Literature, Design analysis & Fabrication of Electric cargo bikes

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Abstract- **Addressing the issues of climate change and energy resource challenges, a mobility transition is critical to move from private fossil fuel cars to sustainable transportation options in both passenger and freight sectors. A significant reason why citizens rely on private cars is for tasks such as parcel delivery, shopping, and transporting children. However, new electrified mobility options, such as electric cargo bikes (e-cargo bikes), offer an alternative that can reduce car dependency. These bikes are becoming more prevalent in city transportation systems due to technological advancements, improved infrastructure, and government support in several countries. This paper aims to provide a comprehensive international review of the role of e-cargo bikes in urban transportation. It synthesizes global studies on e-cargo bikes, examining aspects such as typology, technical parameters, user characteristics, and the readiness of cities to adopt this emerging mode of transport. Additionally, the paper analyzes and compares the barriers and driving factors for the development of e-cargo bikes, considering social, economic, environmental, and regulatory parameters across different countries.**

Keywords: **Micro mobility e-Cargo Bike Urban freight transportation Sustainable mobility Urban transportation e Mobility.**

INTRODUCTION

Greenhouse gas (GHG) and CO2 emissions continue to rise globally, exacerbating the threats and challenges posed by climate change to our future. According to the 2030 Agenda for Sustainable Development (2015) and the New Urban Agenda (2016), climate change and global warming severely impede the achievement of sustainable urban development. This issue is likely to worsen with the ongoing urbanization process, as it is projected that more than 70% of the global population will reside in urban areas by 2050 (Dodman et al., 2022). The Paris Agreement (2015) targets limiting the temperature increase to 1.5°C, necessitating that governments, private organizations, and civil society address high-emission activities across various sectors through diverse measures.

At the governmental level, sustainable development strategies must encompass policy integration, long-term planning, decentralized cooperation, multi-stakeholder and multi-level governance, and a transparent system for assessment, action, monitoring, and reporting (OECD, 2006; UN-Habitat, 2018). One sector that is particularly critical due to its substantial contribution to GHG and CO2 emissions is transportation. The transportation sector is responsible for 23% of global energy-related CO2 emissions, making it a key focus for emission reduction.

Transportation and its environmental impact: The transportation sector is a major contributor to greenhouse gas (GHG) emissions, with passenger and freight movement accounting for a significant portion. Research by Jaramillo et al. (2022) suggests that this sector is responsible for roughly 69% of direct emissions and 15% of global GHG emissions altogether.

Sustainable transportation solutions: Policymakers have a role to play in mitigating this impact by promoting sustainable mobility options within their cities. This includes facilitating the adoption of non-fossil fuel based transportation modes for citizens.

The rise of e-cargo bikes: E-cargo bikes are emerging as a promising sustainable transportation solution, particularly in European cities. These electrically-assisted cargo bicycles are seen as environmentally friendly with the potential to significantly reduce reliance on private cars compared to other cycling options. However, research by Gruber et al. (2022) and Schliwa et al. (2015) suggests that public incentives and promotional efforts for e-cargo bikes are still lacking.

Impact on mobility behavior: The effectiveness of new transportation modes in influencing citizen mobility patterns depends on various factors. These factors, as identified by Mostofi (2022, 2021), Tarnovetckaia and Mostofi (2022), and Mostofi et al. (2020a, 2020b), include the specific urban environment, socioeconomic demographics, cultural context, and land-use patterns. The influence of these factors can vary significantly across different cities, and even produce contrasting effects.

Research by Akiva et al. (2020), Büttgen et al. (2021), Caggiani et al. (2021), Conway et al. (2017), Elbert & Friedrich

(2020), Gruber et al. (2022), Gruber & Rudolph (2017), Gruber & Thoma (2019, 2020), Gunes (2021), Hagen & Scheel-Kopeinig (2021), Katsela et al. (2022), Llorca & Moeckel (2021), Nascimento et al. (2020), Niels et al. (2018), Nürnberg (2019), Robichet et al. (2022), Sheth et al. (2019), and Zhang et al. (2018) indicates a growing interest in the use of e-cargo bikes for private transportation, though the research remains limited. A systematic review by Narayanan and Antoniou (2022) primarily examines e-cargo bikes in the context of city logistics, with only a brief mention of their private mobility applications.

This paper explores the private use of e-cargo bikes, compiling relevant studies and addressing the following key questions to analyze e-cargo bikes and their (potential) users:
- Q1: What typologies are available?
- Q2: What are the personal characteristics of e-cargo bike (potential) users?
- Q3: What are the travel characteristics of e-cargo bike (potential) users?
- Q4: What is the state of readiness for e-cargo bikes in cities?
- Q5: What are the main factors driving the implementation of e-cargo bikes?

relevance to the main research purposes of this study.

