urban; freight; city logistics; metro; council warehouse; bento box

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URBAN FREIGHT DISTRIBUTION: COUNCIL WAREHOUSES & FREIGHT BY RAIL

Summary. Rail is the one of the highly underused form of freight transportation in the European Union. Majority of the freightage are distributed by trucks and HGVs. With new regulations and socio-environmental concerns urban logistics is facing a new challenge which can be tackled using innovative transport mechanisms and streamline operations. This article sheds light on a system which integrates freight distribution via metro lines in the closest vicinity of the customer, use of council warehouses and further innovative transport mechanisms for final delivery. This system uses existing infrastructure effectively without impacting its surroundings and triggers the reduction of polluting carriers. This system offers the option of immediate implementation which will enable EU to compete with a global freight distribution market.

LOGÍSTICA URBANA: TRANSPORTE FERROVIÁRIO URBANO DE MERCADORIAS

Resumo. O caminho-de-ferro e um dos meios de transporte de mercadorias mais subaproveitado na União Europeia. A maioria da carga transportada é distribuída recorrendo ao transporte rodoviário. A entrada em vigor de novos regulamentos em conjunto com o aumento das preocupações sociais e ambientais, levam a que logística urbana enfrente novos desafios. Desafios estes que podem ser superados através de mecanismos inovadores e ou pela otimização de processos. Este artigo propõe uma nova abordagem através de um sistema que integra o transporte urbano de mercadorias sobre a

rede de metropolitano chegando assim mais perto do destino final da carga, propõe ainda a instalação de pequenos centros de distribuição local e formas inovadoras de transporte até ao destino final da mercadoria. Este sistema utiliza a infraestrutura já existente de forma eficiente e sem impactos para a sua vizinhança, contribuindo assim para a redução da poluição causada pelo transporte rodoviário. Este sistema oferece a possibilidade de implementação imediata o que contribuirá para que a União Europeia possa competir num mercado de transporte de mercadorias global.

1. INTRODUCTION

Urban freight transport is an important subject in today's world. It has social, economic as well as environmental impacts. This field is expected to show accelerated growth with a changing society and with the implementation of the JIT approach; more and more HGVs are expected to take roads for transporting goods within the city. Warehouses are getting smaller and distribution centres are weathering away. The environmental impact (especially increase in GHGs) with the increase in trucks is a major social and environmental concern.

The barbershop dilemma of conflicting objectives is a crucial aspect for freight operators: their obligation to customer demand versus their responsibility towards the community (society). This has been one of the main reasons for the growth in use of rail for urban transport.

The scope of technological and organizational solutions varies with differing cities. This is mainly due to the city structure, client requirements and cultural impact.

An innovative solution keeping feasibility in mind inspired the team to assess the current situation and consider using council warehouses along with new transport mechanism to efficiently deliver goods.

2. NEED FOR CITY LOGISTICS BY RAIL

Road transportation is one of the most polluting and most used modes of freightage. It is responsible for environmental and social difficulties but it particularly affects the society in urban areas thereby enforcing the need to deliver goods in an innovative manner. The level of pollution depends not only on conduction but also on the characteristics of the vehicles as follows:

- An old vehicle supposes a higher level of emissions and hence resulting in greater contamination of the atmosphere. Being an old vehicle it also does not possess the new safety features which make it a liability on the road
- In Urban zone, companies are obliged to use small vehicles, because of the access difficulties for example, the use of small trucks means that more travels are necessary, which has an environmental and economic impact, as it is not possible to realize economies of scale
- Drivers have to deal with speed restrictions and other conduction obligations regarding stops for example, as they can disrupt the traffic, drive to more fuel consumption and a rise in pollutant emissions
- If the traffic is not well organized, congestion problems can appeared, as non-motorized vehicles are sharing the same infrastructure with the motorized ones and there also exists a problem between tourism vehicles and industrial/commercial vehicles
- Financial helps and penalizations (taxes) were implemented (congestion charges, area licensing, etc.) in London, Stockholm and Milan

All of those problems are economics and societal, as they affect not only the efficiency of the transport but also the quality of life of the citizens and their health, beyond other things.

2.1. Sustrail: The Sustainable "Freight vehicle-Track" system

A sustainable and efficient freight transport in Europe plays a vital role in having a successful and competitive economy. Freight transport is expected to grow by 40 % (in tonne-kilometres) by 2030 when more freight and more passengers will have to travel by rail to meet Europe's short, medium, and long-term traffic needs [1]. In this context, rail transport is unique in its complexity. It is the only transport sector that must consider the vehicle, the transport medium (e.g. the track), and the network (flows, regulations, procedures) in parallel. Rail transport is also unique in the diversity of operating procedures, codes, regulations, guidelines, and business models across EU member states. Change for the rail industry is both necessary and opportunistic. Within this framework, the EU project SUSTRAIL was launched in June 2011, aiming at contributing to a new era in the rail freight sector by adopting a holistic approach, implementing a clear methodology and viable procedures for a combined improvement in both freight vehicles and track components.

