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Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Urban Rail System for Freight Distribution in a Mega City: Case Study of Delhi, India

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Abstract

The organization of urban freight distribution in developing countries is based on use of road vehicles which often results in high levels of traffic congestion, lack of parking space, lace of appropriate loading and unloading area which affects its efficiency. With the growing economy and increasing population Indian cities are focusing on their infrastructural development to mainly handle the passenger movement whereas freight sector is in complete negligence and further which contributes to the negative externalities like emission, safety, congestion and energy costs. Urban freight distribution through environmentally friendly modes is one of the advocated sustainable strategies worldwide which have immense potential to lower down the congestion and pollution levels owing to existing practices of freight distribution. This paper is an attempt to explore the potential of ring rail and metro rail system, presently used for passenger services, to be also considered for the distribution of freight, particularly postal and couriers in city of Delhi.

Keywords: Urban freight; urban rail; logistics; spare capacity; supply chain

1. Introduction

The movement of goods within urban areas is vital since cities are the center of economic and social life. Freight movement in the cities often puts considerable strain on urban transport infrastructure and imposes high social costs. Cities are now facing global competition for investment and trade when an efficient transport system is necessary for sustained economic prosperity. The explicit consideration of urban goods movement has the potential to contribute towards achieving the goals of urban transport. The objectives of city planning, in particular, and city transport system

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planning, in particular, is to enable goods movement at desired levels of efficiency of goods movement. Goods movement is increasingly becoming recognized as an integral component of urban transport planning.

India is one of the largest economies in the world and a major emerging market that has a young population, rising investment rates, large domestic demand and globally competitive firm. According to IBEF (2013) report the Indian logistics industry was valued at an estimated US$ 130 billion in 2012-13. It has grown at a CAGR of over 16 per cent over the last five years. As per the Economic Survey 2017-18 report, "With the implementation of GST, the Indian logistics market is expected to reach about USD 215 billion in 2020, growing at a CAGR of 10.5 per cent". The logistics industry employs more than 22 million people and it has grown at CAGR of 7.8 per cent during past five years (Economic Times, 2018). The country's logistics industry worth around USD 160 billion is supposed to increase till USD 215 billion in the coming two years after the implementation of Goods and Services Tax (GST) (Economic Times, 2018). The key growth drivers of logistics industry growth in India are: rapid growth in industries such as automobile, pharmaceuticals, fast-moving consumer goods (FMCG) and retail; increase in trade because of integration of India's economy with world; government initiatives such as FDI regulations, private sector participation and development of logistics infrastructure and increasing trend of outsourcing logistics to third party service providers. The contribution from the movement of goods including freight transportation and storage is about 90 per cent. Aggregate freight traffic is estimated at about 2-2.3 trillion tonne kilometres. Road dominates the mode of freight transport mix and constitutes about 60 per cent of the total freight traffic. Rail and coastal shipping account for about 32 per cent and 7 per cent, respectively, while the share of inland waterways transportation and air is less than 1 per cent each.

The freight movement in cities of India varies by size and function of the cities. While macro level freight traffic data base is generated as part of comprehensive transport plan preparation exercise undertaken from time to time the freight logistics aspects related to supply chain linkages, storage, handling, distribution aspects including the modes used etc. is not given enough importance. The sector is also faced with a number of challenges such as congestion, parking for deliveries and reverse logistics. Due to the lack of comprehensive understanding among decision makers and operators the image of freight and supply chain sector has taken a severe dent. The cities are basically designed only considering the passenger movement and neglecting the major part of the traffic that is goods movement and facilities related to it like truck terminals, warehousing facility, and amenities for drivers and crew and important aspect that is supply chain (Gupta, et al., 2014). The Indian logistics sector is slowly witnessing a transformation from small storage go-downs to large format multi-purpose logistics centers. At present the organized sector has a minor share in the total logistics industry and the market is dominated by small unorganized player but is now rapidly changing towards more organized players entering in logistics market. It is observed that while in 2007 the unorganized market share was almost 93% of the entire logistics sector, it is rapidly reducing with market becoming more organized with an estimated share of 15% share in 2013. This transformation has also been due to several policies aiming at encouraging investment in the sector, including free trade warehousing zones and logistics parks (Gupta, et al., 2014).

There are various practices and strategies that were adopted in many Indian cities to cope with the issues related to the freight logistic management, like prohibiting truck entry into the city in day time, restriction on movement of trucks older than 15 years, levying 'Green Tax' on goods vehicle varying with their payload. However, there are lots of issues which needs to addressed so as to make the freight and logistic sector works efficiently, namely-

- Lack of support facilities like storage and warehouse, inland container depots (ICDs), truck terminal, integrated freight complex (IFC) etc. for freight and logistics system makes them to create their own habitat which doesn't comply with the city structure and hence haphazard development is done and causing chaos and congestion.
- Lack of comprehensive planning as well as limited or no provision for logistic related facility, private players or truck operators started developing warehouse and storage facility at city periphery, leading to unplanned and sprawled development of the city.
- Negligence towards rail-based freight transportation.

