International Scientific Journal of Engineering and Management ISSN: 2583-6129
Volume: 04 Issue: 01 | Jan – 2025 DOI: 10.55041/ISJEM02202
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Design, Anlysis and Manufacturing of Electric Utility Vehicle

Joginder Singh[1], Rohit Sharma[2], Amaan Khan[3] and Satyam Kumar Singh[4]

[1, 2, 3, 4] Manav Rachna University
Department of Mechanical Engineering,
Faridabad-121010, Haryana, India

Abstract. Electric Utility Vehicles (EUV) is a viable option of transportation that is able to serve the short-range transportation and is less harmful on the environment. The article reports a systematic design, analysis and production of a EUV the proposed use of which is on campus and industrial levels. The project involves identification of the problem, conceptual design, chassis modelling by use of Computer-Aided Design (CAD) and analytical stress calculations and structural validation by Finite Element Analysis (FEA). The chassis was constructed out of thin sections of mild steel and fitted with the necessary mechanical and electrical parts. The prototype was experimentally tested showing sufficient load-carrying capacity, structural safety and stability in its operation. The findings affirm that the innovative electric utility vehicle is applicable in low-speed utility processes and promotes the sustainable movement efforts.

Keywords: Electric Utility Vehicle, Low and High Fidelity Prototype, CAD Design, Analysis, Physical Testing

1 Introduction

The fast development of the transport factor and the growing environmental issues have increased electrification as one of the possible variants of a sustainable alternative to the traditional fuel-based system. Electric utility vehicles are programmed to perform tasks over low distance and speeds including material handling in campuses, industrial plants, hospitals, and agricultural settings. These cars have such benefits as zero tailpipe emissions, low operation costs, less noise, and easy maintenance. As we incorporate the electric drives and light structural design the electric utility vehicles offer efficient and reliable performance to utility functions. In the case of engineering education, design and development of such vehicles allows engineering students to design, analyze and develop structural problems and mechanical design as well as manufacturing processes to real world problems. The paper discusses the design, analysis and production of an electric utility vehicle with a focus on the design of the chassis, structural validation, fabrication methods and experimental analysis concerning safe and sustainable utility transportation.

2 Problem Identification

Gardeners in large institutional campuses, landscaped grounds must carry heavy flower pots, bags of soil, tools and plants regularly between nurseries and greenhouses and plantation areas. Conventionally, this is done by hand with the help of trolleys or wheelbarrows which makes it a physically demanding task that consumes more time and causes musculoskeletal injuries. There are also some instances of utility vehicles powered by fuels but produce noise, emissions and cannot be used in small garden paths. Moreover, fuel powered cars make operations more expensive and harmful to the natural environment. The lack of a small, noisy, and environmentally friendly method of transport led to the creation of a EUV that will be used in gardening work. The main issue that is discussed in this paper is to come up with a car that is safe enough to transport plant pots and gardening tools over a short distance and, at the same time, to be easy to use, less manual labor required, and not contribute significantly to the ecological footprint in the landscaped and pedestrian-accessible zones.

3 CAD Model

To have an idea of the rough structure, layout and space arrangement of the major components of the EUV, a rough CAD model of the EUV was created during the first design process. The initial model oriented towards determining the chassis geometry, wheelbase, track width, ground clearance and platform on which the loads will be carried to deliver gardening pots and materials. The frame, wheels, driver seat, steering column and the position of the battery were represented by basic shapes and simplified components. The main aim of rough CAD model was to estimate proportions, clearance of components and load distribution, but not with detailed features. This model allowed a rapid design cycle and early determination of possible design limits to stability, maneuverability and accessibility in garden pathways. The crude CAD model was used as a starting point on the further refinement and creation of a high-fidelity CAD model that was used to do structural analysis and manufacturing planning.

