Advances in Sciences and Arts

Journal homepage: https://asa.must.ac.mw/

RESEARCH ARTICLE
Vol. 1 Issue 1

Category
Engineering

Correspondence to:
ekhundi@must.ac.mw

Citation
Khundi. (2023). Low-cost ride-on toy cars for children living with mobility disability in low- and middle-income countries. *Advances in Sciences and Arts*. 1(1), T011-0004, https://doi.org/10.37872/ T011-0004

Supporting info
This can be found on the journal's official website on https://asa.must.ac.mw/

Received
6th Jun 2022

Accepted
11th Nov 2022

Published
13th Nov, 2023

DOI
https://doi.org/10.37872/T011-0004

Low-cost ride-on toy cars for children living with mobility disability in low- and middle-income countries

Edwin Khundi

Malawi Institute of Technology, Malawi University of Science and Technology.

Abstract: Many children with disabilities, most especially in low- and middle-income countries such as Malawi, face mobility related challenges. Different studies recommend the use of ride-on-toy cars to increase mobility and socialization of children with disabilities. Besides, the ride on toy cars can also be used by able bodied children for recreational purposes. However, both disabled and able-bodied children from low- and middle-income countries (LMICs) do not have access to good quality ride on toy cars because the commercial ones, which are mostly imported, are expensive. Hence there is need to design, manufacture and test a safe and low-cost ride-on toy car that can be purchased locally by parents or organizations for both able bodied children and those with disabilities. In this study, a low-cost ride on toy car was designed using SOLIDWORKS® computer aided design software and later fabricated using conventional manufacturing methods such as centre lathe machining, welding, soldering, woodworking, and polishing. The specifications of the ride-on toy car were formulated in line with ISO standards ISO 8124 and British Standard (BS EN 71) which are about safety for toys. The performance of the fabricated prototype was tested by subjecting it to a loading of a male subject weighing 65kg. The performance of the car was satisfactory and could reach maximum speed of 20km/hour during maximum load of 65kg.

Keywords: *Disability; Ride-on-toy car; Mobility; Assistive devices; Recycling; Reuse; Locomotion Experience*

1. Background

Children with severe mobility disabilities depend on external support from parents or other well-wishers to assist them in moving from one place to another. Assistive devices can increase self-directed mobility and minimise the dependence on the need for external support for mobility purposes. Ride-on toy car can be used as an assistive device that can enable children with disabilities to have improved mobility thereby increasing their chances to learn, interact socially and have fun (Logan et al., 2017). In Malawi, wooden ride-on carts such as the one shown in Figure 1, are used for medical purposes and as wheel chairs for people with disabilities.

Figure 1: Wooden ride-on carts used for medical purposes at Queen Elizabeth Central Hospital in Malawi.

Recently there has been an increased interest in using powered ride-on toy cars as an assistive device for children with disabilities (Logan et al., 2020). Ride-on toy cars have a positive impact on child development since they promote locomotion experience (Allegretti, Barnes and Berndt, 2018). Locomotion experience for infants is crucial since it contributes to their developmental process and widespread consequences related to psychology and skills (Campos et al., 2000). Statistically, the demand and revenue for ride on toy cars has been increasing globally (Market, 2022; Tan and Tan, 2018). The main key players in ride-on toy cars are from developed countries such as United States of America (USA), Japan and China, as such, ride-on toy cars are usually expensive for users in low- and middle-income countries (LMICs). The high price, due to the importation process of assistive devices is one of the barriers to accessing assistive devices such as ride-on toy cars (Edusei & Mji, 2019; Olarewaju et al., 2021). Thus, there is a great need to design and manufacture low-cost and motorized ride-on toy cars for both able-bodied children and children with disabilities. The aim of this study was to explore barriers to the use of ride-on toy cars and thereafter design and manufacture a low-cost powered toy car. SOLIDWORKS® 2014 computer aided design (CAD) software was used to design and simulate the ride-on toy car. Thereafter, a prototype was developed using conventional manufacturing methods.

2. Methods

2.1 Observation study

The observation study was conducted to explore materials that can be reused or recycled to manufacture the ride-on toy car. This involved visiting car breaking centres and automotive and hardware markets. The locations that were purposively selected were: Limbe, Ndirande, and Zingwangwa markets in Blantyre city, Malawi. In addition to observation, vendors were asked questions about which spare parts were recycled or brand new, which parts were frequently bought, and which challenges were most common during their daily operations.