3. SYSTEM DEFINITION

The whole system is defined in such a way that the existing resources are used to its fullest capacity in an optimal manner. The goods from the manufacturer reach city warehouses and from there goods are taken to the council warehouses (common storage places in metro stations controlled by a local civic body) in Bento boxes via metro. Goods from council warehouses are then taken to the respective destination in different means depending upon the distance and size of the goods (Fig. 1). The main objective of this paper is to install council warehouses wherever necessary and take the goods to as close as possible to the destination via metro and store in the council warehouse. The entire system is indicated in Fig. 2 which takes into account the entire flow of goods.

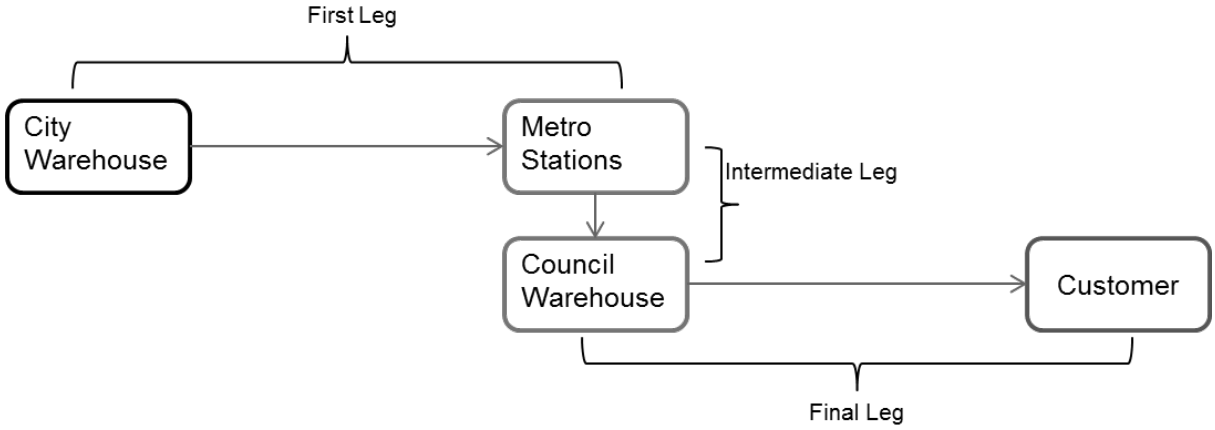


Fig. 1. Important Stages of the System
Fig. 1. Fases importantes do sistema

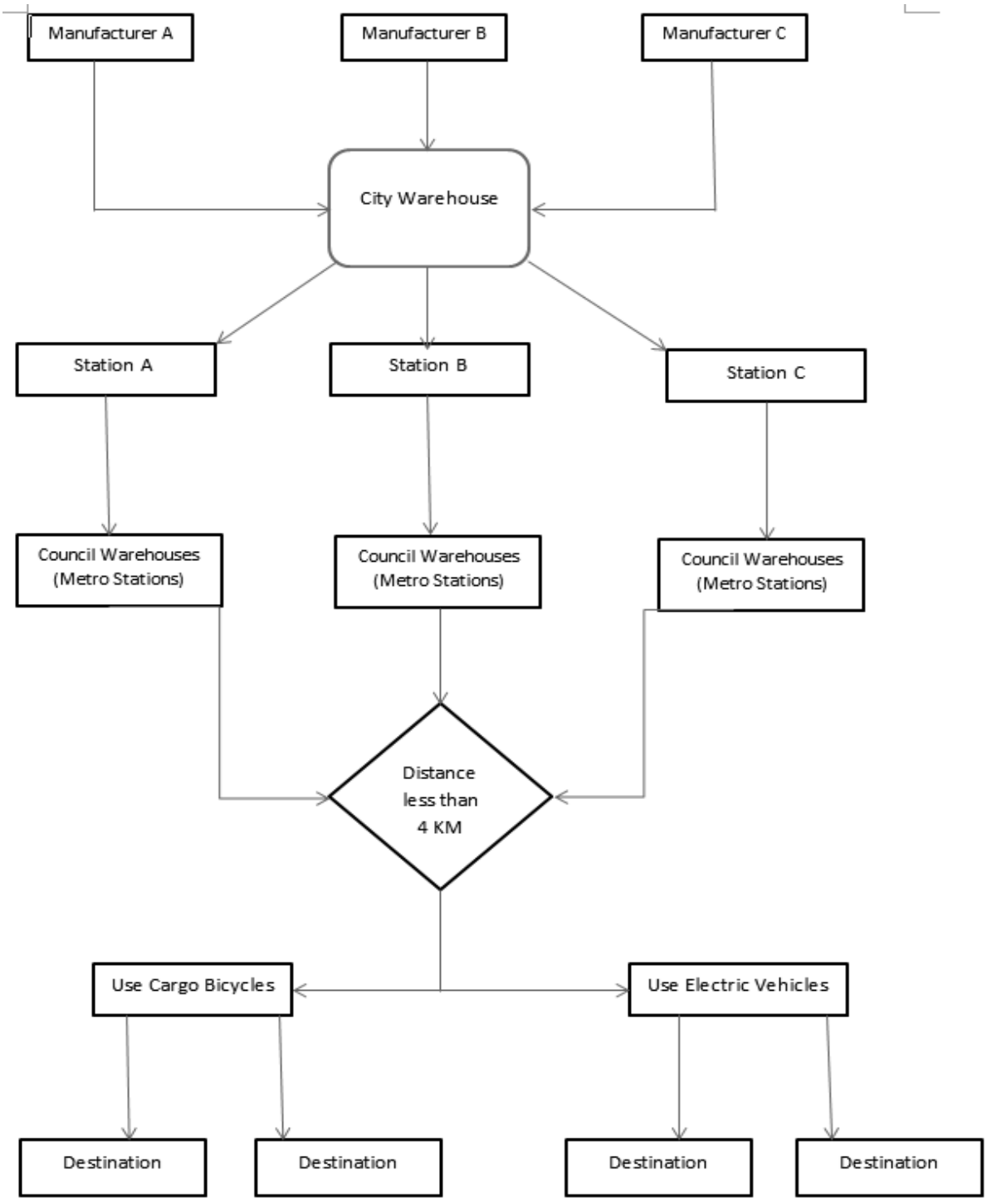


Fig. 2. System flow of goods
Fig. 2. Sistema de fluxo de bens

4. FIRST LEG – FREIGHT FROM CITY WAREHOUSE TO COUNCIL WAREHOUSES

The city warehouses serve as a centre for all distribution in the area. They are usually located on the outskirts of the city allowing the size of the warehouse to be substantial to accommodate all goods. The idea is to have this warehouse located as close to or at the metro station which allows frequent access to the station and the goods can be loaded on easily. During the first stage of the logistic chain the goods are (at the city warehouse) divided in order quantities and stacked in Bento Boxes [2]. These boxes act as containers which can be easily trolleyed from the warehouse to the adjacent metro station. This is possible because of the wheels provided at the base of the Bento Box as shown in Fig. 3 [3]. The Bento Boxes can contain single customer units or mixed units depending on the scale of demand.

Fig. 3. Example of Bento Box
Fig. 3. Exemplo de Bento Box

Furthermore, the freight metro, is transformed into a hollow units (without seats and grab poles) allowing a substantial number of boxes to be fit in one coach. This allows fast and easy manoeuvring of the boxes in and out of the metro. This solution allows the elimination of cranes and other expensive infrastructure which is traditionally used by freight wagons to transport the TEU