International Scientific Journal of Engineering and Management ISSN: 2583-6129
Volume: 04 Issue: 01 | Jan – 2025 DOI: 10.55041/ISJEM02202
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

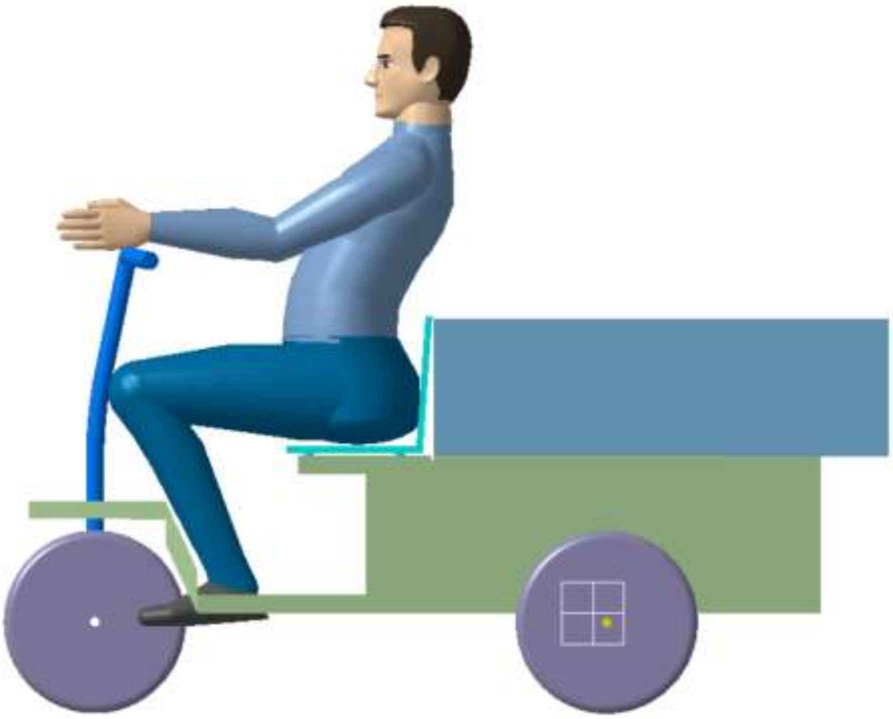

Fig. 1. Rough 3D CAD Model of EUV

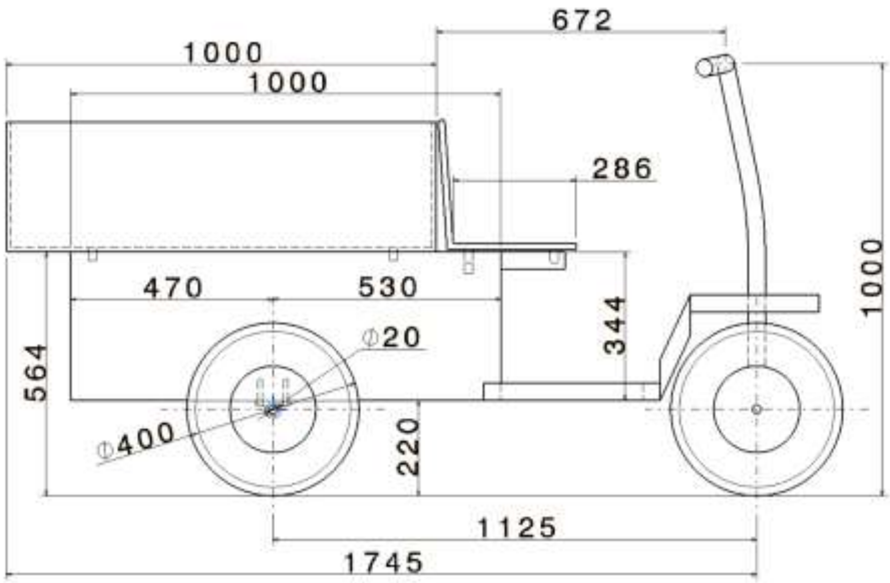

Fig. 2. 2D Drawing of Rough 3D CAD Model of EUV

4 Low Fidelity Prototype

The original design concept was also manifested in the functional layout, and then a low-fidelity prototype of the EUV was created to confirm that the design was correct in terms of functionality and layout prior to the actual modeling and construction. The prototype has been made of low cost and readily available materials like wooden pieces, metal rods, metal strips, plywood, cycle tyres, chair and basic fasteners to depict the chassis frame, load platform, and driver seating position. This prototype was not aimed at the structural strength but functional evaluation of the dimensions, ergonomics and accessibility. The prototype of low fidelity assisted in testing the convenience of loading and unloading gardening pots, the visibility of the driver, turning radius, and maneuverability on the narrow gardening paths. It also enabled evaluation of the positioning of components, i.e.: battery and motor positioning, to determine even weight distribution. The feedback that was received in this stage by gardeners was used to enhance practicality and user comfort. The prototype with low fidelity was very essential in the reduction of design mistakes and in the development of the final CAD model and the physical prototype.

Fig. 3. Low Fidelity Prototype of EUV

5 High Quality 3D CAD Model

Upon completing the concept and verifying the rough design, a three dimensional CAD model of the EUV of high quality was created. This elaborate model was developed with professional computer aided design software and it contained accurate dimensions, material properties and assembly constraints. The chassis frame and other key parts like the suspension system, steering system, load platform, electric motor, battery pack, and the seating of the driver were modeled correctly. The