Selection and Analysis of Studies

During the inclusion phase, 36 scientific articles, journal articles, conference proceedings, and reports were selected for review. These studies were categorized into eight sub-topics based on the research questions outlined in the introduction. The following sections provide a detailed analysis of each of these categories, grouping the findings from the 36 reviewed studies accordingly

Sections Overview

Cargo cycles and e-cargo bikes have been available in the market for several years, with research on e-cargo bikes beginning around 2014. Early studies focused on logistics, while research from 2018 onwards has increasingly addressed personal mobility. The geographical focus of the data is predominantly from the USA and Europe, often referred to as WEIRD (Western, Educated, Industrialized, Rich, and Democratic) countries.

Payload Capacity and Design

Cargo cycles, including e-cargo bikes, come in various designs with payload capacities ranging from 50 kg to 250 kg, and in some cases, up to 400 kg depending on their type and intended use (Wrighton & Reiter, 2016; Riehle, 2012; Schier et al., 2016). These bikes typically feature 2 or 3 wheels, such as long john bikes, longtail bikes, and trikes, each equipped with specific cargo containers and, often, electrical assistance (Gruber & Narayanan, 2019; Schliwa et al., 2015).

The electrical assistance provided by e-cargo bikes includes technical specifications related to the battery and motor, which influence the bike's power and range. E-cargo bikes are categorized based on their speed: Pedelec-25, which has a top speed of 25 km/h and is generally considered a conventional bike, and Pedelec-45, or S-Pedelec, which can exceed 25 km/h and requires a license, insurance, and safety equipment (Cairns & Sloman, 2019; Gruber & Narayanan, 2019). Different countries have established varying regulations concerning speed and power. The EU Regulation 168/2013, for instance, sets a speed limit of 25 km/h and a net power range between 250 and 1000 Wh for L1e-A vehicles, classifying other light two-wheel powered vehicles as L1e-B or two-wheel mopeds.

The range of an e-cargo bike's battery can vary significantly based on factors such as battery size, number of stops, degree of acceleration, physical effort by the rider, topography, and payload. Typical ranges are between 50 and 100 km (Schier et al., 2016). Koning and Conway (2016) found an average battery capacity of 375Wh, yielding a range of about 42 km on a full charge. Using Robert Bosch's tool for e-bikes, a 300 kg load e-cargo bike with a 300Wh battery can travel between 19 km and 42 km, depending on environmental conditions.

Characteristics of Users

Demographics

Studies on cargo cycles and e-bikes have shown that users and potential users tend to be young, (upper-)middle-class males with high levels of education (Becker & Rudolf, 2018a; Boterman, 2018; Bourne et al., 2020; Dorner & Berger, 2020; Hess & Schubert, 2019; Riggs, 2016). These individuals often already use conventional bikes for transportation and live in households with children and available cars (Becker & Rudolf, 2018a; Boterman, 2018;

MacArthur et al., 2014; Riggs, 2016; Riggs & Schwartz, 2015).

Interestingly, some studies on cargo cycle logistics reveal different user characteristics. For instance, messengers who use e-cargo bikes are less likely to own cars, and higher education levels do not necessarily correlate with e-cargo bike usage (Gruber et al., 2014; Gruber & Kihm, 2016). These differences highlight the distinct demographics between private transportation and logistics purposes.

Values

Users and potential users of e-cargo bikes often share common intrinsic beliefs, particularly regarding environmental concerns. For example, in a study by Becker and Rudolf (2018a), over 92% of participants (856 respondents) were "rather" or "very concerned" about climate change, and 84% expressed similar concerns about air quality. This aligns with findings from Bourne et al. (2020), which suggest that environmental values motivate young adults to ride e-bikes. However, Dorner and Berger (2020) noted that personal environmental norms regarding transport bike-sharing are significant only for existing users.

Additionally, technology curiosity is another value that influences the adoption of e-cargo bikes, as noted by Gruber et al. (2014) and Gruber and Kihm (2016), although these studies focused on cycle logistics and messengers' attitudes.

Modal choice and purposes

When analyzing the urban mobility of a population, different pur- poses are identified, depending on several factors such as geographical context, socioeconomic indicators, demographics, and various modal choices (Mostofi et al, 2020c). Common purposes classifications include commuting, which comprises trips made to work and/or school, shop- ping, errands, and leisure, and typical modal choices are represented as private car, public transportation, cycling, and walking (Samaha & Mostofi, 2020). Studies done in cycle logistics, even though their focus is not on private transportation modal shift or purposes, illustrate inter- esting results on the potential demand for e-cargo bikes as a transport vehicle to substitute vans, trucks, and private cars in that sector. Ac- cording to Wrighton and Reiter (2016), 51 % of motorized trips in a city related to goods transport could be potentially shifted to bicycle trans- port based on the average weight of goods and distance covered in this type of trip. Further division in this study shows that approximately 35
% of those trips are exclusively related to household members mobility
and not logistically focused. Nevertheless, the authors do claim the

regarding the substitution of car trips and the main purpose of travel to work (Bourne et al., 2020; Cairns et al., 2017; Castro et al., 2019; Haustein & Møller, 2016; Hiselius & Svensson, 2017; Jones et al., 2016; MacArthur et al., 2014; Thomas, 2021).

