# City Cargo Transportation by Trams

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A city's transport and distribution system requires the effective organization of urban freight deliveries that take into consideration the economic, ecological, and social impact. Implementation of the concept of green logistics necessitates the use of environmentally friendly and energy-efficient modes of transport, which consider the existing infrastructure and the possibility of its development.

Keywords: freight tram ; green logistics

## 1. Introduction

The development and effective functioning of a city's transport and distribution system require the rational organization of the urban transportation of goods, taking into account global trends, as well as economic, environmental, and social requirements.

In the European Union in 2019, transport accounted for a quarter of the global greenhouse gas (GHG) emissions measured in $CO_2$ equivalents, of which 71.7% came from road transportation [1]. Emissions from the transport sector have increased by 33.5% in the past three decades, while global emissions (including industry, energy supply, agriculture, and residential and commercial activity) have dropped by 24% in the same period [2].

The negative impact of transport is particularly significant in urban areas due to the size of their populations. Cities suffer from congestion, noise, and poor air quality. Urban transport is responsible for approximately a quarter of $CO_2$ emissions from transport, and 69% of road accidents occur in cities [3].

In 2015, as part of the Paris Agreement, 197 countries committed to substantially reducing GHG emissions in order to limit this century's global temperature increase to 2 °C [4]. To achieve this goal, in 2020, the European Commission proposed, as part of the European Green Deal, that by 2030 GHG emissions would be reduced by at least 55% compared to 1990 and zero net emissions would be achieved by 2050 [5]. As a part of this effort, a 90% reduction in GHG from transport should be achieved by 2050. In 2019, 74% of goods transported over land in the European Union were carried by road and only 17% by rail [6]. Meanwhile, the well-to-wheel GHG emissions for rail transport are on average 5.7 times lower compared to road transport [2].

Thus, there has recently been a significant increase in the environmental requirements for the organization of transport processes and an emphasis on the development of green supply chains. Due to the scope of the impact of transport on inhabitants (the emission of exhaust gases, congestion, noise, etc.), there is a strong need to reorganize transport systems in cities. This necessitates the use of environmentally friendly means of transport and a shift towards public transport modes [7]. This must take into account the constraints associated with the existing infrastructure and the need to provide transport services for passengers as well as to supply goods to all the businesses, organizations, etc., operating in the city. Planning deliveries in the city, which reduce the negative impact of transport, is a challenge and requires the right tools.

## 2. Urban Transport Policy

Global trends in the development of production and transport systems aim at the use of energy-efficient technologies [8][9][10], a reduction in the negative impact on the environment [11][12], and the provision of social benefits [13]. At the same time, development of the infrastructure network, namely the choice of locations for infrastructure facilities and the organization of the distribution system, should contribute to an increase in the profits of transport companies [14].

In cities, the key issue is to ensure freight deliveries both to shops, service points and, thanks to the development of e-commerce, to individuals. This requires setting up distribution centers and warehouses, and then delivering shipments,

many of which are transported in small batches to end users [15][16].

Thus far, shipments have mainly been transported by road transport using vehicles with combustion engines. Greater environmental awareness and legal regulations aimed at limiting the negative impact on the environment call for a change in the way goods are distributed.

European Union policy focuses on the development of transport systems which consume less energy and therefore produce less pollution. To reduce the negative, transport-related, external costs in urban areas, the interface between long-distance and last-mile transport should be organized more efficiently to limit individual deliveries. One of the major goals is to halve the use of conventionally fueled cars in urban transport by 2030, to phase them out of cities by 2050, and finally to achieve $CO_2$-free city logistics in major urban centers by 2030 [3].

The most important changes are restrictions on conventional vehicles entering city centers (low-emission zones), road pricing, and even the exclusion of entire zones from road traffic [17]. Conventional vehicles are also being replaced by low-emission vehicles, mainly electric ones, and rail transport is being promoted in order to switch transport modes. The integration of freight and passenger transportation systems, by performing sustainable vehicle routing, and by adopting combined transportation, is strongly encouraged in order to increase the efficiency of urban transport systems [18][19]. Such actions now force transport and logistics companies to work on alternative ways to deliver goods in urban areas.

## 3. Use of Freight Trams

In view of the rapid development of green logistics [20][21], significant attention is being paid to the expansion of the scope of use of freight trams in terms of product supply within the city transport and distribution system [22][23][24][25].

The decision to use freight trams for urban transport is due to the following factors:

- reduction in the number of trucks on the city road network, which positively affects the condition of the road surface and reduces the number of accidents;
- optimization of the use of the existing rail infrastructure and network of intra-city trams;
- reduction in the negative impact of freight transport on the environment, especially of GHG emissions in the city;
- the need to ensure supplies to zones closed to traffic or with limited traffic.

On the other hand, the use of rail transport faces restrictions related primarily to limited physical flexibility, competition with passenger services for line capacity, and the perception that use of the rail infrastructure and related systems would incur high costs [26].