high-quality CAD model allowed detailed evaluation of the component fitment, checks of the interference, and distribution of masses. It also assisted in the creation of detailed manufacturing drawings, bill of materials and assembly sequence. Refinements were made in design in order to increase structural rigidity, stability as well as ease of servicing. Moreover, the structural analysis employed on the finite element methods was done on the model. The completed 3D CAD model guaranteed the accuracy of the design and minimized the number of errors during the manufacturing process, which led to efficient fabrication and the quality of the performance of the electric utility vehicle.

Fig. 4. High Quality 3D CAD Model of EUV

International Scientific Journal of Engineering and Management
ISSN: 2583-6129
Volume: 04 Issue: 01 | Jan – 2025
DOI: 10.55041/ISJEM02202
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

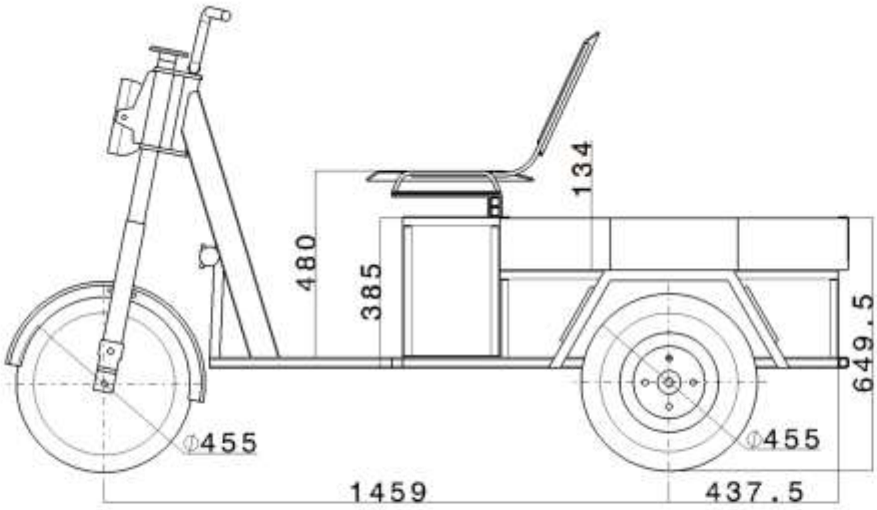

Fig. 5. 2D Drawing of High Quality 3D CAD Model of EUV

6 Structure Analysis

The driver seat structural analysis was conducted to ascertain safety, comfort and longevity to the vehicle usage. The seat system was configured in a way that it could hold the weight of the driver and the dynamic force during the acceleration, braking and uneven surface conditions. The simplified seat frame model was developed through computer-aided design software and mild steel was used as the material of structure because it has a sufficient level of strength and can be fabricated without significant difficulties. The Finite Element Analysis was done using a static load which was the maximum weight of the driver with a reasonable safety factor. The mass of 200Kg was added to the seat. At the structures of the chassis, which were attached to the seat, the boundary conditions were specified. The results of the analysis indicated that the highest values of stresses were significantly below the allowable range of the material, and the deformation that occurred was relatively small. This helps to verify that the seat structure is strong, stable and safe to support long-term use of the electric utility vehicle.