Readiness of E-cargo bikes

The adoption of e-cargo bikes as a valid transportation mode is still very limited worldwide. Although cycling has been pushed as a sus- tainable mode of travel in cities by multiple organizations and govern- ments, cargo cycling has not been part of the conversation. The view has predominantly relied on seeing cargo bikes as a carbon-friendly mode for sustainable logistics, but not much has been said about its purpose for personal mobility. The following sections present a variety of bar- riers to e-cargo bikes, firstly from a point of view of (potential)users, then particular attention is given to infrastructure and policy barriers.

Barriers

Several limitations to e-cargo bikes are discussed as barriers for people to acquire, use, and promote this mode in cities. Aspects related to safety are particularly mentioned across studies, as concerns of riding next to heavy vehicles or difficulty of passing large vehicles are identi- fied (Liu et al. 2020), chances of theft (Bourne et al., 2020; Gruber & Thoma, 2020; Riggs & Schwartz, 2015). Components related to mobility with children also concern the safety of (potential)users as Riggs (2016) and Riggs and Schwartz (2015) mentioned factors such as children being too young for the seats or the lack of adequate placement for them. Besides safety, barriers can be grouped along Bourne et al. (2020) classification of individual, social, and physical constraints. Less effort, social stigma, riding in traffic, respectively, are factors that influence the adoption of electrically assisted bikes, like e-cargo bikes (Gruber & Thoma, 2020; Nascimento et al., 2020; Thomas, 2021). Moreover, vehicle limitations identified by Gruber and Thoma (2020) also play a barrier role, as low spatial coverage due to the available range is worrisome to certain groups. Additionally, issues about low electric range, or perception of such, limit (potential) users' adoption of e-cargo bikes (Bourne et al., 2020; Jones et al., 2016: Riggs & Schwartz, 2015). Capital costs are also identified as a barrier, especially considering that e-cargo bikes have a much higher price than conventional bikes, exceeding in most cases the thousands of dollars, and other electrically assisted bikes to a lesser extent too (Bourne et al., 2020; Gruber et al., 2014; Jones et al., 2016; Lee & Morales, 2020; Thomas, 2021). Never- theless, it is important to acknowledge that these studies did not mention purchase costs to be a main barrier which could be explained by the fact that many samples include already owners and inclined target demographic of active mobility. Finally, the barriers mostly identified in different studies and research are infrastructure concerns and policies.

