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The Perspective of Cargo Bikes in the Sustainable Supply Chain

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Abstract:

Purpose: *The research aim is to analyse the potential of cargo bikes as an element of city logistics. The research investigates the perspective of using cargo bikes for sustainable urban freight transport by comparing bicycle infrastructure in 15 cities.*
Design/Methodology/Approach: *The article uses qualitative research methods: an analysis of literature on cargo bikes; and a case study for cycle infrastructures in selected cities. The article's first part is based on exploring the literature on European transport strategies and policy. Then, a comprehensive literature review of cargo bikes was conducted with a particular focus on the benefits and challenges of cargo bike usage (for cities and logistics companies). The last part of the paper explores bicycle infrastructure in selected cities.*
Findings: *This study's results confirmed that cities considered model cycling cities in the literature also performed best in this study. Moreover, adequate bicycle infrastructure seems to be necessary to encourage logistics companies to choose this mean of transport.*
Practical Implications: *The research results and recommendations provide valuable guidance for city planners who are responsible for transport infrastructure and sustainable transport development. Furthermore, the research contributes to the growing body of knowledge on cargo bike usage by logistics companies.*
Originality/Value: *This paper improves understanding of how to develop cycle logistics to reduce the adverse impacts of urban goods deliveries without reducing the quality of city living. Replacing cargo deliveries with bicycles has much greater potential in cities that have adequate bicycle infrastructure.*

Keywords: *Cargo bike, transport management, sustainable supply chain, bicycle infrastructure, urban mobility, city logistics.*

JEL codes: *O18, R40*

Paper Type: *Research Paper.*

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1. Introduction

In the face of the global climate crisis, additional actions are being taken to improve the ecological situation in the world. The transport sector generates approx. one-third (29%) of total GHG emissions globally, and is responsible for an even larger proportion of CO^2 emissions, while road transportation accounts for half of it (International Energy Agency, 2021).

The European Union countries decided that the EU would take action to become the world's first economy and society to become climate-neutral by 2050. To meet these challenges, the European Green Deal action plan was created (European Union, 2019).

To achieve climate neutrality by 2050, according to the European Green Deal, countries must reduce greenhouse gas emissions by 90% by 2050, compared to 1990 levels. According to the European Environment Agency, approximately one-fourth of the EU's total carbon dioxide emissions in 2019 came from the transport sector, of which 71.7% were from road transport (European Environment Agency, 2022), (Eurostat, 2022).

Sustainable forms of transport are essential for achieving the EU’s climate, and zero pollution objectives. Cycling is one of the most sustainable and efficient, with considerable potential to support the decarbonisation of urban transport and help achieve the EU goals. The importance of further developing cycling is in particular key for European cities as part of EU climate objectives.

The European Parliament adopted a resolution on developing an EU cycling strategy in February 2023 (European Parliament, 2023). The principles included in the strategy are expected to help deliver on the EU climate and environmental targets, including in particular the Zero Pollution Action Plan (European Union, 2021), and the Sustainable and Smart Mobility Strategy (European Union, 2020). The EU is a frontrunner globally in shaping supply chain and value chain sustainability as part of its strategy to decarbonize the EU economy through several regulations and legislation.

Each year the European economy loses 1% of its GDP due to traffic congestion (European Commission, 2011). Cargo bikes are an effective solution for this sort of last mile urban freight transport. These bikes have the potential to tackle the environmental, logistics, and traffic issues facing many European cities, all while providing a new perception of mobility. Cycling within Europe produces global benefits of 150 billion euros per year of which 90 billion euros are positive externalities for the environment, public health and the mobility system.

Approximately 750,000 jobs are linked to cycling in the pan-European region. In urban areas with proper cycling infrastructure, bicycles are by far the fastest and most reliable mode of transport. Cycling is playing an increasingly important role in the urban transport of goods, in particular parcel deliveries and shopping, thanks to cargo bikes and alike. To reach the full potential of cycling, cycling policies should reflect this diversity (European Commission, 2023).