To address the various issues because of freight distribution in urban areas, there are various sustainable freight distribution practices like usage non-motorised transport (NMT) and logistic sprawl providing inter-modal connectivity to goods movement. There are issues related to health and safety which requires immediate action, hence there is an urgent need to have an appropriate planning strategies and policies to enable a healthy and safe urban freight operation environment using green modes such as NMT's (Gupta, 2016). Whereas in the context of case study as Delhi, city has observed an uneven distribution of logistic facility when compared to population distribution. According to the study done on logistics sprawl in timber market in Delhi by Gupta et al. (2016), Delhi has witnessed sprawl of 100m/year towards the outwards direction of the city and this has led to considerable increase in terms of freight vehicle on road and leading to emission and consumption of fuel (Gupta & Garima, 2016).

According to the Robinson et al. (2004) paper on rail in Urban Freight, urban rail service in urban area has good potential apart from passenger service, transportation of goods that is of high market value and time sensitive commodity can be done. To reduce the external costs due to road transportation of goods in terms of environmental emissions, fuel consumption and total handling time, urban rail system can be used for the same. Rail freight has potential for exploitation in urban areas apart from the regional transportation system. Urban freight distribution through rail can contribute in many ways as it will help in to decrease the heavy vehicle traffic and decongests the road, further it has direct implication on reduction in environmental pressure but due to the present practice of land use and non-consideration of existing rail service and infrastructure in planning process, rail is losing its existence in the service sector and further with the development in the technology has completely ignored the potential of rail infrastructure, the preservation of the railway infrastructure is very important, apart from the conventional usage of rail system for passenger movement, it has to break through for the higher level of services like large scale goods movement at regional level as well as urban level too (Robinson & Mortimer, 2004).

2. Rail based urban freight distribution

The ability to transport goods safely, quickly and cost effectively is one of the foundations of globalization and economic growth and is based on an efficient freight transport system. Indeed, statistics show that transport demand is closely linked to economic development. Between 1995 and 2008 freight transport within the - European Union (EU) increased as faster than the economy, with an average annual growth of 2 %. Moreover, during the economic recession (2008-2009), the decrease of 4.2 % of EU gross domestic product (GDP) accompanied by a decline of 11.2 % in freight transport (Behrends, 2011). The second half of the 20th century found changes in the modal split of inland Freight transport. The need for mass production led to the spread of new philosophies of logistics, e.g. just in time and lean production, increasing the importance of time, reliability and speed. Figure 1 suggests that the road sector was able to capitalize on the growing need for movement of goods, rather than taking the opposite direction market share of rail freight industry (IMechE, Institution of Mechanical Engineers, 2009).

This trend in freight transport is a source of concern regarding sustainability as road freight brings some negative impacts on the planet (environmental sustainability), in people (social sustainability) and benefit (economic sustainability) (Quak, 2008). In fact, estimated external costs of road and rail freight in the European Union show that road transport has higher external costs per tonne - km rail freight which goes up to five times (Amos, 2009). Urban traffic is more polluting than freight of long distance, which is caused by the number of short trips and the number of stops for distribution in the city (Schoemaker, 2006). In addition, some of the above mentioned are also external factors directly related to urban density: Higher density intensifies traffic congestion and air pollution (Cox, 2000).

Some of the sustainable strategies which have been adopted in various European nations to lower down the congestion and pollution level in the respective cities as a result of freight movement include Low Emission Zones (LEZ), Combined Use Lanes, Preferential zoning, Unattended delivery systems and Reverse Logistics, Freight Villages, Low Emission vehicles, environment friendly modes (through existing Rail or tram system), alternative fuels etc. Amongst all these measures use of low emissions vehicles for freight distribution in urban areas has immense potential to result in sustainable freight distribution patterns in urban areas. Urban rail is increasingly being viewed as an alternate potential sustainable distribution mode.

Rail can achieve up to 50% of reduction in energy consumption per tonne – km compared to road-based freight transport systems (Ford, et al., 1995). Moreover, the railway also allows the major axis weights and higher capacity of cargo volume for lighter weight products. However, the railroad failed to capitalize on its advantages in order to be used worldwide for urban distribution of goods. The main weaknesses were identified are: poor door to door capacity; inflexibility; competition with passenger services line capacity; the perception of rail infrastructure and high costs related system (Robinson & Mortimer, 2004). It is important that railway disadvantages are overcome and treated for urban freight Rail transport that can be put into practice and people can get great benefits it offers. Urban projects of railway transport (tram, metro and light rail) appear to be as a possible solution to this case of freight distribution in urban areas. A motivation to develop new projects arose in order to create an efficient distribution of products by increasing productivity, having economic and environmental benefits and minimizing emissions and traffic congestion, as well as the noise pollution generated by traffic (Marinov, et al., 2013). However, these objectives require significant and major investment in order to implement, mainly in infrastructure, construction and maintenance.

3. Global case studies

To study and understand various aspects related to rail-based freight deliveries in urban areas focusing basically on their network, commodity, operational and management characteristics, constraints is any as well as advantages and disadvantages if any in terms of environment, economy and energy, certain cities having rail or tram network is selected to review their practice to carry out this study.