from the distribution centres to the train and subsequently from the train to the council warehouses. Concerns regarding rolling stock can be addressed by using old regular passenger units and stripping the interiors to accommodate the Bento Boxes. This is chosen because it is the cheapest available solution to reinforce the use of freight metros without having to invest heavily in the coaches.

The operation of the freight trains will depend on the city but the objective is to have freight metros running during off-peak hours as well as during other times of the day where the freight metro can be accommodated keeping the minimum headway in mind as well as the waiting time at the station. In order to keep the waiting time at the stations to a minimum, so as not the interact with the passenger metros, and optimize the flow of these boxes a *LIFO – Last in First out (*if all platforms are at the same side of the train) or *FIFO - First in first out* (if the platform ate the terminal is in opposite side of the stations) system can be implemented.

The main goal is to try and fit freight metros between regular passenger services as shown in Fig. 4; here station 3 wants to create a freight metro service. Depending on the allowable headway, signalling system and frequency of trains the passenger service may or may not have to suffer delay. This can be anticipated and mitigated by changing timetables and accommodating freight as well as passenger metros as shown in Fig. 5.

As an Example, this document will focus on through the metro network of Porto (Fig. 6), in Portugal. This system has a light rail vehicle network which is distributed over 67 km over 6 lines mainly at the surface along with 14 underground stations. We have choosen 3 stations (on black at figure) namely 1. ***Bolhão***, which serves the main commercial streets at the city centre, 2. ***Sete Bicas***, which 450 m away from one the major shopping centres of Porto Metropolitan Area, and 3. ***Espaço***

Natureza, which is beside the most important industrial area of the region. Among the 3 choosen stations, *Bolhão* is the only station which runs underground.

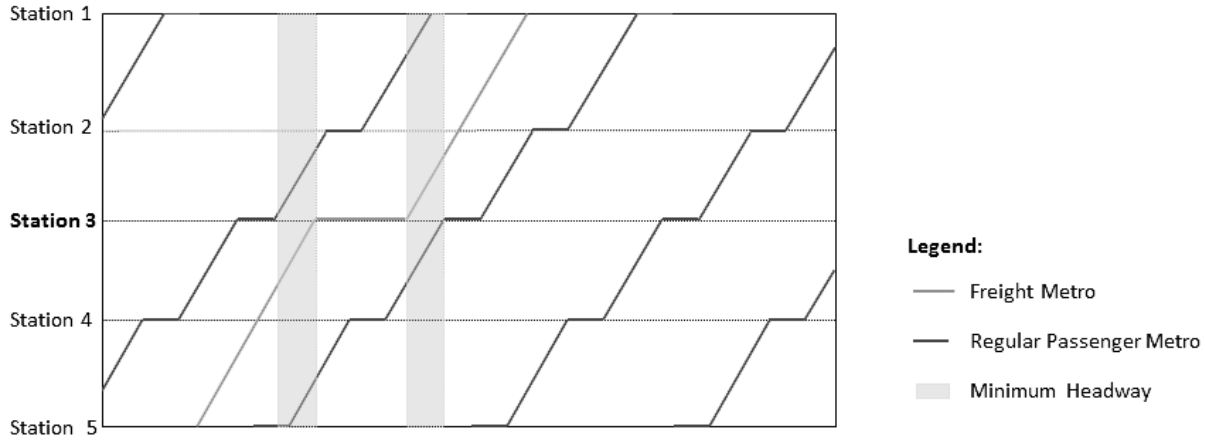


Fig. 4. Introduction of a freight metro without changes in the regular service
Fig. 4. Introdução de um metro de mercadorias, sem alterações no serviço regular