Browne et al. [27] considered the scope and opportunity for an increase in the use of rail for urban freight transport and assessed the barriers to its wider implementation. The authors concluded that planning limits and the complexity of engaging with a range of stakeholders make it difficult to implement rail solutions for urban freight. Thus far, activities undertaken have been aimed more at filling a niche function or experimenting rather than at making wider use of rail transport. However, some initiatives have the potential for wider implementation.

Behiri et al. [28] identified the types of problems related to freight tram operation. The problems were divided into operational (train timetabling, the 2D/3D bin packing problem, freight rail transport scheduling or dispatching, and goods delivery in the departure station), tactical (train frequency and sizing), and strategic (storage-space-sizing in stations). The authors focused on the freight rail transport scheduling problem. They assumed that trains would transport freight and passengers simultaneously and passenger stations could be used for loading and unloading goods. The main objective was to minimise the total waiting time of all shipments at their departure stations. A second objective function was added aimed at maximizing the number of transported orders, to transform the problem into a bi-objective decision-making problem.

Diziain et al. [29] analyzed examples of the use of railways to transport cargo in urban zones in Japan and France. Based on experience, they concluded that a modal shift is being promoted in Europe by the European Commission, governments, and local authorities, and is noticeable in the building and modernizing of infrastructure. However, as the financial engineering of these projects is complex, they take a very long time to implement. The most successful projects use the existing infrastructure.

De Langhe [30] investigated existing freight tram projects, those stopped after a pilot period and hypothetical ones, and identified the success and failure factors. The main success factors were the positive marketing based on environmental benefits and new measures making road transport more expensive, while the factors that hindered the projects were the interference with passenger traffic, stakeholder reluctance, and the initial financial investment.

Behrends [31][32] showed that the environmental benefits of a modal shift from road to rail in urban areas depended on the location of the intermodal terminal and destination point, and identified possible actions at a local level to improve both competitiveness and environmental benefits. The environmental benefits of implementing a light freight railway system were calculated in research provided by Pietrzak et al. [33]. In addition, De Langhe et al. [22] stated that only viable projects from an economic and a socioeconomic perspective have a chance of success.

Pietrzak and Pietrzak [25] considered the introduction of freight trams in selected Polish cities and noted that the implementation of this solution should be adjusted to the local conditions so that the tram transport system is not disturbed while providing its basic function, i.e., serving public passenger traffic.

In Europe, several cities have introduced solutions for the delivery of cargo by freight tram:

- In Poland, trams were used to transport cargo in 12 cities in the years 1866–1954 (but mainly before World War II). The most developed freight tram operated in Koszalin, where in 1926 nearly 6 thousand tons of cargo were transported by tram (and a total of 30 thousand tons throughout its lifetime). An interesting solution was applied in Szczecin, where several sidetracks were built to enable freight trams to deliver post parcels directly to post offices [34].

- Amsterdam (City Cargo)—A goods delivery service by freight tram to the center of Amsterdam started in 2007. Ultimately, 52 freight trams with a capacity of 30 tons were to perform 6 journeys a day. The investment was to cost EUR 100 million and be ready in 2012. The goal was to halve deliveries by trucks in the city and cut GHG emissions by 20%. Along the route, there were two cargo transshipment points from which goods were transported by small electric cars to customers in the center. The project ended in 2009 due to the financial insolvency of the company operating the tram service.

- Dresden CarGoTram—In 2000, a freight tram which carried automotive parts to a Volkswagen factory in the city center was launched in Dresden. The choice of this solution was determined by the fact that both the warehouse and the factory were close to existing tram lines with sufficient capacity, which resulted in lower infrastructure investment costs. The tram delivered 300 thousand tons of products per year with 10 daily trips [28]. The service was axed, however, following the car manufacturer’s adoption of a revised logistics operation.

- Paris TramFret—In 2011, a pilot program was introduced in Paris to check whether the current tram infrastructure was capable of handling both passenger and freight trams. During the tests, two empty trams ran from Monday to Saturday off-peak hours on the T3 tram line. The concept of introducing these vehicles assumed servicing 128 supermarkets and hypermarkets located up to 500 m from the T2 and T3 lines [35]. In Paris, no business partner was found, but the project was continued in 2017 in the city of Saint Etienne for the delivery of supplies to two casino markets in the city center. Due to the casino’s withdrawal, the project was suspended in 2018.

- Vienna (GüterBim)—In 2005, pilot rides were carried out to check whether a freight tram could be used for the transport of goods within the city. Despite positive tests confirming that the existing tram infrastructure in Vienna was sufficient to introduce freight trams and would cause no delays to passenger trams, the project was abandoned due to investment costs, i.e., sidetracks and rolling stock [36].

- Zürich (Cargo Tram, E-Tram)—In 2003, a waste collection service by freight tram (Cargo Tram) was introduced from the collection points in the city to the recycling center. In 2006, the E-Tram was added, which collects electronic equipment and household goods. Both trams run once a month on average.

More information about freight tram projects can be found in de Langhe [30] and Arvidsson and Browne [36].

Although the issue of freight transport by trams has already been the subject of research and analysis, further work is required to assess the technical feasibility and economic efficiency of such transport.

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