This paper contributes to new research that analyses the potential of cargo bikes to make city logistics more sustainable and explores ways to encourage their diffusion. It suggests a sustainable city logistics framework for urban management, logistic operations and future research, to introduce the potential of using cargo bikes for sustainable urban freight transport. This article uses qualitative research methods: an analysis of literature on cargo bikes; and a case study for cycle infrastructures in selected cities.

2. The Potential of Cargo Bikes – Literature Review

2.1 Cargo Bike characteristics

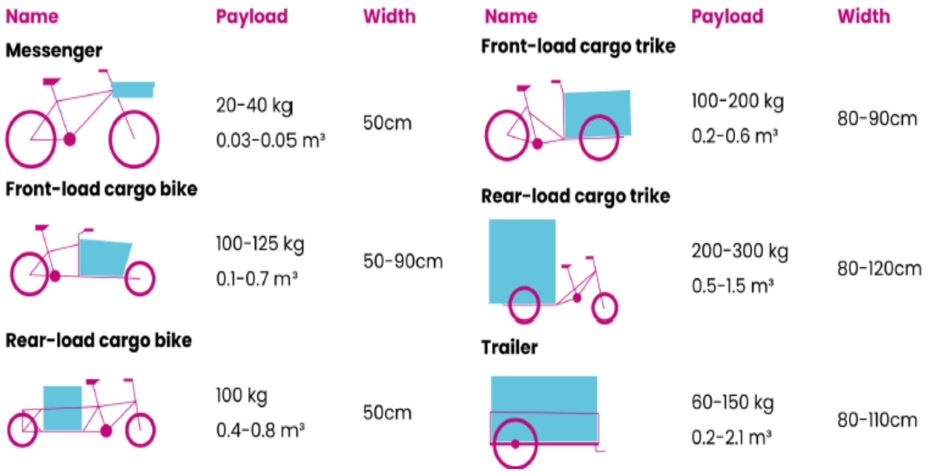
Cargo bikes are bicycles that have been specifically designed to carry cargo. Load capacity and prices of these bikes vary greatly as well, with lighter bikes priced at €1000-€2000 managing a load of up to 80 kg while heavier bikes ranging anywhere from €2000-€12000 being capable of moving up to 350 kg. Every kind of freight transport, going a distance of 7 km or less and weighing under 200 kg/m3 could be done by cargo bike (CycleLogistics, 2019).

Loads up to 300kg and two cubic metres can be carried by the largest capacity cargo trikes and trailers (Figure 1). By comparison, a standard panel van such as a Ford Transit typically has a payload capacity of 900kg and six cubic metres. More than half of all available load-carrying cycles are offered with electric assistance, helping riders to carry heavier loads further and for longer without fatigue. In the mail and parcel sector, cycle freight riders can cover total distances of up to 80-100 kilometres per day. However, to match the number of deliveries per day that a van can make (10-15 per hour), cycle couriers typically need to reload, which limits the service radius to between two and eight kilometres (Transport for London, 2018).

2.2 Areas of Usage and Infrastructure

The research conducted in Cambridge, Edinburgh, Leeds, London and Manchester reveals that the cycle logistics has been identified to be a viable alternative to motorised vehicles and describes the use of human-powered or electrically-assisted standard bicycles cargo bikes and cargo tricycles for the transport of goods, primarily in urban areas. Services covered by cycle logistics are first mile, last mile, last metres and express services. Moreover, the geography of cities plays a major role in the viability of cargo bikes as an alternative to motorised vehicles. High density urban areas, as well as narrow streets in historical city centres, naturally contribute to the attractiveness of cycle logistics (Schliwa *et al.*, 2015).

Figure 1. *Cargo bike characteristics*.