Infrastructure

E-cargo bikes as their classification of Pedelec entitles ridership in cycleways, which according to (potential)users is the main constraint for its adoption. The infrastructure of cycle roads is deemed as a problem, not only for e-cargo bikes or cargo cycles but also for e-bikes and con- ventional bicycles in general (Bourne et al. 2020). Cycling infrastructure in cities and the components of these as width, maintenance, accessi- bility, connectivity, road traffic, and parking allocation are some of the issues highlighted (Becker & Rudolf, 2018b; Bourne et al. 2020; Gruber & Rudolph, 2017; Gruber & Thoma, 2020; Liu et al. 2020; Jones et al., 2016; Riggs & Schwartz, 2015; Thomas, 2021).
Particular emphasis is put on 3 factors mentioned: road traffic, the width of cycle lanes, and parking allocation. Here, road traffic refers to the ability to cycle safely and efficiently, which may be achieved by implementing dedicated bike lanes and bike-friendly junctions (Gruber & Rudolph, 2017). Vital elements identified in road traffic include the type of infrastructure, the traffic volume of heavy vehicles and the traffic volume of cars, from which traffic volume of heavy vehicles is highly potential for e- cargo bikes as a means to replace the other vehicle mentioned in what they refer to as ‘private logistics’, or household errands.
Focusing on modal choice with cargo cycles, the study done in the USA by Riggs (2016) found a 41 % reduction in private car trips with the introduction of cargo bikes, rising to a total of 69 % of respondents having this new mode of transportation as their primary modal choice. The reduction in private car trips is represented as 1–2 trips per week. Moreover, another study by Riggs and Schwartz (2018), also in the USA, on cargo bikes expands on the results above, highlighting that “when looking at the difference between genders, both men and women saw a decrease in all other modes as a result of the introduction of a cargo bike” (p. 103). In Berlin, a study done for the e-cargo bike sharing company AvoCargo by Weber et al. (2022), indicate that 40 % of trips done by e-cargo bike users replace private car transport, 22 % replace public transport, 20 % cycling, 14 % walking, and 4 % others. However, the international studies about the impact of e-scooters (as another type of e- micro mobility) indicate that their regular users mostly replaced walking and non-motorized modes by e-scooters rather than private cars (Ş engül & Mostofi, 2021). Therefore, in the urban mobility sector, e- cargo bikes have more stustainable impacts than e-scooters on mobility behaviors of citizens to encourage them to shift from private car. Moreover, Cairns and Sloman (2019) identified a range of studies in the logistics and freight sector that portray a wide range of substitution potential for e-cargo bikes, suggesting an average 10–30 % of trips.
When observing purposes involved in the modal choice, Bjørnarå et al., (2019) study done in Norway observed a significant decrease for trips done to the workplace and kindergarten in all seasons, although no significant reduction was identified for grocery stores trips. What type of trips are more commonly done by cargo cycles and/or electrically assisted bikes? According to the of Becker and Rudolf (2018a) in Ger- many, the most common purpose for cargo cycle trips are the transport of groceries or bottle crates, shopping, doing errands. Riggs and Schwartz (2018) results show that the main purpose is commuting to work while going to school represents only a small percentage of trips. Weber et al. (2022) main identified purposes are transporting children, moving heavy loads, and for shopping. The Bike Monitor in Germany report from SINUS (2021) shows similar results, although it includes a purpose not listed by other papers: transporting pets. According to SINUS (2021) the main purposes are shopping, transporting bulky ob- jects, transporting pets, and only then transporting children, very close to commuting to work or for work. Riggs and Schwartz (2018) also state that 56.3 % of men and 78.0 % of women utilize the cargo bike to transport children, highlighting the importance of this mode for such a purpose. Electrically assisted bikes studies have similar findings different schemes represent the diversified adoption possibilities for this mobility system (Movmi, 2022). Berlin portrays a good example of how cities can promote the adoption of e-cargo bikes through different measures, as private companies such as AvoCargo and Sigo are inte- grated with its public transport through their MaaS stations known as Jelbi (Jelbi, 2022) and with CSOs’ as fLotte through the German bike association and the national and local government to create the “fLotte kommunal” a non-for-profit system of e-cargo bike sharing (Bezirksamt Friedrichshain-Kreuzberg von Berlin, 2022).
Policies are now being focused on incentivizing the purchase and use of electrical vehicles, ranging from private cars, bikes, and also cargo bikes. Particularly in Europe, governments are now setting funds for businesses, municipalities, and private individuals for them to apply and receive a subsidy for acquiring an e- cargo bike. (See Table 2).
The table presented represents subsidies and measures done at different European countries but is not exclusively done by the central government. Many regional and local authorities have implemented their own subsidies for e-cargo bikes and other sustainable modes of transport. Furthermore, policies that aim at businesses or municipal organizations

are not considered in the table.
Although it is recognized the effectiveness of incentives and rebates policies for the acquisition of certain goods or services, an important aspect that can be neglected is equity. Studies researching the transition towards clean energy vehicles, plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV), mostly, have shown worrying con- cerns related to equity outcomes where low-income and vulnerable groups are disadvantaged compared to wealthy households. Rebates do in fact increase EVs market share even though these programs are pri- marily beneficial for higher income households (Hardman et al., 2017; Caulfield et al., 2022; DeShazo, 2016). Multiple studies have discussed the Clean Vehicle Rebate Project in California finding that it gave out more incentives per family to privileged, better-off communities with primarily white residents and intermediate NO2 levels. These commu- nities also had higher incomes and better education levels (Ju et al., 2020; St. Louis and Rubin, 2016; Guo and Kontou, 2021). A common factor across these studies is the design of the incentive and rebate program. Many of these programs have no cap on purchase price, they work in a refund approach, and are not income-tiered which causes equity-related issues for the transition towards electric mobility.

Factors driving E-cargo bikes

Decision-making when adopting certain modes of transportation depends on several factors which can be divided into barriers and drivers. Barriers were described in section 3 and the identified drivers will be the topic of this next section. Factors were classified into three elements as economic drivers, social drivers, and environmental drivers. Each can have different levels of influence on (potential)users based on their characteristics such as demographics, perceptions, and values.