2.2 Concepts development and evaluation

Four concepts were developed using conventional brainstorming methods. Thereafter the concepts were evaluated using the Pugh evaluation matrix. A positive sign (+) was used to mean “better than”, while negative sign (-) was used to mean “worse than”, and a letter “s” was used to mean “same as” during the evaluation using the Pugh Matrix.

2.3 Computer Aided Design (CAD) Software

The software that was used to design the CAD model of the powered ride-on-toy car was SOLIDWORKS®2014.

2.4 Materials

The materials that were used to develop the physical prototype include: plywood, polyvinyl chloride (PVC) plastic pipes, steel rods, bicycle crank-chain mechanism, bearings, three-way switch, 12V battery, recycled wiper motor, electric cables, DC bulbs, glue, and paint.

2.5 Data processing and analysis

The quantitative data that was available during the study was from simulation of the CAD model using SOLIDWORKS®2014. The quantitative data was analysed and visualised SOLIDWORKS colour map features. The statistical analysis was mainly focused on descriptive statistics such as mean, minimum and maximum values of displacement, strain, and stresses.

3 Results

3.1 Observation and interview results

There were different observations and responses that were collected during the observation study. Table 1 summarises the results of observation and responses from vendors. It was observed that car parts from broken cars were in abundance in all the three local markets where observations were carried out.

Table 1: Observation and vendor response results

Source	Scavenged parts	Brand new parts	Parts frequently bought	Challenges
Observation	Wiper motors	Spark plugs	Spark plugs	Lack of infrastructure
	Batteries	Chain	Adhesives	Financial challenges
	Some Bearings	Screws		Networking challenges
	Engine parts	Bearings		Lack of quality control systems
	Pipes and metal sheets	Belts		Hygiene challenges
	Spanners	Oil filters		
	Bolts and nuts	Bicycle hardware parts		
Automotive spare parts vendors	Car parts of mainly the following car makes: Toyota, Nissan, and Mitsubishi	Spark plugs	Spark plugs	Financial challenges
		Chain	Chain	Security challenges
		Screws	Screws	Accidents
	general electrical components	Bearings	Oil filters	
		Belts	Bicycle hardware parts	
		Oil filters		
		Bicycle hardware parts		

Hardware vendors	Some car parts general electrical components e.g. plugs, sockets, bulbs, etc. Household hardware items such as pipes, sockets, cables, etc	General electrical components e.g. plugs, sockets, bulbs, etc. Household hardware items such as pipes, sockets, cables, etc	General electrical components e.g. plugs, sockets, bulbs etc. Household hardware items	Financial challenges Security issues Accidents

3.2 Concepts

3.2.1 Concept 1: Powered ride-on toy car with one motor

In this concept, the motorised toy car was theorised to have one DC motor, four wheels, side pivot steering system (Davis or Ackerman), one rechargeable battery, relay, belt or chain system, brakes, bearings, shock absorbers, 6 pin toggle switch, power and mode knobs, speedometer, battery meter, chair with seat belt and the toy car's body. The main principle of operation of the motorised toy car is that of a DC motor. The direction of rotation of a DC motor can be altered by changing direction of current using a 6-pin toggle switch. Thus, the toy's car forward and reverse movement can be altered by changing direction of current using a 6-pin toggle switch. In this concept, the battery ride-on toy car would be externally charged. Figure 2 shows a sketch of the first concept.

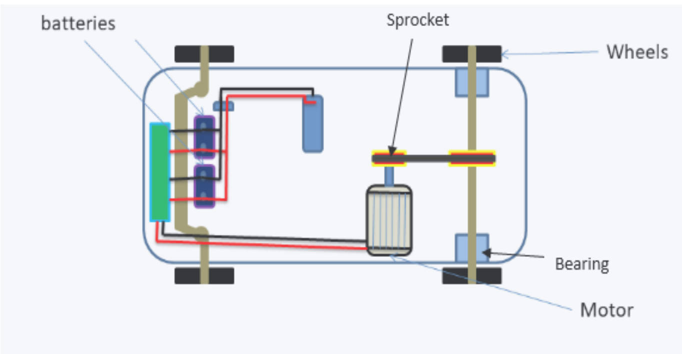

Figure 2: Diagram of the first concept

3.2.2 Concept 2: Spring and manual powered ride-on toy car

The second concept consisted of the following parts: pedalling mechanism, four wheels, side pivot steering system (Davis or Ackerman), chain mechanism, spring mechanism, brakes, bearings, shock absorbers, chair with seat belt and the toy car's body. The main principle of operation of the manually driven ride on toy car is that of manually rotating pedals connected to a spring mechanism for driving wheels. The chain mechanism is used to coil the spring which in turn recoil to power the ride-on toy car. This is the same principle of operation of a bicycle. Figure 3 shows a labelled diagram of the second concept.