Source: *Verlinghieri, at al., 2021*

Last mile and first mile services handle the local distribution or collection of goods as part of a larger distribution chain. Last mile services are typically carried out by, or on behalf of, national mail carriers and retailers. Furthermore, cyclists using cargo bikes can benefit from the versatility of bike-train connections. Cities all over Europe have facilitated intermodality by installing secure cargo bike parking at transport hubs.

Malmo, Maastricht, Cambridge, and Utrecht are among those cities that have inaugurated cargo bike parking at train stations. One of the most visible elements of a company’s supply chain is the transport process and most cargo bikes are big enough to display advertisements, logos, and messages that companies can use for marketing purposes. The successful use of cargo bikes by many of the world’s largest express carriers in the last mile logistics process shows a commitment to carry on the sustainable transition (CycleLogistics, 2019).

Based on European Cyclists’ Federation there was over 460,000 km of cycling infrastructure analysed and mapped across Europe in 2023 (European Cyclists’ Federation, 2023). The newest analysis from 2024 (data from 37 countries and 1502 regions) reveals the cycle infrastructure reached 467,732 km, where 378,548 km of cycle infrastructure is segregated (European Cyclists’ Federation, 2024).

2.3 Economic Benefits

Building cycling infrastructure consistently yields higher returns and benefit-cost ratios than major road and public transport projects while costing a fraction of the price. Investments in the London Cycle Network produced a 4:1 return (Cycling UK, 2016). An investment of one euro into the cycle paths of Helsinki will generate nearly €8 worth of benefits. One cycled kilometre in Helsinki generates around €0.30 to €1.30 in benefits, depending on how much the city invests in cycle lanes. Similar results have also been reached in studies carried out in Denmark: benefits generated by cycling are worth €0.28 per kilometre, whereas driving a car costs society €0.19 per kilometre (Helsinki City Planning Department, 2015).

Cargo bikes proved to be very efficient in dense urban areas where most delivery rounds are short. In many ways they perform better than motorised vehicles, saving money and increasing efficiency. Throughout Europe, an increasing number of companies use e-cargo bikes to deliver goods to their customers cost-effectively, quickly and reliably. The use of e-bikes is growing at the national level. France's national postal service La Poste already uses 20,000 e-bikes to deliver and collect mail and it plans to expand its fleet to 30,000 soon (European Cyclists' Federation, 2016).

2.4 Cargo Bike – Sustainable Supply Chain Element

Cycle freight is an emerging sector with significant potential in cities. Research carried out in 2017 in London found that, with support from all partners, up to 14% of vans could be replaced by cycle freight by 2025. Each light goods vehicle (LGV) replaced in central London saves over one tonne of CO^2 and almost three kilograms of NOx per year. This is equivalent to a damage cost saving of £270 per year per vehicle.

Furthermore, journeys made by cycle can be 25 to 50% faster than those made by van. Cycles also have more freedom to park close to their destination. Shorter and more reliable journey times can give businesses more flexibility in when deliveries can be made and in the range of services they can offer. (Transport for London, 2018).

However, research from 2021 reveals the service performed by the Pedal Me freight cycles is an average of 1.61 times faster than the one performed by a van. Moreover, in the 98 days of work sampled, Pedal Me helped save a total of 3,896 Kg of CO^2 and over 5.5 kg of NOx, showing that cargo bikes can serve their customers better than a van without generating many of the externalities currently associated with urban freight.

Previous systematic studies have estimated that just over half of all motorised freight logistics in urban areas could be done by cargo bike. Expanding cargo bike services to replace 10% of the van-km currently driven in London would mean saving as much as 133,300 tonnes of CO^2 and 190 thousand Kg of NOx per year. At the same time, it would reduce urban congestion and free a total of 384,000 sqm of public space usually occupied by parked vans and 16,980 hours of vehicle traffic per day (Verlinghieri *at al.*, 2021).