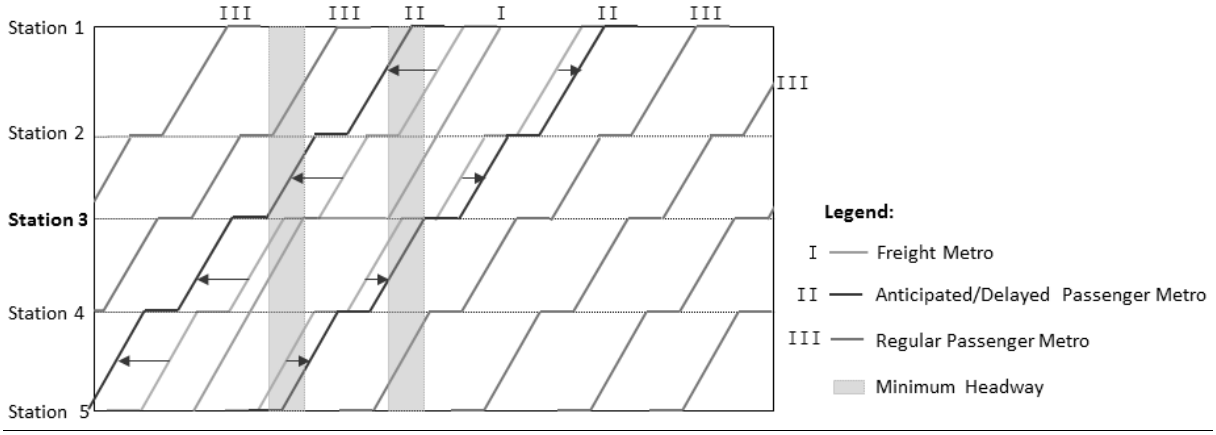


Fig. 5. Introduction of a freight metro with changes in the regular service
Fig. 5. Introdução de um metro de mercadorias com alterações do serviço regular

The minimum Headway on the entire network is 5 minutes and the maximum is 30 minutes in some sections at a certain times. The tables (1 - 3) [4] below represent the number of trains per hour by line. Table 1 is for workdays, Table 2 is for Saturdays and Table 3 is for Sundays and Holidays.

Table 1

Trains per Hour by different line – workdays

Hours	Comun Section - Lines A,B,C, E and F	Line A	Line B	Line C	Line D	Line E	Line F
6am-7am	12	4	2	2	6	2	2
7am-10am	12	6	4	6	10	3	5
10am-4pm	12	6	4	4	10	3	5
4pm-8pm	12	6	4	6	10	3	5
8pm-9pm	12	4	4	2	5	2	2
9pm-10pm	10	4	2	2	4	2	2
10pm-1am	7	4	2	2	4	2	2