Economic

The economic drivers are related to the total cost of ownership (TCO) for e-cargo bikes, particularly compared to driving a private car. Even though capital costs have been identified as acting as a barrier due to its high investment (Bourne et al., 2020; Gruber et al., 2014; Jones et al., 2016; Lee & Morales, 2020; Thomas, 2021) compared to conventional bikes; it still represents a fraction of purchasing a private car or even public transportation in certain cases for long-term. The market price of e-cargo bikes can range between 2,000€ and 5,000€, depending on the brand and specific typology. Nevertheless, the TCO of e-cargo bikes compared to private cars is significantly lower per km driven due to savings during use as costs can be between 0.08€/km to 0.213€/km for the former whereas 0.35€/km to 0.621€/km, representing a worst-case reduction of 39.1 % to a best-case reduction of 87.1 %, conditional on certain assumptions as to the price of the local electricity grid mix, materials use, maintenance and repairs, insurance and taxes (Gruber & Rudolph, 2018; Palau, 2021).
Even though the purchase price is a limitation for (potential)users,
European Cycle Logistics Federation (2021; 2022) expect a projected growth by 38 cargo cycle companies since 2019 of 38.4 % in 2020, and 66 % in 2021. Results from a market analysis performed in Germany by the Zweirad-Industrie-Verband (2022) confirm the trend of cargo cycles in Europe with a 39 %, 99 %, 206 % yearly sale increase compared to 2018. In 2021 the sale of cargo cycles amounted to approximately 167,000 units, from which 120,000 were e-cargo bikes (ZIV, 2022). This also supported by the Cargo Bike Manufacturers and Operators Survey (2022) that shows an approximate 450,000 total cargo bikes purchases in 2022. Moreover, the deterrent of high capital costs for e-cargo bikes can be overcome in cities with the implementation of e-cargo bike- sharing schemes which have started to gain traction, particularly around Europe, with companies and grassroots initiatives such as Avo- Cargo, Cargoroo, Baqme, Carvelo2go, and Freie Laster¨ader.

Social

Along with economic drivers, literature on electrically assisted bikes and e-cargo bikes also identified social components which promote the adoption of these modes of transport. The social components refer to aspects such as wellbeing, accessibility, and liveliness. E-cargo bikes offer to perform exercise which increases physical activity, improving overall health for many (potential)users are important (Cairns et al., 2017; Bourne et al., 2020; Thomas, 2021). As Oja et al. (2011, p. 508) state there is a “positive relationship between cycling and health and functional benefits in young boys and girls and improvements in cardiorespiratory fitness and disease risk factors as well as significant risk reduction for all-cause and cancer mortality and cardiovascular, cancer, and obesity morbidity in middle-aged and elderly men and women”. Complementary to physical health, cycling also improves the mental health of users, providing higher satisfaction, reduced stress, and more pleasant journeys, compared to other mobility options (Gate- rsleben & Uzzell, 2007; Gruber & Rudolph, 2017; Heinen et al., 2011; Titze et al., 2007; Willis et al., 2015; Winters et al., 2011).
The adoption of e-cargo bikes can be brought about by accessibility
and liveliness drivers for more dynamic, inclusive, and climate-friendly cities. Factors such as increased access to

communities due to distance or topography, the possibility of use by people with limited motor capac- ities, intergenerational mobility, gender- neutral opportunities in transport, and modal shift from private cars are linked to promoting its use (Bjørnarå et al., 2019; Bourne et al., 2020; MacArthur et al., 2014; Riggs & Schwartz, 2018; Thomas, 2021).

Emission Savings

E-cargo bikes hold significant potential for addressing climate change and global warming, especially due to the modal shifts in transportation behavior among urban dwellers. Studies have quantified the emission savings when e-cargo bikes replace private car trips. Becker and Rudolf (2018b) reported that replacing car trips with e-cargo bikes resulted in avoiding 920 kg of CO2 emissions. Koning and Conway (2016) calculated the emissions during use at 0.507 g of CO2 per kilometer and 3.4 g of CO2/km, considering the load of a 150 kg e-cargo bike. Hiselius and Svensson (2017) forecasted that e-bike usage could lead to avoided CO2 emissions of around 394 kg per person based on changes in travel behavior.

Comparison with Urban Logistics

The main distinction between private transportation and urban logistics studies using cargo cycles is the type of fossil-fuel vehicles being replaced. Urban logistics often focuses on replacing vans and trucks, whereas private transportation typically involves replacing passenger vehicles. Despite this difference, the primary concern remains the reduction of fossil-fuel vehicle usage. It is crucial to note that CO2 emissions savings in urban logistics depend on the electricity mix of the area, where renewable energy sources can significantly amplify the impact, and the number of fossil-fuel vehicles replaced by e-cargo bikes. (See Table 3 for a summary of emission savings).

Conclusions

This research systematically reviews the characteristics of e-cargo cycles, travel behavior, personal features of users, and the constraints and drivers influencing their adoption. Key points include:

1. Typologies of E-Cargo Bikes: E-cargo bikes vary in design based on the number of wheels, position of the driver, storage container, and purpose. They include models like long john bikes, longtail bikes, and trikes, each with specific features and possible electrical assistance.

2. User Characteristics: E-cargo bike users are typically young, educated, middle-class males with environmental concerns and a tendency to use conventional bikes. These users often have children and cars in their households.