CarGo-Tram (Dresden)

CarGo Tram was established by Volkswagen in collaboration with DVB, Dresden's traffic enterprise. The system is operational since March 2001, connecting Volkswagen's "transparent factory" with its logistics center, located in Dresden- Freidrichstadt. As the "transparent factory" is not located in any industrial area as it is in the heart of the city with historical characteristics. This is why there is just a limited stock capacity and waiting areas at the Transparent Factory. Volkswagen's logistics center built four km away in an industrial area which takes 15 minutes for one trip, which has a great hinterland connection. Also, Volkswagen uses existing 'public rail network' of the city to avoid congestion due to new infrastructural introduction and also transfer of automobile parts is not done throughout the day as it has limited number of trips. The transportation of automobile parts from industrial area to its production location that is Transparent Factory as it is due to the factory's location in an environment sensitive zone, thus city friendly transport system was required so as to avoid traffic and congestion into the city center. The factory and the logistic center were located immediate to existing tram network, so there was no need of any further investment in transport infrastructure. Transport of automobile parts by CarGo Tram allowed a continuous transport flow with high utilization of the tram and also transportation of goods through rail is a long tradition in Dresden as perishable items, linens, machines and parts were being transported by train in the last century.

CityCargo (Amsterdam)

CityCargo was established in 2007 which was in function till 2009 (due to financial constraint for further extension of system, service was terminated), the service was initiated with the objective of reduction in congestion by 50% (from 5000 trucks to 2500 trucks on road) and replacing them with trams, cutting pollution by 20% (up to 16% reduction in particulate matter, carbon dioxide (CO_2) and nitrogen oxides) *(Chiffi, 2007)*. It is observed that more than half of the particulate matter in emissions in the city is caused by diesel based traffic and that more than 35% of emissions derive from inner city goods transport *(Architects, 2009)*, which is responsible for air pollution (sulfur), congestion and noise annoyances (Chiffi 2007). This is the main reason why City Cargo decided to implement a new system of urban freight movement using the existing infrastructure for streetcars in an innovative way: replacing Trucks with Trams *(Architects, 2009)*.

CityCargo of Amsterdam has developed a fleet of non-polluting vehicles to deliver cargo via the city's underutilized streets *(Halbu, 2008)*. Once they have a fleet of e-delivery vans that can then take individual deliveries to their exact destination that is delivery points *(Leech, 2008)*. CityCargo trams are planned and designed to travel behind the existing passenger tram so that they would not have any interference with the normal schedule of passenger service *(Leech, 2008)*. Hence, for the efficient system to operate around 50 special cargo trams and 400 e-cars were deployed in order to supply shops, supermarkets and the catering industry in the city center of Amsterdam. Each unloading or loading operation takes 10 minutes of time on average, so each site or station was active for 40 minutes out of each hour during the morning peak hour. The system was presented as very cost efficient as one cargo tram can transport the same amount of goods as four (7.5 ton) trucks *(Chiffi, 2007)*.

Monoprix (Paris)

Monoprix in Paris is operational since November 2007. This system utilizes existing rail system as well as CNG vehicles for the transportation of perishable goods to 90 designated supermarkets. Regional Passenger Trains under brand name of 'Monoprix' moves goods from suburban distribution location to a building in Paris from where CNG trucks move goods to their last destinations during night trips. From the city periphery goods were loaded on train and then it is transported to designated station which were designed to cater goods traffic also and with loading and unloading facility for goods on CNG operated vehicles which further transfers the goods to designated supermarkets. The transported freight consists of packaged water, milk, juice and soda from city peripheral to city center and commercial areas. The main results are the following *(Zunder, 2011)* –

- Total 10,000 trucks were replaced by Monoprix which leads to reduction of 700,000 km of truck km and also 70,000 liters of fuel is saved.
- Reduction in pollution level.
- Initial disadvantage in terms of fixed cost as it is observed that there is 26% of hike in transportation cost per pallet.
- Externalities in the form of congestion, noise pollution, and emissions are observed to be reduced.

Monoprix brings the challenges of building the rail freight transport in urban areas, such as the need for broad logistics facilities constrained to the railway network and some retail companies that have at least a small amount of goods to be delivered daily to the city.

Cargo Tram (Zurich)

Cargo Trams for 'Reverse Logistics' in Zurich started in March 2005 to reintroduce the freight transportation to the tram network. To address the issue of collection and recycling of bulk refuse generated approximately 300 tonnes per year and also Zurich had an extensive tram network which can sustain to cater this issue of reverse logistics. In monetary terms Cargo Tram costs about €20,000 less what an equivalent road-based transport system would have cost. Advantages in terms of savings of emissions and energy (fuel consumption) is as follows-

- It is observed that the road haulage has decreased by 5,020 km and also led to reduction in emissions of CO2 (4,911.3 kg), SO2 (1.4 kg), NOx (80.6 kg), PM10 (2.3 kg), VOC (4.2 kg) and CO (14.6 kg).
- Diesel fuel consumption gone down by 37,500 litres per year by avoiding 960 hours of vehicle running time on roads (Wolfram, 2005).