Cargo bikes could substitute over half of logistics and a quarter of commercial deliveries in European cities (European Cyclists' Federation, 2016). Other studies reveal that cargo bikes could replace 20% of vans in urban areas (European Commission, 2023). European study suggests that 1.5 to 7.5% of urban motorised traffic could be shifted to e-cargo bikes (Cairns and Sloman, 2019). In the Netherlands, approximately 60% of inner city deliveries from logistics company DHL are made using e-cargo bikes (The Bicycle Association of Great Britain, 2018).

To summarise the advantages and disadvantages of cargo bikes and vans, table 1 was created. Cargo bikes have more advantages than vans, but they have several key limitations: lower capacity and users need forward planning to transport tools and materials in their bikes.

Table 1. *Comparison of advantages and disadvantages between cargo bikes and vans*

Cargo bikes	**Vans**
Advantages	
Time-saving quicker when navigating traffic in urban areas	Versatility: with long range capability, vans, can take large loads and be used for a wide variety of professional tasks
Parking: easier to park due to smaller size	Advertisement: a van looks professional and represents the company
Advertisement: e-cargo bikes are uncommon and attract attention, which boosts business	Reliable and practical
Eco-friendly	Convenience: vans provide space to work in, a level of comfort and shelter from the weather
Good value	
Disadvantages	
Forward planning: with a smaller capacity than a van, e-cargo bike users need to plan more on how to transport tools and materials in their vehicles.	Cost: including fuel, tax, insurance, vans often account for a sizeable proportion of regular expenditure
Lower capacity than vans	Parking: this adds time and cost onto projects
	Carbon footprint: a minority raised pollution as a concern

Source: *Own elaboration based on Green Alliance, 2022.*

2.5 Factors Influencing the Penetration of E-cargo Bikes

The factors that influence the penetration of E-cargo bikes (both purchase and willingness-to-use) are identified and categorised below, with a focus on decision-makers, as well as city policy makers. Based on a comprehensive literature review of electric cargo bikes 23 different factors can be found in Table 2. These factors are grouped into 6 categories: Operational, Vehicular, Infrastructural, Workforce, Organisational, and Policy-related (Narayanan, Antoniou, 2022). E-cargo cycles are more suitable to deliver small volumes, and not heavy goods. Apart from cycle lanes, adequate parking facilities are also a necessity. Parking policy for conventional motorised vehicles also plays a significant role in the shift to E-cargo cycles. Higher parking fines for conventional modes support the penetration of E-cargo cycles.

Table 2. *Classification of the factors influencing the penetration of E-cargo cycles*

Operational	**Vehicular**	**Infrastructural**	**Workforce**	**Organisational**	**Policy**
Delivery density	Technology failure likelihood	Cycling infrastructure	Socio-demographics	Business sector	Vehicle access restriction
Goods types	Electric range	Urban morphology	Car ownership	Perception of operational benefits	Parking policy
Catchment area	Weather protection	Charging stations		Perception of soft benefits	Trial schemes
	Purchase price	Overnight storage facilities		Interests towards technology and innovation	Information dissemination
				Attitude towards sustainability	Monetary incentives
				Managerial support	

Source: *Own elaboration based on Narayanan, Antoniou, 2022*

2.6 Cargo Bikes for Small Businesses

Based on a study carried out in Dublin for small businesses factors influencing e-cargo bike mode choice are as follows: maximum daily temperature, total trip time, months since the service's launch, and trip length. The effect of wet weather is exacerbated by a drop in temperature, making e-cargo bikes less appealing as a delivery mode for small businesses. As travel time increases, the mode's attractiveness decreases significantly. The study demonstrates that there is a strong joint effect of rainfall conditions and temperature on e-cargo bike mode choice by small businesses. The average trip length was 3.34 km while the average trip time was 14 min (Malik *et al.*, 2023).

3. Case Study – Analyses of Bicycle Infrastructure

The advantage of a cargo bike is the ability to bypass traffic jams and move faster in the city compared to a delivery vehicle (van or truck). Appropriate transport infrastructure is necessary to meet these conditions: dedicated bike paths in the roadway or a dedicated bike path on the sidewalk. Due to its cargo box, a cargo bike cannot pass vehicles stuck in a traffic jam in the middle of the roadway (as is the case with regular bikes or motorcycles).