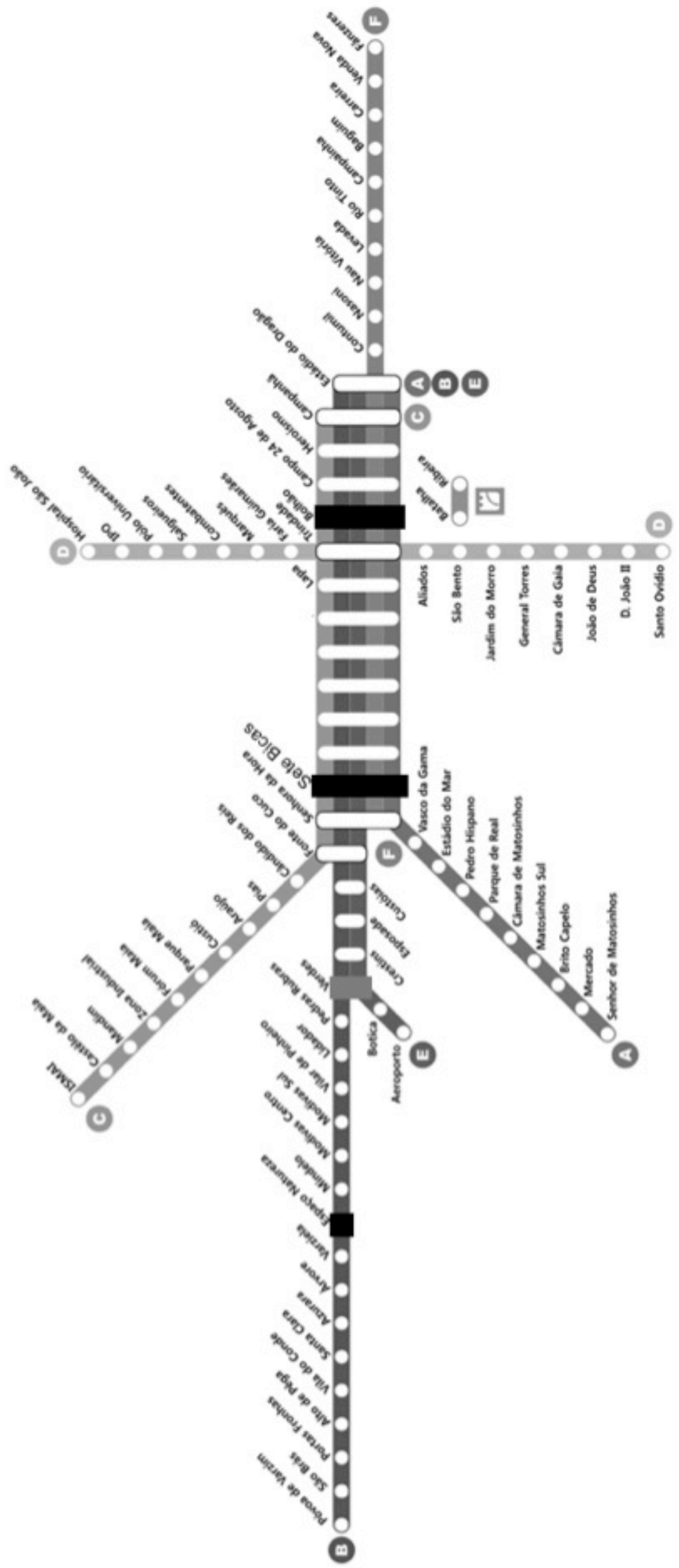


Fig. 6. Metro of Porto network diagram modified by author, important industrial areas and commercial areas shown in black, city warehouse shown in grey
Fig. 6. Diagrama da rede do metro do Porto modificado pelo autor, áreas industriais e comerciais importantes a preto, armazém da cidade a cinzento

Table 2

Trains per Hour by different line – Saturdays

Hours	Comun Section - Lines A,B,C, E and F	Line A	Line B	Line C	Line D	Line E	Line F
6am-7am	10	4	2	2	4	2	2
7am-8am	10	4	3	2	6	2	2
8am-1pm	12	6	5	4	9	2	2
1pm-6pm	12	6	5	4	9	2	3
6pm-7pm	12	6	3	2	9	2	3
7pm-8pm	12	6	2	2	6	2	3
8pm-9pm	12	4	2	2	4	2	2
9pm-10pm	10	4	2	2	4	2	2
10pm-1am	7	4	2	2	4	2	2

Table 3

Trains per Hour by different line - Sundays and Holidays

Hours	Comun Section - Lines A,B,C, E and F	Line A	Line B	Line C	Line D	Line E	Line F
6am-7am	9	4	2	2	4	2	2
7am-8am	9	4	2	2	4	2	2
8am-1pm	9	4	2	2	4	2	2
1pm-6pm	10	6	3	2	6	2	3
6pm-7pm	10	6	2	2	6	2	3
7pm-8pm	10	6	2	2	6	2	3
8pm-9pm	10	4	2	2	4	2	2
9pm-10pm	10	4	2	2	4	2	2
10pm-1am	7	4	2	2	4	2	2

In this example, at the first look the location for the distribution centre would be the station of Verdes (connection between lines B and F, in grey on network map) because, it is beside the airport, but not too close the passenger terminal. It is 7 km to the Port of Leixões (2nd busiest port in Portugal in tonnage loaded), well served by the motorways network and spaceous for better infrastructure development (city distribution centre).

5. INTERMEDIATE STAGE – FREIGHT FROM METROS TO COUNCIL WAREHOUSE

5.1. Council Warehouses

What is a Council Warehouse?

It is a common building for the storage of goods, merchandise etc. It will be setup in the metro stations depending upon the various conditions such as:

1. Proximity to City Centre i.e. commercial areas;
2. Accessibility to Industrial hubs;
3. Space Constraints;
4. Geographical Importance.

Council Warehouses will be run and maintained by the local governing body. All companies can rent spaces in the council warehouses instead of having separate warehouses which eliminates

overheads for the organisations to a greater extent. It also opens up a new business model as these warehouses can be privatised like some of the highways in the world [5].

5.2. How it works?

Freight from the city warehouse reaches the closest metro station in the vicinity of the customer by metro. Freight will be handled by bento boxes which need a key to access the goods inside the box. Freight before going to council warehouses will go through a check point from where it will be distributed to the corresponding company's storage area in the warehouse located in the metro station itself. Each company depending upon their availability of local transport will access the freight in the council warehouse (Fig. 7).