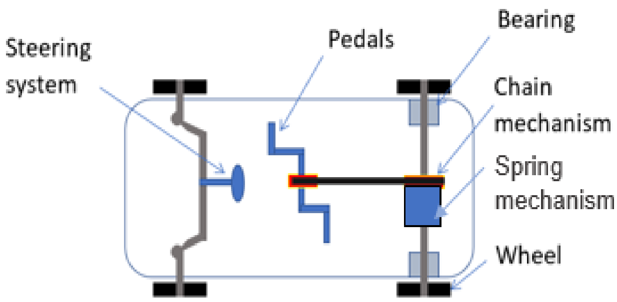

Figure 3: The second concept about spring and manual driven ride on toy car

3.2.3 Concept 3: Engine powered ride-on toy car

The third concept consisted of the following parts: petrol engine, fuel tank, fuel injection system, DC motor, four wheels, side pivot steering system (Davis or Ackerman), one rechargeable battery, relay, belt or chain system, brakes, bearings, shock absorbers, 6 pin toggle switch, power and mode knobs, fuel gauge, water temperature gauge, oil pressure gauge, speedometer, battery meter, chair with seat belt and the toy car's body. The main principle of operation of the engine-powered toy car is that of a petrol or Otto cycle for a four-cylinder engine. Petrol fuel would be used as the source of energy for the toy car. The main advantages of this concept include the ability to operate a long distance before refuelling and high-power reliable performance. Figure 4 shows the sketch of the third concept about engine powered toy car.

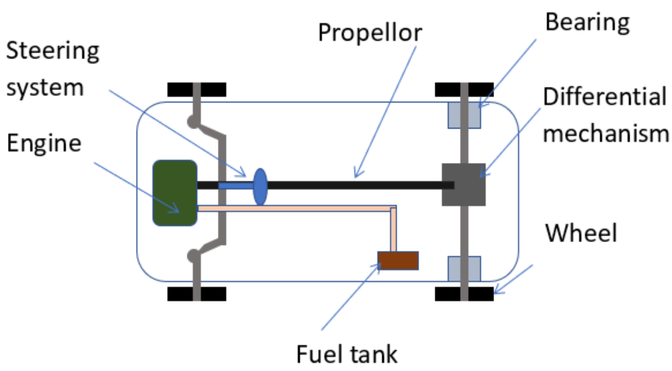

Figure 4: Engine powered ride-on toy car

3.3 Concept evaluation

The developed concepts were evaluated using the Pugh evaluation matrix. The results of the evaluation process of the three concepts is shown in Table 2. The reference for evaluating the concepts was the standard manual ride on toy car. The results of the evaluation process showed that the first concept about the electrically powered ride-on was the winning concept since it had a highest score with five positives and two negatives.

Table 2: Concept evaluation using Pugh decision matrix

Criteria/item	**Reference**	**Concept 1: Electrically powered**	**Concept 2: Spring and Manually powered**	**Concept 3: Engine powered**
Speed	S	+	S	+
Cost	S	-	-	-
User friendliness	S	+	S	-
Reliability	S	+	S	+
Emissions	S	+	S	-
Noise	S	S	S	-
Maintenance	S	-	-	-
Safety	S	+	S	-
$\sum \boldsymbol{negatives}(-)$	0	2	2	6
$\sum \boldsymbol{positives}\,(+)$	0	5	0	2
$\sum \boldsymbol{Same}\ (\boldsymbol{S})$	8	1	6	0

CAD model of the ride on toy car

The computer aided design model was developed using SOLIDWORKS® 2014. The model of the designed toy care is shown in Figure 6.

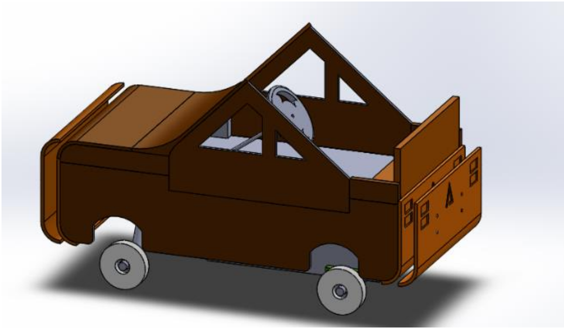

Figure 5: CAD model for the ride-on toy car

The car as viewed from the side, back and top is presented in Figure 5.