Since January 2006, another freight tram was initiated that is called E-Tram, this is introduced for collection and disposal of electronic and electric waste. There were nine pickup points for the freight tram with 18 trips per month by both the Cargo Tram and E-Tram. Also, it is observed that 43% of the waste was not dumped anywhere in the city it is being under recycling process reducing a significant amount of externalities from the environment. Cargo Tram costs around 1000 Euros for every working day and it provides door to door service to avoid private car trips that were made to dumping sites. There is a wide concept of offering the residents a better quality of life without car ownership, which includes attractive local amenities, higher level of public transport facility and promoting car sharing to reduce number of private vehicles on road.

Hence, the main weaknesses were identified are: poor door to door capacity; inflexibility; competition with passenger services line capacity; the perception of rail infrastructure and high costs related system (Robinson & Mortimer, 2004). It is important that railway disadvantages are overcome and treated for urban freight Rail transport that can be put into practice and people can get great benefits it offers. Urban projects of railway transport (tram, metro and light rail) appear to be as a possible solution to this case of freight distribution in urban areas.

Newcastle Metro System

Newcastle Metro System (NMS) is operational since 1980, it is the second largest of the three rapid transit metro systems in UK. As per the ridership data provided by the system, more than 40 million public journeys per year has been performed with a daily ridership of 113,000 in the year 2009-10. There are some features in the NMS network that could lead to successful urban freight movement by rail (Montarghi & Marinov, 2012)-

- There are heavy rail links connecting the Central Station from Newcastle to London and Scotland along the east coast. This opens a window to the use of national rail network.

- There are multiple estates accessible by rail within fifteen minutes (namely the MetroCentre – Europe's largest indoor shopping mall). This means that there are many retailers that may be viewed as future customers of this kind of service.
- The network itself provides good links between the airport and the centre. Goods arriving by air could be easily transported to the city centre by rail.
- The network has also good links to South and North Shields, providing ferry links to other UK ports and abroad. This means that inter-modality with the maritime transport is also an option, widening the markets available even more.

As NMS is designed for passenger service, so the technical operations to be involved in the freight handling should be short. Unloading / loading operations should not affect the normal operation of passengers, therefore, restricting deliveries in sections of low volume is done. Under this option, the infrastructure requirement will be less and, in many cases, platforms and existing facilities are sufficient to cater the freight demand. In addition, the labourer force needed to treat with cargo can be small and relatively unskilled. One possible solution is the use of small specialized logistics boxes, which can be processed and handled manually (Montarghi & Marinov, 2012).

Dusseldorf (Germany)

The heavy rail freight operation in Dusseldorf is a result of freight policy in which the city supports rail and intermodal transport so as to achieve the shifting of mode from road to rail. The most important decision was to preserve the rail infrastructure by connecting it with more number of sites in the city and this can be achieved by integrating transport planning with the city planning process (Robinson & Mortimer, 2004). In order to improve productivity, shorten the transit times and create new connections, the city's plan included the following (Robinson & Mortimer, 2004) (Browne, et al., 2014)-

- Implementation of an efficient central goods sorting system and enhancing its accessibility with local shunting yards.
- To make rail freight system more efficient, number of rail routes were increased which is independent of the passenger network.

4. Freight profile of Delhi

4.1. Trade Profile

As per the details from Census 2011 of India, Delhi has a population of 16.75 Million, an increase from figure of 13.9 Million in 2001 census. The average annual exponential growth rate of population of Delhi during 2001-2011 has been recorded as 1.92%. The total area of Delhi is 1,483 sq. km. with population density of 11,320 per sq. km which is higher than national average 382 per sq. km. In 2001 the population density of Delhi was 9,340 per sq. km, while nation average in 2001 was 324 per sq. km. Delhi's economy has grown at 12% per annum during 2004-12 and is dominated by the tertiary sector which accounts for 87% of the state's GDP. The vehicular population in the national capital registered a 135.59% jump between 1999-2000 and 2011-12 to touch 74.53 lakh. At present there are about 15 lakh registered goods vehicles in Delhi out of which 38% vehicles have local permit and rest has inter-state permit. Around 58,000 goods vehicles make multiple trips for distribution of goods within Delhi.

Trade and commerce have played a pivotal role in promoting the growth of Delhi's economy by making a significant contribution in terms of tax revenues and providing gainful employment to a large section of the society. Delhi is the biggest trade and consumption center in North India. The city distinguishes itself as a center for entry port of trade which means that large part of its economy activity is concerned with the redistribution of goods produced elsewhere and imported for local sales as well as for distributed to other states. It has attained the status of a major distribution center by virtue of its geographical location, historical factors and availability of infrastructural facilities etc.

As per Economic Survey of Delhi 2001-2002, there are about 37,000 wholesale enterprises in Delhi with an employment of about 0.16 million. In addition, there are about 6,500 enterprises of Storage and Warehousing providing employment to 27,000 persons. The total number of establishments found to be operating during 2005 in the geographical boundaries of National Capital Territory of Delhi was 757,743. Of this, 41% were own account enterprises and the remaining 59% were establishments those were employing at least one hired worker. In 2011, there were approximately 400,838 wholesale & retail trade establishments. And the total storage & warehousing establishments were about 30,676 which give a rate of 183 warehousing and storage establishments per lakh population in 2011. The major economic activity group of 'Retail Trade' with 48.9% of share in total establishments ranked first followed by 'Manufacturing (including repair the Master Plan of Delhi 2021 clearly emphasize that wholesale markets of Delhi plays a very vital role and Delhi deal in about 27 major commodities, covering all items especially timber, fruits & vegetables, Food grains, textiles, iron & steel etc. 49% of the fuel, 47% of Food grains, 44% of iron & steel and 78% of fruits and vegetables imported to Delhi are redistributed to other parts of the country as well as foreign nations also as per the Economic Survey of Delhi 2012-13.