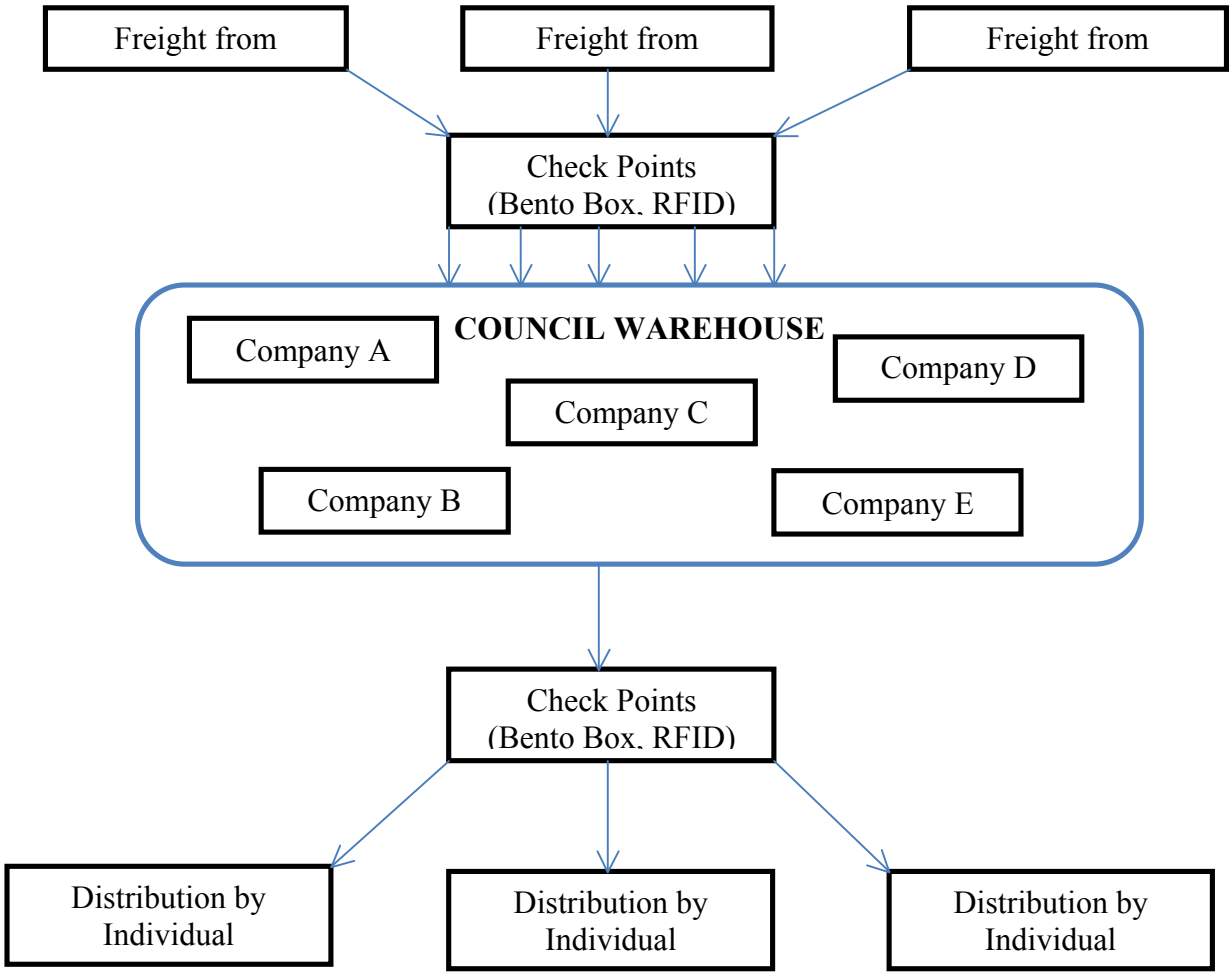


Fig. 7. System Flow of goods
Fig. 7. Sistema de fluxo de bens

5.3. Warehouse Structure

When we talk about a common warehouse then lot of substantial amount of attention needs to be given to the warehouse structure. Modern warehouses are equipped with all sorts of technical equipment that enables goods to be efficiently stored. This equipment includes operator-less conveyor systems that move through various warehouse zones as though they were guided by an invisible force or stock pickers who select products from the pick locations in racks based upon instructions they receive on headsets from a central computer (Fig. 8). The following graphic and detailed explanations provide insights into the most important processes in a warehouse [6].

Fig. 8. Flow of goods in council warehouse
Fig. 8. Fluxo de bens no armazém do município

Identification is usually done by scanning a barcode barcode attached to the goods. However, new innovative technologies like RFID Radio frequency identification allow for contactless scanning of goods. As a result, the contents of a whole pallet can be read at once by the radio signal emitted by RFID chips as soon as the shipment passes a gate or similar checkpoint. But definitely Bento box is the future if the council warehouse will be installed.

Storage racks

Products can be stored in all sorts of ways in modern warehouses. Key criteria that apply here are not only which product is to be stored but also how quickly it must be available again. A distinction is also drawn among drive-through racks that are primarily used for picking. Push-back racks Push-back rack are designed for infrequently needed products, and high-bay racks High-bay rack are frequently employed by industrial and retail companies.

Racking

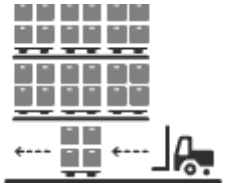
Racking is frequently used to store non-palletized goods, small parts or bulky items. Generally speaking, they are suited for storing small to medium quantities of goods involving a large number and wide array of items.

Pallet-racks

Pallet racks store pallets or stillages. They are used to store small to large quantities involving a large number of goods or assortments of goods.

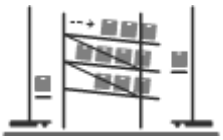
Drive-in racks

Drive-in racks are used to store large quantities involving a small number of heavy items. They are also suited for fragile goods and non-stackable load unis.