3. Travel Characteristics: E-cargo bikes are used for various purposes, with travel distances averaging between 5.8 km and 21.5 km per trip. Time spent riding e-cargo bikes varies, with studies indicating an average of 51.3 minutes per week to over 150 minutes weekly, depending on the context and purpose.

4. Perceptions and Values: Safety, environmental concerns, and exercise benefits are key factors driving e-cargo bike adoption. Negative perceptions include maneuvering difficulties and feeling like an obstacle to other cyclists. Positive perceptions include potential car replacement, enhanced exercise, and overcoming physical limitations.

5. Emission Savings: E-cargo bikes significantly reduce CO2 emissions when replacing car trips. The extent of emission savings depends on factors such as the type of replaced vehicles.

Future Research Directions

Further research is needed to explore the full potential and impact of e-cargo bikes, particularly in diverse geographic and socio-economic contexts. Future studies should focus on:

- Longitudinal Studies: Assessing long-term impacts of e-cargo bike adoption on travel behavior and emission savings.
- Policy Implications: Evaluating the effectiveness of policies promoting e-cargo bike usage and their role in urban mobility planning.
- Technological Advancements: Investigating improvements in e-cargo bike technology, such as battery life and load capacity, to enhance their utility and adoption.

Understanding these nuances will be crucial for policymakers, urban.

DESIGN ANALYSIS

As a viable alternative to traditional and electric cars and vans, e-cargo bikes have the potential to improve the sustainability of urban logistics operations, particularly for last-mile deliveries. In this study, e-cargo bike trips are modelled from a small business pilot rental scheme, and the effects of identified variables of: a) trip length and b) rainfall conditions on the attractiveness of e-cargo bikes as a mode of goods delivery are assessed. For the study, an intelligent modelling framework consisting of a) Data Acquisition System, b) Intelligent Learning Unit, and c) Output

Unit is built. The effectiveness of the learning system is evaluated through its application as a case study in Dublin, Ireland. It is discovered that small businesses prefer e-cargo bikes for goods delivery over longer distances in warmer and drier weather conditions. There is a strong interaction effect between weather and distance.

An electric cargo cycle which contains an adjustable frame, for changing the size of the cargo space, as well as the bike length is designed and developed. The developed prototype is built by using a normal bicycle as the base, with addition of a self-designed frame for the purpose of carrying cargo bucket. The developed design has a weight of 70 kg with 240 cm, 95 cm and 40 cm as length height and width respectively. The designed cargo bike has a load carrying capacity of 120 kg. The design is powered with 250 W electric motor and can move with maximum speed of 25km/hr. The steering mechanism is rocker arms based. The steering mechanism, cargo bucket and the base frame are made in two parts for commuter convenience. The cargo bucket is front mounted, on a sliding frame that enables one half of the bucket to be slid into the other half. The design has both electric and non-electric driving modes. The design find application for delivering goods, usage for short transport of goods, and industrial work. Also, the electric driven feature helps in climbing elevated terrain and reduces fatigue during the load carrying. Testing of the product was made and was found suitable for the designed parameters.

The proposed design was planned to overcome the existing problems as stated above which as a cargo compartment, where space can be adjusted according to the user’s need. The design has both electric and non-electric driving modes.

The cargo bucket is front mounted, on a sliding frame that enables one half of the bucket to be slid into the other half, using a mechanism similar to a drawer. The electric driven feature helps in climbing elevated terrain and reduces fatigue during the carrying of load. The design was developed in AutoCAD and Solid Works Software as shown in Fig. 1 to 4.

Figure 1.: Isometric View

Figure 2.: Right View

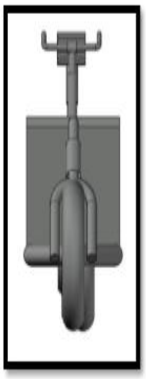

Figure 3.: Front View

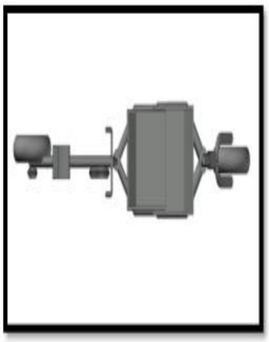

Figure 4.: Top View

DESIGN AND CALCULATION

SPEED AND TORQUE CALCULATION Any vehicle have its own speed based on its given parameters such as motor rating, load, self-weight, etc., and the speed indirectly depends on the torque required to move the vehicle. Thus we calculated the speed and torque of our designed e-cycle considering with some assumptions. a). No load calculation Turkish Journal of Computer and Mathematics Education Vol.12 No.10 (2021), 5848-5862 Research Article 5851 Given Motor power = 600 watts Speed of the motor = 500 rpm

Diameter of the wheel = 622 mm Gear ratio between the motor and the wheel sprocket is 1:1 so the same speed is transferred from motor to wheel. Assumption: No load including driver and self-weight is neglected.