This section analyses the availability of bicycle paths in cities to investigate the potential of using cargo bicycles in large cities. The case study compares the number of inhabitants, the area of the city (land surface) and the length of bicycle paths. Data for Polish cities were taken from the Central Statistical Office in Poland (Główny Urząd Statystyczny, 2024).

The study included 12 Polish cities with the largest number of inhabitants, as well as 3 foreign cities. When selecting Polish cities, the most important criterion was the number of inhabitants in 2023. The study included cities with more than 240,000 inhabitants. The number of inhabitants translates into the number of deliveries in the city, as well as the number of logistics companies.

The second criterion was the area of the city - the study included cities with an area of more than 100 square km. Finally, the study included cities with a population density of more than 1,300 people per square km. In Poland, there are cities with a large area and at the same time a relatively small number of inhabitants, e.g. Zielona Gora: area 275 square km.; population 139,000 inhabitants; population density 505 inhabitants per square km. Such cities were deliberately eliminated from the study because transporting cargo by bike in such areas is less reasoned - the density of parcel deliveries will be lower, and there is also a smaller problem of transport congestion and air pollution caused by transport.

The study included three foreign cities to refer to and compare conditions in Poland and Europe. Copenhagen and Amsterdam are model cities, where cycling culture has been developing for several decades. These cities are friendly to cyclists, develop cycling infrastructure and strive to provide zero-emission transport in the city centre. From 2025, all mopeds, scooters, vans, trucks and boats that run on fossil fuels will no longer be allowed past the S100 city ring (city centre).

There are also plans to expand the zero-emission zone to the A10 ring road in 2028 (Amsterdam City Hall, 2024). London, on the other hand, represents a mega city, where cycling culture has been developing for a dozen or so years. Additionally, in the theoretical chapter, London was presented as one of the city that is intensively implementing actions to support cargo bikes. The city has conducted many studies in this field (Transport for London, 2018).

In this study, the city with the largest population is London, with almost 10 million people. The next cities have significantly smaller populations: Warsaw 1.9 million, and Amsterdam 1 million. Most Polish cities have between 0.3 and 0.5 million inhabitants. The cities with the largest areas are London, Warsaw, and Szczecin.

The study indicates the land surface of the city, not the total area, which may include large water areas. The total area of the city of Amsterdam is 219 square meters, while the land surface is 165 square kilometres. The area of Gdansk in 2023 increased from 266 to 683 square kilometres when taking into account the sea waters located in the Bay of Gdansk, the area of which was included in the administrative boundaries of the city of Gdansk under the UN convention.

However, the area of water (the Baltic Sea) is not inhabited and cannot be used as an element of bicycle infrastructure, so it is deliberately not included in this study. The highest population density occurs in foreign cities and is over 5.5 thousand inhabitants per square kilometre. Among Polish cities, the highest population density is in Warsaw (3.6 thousand inhabitants per square kilometre), and the lowest in Szczecin (1.3 thousand inhabitants per square kilometre) (Table 3).

Table 3. *Comparison of bicycle infrastructure in 15 cities.*

Polish cities	**Numer of inhabitants (2023)**	**Land surface in square km.**	**Population density**	**Total length of bicycle paths (km)**	**Bicycle paths per 100 km2**	**Bicycle paths per 1000 inhabitants**
Warsaw	1 861 975	517	3601	773	150	42
Cracow	803 283	327	2457	319	98	40
Wroclaw	675 079	293	2304	368	126	55
Lodz	658 444	293	2247	245	84	37
Poznan	541 316	262	2066	345	132	64
Gdansk	486 345	266	1828	223	84	46
Szczecin	391 566	301	1301	162	54	41
Lublin	331 243	148	2238	197	133	59
Bydgoszcz	330 038	176	1875	138	78	42
Bialystok	292 600	102	2869	169	165	58
Katowice	280 190	165	1698	108	66	39
Gdynia	242 874	135	1799	87	64	36
Examples of foreign cities						
London	9 648 110	1 572	6137	400	25	4
Amsterdam	918 100	165	5564	400	242	44
Copenhagen	653 664	90	7263	546	607	84