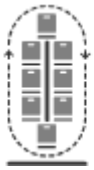
Drive-through racks

Just like drive-in racks, drive-through racks are used to store large quantities involving a small number of heavy items - as well as fragile goods and non-stackable load units.



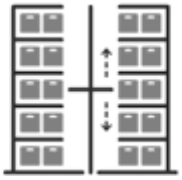
Flow-through racks

Flow-through racks are frequently used for picking in distribution warehouses. Medium quantities involving small and intermediate-range numbers of items are stored on the racks.



Storage carousels

Storage carousels are frequently used for small-parts storage systems, replacement-parts storage, tool storage, pharmaceuticals storage or document storage. Small to medium quantities involving intermediate-range to large numbers of items are stored in storage carousels for picking purposes.



High-bay racks

High-bay racks are most frequently found at industrial and retail companies. They store small to large quantities involving large numbers of items or assortments.

5.4. Scope of Council warehouses

1. More space utilisation in the metro station.
2. Less overhead cost for the companies.
3. Easier access as most of the metro stations is equipped with necessary infra-structure like elevators, more parking spaces, etc.
4. Less Paper Work.
5. More security as almost all the metro stations is watched by CCTV cameras.

Challenges
One critical factor that contributed to the problems over freight deliveries is the absence of adequate forums where stakeholders can communicate with each other.

6. FINAL LEG – FREIGHT DISTRIBUTION TO CUSTOMERS

The distribution system had to be adapted to several environmental, social and economic changes and it has to take into account a wide range of characteristics and requirements. Since the distribution is highly sensitive to the customer requirement, volume of goods and availability of infrastructure multiple solutions are considered. The interested reader is also referred to [20].

6.1. Electric Trucks

Electric light goods vehicles or trucks are becoming more and more common in the logistics industry. Since our model is dependent on transportation of goods with short distances, these vehicles are ideal for such movement. The payload capacity of these vehicles ranges from 2.8 tonnes to 7.4 tonnes with a travel distance varying from 65 km to 160 km [7]. The vehicles of choice would depend on the volume and weight of goods but these would serve the industry fruitfully and help reduce carbon emissions.

According to the EU commission transport is the second biggest culprit for greenhouse gases [8]. As shown in the figure (Fig. 9) below, road transport accounts for the majority of the emissions in this

sector and active methods are in place to reduce this. Electric vehicles help curb these emissions and allow for a better society.

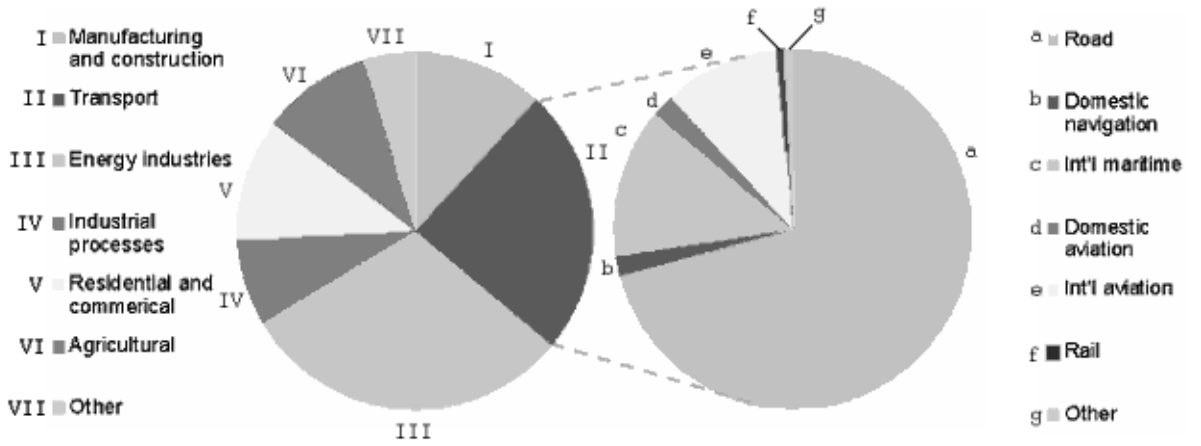


Fig. 9. EU greenhouse gas emissions from transport and other sectors and by mode of transport, million tonnes of CO_2 equivalent, 1990-2007

Fig. 9. Emissão de gases de efeito de estufa na UE para o sector dos transportes e outros sectores por meio de transporte, em milhões de toneladas equivalentes de CO2 1990-2007

6.2. Airships

Commercial airships could be used as futuristic freight vehicles, replacing traditional aircraft and reducing the need for airport expansion, as observed by researchers at University of Oxford. Research undertaken at University of Oxford by Sir David King, director of Smith School of Enterprise and the Environment, and researcher Chris Carey showcases the potential of airship freight [9].

Potential benefits of airships include their ability to take off without need of rigorous infrastructure from land or water, therefore negating the need for long runways. They also have long range capabilities and high energy efficiency, and could potentially have a load capacity more than nine times that of a Boeing 747-400F freighter aeroplane. Their flexibility of route and landing place would give airships an advantage over air, rail and marine freight, and would dissolve the need for extensive road freight to and from ports and airports. Airships could range in length from around 50 m to 100 m, meaning they could be small enough to land in spaces such as football pitches, or could need larger landing locations.