Wkt, Power (P) = 2 * 3.14 * N * (T/60)
600 = 2 * 3.14 * 500 * (T/60)
Therefore,
T = 11.46 Nm
Where, T = Torque N = Speed of the motor Speed of the vehicle
= Speed of the wheel
* Circumference of the wheel = 500 * (Diameter of the wheel * 3.14)
= 500 * (622 * 3.14)
= 976540 mm/min
Speed of the vehicle = 58.59 Km/hr
From the above calculation found that, during zero loads or no load the torque produced from the motor will be 11.46 Nm
and the speed of the e-cycle is 58.59 Km/hr.
b). With load calculation Given Motor power = 600 watts
Speed of the motor = 500 rpm
Diameter of the wheel = 622 mm
Gear ratio between the motor and the wheel sprocket is 1:1 so
the same speed is transferred from motor to wheel.
Assumption:
i). Driver weight = 60 kg ii). Cycle self-weight = 5 kg
iii). Additional load = 10 kg
Total load = 75 kg = 75 * 9.81
= 735.75 N
So the total load acting on the cycle will be 735.75 N,
this can be divided into two loads for front wheel (Ff) and rear wheel
(Fr). Ff = Fr = (735.75 / 2)
= 367.875 N
Where the reaction on each wheels,
Rf = Rw = Co-effiectioent of the friction * weight on the each wheels
= 0.2 * 367.875
= 73.575 N
To find the torque on rear wheel,
Torque (Tf) = Rw * (Diameter of the wheel /2)
= 73.575 * (622/2) = 22881.825 Nmm
T = 22.88 Nm Wkt.,
Power (P) = 2 * 3.14 * N * (T/60) 600
= 2 * 3.14 * N * (22.88/60)
Therefore,
N = 250 RPM
Where,
T = Torque
N = Speed of the motor Speed of the vehicle
= Speed of the wheel * Circumference of the wheel
= 250 * (Diameter of the wheel * 3.14)
= 250 * (622 * 3.14) = 489246.54 mm/min
Speed of the vehicle = 29.5 Km/hr
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Thus, from the above calculation we understand that when the load is applied, the torque required is increasing and the speed of the cycle is decreasing. So, speed may reduce depends on increasing of load on the cycle.

REVIEW FABRICATION –

COMPONENTS- "CARGO BIKE" is the electrically operated consisting of the following different sub-components :

1) D.C. Motor
2) Frame
3) Charger
4) Battery
5) Wheels
6) Drive (CHAIN)

1) D.C. Motor: - The motor is having 250 watt. capacity with maximum 800 rpm with torque capacity of 50 Nm. It's specifications are as per the following:- Current rating -- 15 Amp Voltage rating – 12 Volt D.C. Cooling --- air cooled Bearing —- single row ball

Fig.- D.C MOTOR

2) Frame: - It is made from the mild steel body along with some of the light weight components. Welded in suitcase shape which serves as the base to hold all the accessories such as motor, weight of the load to be conveyed and the weight of the person driving the unit. Also it should be able to overcome the stresses, are coming due to different driving and braking torques and impact loading across the obstacles in the traveling ways. It is with the linkage and wheels to propel it and the platform plates. It is drilled and tapped enough to hold the support plates.

Fig.- FRAME

3) Platform:- It is the robust base for holding the uniformly or concentrated load along with the weight of the driving person. It is manufactured from the mild steel angle of 40x40x5mm c.s. size welded in suitcase shape with top sheet of 3 mm thickness. Platform is directly bolted and welded to the framed platform, the alignment of the platform is always kept perfectly horizontal while it is loaded or un-loaded.

Fig.- PLATFORM

4) Battery:- It is the accumulator of electric charge. It must store the electrical energy produced by the generator by the electrochemical transformation and give it back again on demand. e.g. while starting. Construction: - The basic element of battery is the cell. It contains the plate block which consists of a set of positive plates and a set of negative plates. The individual plates are separated from one another by separators placed in between. The cell is filled with the mild sulphuric acid. The block cases e.g. of a 12V battery, is divided in to six cells that are mutually sealed and are

tightly closed at the top by the block case cover. The individual cells are connected in series by the cell connector. At the first and the last set of plates, the end poles are welded. Following are the different components of battery:- Block case, block cover:- It is manufactured from acid resistant insulation material, partly from the hard rubber, mostly from plastic. E.g. polypropylene. Plates:-. The battery therefore needs relaxation pauses during high current discharges. Deep discharge:- Complete discharge of a battery must be avoided since the resulting lead sulphate has a larger volume and therefore there is the danger of breakage of the effective mass from the plate grid. Deep discharged batteries should be immediately recharged. Negative _ positive + lead battery Discharging

Fig.- BATTERY

5) WHEELS :- One of the primary benefits of having a smaller diameter front wheel on a cargo bicycle is the optimized load distribution it facilitates. By lowering the cargo's center of gravity, especially when the cargo is placed in front of the rider, stability is significantly enhanced.