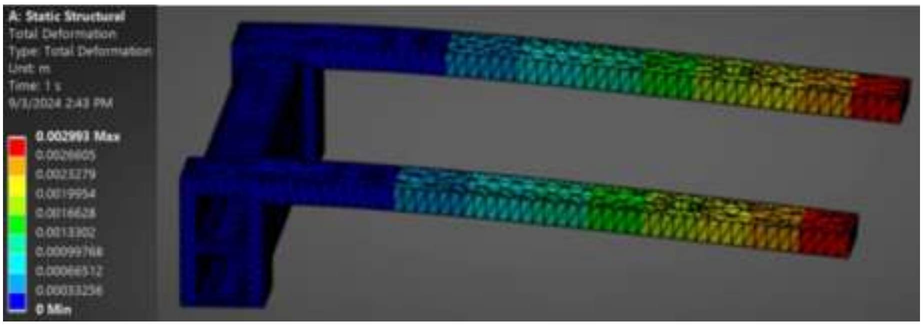

Fig. 6. Structural Analysis of Seat of EUV

7 Manufacturing of EUV Chassis

The electric utility vehicle involved in the production of the chassis was manufactured using the conventional machine tools in order to attain the dimensional accuracy and structural reliability. Based on completed design drawings, a choice of mild steel was made and first a lathe machine was used to face, turn and size precisely shafts, spacers, and mounting parts. A milling machine was used to make flat work, slots and mounting features needed in motor brackets and suspension supports. A drilling machine was also used to produce the accurate holes of the fasteners and component parts to allow accurate positioning and placement of other parts. Subsequent grinding was done in order to enhance the surface finish, burrs, and close tolerances in critical areas. These machining processes helped in the better fitments and load distribution in the chassis structure. The chassis parts were produced in a repetitive and consistent fashion using production standard workshop machines. This strategy allowed the chassis to be to design specifications and at the same time to be manufactured at a low cost and to low-end level of manufacturing that students could handle.

Fig. 7. Manufacturing of Chassis of EUV

8 Welding of EUV Chassis

The electric utility vehicle welding was conducted by use of arc welding to make the welding joints robust and strong structures. A special welding jig was designed and built to achieve more dimensional accuracy and a shorter time of fabrication. The structure was created by designing the chassis geometry; the structure was inaccessible in all areas except the welding sites so the fixing was carried out with the help of this fixture. This design reduced non-congruity, distortion, and interdimensional differences. Electrodes made of mild steel that would fit in the chassis material were used to ensure that they fused well and penetrated sufficiently. The parameters controlling the welding process like the current and the angle of the electrode were taken great care so that the quality of the welds could be ensured without changes. It was welded in a sequence strategy in order to minimize any residual stresses and thermal distortion. Once welding was done, slag cleaning and inspection of surface were done to ensure that there were no defects on the surface and continuity of the joints. The con-sistent quality, productivity, and structural integrity of the chassis of the electric utility vehicle were achieved through arc welding, with an intentionally designed and constructed fit, leading to the better quality of the welds.