However, the development of freight airships is hindered by their maximum velocity at around 140 km/h – slow in comparison with fixed wing aircraft, due to airships' drag from their large gas envelopes. There are also concerns over stability in high winds, although hybrid airships – which use aerodynamic lift as well as the traditional envelope (balloon) filled with a lifting gas – are heavier and thus more stable. Boeing has a rotorcraft airship currently in development with Canadian company SkyHook International capable of carrying a 40t load, while Skycat 220 freight vehicles capable of transporting transport loads of up to 220t are under development by UK companies World SkyCat and Hybrid Air Vehicles.

6.3. Hybrid Trailers

The Walmart Advanced Vehicle (Fig. 10) Experience is a tractor-trailer combination (Tab. 4)[11] that features leading edge aerodynamics, an advanced turbine-powered range extending series hybrid powertrain, electrified auxiliary components, and sophisticated control systems all in one package, developed in support of the company's industry-leading sustainability program[10].

Table 4

Combination of Tractor – Trailer by Walmart

Tractor	Trailer
Advanced aerodynamics (20% aero improvement from current Model 386)	Trailer body built almost exclusively with carbon fiber; single-piece 53' panels in roof and sidewalls
Microturbine-powered series hybrid electric drivetrain is clean, efficient and fuel flexible	Use of advanced adhesives eliminates need for most rivets
Centered driver's seat that can rotate 180°	Convex nose shape enhances aerodynamics while maintaining cargo capacity
Electronic dashboard with customizable gauges and performance data	Solid, 53' one-piece floor reduces weight without sacrificing strength or performance
Sliding driver's door and fold out step for safety and security	Next-generation low-profile LED lighting is more energy efficient and less prone to damage

Fig. 10. Walmart Advanced Vehicle
Fig. 10. Veículo avançado da Walmart

6.4. Cargo Bikes

As countries head towards more environmentally friendly freight vehicles, the use of cargo bicycles is an effective and efficient way to transport small volume goods for very short distances. This mean of transport usually related with leisure and small commuting trips, has become extensively favourable for small loads of cargo. There are considerable urban distribution consolidation centres make use of such vehicles, including *La Petite Reine in Paris* (Fig. 11), which uses electrically assisted bicycle delivery [12], also the UK, there is Outspoken Delivery operating in Glasgow and Cambridge, using bicycle couriers who provides mail services or at least the end stage of mail services for large volumes. [13]

La Petite Reine is a delivery company which uses a tricycle with electrical assistance accommodating a special container in the back. The company was created in 2002 in Paris and today it delivers one million parcels a year in several European cities [14].

In Amsterdam, DHL had the initiative to convert a typical tourist boat in a floating distribution centre, and from the boat they used bicycles to transport the goods until their final destination. The system consists of allowing the boat to float through the canals of Amsterdam, which is connected with 20 bicycles-couriers through telecommunication devices. A result of this measure, 10 vans of DHL were no longer driving through the city centre of Amsterdam thereby reducing congestion and reducing emissions. [15,16]

Fig. 11. Cargo Bike Paris
Fig. 11. Bicicleta de mercadorias Paris

7. DISCUSSION

A case study on metro station of Porto was considered in order to see the extent of implications our system can have on the existing urban freight transportation and environment. On future implementation of our system it is certain that the pollution level in the city can be reduced to a great extent from the below mentioned data. The estimated reduction in cars due direct influence of Metro of Porto, was 11,130 cars out of 356 099 total cars used [17]. Calculation of the reduction of emissions due metro of Porto after the 1st stage of the project is (Tab. 5) [17].

Table 5

Reduction in road transport after introduction of metro

	Distance which was not travelled (km)	Saving of emissions at national level (ton)	Saving of emissions at local level (ton)
Total	81 080 681	34 198	42 046

Comparing with what was expected before the construction of the metro network and what really happened after the construction of the metro; the greenhouse gas emissions reduced 10.4% more than what was expected (33.6kton of CO2 facing 30.4kton). From the above data it is very much clear that when we use metro instead of road transport for freight transportation in urban areas, it will have a major positive impact on the environment and it also reduces the overhead costs for individual companies when council warehouses are used to store goods instead of individual warehouses.

8. CONCLUSION

Urban transport is a high rising agenda in many cities. However, relatively little attention has been paid to urban freight compared to passenger transport hence this study mainly focuses on freight transport by rail within cities coupled with council warehouses. It was aimed at designing a system by using the existing resources in an optimal manner. As per the system proposed, when we use the electric cars or CNG trucks in cities to carry goods, the CO_2 levels reduces by 47% and NOx levels reduces by -56%. So it is certain that increase in the use of metro will definitely have a positive impact on the environment. With new regulations for emissions of greenhouse gases, the urban freight transport sector will get it is long overdue attention in terms of operations and technology.

The concept presented in this paper also stresses on the importance of urban freight transportation by rail with the scientific inclusion of a new concept called “Council Warehouses”.

Although, Europe was the birth place of Railway Industry it appears that the European Union lags behind big time when compared to other developed countries across the world in term of the volume of goods transported by rail. Hence, it is high time that the European Union has to focus on the ways to increase the freight transportation by rail in order to cope up with the denuding global market.

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