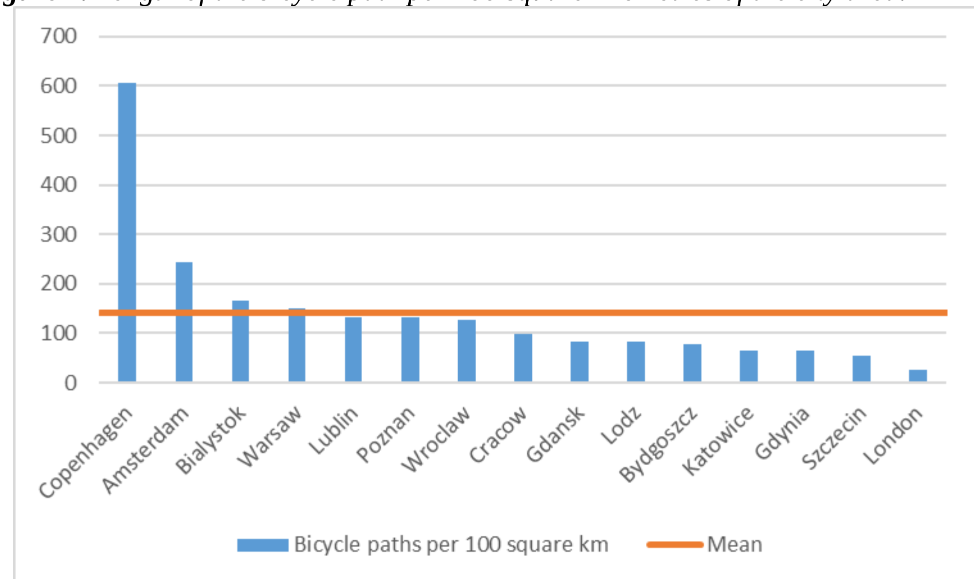
Source: *Own elaboration.*

Another indicator included in the study is the total length of bicycle paths in the city. It should be noted that road traffic law differs in European countries and therefore the definition of a bicycle path. In Poland, the Central Statistical Office defines a bicycle path as: a separate bicycle path (located in the roadway); a road separated from the carriageway; a road separated from the pavement; roads included in pedestrian and bicycle routes. Cycling in a bus lane is not allowed. In some countries, cyclists are entitled to use a bus lane, but this is usually not included in the bicycle path statistics. An example is London, where most bus lanes can be used by cyclists (Transport for London, 2024).

In terms of the total length of bicycle paths, Warsaw dominates – 773 km –, having almost twice as many paths as London or Amsterdam (400 km each) (Transport for London, 2024) (Amsterdam City Hall, 2024). A very large number of bicycle paths have been built in Copenhagen: 546 km (Copenhagen Municipality, 2022). In other Polish cities, the length of paths ranges from 87 km (Gdynia) to 368 km (Wroclaw) (Table 3). The average length of bicycle paths in Polish cities is 261 km and 449 km in foreign cities.

Since cities differ significantly in terms of area, the article calculates the length of a cycle path per 100 square kilometres of city area. This indicator allows to estimate the density of cycle paths in relation to the area of the entire city. The city that dominates is Copenhagen, with over 600 km of cycle paths per 100 square kilometres. The next city is Amsterdam with a value of 242, and then Bialystok with 165 paths per 100 square kilometres. In this statistic, London comes out worst, with only 25 km of paths per 100 square kilometres. The average for all the cities studied is 140 km/100 km^2 (Figure 2).