Fig. 8. Welding of Chassis of EUV

9 Painting of EUV Chassis

The chassis of the electric utility vehicle was painted to improve on the resistance of corrosion, durability and the general look of the vehicle. Before the painting it was ensured that the chassis surface was well cleaned to get rid of dust, grease as well as rust and other residual contaminants. The mechanical treatment of surfaces was carried out to provide adequate adhesion of the coating. A uni-form application of an anti-corrosion primer was initially applied on the whole chassis. The primer coating was used as a protective barrier, so as to prevent oxidation of the mild steel and enhance bonding strength of the resulting paint coat. A finishing coat was applied with the use of spray painting technique after the primer had been dry to ensure a uniform thickness and smoothness on the surface upon application of finishing coat. Controlled drying was also put in place to prevent blistering and uneven coating de-

International Scientific Journal of Engineering and Management ISSN: 2583-6129
Volume: 04 Issue: 01 | Jan – 2025 DOI: 10.55041/ISJEM02202
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

fects. The painted chassis was checked visually on the consistency of coating and surface quality. The process of this painting enhanced the service life and environmental resistance of the electric utility vehicle chassis as well as the aesthetic quality of the same to a larger extent.

Fig. 9. Primer and Paint of Chassis of EUV

10 Assembly of Child Components in Chassis of EUV

Child components assembly in the chassis of the electric utility vehicle were done in a systematic arrangement to guarantee good fitting in functionality and safety. The start point in this process was with the installation of the rear axle that was supported with the help of pillow block shaft ball bearings to ensure that there was ease in rotation and proper distribution of load. Then the piece of the head section was put in at the front of the chassis to fit in steering and control parts. Front and rear tyres were then fitted, and it was then fitted with front shocker to help improve the ride comfort and stability. The driver seat was firmly attached at the appropriate mounting position, to assure of comfort in sitting ergonomically, and also to guarantee safety. Components were also attached and fitted electrical and lighting components like front indicators, headlight, display unit, rear indicators, tail light and brake light as required by design. Components were also correctly fastened and routed so as to prevent interference during operation. There was a functional, reliable, and stable electric utility car as a consequence of this organized assembly style.

Fig. 10. Assembly of Child Components in Chassis of EUV

11 Battery Pack of EUV

Battery technology of the electric utility vehicle is a very important factor in determining its performance, safeguards and its working range. A lithium iron phosphate (LFP) 48 V and 42 Ah battery pack was chosen in the current design since it has good thermal stability, prolonged cycle, and increased safety features. The battery pack was incorporated on the chassis at a low position of the car so as to enhance vehicle stability. The battery was charged with a lithium charger with a rating of 54.6 V and 6 A that made the energy replenishment controlled and efficient. A Battery Management System (BMS) was integrated to control the process of charging and discharging and offer protection against over-voltage, under voltage and overcurrents. Also, the BMS continuously checked the cell temperature to avoid thermal problems and enhance the reliability. There was appropriate insulation and content mounting to avoid mechanical vibrations to the battery system, which increased the general safety and durability of the electric utility vehicle.

International Scientific Journal of Engineering and Management ISSN: 2583-6129
Volume: 04 Issue: 01 | Jan – 2025 DOI: 10.55041/ISJEM02202
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Fig. 11. Battery Pack of EUV

12 Wire Harness of EUV

The harness of the EUV was indeed implemented and made in a manner to establish a reliable power flow and transmission of signals to the electrical and electronic elements. The harness design was made according to the vehicle structure with the intention of reducing the length of wire, voltage drop and electromagnetic interfer-ence. A DC-DC converter was built into and a controller was used to connect the traction system to the rated cables, with a DC-DC converter providing low-voltage power to the auxiliary systems. The display unit was given electric connections to monitor vehicle parameters in real-time. The harness linked the lighting components like the headlight, front indicators, rear indicators, tail light, brake light, and the fog light and associated the light components with the appropriate connectors and protective sleeve. It was implemented with proper color coding and labelling of wires in order to make them easier to identify and maintain. Insulation and routing was well under control to ensure abrasion and short circuit could not happen. This structured wire harness guaranteed the safety in functioning, enhanced dependability, and the facile troubleshooting of the electric utility vehicle system.