4.2. Freight Trends

Delhi being the distributive center of the country receives and distributes huge quantities of goods on a daily basis resulting into heavy freight movement within the city along with generation of inter-regional traffic. According to Gupta et. al. (2007) based on an empirical study the total regional tonnage handled per day in Delhi increased from 134,222 tonnes in 1993 to 192,238 tonnes in 1996. It further increased to 377,030 tonnes per day by 2008 (RITES, 2008). It is observed that while the originating tonnage grew at 2% AAGR from 1996 to 2008, the destined tonnage showed a significant growth of 8% indicating increased consumption rate within Delhi, both for its residents as well as for redistribution to other parts of the country. The details of total daily originating and destined tonnage during the period 1993-2008 in Delhi are given in Table 1 below:

Table 1. Total originating and destined tonnage in Delhi

Traffic Type/day	1993	1996	AAGR (%)	2008	AAGR (%)	2014 (estimated)
Originating Tonnage/day (Tonne)	58114	90488	15.9	113,555	2	127,207
Destined Tonnage (Tonne)/day	76108	101750	11.2	263,475	8	423,977
Total Tonnage Handled/ day (Tonne)	134,222	192,238		377,030		551,184

Source: Gupta et.al (2007), RITES (2008)

Based on the tonnage handled and population the daily goods traffic generation and attraction rates in Delhi are shown in Table 2.

Table 2. Growth trends in goods traffic generation and attraction rates in Delhi

Year	1993	1996	AAGR (%)	2008	AAGR (%)	2014*
Population (Million)	10.1	11.42	-	16.75	-	18
Goods Traffic Generation Rates (kg/capita/day)	5.73	7.97	12%	7.19	-1%	7.07
Goods Traffic Attraction Rates (kg/capita/day)	7.5	8.96	6%	16.68	5%	24

*estimated based on past trends

According to Singh (2016) an estimated 67,120 tonnes of intra- city goods movement through 54,690 vehicles take place daily in the city.

5. Data base

5.1. Case Commodities

For this study the postal and courier cargo has been selected. In Delhi, as per the Annual Report of India Post 2015, there are total 493 delivery post offices (DPO), whereas each DPO serves 38,235 persons within an average service area of three sq.km while for the case of courier parcels for an estimated 400 parcels agencies the average population served by each agency is 47,125 persons with estimated service area of 3.71 sq.km. It is estimated that in all 0.23

million articles are handled daily in the city resulting in an estimated 90 tons of load whereas for the year 2021 and 2026 estimated tonnage is 120 tons and 146 tons respectively (Table 3).

Table 3. Daily Postal Demand of Delhi

Article Type	2016		2021		2026	
	articles/ day	tonnes/ day	articles/ day	tonnes/ day	articles/ day	tonnes/ day
Postcard	42,649	0.11	60,454	0.25	73,659	0.21
Letter	133,278	0.33	184,686	0.75	225,026	0.69
Registered Newspaper	18,989	47.47	25,245	63	30,759	77
Parcels	3,639	8.73	4,937	12	6,016	14
Packets	32,899	32.90	44,270	44	53,940	54
Total	231,455	90	319,592	120	389,400	146

Source: Singh (2016)

For the present study in order to assess the postal and courier potential demand to be moved by urban rail system a one kilometre catchment area on the Metro rail and Ring Rail network was considered. With the help of GIS mapping the number of DPOs and courier agencies within one km catchment of urban rail corridor estimated were 213 and 142 respectively within this catchment area.

5.2. Field Studies

As part of primary surveys establishment surveys were carried out in the catchment area to assess the tonnage handled, modes used in distribution and distribution mileages. The sample size of establishments enumerated were 4% of India Post office and 9.5% of Courier parcels agencies. Besides a sample of 80 freight operators owning light commercial vehicles and tempos were also enumerated to capture the operating characteristics in terms of tonnage handled, trip length and trip time and their willingness to provide the first and last mile service to the proposed rail system These operators were surveyed at truck terminals, vegetable and fruit wholesale markets and timber wholesale market respectively located in different parts in the city. The operators captured were involved in handling various kinds of goods ranging from FMCG, electronics, fruits and vegetables, automobile parts, cement etc. LCVs, tempos and van in particular were covered since they are the potential mode to carry out last mile distribution of 1.5 to 2 km leads of freight between various establishments located in the catchment area along the rail corridor and Metro or Ring Rail.

6. Establishment and operator characteristics

6.1. Establishment Characteristics

On an average 150 kg of postal articles are handled by each DPO whereas courier parcels agencies handle 22 kg of commodity daily. The modes predominantly used in both types of establishments, namely post offices as well as courier agencies, comprise of light commercial vehicles and tempos. The courier agencies also deploy two wheelers motorcycles for distribution purposes (Table 4). The average distribution leads vary between 53 km to 61 km.

