of Industrial Engineers (PIIE).

Marion Ollie V. Zerudo graduated from Mapua University with B.S. degree in Industrial Engineering. She is a member of Philippine Institute of Industrial Engineers (PIIE) Mapua Chapter and also an active member in Operation Research Society of the Philippines (ORSP) Mapua Chapter. Her research interest includes Ergonomics and Human Factors.