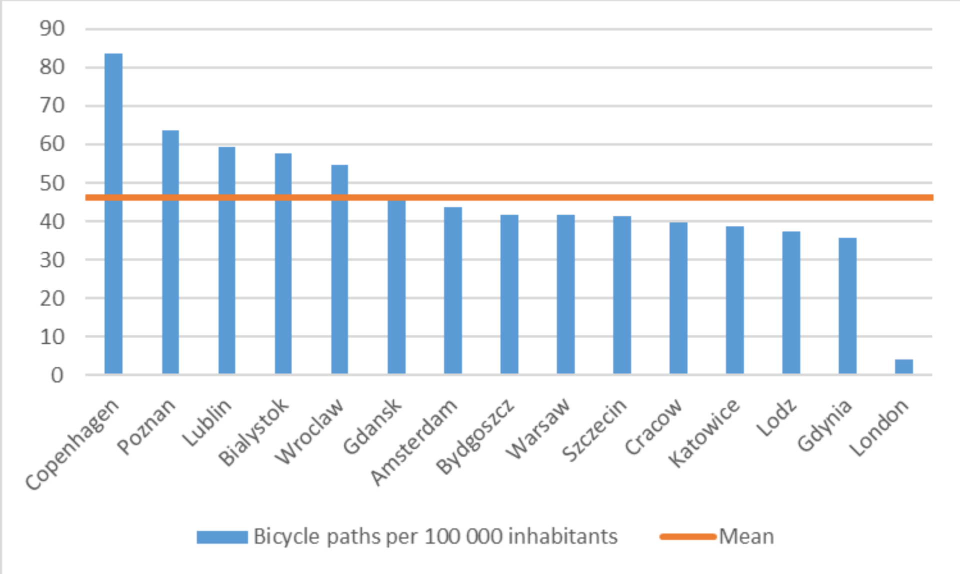
Figure 2. *Length of the bicycle path per 100 square kilometres of the city area.*



Source: *Own elaboration.*

The study also compared the length of bicycle paths per 100,000 inhabitants. Copenhagen again has the highest value of the indicator, with 84 km of paths, but the difference compared to other cities is not as large: the second city is Poznan (64 km of paths), followed by Lublin (59 km of paths). The average for all cities is 46 km, with Bialystok and Wroclaw also above the average. Other Polish cities have values close to the average, with Gdynia having the fewest paths (36 km). The city with the definitely lowest length of paths per 100,000 inhabitants is London - 4 km - which means that there are 21 times fewer paths in London than in Copenhagen (Figure 3).