Table 4. Establishment Characteristics

	India Post	Courier
Number of Establishment	493	400
Number of Sample	20	38
Establishment within 1km catchment	213	142
Average tonnage/ establishment (kg)	143	22
Modes Used	LCV, MCV, Tempo	LCV, Tempo, 2W

Average Trip Length (km)	53	61

6.2. Operator Characteristics

To assess the feasibility of the study, various operators were surveyed in selected locations like Sanjay Gandhi Truck Terminal, Punjabi Bagh Truck Terminal, Azadpur Sabji Mandi, Okhla Mandi, Kirti Nagar Timber Market etc. As in the study only two commodities postal and courier were considered but to develop it as a model for number of goods, operators were surveyed of various background that is FMCG, electronics, fruits and vegetables, automobile parts, cement etc. On an average a transport operator handles a load of 1.5 tonnes per day for distribution over a lead of 4 km. nearly two third of operators captured were interested to shift to new arrangement of freight distribution (as shown in Table 5).

Table 5. Operator Characteristics

Number of Sample Surveyed	75
Type of Modes	LCV, Tempo, Van, Auto
Type of Goods Carried	FMCG, Electronic, Postal, Vegetables
Average Tonnage Handled (tonnes)	1.5
Average Time taken (min)	30
Average Trip Length (km)	4
% Willing to shift to the new system	65

6.3. Estimated Daily Tonnage Demand

Based on field studies as well as secondary data of annual report on postal services, it is estimated that the average weight of each article/ commodity is 300 grams which is validated with the estimate arrived taking daily tonnage generated to be 90 tonnes per day in the city. Accordingly, the estimated tonnage generated from the both postal and courier services lying within one-kilometre catchment of the Metro and Ring Rail is 40 tonnes per day with respective shares of India post and courier agencies being 37 tonnes and 3 tonnes respectively.

7. Spare capacity assessment on urban rail system

For this study two urban rail system has been considered to transport the case commodity, namely Delhi Metro and Ring Rail. From the passenger ridership trends data and number of coaches operated over time of the day, time slots were identified in which freight operation can be carried out without interfering with the passenger operation. In case of Metro on all the five lines the time period in morning 5 am to 6 am and 11 pm to 12 am in night is identified as feasible for freight operations whereas in case of Ring Railway the EMUs running passenger services its vendors coach will be utilized for the freight deliveries during the operational hours (DMRC Ltd., 2016).

The availability of spare capacity in Metro and Ring Railway has been calculated being considering following assumptions:

- Per person weight = 75 kg
- (Average person's weight = 68 kg and average baggage weight = 7 kg)
- Capacity of each Car = 375 persons
- For spare capacity calculation first and last trips were considered to avoid interference in passenger service.

Based on the above assumptions the spare capacity available in metro rail is 7,332 tonnes while in Ring Rail it is 230 tonnes respectively assuming capacity of one Vendor's Coach = 23 tonnes; and number of trains available = 10. Hence, total spare capacity available in both the rail systems is 7,562 tonnes (Table 6).

Table 6. Urban Rail Spare Capacity

Urban Rail		Total Capacity Available (tonnes)	Capacity Available in First and Last Trip of Metro Service (tonnes)
	Red	1,695	1,030
	Yellow	1,662	1,662
Delhi Metro	Blue	5,156	2,509
	Green	31,854	1,373
	Violet	1,302	758
Ring Rail		230	230
Total		41,899	7,562

Source: DMRC (2016)

8. Development of alternate scenarios and evaluation

8.1. Alternate Scenario Development

To assess the feasibility of the introduction of new system four scenarios along with Business as Usual (BAU) has been developed by integration of new modes will be in terms of Metro, Ring Railway and LCVs or Battery operated vehicles for the transfer of goods, whereas, there is complete change in supply chain in last scenario by shifting of depots near to the AMPC and RMS services.

Business as Usual (BAU)

The existing supply chain (Figure 1) of postal and courier service has been considered with all the aspects of total handling time, infrastructure requirement and transport mode used for transfer of the respective commodity. Whereas, movement of Postal goods from AMPC and RMS to four depots through road based transport system, from Depot to DPOs again through road transport and from DPOs to neighbourhood post offices through NMTs has been considered same as of present practice.