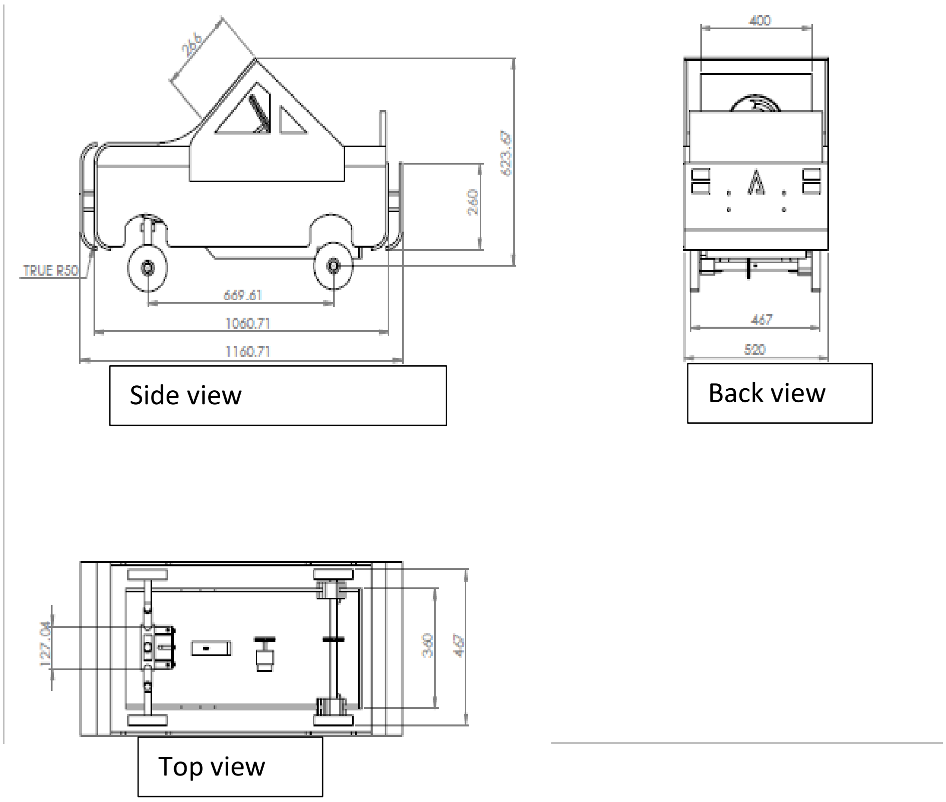

Figure 6: Detailed drawing of the ride-on toy car

3.4 Simulation results

The components of the prototype were subjected to static loading tests in SOLIDWORKS. The results showed that the prototype would withstand the design load of 800N. Figure 7 shows stress distribution after simulation test of a static load of 400N on the rear axle. It was assumed that the rear and front axles would bear equal amounts of loading, 400N if the passenger has a weight of 800N.

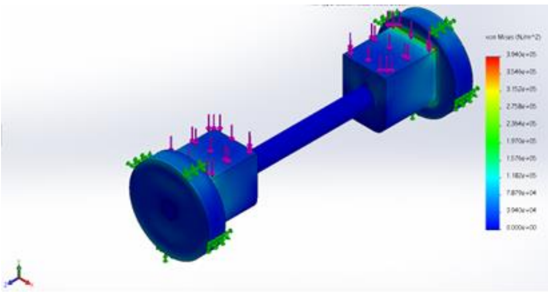

Figure 7: Simulation results showing stress distribution at the tyre of the ride-on-toy car

The maximum stress results at the axle and tyre assemble was $3.94 \times 10^5 N/m^2$ which was less than the yield stress of steel, the selected material for fabricating the axle and tyre rim. Table 3 shows the minimum and maximum strain and stress simulation results. Besides, the maximum deflection of the axle was found to be $9.88 \times 10^{-5} mm$. The deflection was very negligible and wouldn't be noticed physically.