Figure 3. *Length of bicycle paths per 100,000 inhabitants.*

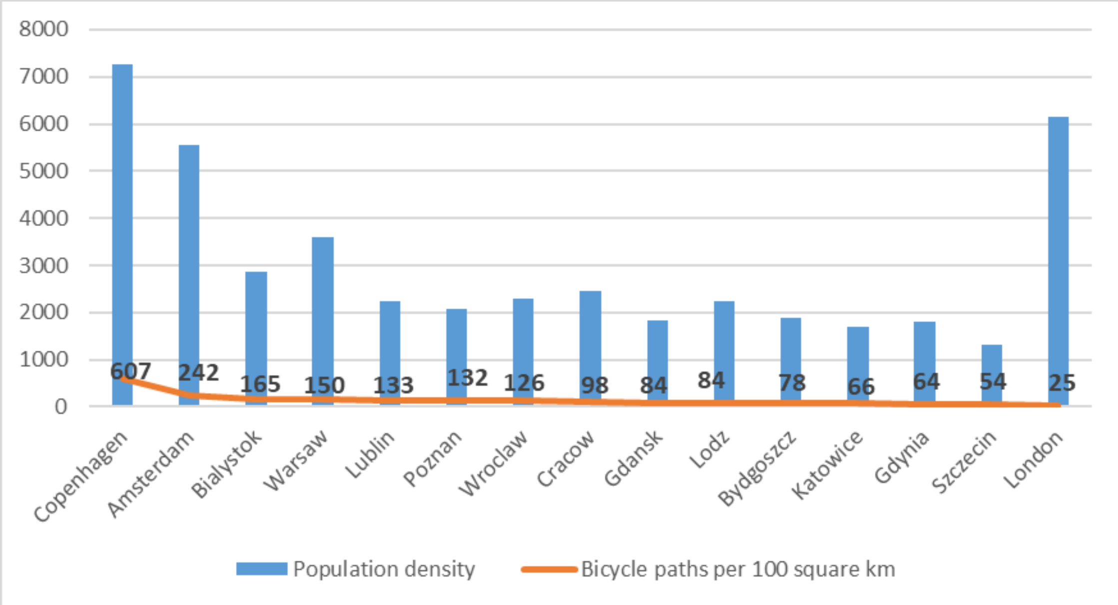


Source: *Own elaboration.*

The next figure compares population density with the length of bicycle paths per 100 square km. Copenhagen has the highest population density and the highest length of bicycle paths per 100 square km. Amsterdam is the second city in terms of length of paths and the third city in terms of population density. Among Polish cities, Bialystok and Warsaw have a relatively high population density and length of bicycle paths.

However, the key conclusion from the figure is the lack of correlation between population density and length of bicycle paths per 100 square km. London has the second highest population density and the shortest length of paths. In Poznan and Lublin, on the other hand, the length of paths is relatively high while the population density is low. It can be seen that the three Polish cities (Katowice, Gdynia, Szczecin) with the shortest length of paths also have the lowest population density (Figure 4).

Figure 4. *Population density and the length of bicycle paths per 100 square km.*



Source: *Own elaboration.*

4. Conclusions and Recommendations

Urban transport management plays a key role in improving logistics processes. Many cities have included the development of bicycle infrastructure and activities aimed at encouraging more widespread use of bicycles as a means of transport in their transport policies.

The use of cargo bicycles as one of the elements of the sustainable supply chain will gain importance in the coming years. The developments in city logistics are leading to an increasing number of smaller, time-sensitive deliveries. The parcel market has consistently grown over the past decade, with emerging business models such as ship-from-store (both B2C and B2B) and quick commerce (Bram, et al., 2024).

Moreover, companies are increasingly striving to become more sustainable. To address the challenges of faster delivery, green transport (low/zero-emission), and limited space in dense cities, cargo bikes present itself as an innovative solution.

This paper improves understanding of how to develop cycle logistics to reduce the adverse impacts of urban goods deliveries without reducing the quality of city living. Most studies of e-cargo bikes tend to focus on deliveries in urban areas where they offer significant potential to cut both greenhouse gas and particulate emissions compared to diesel vans. Replacing cargo deliveries with bicycles has much greater potential in cities that have adequate bicycle infrastructure.

Adequate bicycle infrastructure seems to be necessary to encourage logistics companies and individuals to choose this mean of transport.

Amsterdam and Copenhagen are considered to be model cycling cities and the results of this study also confirm this – the cities are characterised by the highest length of bicycle paths per 100 square kilometres. Cities with the shortest length of bicycle paths (Katowice, Gdynia, Szczecin) are also characterised by the lowest population density. In these cities, the potential for the development of deliveries using cargo bikes is the lowest.

Among Polish cities, Warsaw has the greatest potential for the development of cargo bikes deliveries, as it has the most extensive bicycle infrastructure, a high indicator of length of bicycle paths per 100,000 inhabitants and a high indicator of length of bicycle paths per 100 square km. There is also high potential in the city of Bialystok, Poznan, Lublin.

This study has some limitations. In the next research, the possibility of parking cargo bikes should also be taken into account, e.g. the availability of parking lots for cargo bikes. Furthermore, since the greatest transport congestion occurs in city centres and the highest delivery density is there, the study can calculate the length (or density) of bicycle paths in the city centre. This will reveal cities with a large number of kilometres of paths located on the outskirts of the city, which may be important for inhabitants bike trips (regular bikes) but less crucial for cargo bikes.

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