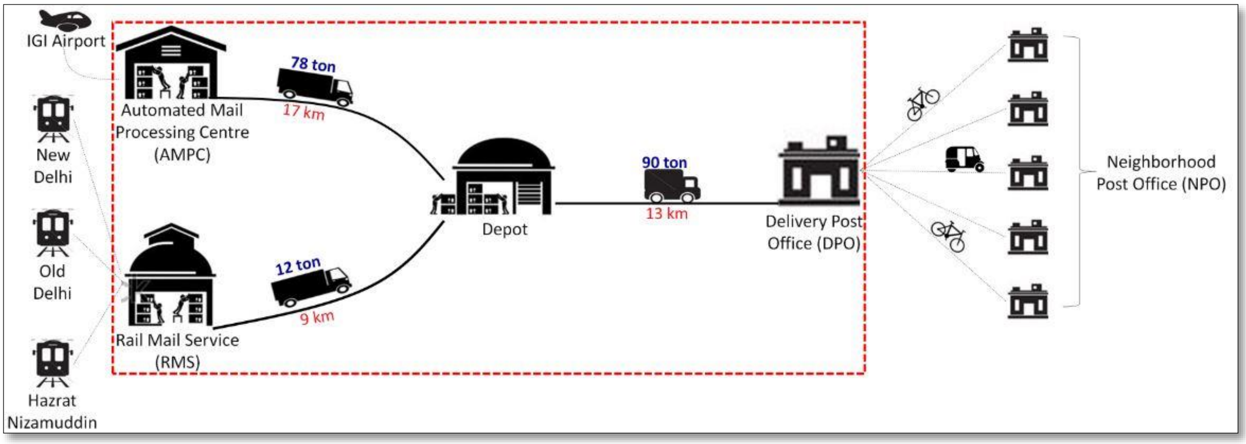

Figure 1. Supply Chain of Postal and Courier Service in BAU Scenario

Scenario I

In this scenario (Figure 2) it is assumed that the first step movement between the AMPC/ RMS to the four depots will be replaced with the existing Ring Railway and Metro system as all the four Depots are within the one km catchment of urban rail corridor and both the AMPC and RMS have connectivity with nearest Metro and Ring Rail stations thus 100 per cent of tonnage can be transferred through the urban rail system. Distance of 13 km will be covered by the Metro and Ring Rail to the respective depots. But this intervention will require multiple handling in between AMPC, RMS, Depots and Stations. For this purpose and to minimize the number of vehicles from AMPC to

Aero City Metro Station MCVs will be intervened and from RMS to New Delhi Metro Station, LCVs will be used and for the further movement from the stations having collection hub to depots, light commercial vehicles will be required to transfer the postal goods.

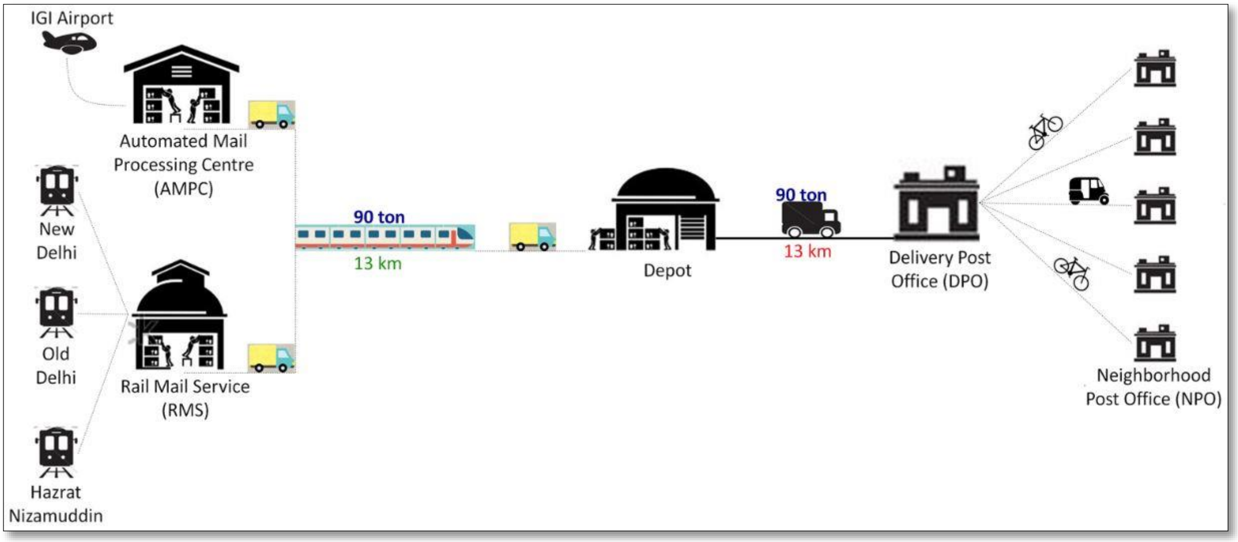

Figure 2. Scenario I

Scenario II

In this scenario (Figure 3), the intervention in the second step movement is done and for this only those DPOs and courier agencies have been selected which were falling within one km catchment of the urban rail as per the analysis of operator survey. From the survey and mapping, 213 DPOs are along the urban rail corridor and 142 Courier agencies are along the rail corridor, which both accounts for 38 tonnes of goods that will be transferred through this new intervention in the supply chain. There will be reduction in emission for the 13 km of distance as well the intermediate transfer between station and Depot/ DPOs will be done through NMTs.