Table 3: Strain and Stress minimum and maximum values

Name	Type	Min	Max
Stress	VON: von Mises Stress	0.000e+00N/m^2 Node: 23047	3.940e+05N/m^2 Node: 122
Strain	ESTRN: Equivalent Strain	0.000e+00 Element: 14789	1.008e-06 Element: 4954
Displacement	URES: Resultant Displacement	0.00e+00mm Node: 23047	9.880e-05mm Node: 21861

3.5 Prototype of the ride on toy car

The prototype was manufactured using conventional methods and tested at the mechanical engineering laboratory of the University of Malawi- The Polytechnic, currently known as Malawi University of Business and Applied Sciences (MUBAS). Figure 7 shows the manufactured prototype.

(a) (b)

Figure 8: (a) Physical prototype of the ride-on toy car (b) testing the prototype using a subject of 62kg.

4 Discussion

The development process of the ride-on toy car for children with disability in this study resulted into development of three concepts. The first concept was about an electrically powered ride-on toy car. The benefits of an electrically powered vehicle include negligible emissions, noise-free, lower energy consumptions (Gelmanova et al., 2018; Riezenman, 1992; Íñiguez et al., 2012). However electric vehicles tend to have small battery capacity which wears quickly, lower performance, longer charging or fuelling time as compared to internal combustion engine powered vehicles (Gelmanova et al., 2018; Ghasri et al., 2019). The second concept was about a manually driven ride-on toy car. The main advantages of a manually powered system include being quiet, clean with negligible emission, low operation cost since it does not need purchase of fuel or any other source of power, and relatively low cost to purchase (Archibald, 2016). However manually powered ride-on toy cars are labour intensive as such not user friendly to children with disabilities. The other concept that was developed was about an engine powered ride-on toy car. Internal engine powered ride-on toy cars are powerful and perform better for a longer range than electric and human powered vehicles.

The concepts were evaluated using the Pugh Evaluation Matrix. Pugh Evaluation matrix involves carrying out a pairwise comparison of different concepts to selected reference based on selected set of criteria and thereafter selecting best concept based on scores (Guler & Petrisor, 2021). The advantages of using the Pugh matrix include: being a simple and easy tool for evaluating concepts, being structured and efficient to evaluate the concepts cogently, ability to quickly eliminate non-viable concepts (Isixsigma, 2022). The criteria that were used to evaluate the three developed concepts include: speed, cost, user friendliness, reliability, emissions, noise, maintenance, and safety. As shown in Table 2, the first concept about electric ride-on toy car scored more positives than any other concept and hence was selected as the concept to be developed further.

The selected concept was developed further using Computer Aided Design (CAD). The CAD model for the first concept was developed using SOLIDWORKS®2014. The CAD model is shown in Figure 5. The concept was designed to be operated by one child. The detailed drawing for the concept is shown in Figure 5. The dimensions of the ride on toy car were: 1.16m long, 0.52m wide and 0.42 high. The selected concept was manufactured locally using the following materials: plywood for manufacturing the body or the hood of the car, hardwood timber for manufacturing the chassis of the ride-on toy car, steel round bars and sheet for manufacturing axles and steering mechanism, bicycle chain drive mechanism for the transmission system of the toy car, re-used car wiper motor as the engine, and 12V battery as source of power for the wiper motor.

The manufactured ride-on toy car was tested both in lab and road settings. The performance of the car was satisfactory reaching a maximum speed of 20km/hour with a load of 80kg.

The test results of the ride-on toy car from both simulation and laboratory performance test showed that the designed ride-on toy car was strong enough to handle up to 800N load. This shows that the designed ride-on toy car would be structurally rigid and perform well when used by children with disability with a mass of up to 800N.

The use of powered ride-on toy cars can improve sensorimotor experience of children with disability. Sensorimotor experience that can be gained by using ride-on vehicles can assist children to improve development of their human intelligence, social networks, and psychological muscle (Chiulli et al., 1988; Huang et al., 2018). Statistically, despite a huge demand for assistive devices, only 10% of people with disability specifically from low and middle income countries (LMICs) have access to assistive devices due to cost related factors (Alqahtani et al., 2021). Therefore, there is a great need to design more affordable mobility assistive devices that can be used for children with mobility disabilities in LMICs.

One solution that this study proposes is to minimise the cost of ride-on assistive devices by recycling parts from automotive industry. In Malawi, recycled car parts can be found in many local markets or car breaking points such as Limbe, Ndirande, and Zingwangwa markets in southern Malawi.

5 Conclusion

In conclusion, the developed ride-on toy car showed satisfactory performance hence it can be used as ride-on toy car for children both able bodied and those with disability. The developed ride-on toy car can be used to carry a pay load of at most 80 kg. The total cost for the developed toy car was $30. The development of the ride-on toy car using recycled parts can reduce cost of producing ride-on toy cars, minimise land pollution due to landfills of non-reused or non-recycled automotive parts, and empower local car breakers economically through increased usage of recycled parts. The future work of this study will be to conduct clinical studies to obtain user feedback.