Fig. 12. Wire Harness of EUV

13 Physical Testing of EUV

The electric utility vehicle was physically tested to check the performance of the vehicle, its reliability and viability in its day to day operations in the campus setting. Its usage was in a normal working condition where the vehicle was used by the peons to move materials, files, and other utility items across various points around the campus. The tests were directed at such parameters as carrying capacity, maneuver-ability, braking power, and convenience in operation. The car was also tested in internal roads of different surface conditions to test the ride comfort and stabil-ity. Start-stop operations were repeated over to test the re-sponses of acceleration and control behavior. Battery discharge behavior was also monitored within the normal use to approximate useful range. The observations made by the opera-tors were noted to determine the ergonomics, visibility, and handling ergonomics. Based on the results, it was shown that the vehicle was reliable when moving short-distance materials with minimum effort on the part of the people using it. This physical test confirmed the feasibility of the practical relevance of the electric utility vehicle to the campus logistics and the daily working activities.

Fig. 13. Physical Testing of EUV within the Campus

14 Failure of Rear Shaft during Physical Testing of EUV

When testing the electric utility vehicle physically in the campus, the failure was witnessed in the shaft at the back when overloaded. During the period when the vehicle was being loaded to carry items that were way beyond the stipulated load capacity, the rear shaft underwent undue torsional and bending stresses. Consequently, the shaft broke up into two distinct portions when it was in operation causing instantaneous termination of power to be transmitted to the back wheels. Inspecting the failed part visually suggested that the failure had happened at one of the stress concentration regions where the effects of the large loads and repeated load cycles gave rise to the fracture of the material. What was demonstrated by the incident is that the initial shaft design has its limitations when it comes to the overload conditions during the real-world usage. This was not gone bad to cause any injury because the test was done at low speed within the academia. The shaft failure observed was very helpful in highlighting the flaws of the design and including better load capacity, choice of material as well as safety considerations in further designs.

Fig. 14. Failure of Rear Shaft during Physical Testing of EUV within the Campus

15 Redesign and Manufacturing of Rear Shaft of EUV

The redesign of the rear shaft of the elec-tric utility vehicle became necessary after the failure witnessed during the physical testing so as to maximize its bombast and durability. The redesign procedure was based on a thorough inspection of loading circumstances and stress dis-distribution over the length of the shaft. The rear shaft diameter was made larger in order to enhance the load carrying capacity, and this substantially decreased torsional and bend-ing stresses in service. The concentration points of stress that were determined during the previous design were eradicated through the changes in geometrical transitions and rounded off angles. The fillets were placed at the important areas like shoulder steps and bearing seats so as to enhance the ease of flow of the stress and reduce the chances of crack formation. The improved shaft design was produced under the conventional ma-chining operations through enhanced dimensional accuracy and finish. The inspection which was done after manufacturing showed that the manufacture met the changes in specifications of the design. The design modification proved effective as the redesigned rear shaft showed better structural integrity and strength on further testing.

International Scientific Journal of Engineering and Management ISSN: 2583-6129
Volume: 04 Issue: 01 | Jan – 2025 DOI: 10.55041/ISJEM02202
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Fig. 15. Redesign and Manufacturing of Rear Shaft of EUV

16 Finished Product with Technical Specifications of EUV

The ultimate product that is to emerge in the course of this study is a fully operational electric utility vehicle that will facilitate the efficiency transportation of materials in a sustainable environment in the campuses. The car is constructed to have a personal-made steel chassis and frame that has enough structural integrity to support cargo weights to 150 kg with safety. Motor Propulsion A 1200 W BLDC hub motor in a front-wheel-drive installation provides top efficiency, low noise, low maintenance and a top speed of 46km/h. A smart motor controller with brake sensors and a display panel provide the motor controller with smooth power delivery and good control. A 48 V 42 Ah LFP battery pack acts as energy storage and is charged with a 54.6 V, 6 A lithium charger and a Battery Management System (BMS) controls the charging process and monitors temperature to ensure improved safety. The car has got an enclosed cargo bed, front telescopic suspension and brakes of the hydraulic type that are used to ensure stability and safety. A DC converter DC converts the DC into 12 V DC, which is used to power the accessories such as headlights, tail lights, indicators, horn, digital dashboard, reverse gear switch, as well as the parking brake system. A typical AC power point is used in the charging system and the time taken to charge the battery is about 4 hours, which provides a reasonable range of up to 100 km of driving on a single charge.