Fig.- Wheels

6) Chain Drive:- A chain is made up of a series of links with the links held together with steel pins. This arrange makes a chain a strong, long lasting way of transmitting rotary motion from one gear wheel to another. Block case Negative Plate Positive plate Separator Web Electron flow PbO2-H2SO4-SO4+Pb++ Chain drive has one main advantage over a traditional gear train. Only two gear wheels and a chain are needed to transmit rotary motion over a distance. With a traditional gear train, many gears must be arranged meshing with each other in order to transmit motion.

Fig.- BRAKES

- SEAT: - A great looking carbon fiber bucket seat shell provides excellent lateral support while allowing the upper body freedom to lean into corners. The raised front portion of the bucket seat shell prevents the rider from sliding down in the seat in rough terrain. A built in relief rib eliminates uncomfortable pressure on the tailbone region. The reversible seat cushion is made from practically indestructible material and is removable for washing. The adjustable lumbar cushion offers added comfort on those long rides. The seat uses quick nuts for easy removal and is mounted to the frame using rubber isolators to help soak up the bumps.

Fig.- SEAT

- SPROCKETS:- The chain converts rotational power to pulling power, or pulling power to rotational power, by engaging with the sprocket. The sprocket looks like a gear but differs in three important ways: 1.Sprockets have many engaging teeth; gears usually have only one or two. 2.The teeth of a gear touch and slip against each other; there is basically no slippage in a sprocket. 3.The shape of the teeth are different in gears and sprockets.

Fig.- SPROCKET AND CHAIN

WORKING:

Principle: - The machine entitled “Battery operated – triscooter” Works on the principle that the motive force of an A.C. motor which receives the electricity energy stored in the d.c. battery converted with the help of D.C. to A.C. converter circuit.

Operating procedure:- here prior to start the two wheeler starting switch, it ensured that whether the battery is fully charged. Unless it is charged using the inverter circuit, consisting transistorized integrated circuit. Types of Sprockets Section Of wheel.

Working medium:- Here the chemical reaction which is taking place, evolves the energizing current which is responsible for motivation of the prime mover. This chemical reaction takes place while discharging of the battery. The sulphuric acid, being the working medium is separated into columns of positive H ions and negative SO4 ions by mixing with water. If the poles of the cell are connected by a load (incandescent lamp), electrons flow from the negative pole to the positive pole. Due to the scarcity of electrons at the negative pole, bivalent positive lead is produced from the neutral lead which combines with the bivalent negative SO4 group to form lead sulphate PbSO4. At the positive pole, bivalent positive lead is produced from the quadrivalent positive lead of the oxide through the electron supply. The combination with O2 is therefore ruled out and a combination with SO4 is introduced, lead sulphate PbSO4, is likewise produced. The oxygen atoms released combine with the hydrogen atoms of the electrolyte to form water. The density of the battery acid decreases. Operation:- The switch is put on the electric energy in the form of electric current flows from the battery to the d.c. to a.c. converter circuit where the direct current waveform is made sinusoidal due to the operational transistorized d.c. to a.c. amplifying circuit. The small intensity a.c. current across the out put is again amplified using the amplifier circuit. This amplified current is fed to the stator winding of the a.c. motor, which drives the circuit through the condenser. Condenser is the device which acts as a storing the electrical energy and delivering it at the time of requirement type of device . The motive power of the electric drives the sprocket wheel installed on the motor shaft. The sprocket wheel being coupled to the another sprocket wheel installed on the rear wheel through the chain drive, rotates the rear sprocket wheel. The rear sprocket wheel being installed on the rear wheel drives the wheel. Thus the two-wheeler is mobiled using the electric power. Sprockets - Chains An important design consideration in rotating mechanical components is slippage between components. Pulleys and ropes/belts/cables are driven by friction, implying the possibility of slippage between the components. To help achieve no slip, the pulley can be replaced by a sprocket (a toothed wheel as opposed to a grooved wheel), and the belt or rope can be replaced by a chain (a loop of loosely pointed links). Design relations for sprockets-chains are very similar to those desired for pulleys. Because the number of teeth that can be fabricated on a sprocket is dependent on the sprocket ratios, the velocity ratio becomes Vr = Number of teeth on driven sprocket = Nd Number of teeth on driver sprocket ND Shaft alignment is important also when driving through belts. The plan view here shows a motor equipped with a belt pulley and mounted on slide rails which are fixed. During installation the motor can slide on the rails and is positioned by the two adjusting screws so that the belt is correctly tensioned and the motor axis is perpendicular to the belt length (if it isn't perpendicular then the belt might run off the pulley). When adjustment is complete the motor is secured to the rails.

FABRICATED DESIGN OF PROJECT :

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