Acknowledgments

I would like to acknowledge the technical support from engineering lecturers at the University of Malawi – The Polytechnic, especially Dr. J.K Gondwe and Mr. Chinombo who were my supervisors of the first phase of the project of developing the ride-on toy car.

Author Contributions

There is no co-author of this paper. This is the original work of the author.

Funding

The funding of this research was from both the author and the Engineering Department of University of Malawi – The Polytechnic, now called Malawi University of Business and Applied Sciences (MUBAS).

Declaration of conflict of interest

There is no conflict of interest. The research was carried out for academic purposes only.

References

Alqahtani, S., Joseph, J., Dicianno, B., Layton, N. A., Toro, M. L., Ferretti, E., Cooper, R. (2021). Stakeholder perspectives on research and development priorities for mobility assistive-technology: a literature review. *Disability and rehabilitation: assistive technology*, *16*(4), 362-376. https://doi.org/10.1080/17483107.2019.1650300

Archibald, C. M. (2016). *Design of human-powered vehicles*. ASME Press.

Campos, J. J., Anderson, D. I., Barbu-Roth, M. A., Hubbard, E. M., Hertenstein, M. J., & Witherington, D. (2000). Travel broadens the mind. *Infancy*, *1*(2), 149-219. https://doi.org/10.1207/S15327078IN0102_1

Chiulli, C., Corradi-Scalise, D., & Donatelli-Schultheiss, L. (1988). Powered mobility vehicles as aids in independent locomotion for young children: Suggestion from the Field. *Physical therapy*, *68*(6), 997-999. https://doi.org/10.1093/ptj/68.6.997

Edusei, A., & Mji, G. (2019). An introduction to a special issue on the role of assistive technology in social inclusion of persons with disabilities in Africa: Outcome of the fifth African Network for Evidence-to-Action in Disability conference. *African journal of disability*, *8*(1), 1-4.

Gelmanova, Z. S., Zhabalova, G. G., Sivyakova, G. A., Lelikova, O. N., Onishchenko, O. N., Smailova, A. A., & Kamarova, S. N. (2018). Electric cars. Advantages and disadvantages. *Journal of physics: Conference series*, *1015*, 052029. 1-6. https://doi.org/10.1088/1742-6596/1015/5/052029

Ghasri, M., Ardeshiri, A., & Rashidi, T. (2019). Perception towards electric vehicles and the impact on consumers' preference. *Transportation research part D: Transport and environment*, *77*, 271-291.

Guler, K., & Petrisor, D. M. (2021). A Pugh Matrix based product development model for increased small design team efficiency. *Cogent engineering*, *8*(1), 1923383.1-14. https://doi.org/10.1080/23311916.2021.1923383

Huang, H.-h., Huang, H.-W., Chen, Y.-M., Hsieh, Y.-H., Shih, M.-K., & Chen, C.-L. (2018). Modified ride-on cars and mastery motivation in young children with disabilities: Effects of environmental modifications. *Research in developmental disabilities*, *83*, 37-46.

Isixsigma. (2022). *Pugh Matrix Definition*. @isixsigma.

https://www.isixsigma.com/dictionary/pugh-matrix/

Logan, S. W., Feldner, H. A., Bogart, K. R., Goodwin, B., Ross, S. M., Catena, M. A., Galloway, J. C. (2017). Toy-Based technologies for children with disabilities simultaneously supporting self-directed mobility, participation, and function: A Tech Report [Technology Report]. *Frontiers in robotics and AI*, *4*.1-13

Riezenman, Michael J. "Electric vehicles." IEEE spectrum 29.11 (1992): 18-21.

Olarewaju, T. I., Healy, A., & Chockalingam, N. (2021). Barriers to accessing assistive technology in Africa. *Assistive technology*. *https://eprints.keele.ac.uk/id/eprint/10062/1/Barriers%20to%20Accessing%20Assistive%20Technology%20in%20Africa.pdf*

Íñiguez, J. I., Íñiguez-de-la-Torre, A., & Íñiguez-de-la-Torre, I. (2012). Human-Powered Vehicles–Aerodynamics of Cycling. Lerner, J. C., & Boldes, U. In *Applied aerodynamics*. IntechOpen, Rijeka