Fig. 16. Finished Product i.e. Electric Utility Vehicle

17 Conclusion

The paper effectively introduces the entire design, analysis and manufacture of an electric utility vehicle which was designed in response to the need of efficient and environmentally safe transportation of material in a campus set up. The project started with the proper identification of the problems, which were the reduction of the manual work and the enhancement of the performance of the operations related to the short-range cargo transportation. According to this need, a suitable design idea was determined and translated to a simple CAD model allowing prior visualization and layout planning. The prototype was then made in low-fidelity to test-verify the ergonomics and simple functionality. A quality CAD model was then made ready and then structural analysis done so that it meets safety and load carrying capacity. The manu-facturing stage involved chassis manufacturing, arc welding and surface painting to give it a stronger usability. Child component assembly, wireless harness assembly and installation of electrical and mechanical systems were done in a systematic manner. The physical testing in actual campus load conditions showed that there was a failure in the rear shaft caused by over loading and this is what prompted to redesign and produce a new shaft with higher strength. The modified vehicle showed good performance, a factor that validated the iterative design method and ensured that the issue of the electric utility vehicle was possible to use in the campus in a sustainable manner.

References

1. Chan, C.C.: The state of the art of electric, hybrid, and fuel cell vehicles. *Proc. IEEE* **95**(4).
2. Ehsani, M., Gao, Y., Longo, S., Ebrahimi, K.: *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*. CRC Press, Boca Raton (2018)
3. Larminie, J., Lowry, J.: *Electric Vehicle Technology Explained*. Wiley, Chichester (2012)
4. Mi, C., Masrur, M.A., Gao, D.W.: *Hybrid Electric Vehicles: Principles and Applications*. Wiley, New York (2011)
5. Ashby, M.F.: *Materials Selection in Mechanical Design*. Butterworth-Heinemann, Oxford (2017)
6. Ulrich, K.T., Eppinger, S.D.: *Product Design and Development*. McGraw-Hill, New York (2016)
7. Pahl, G., Beitz, W., Feldhusen, J., Grote, K.H.: *Engineering Design: A Systematic Approach*. Springer, London (2007)
8. Kalpakjian, S., Schmid, S.: *Manufacturing Engineering and Technology*. Pearson, Boston (2014)
9. Groover, M.P.: *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*. Wiley, New York (2015)
10. Hibbeler, R.C.: *Mechanics of Materials*. Pearson, London (2018)
11. Budynas, R.G., Nisbett, J.K.: *Shigley's Mechanical Engineering Design*. McGraw-Hill, New York (2015)
12. Messler, R.W.: *Principles of Welding: Processes, Physics, Chemistry, and Metallurgy*. Wiley, Hoboken (2008)
13. Jeffus, L.: *Welding: Principles and Applications*. Cengage Learning, Boston (2016)
14. Bansal, R.K.: *Strength of Materials*. Laxmi Publications, New Delhi (2018)
15. Heisler, H.: *Vehicle and Engine Technology*. Butterworth-Heinemann, Oxford (2002)
16. Bosch Automotive Handbook. *Automotive Systems and Components*. Bosch, Stuttgart (2018)
17. SAE International: *Electric Vehicle Safety and Design Standards*. SAE Publications, Warrendale (2019)
18. Degarmo, E.P., Black, J.T., Kohser, R.A.: *Materials and Processes in Manufacturing*. Wiley, New York (2012)
19. Miller, R.K.: *Design for Manufacturability Handbook*. McGraw-Hill, New York (2008)
20. ISO 26262: *Road Vehicles – Functional Safety*. International Organization for Standardization, Geneva (2018)