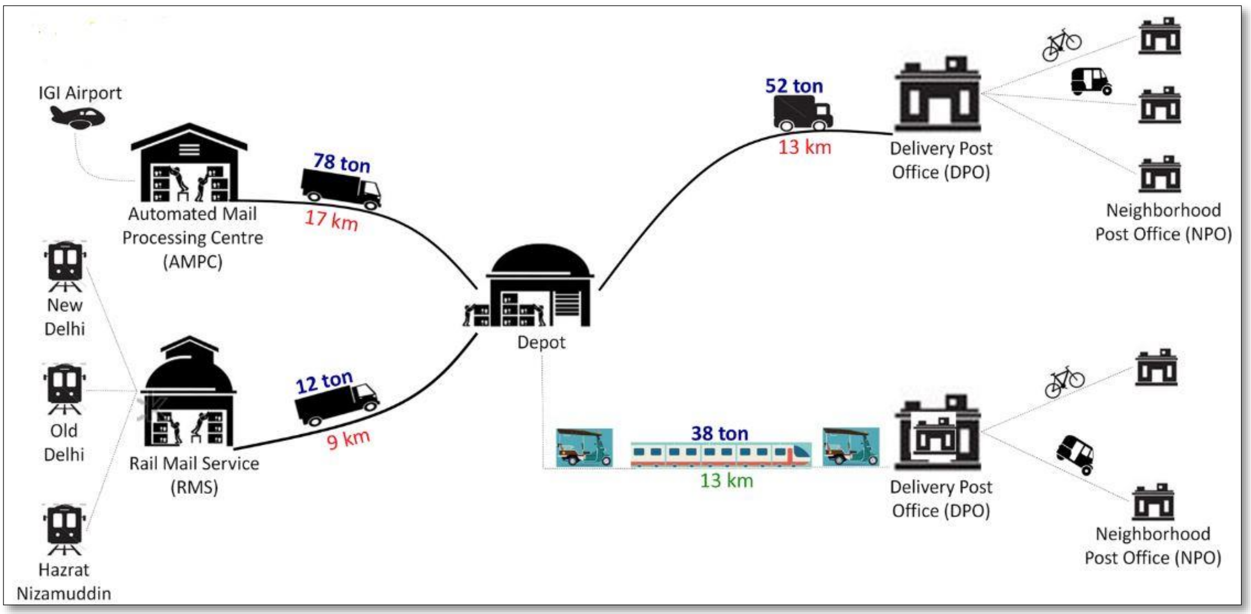

Figure 3. Scenario II

Scenario III

In this scenario (Figure 4), the intervention in both the movements has been done. This scenario is combination of Scenario I and II. In this Scenario, only movement that is performed between depot and DPOs, that too are outside the catchment zone of one km, will be road based and transferring 52 tonnes of commodity for an average trip length of 13 km. In this Scenario, in first step movement there will be MCV and LCV but for the step two movement only NMTs will be used for the intermediate handling.

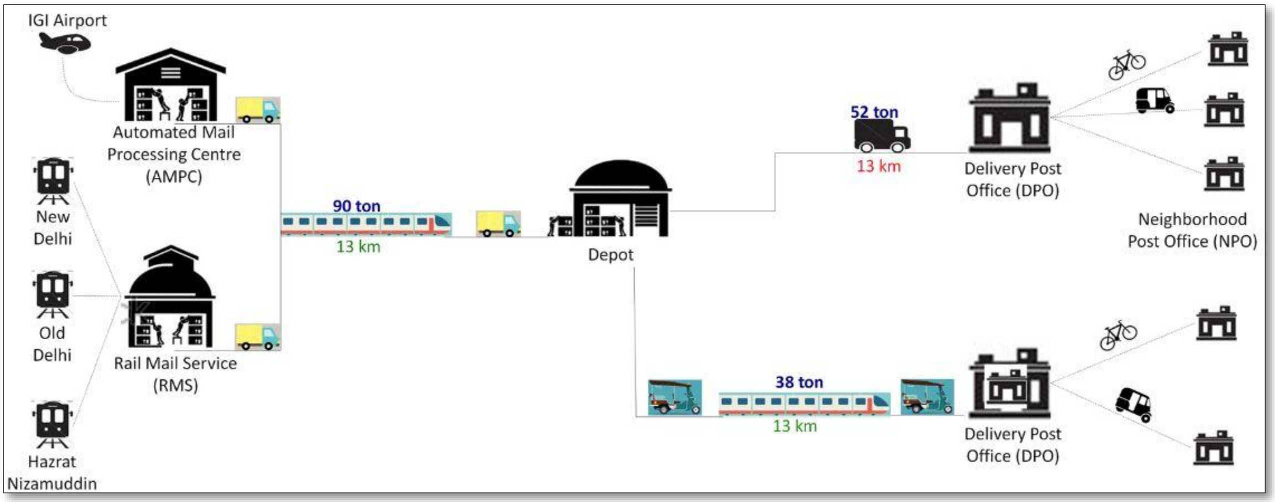

Figure 4. Scenario III

Scenario IV

In this scenario (Figure 5) there is a complete change in supply chain with respect to the BAU wherein shifting of depots near to the AMPC and RMS facilities are proposed to eliminate the intermediate road-based transfer of the commodities that between AMPC/ RMS and depots. In this particular scenario, for the study DPOs lying within the one-kilometre catchment of the urban rail corridor is considered. It is being proposed that some of the metro stations on basis of space available and maximum number of DPOs in its accessibility will having collection hubs from where parcel packets will be collected and delivered to respective DPOs. Considering the best practice of Mumbai Dabbawallas, unique identification codes will be developed to have the synchronization in the system. In this particular scenario for the study, only 38 tonnes of postal goods will be considered and being transferred through the existing rail system and intermediate handling will be done through non-motorized transport system.

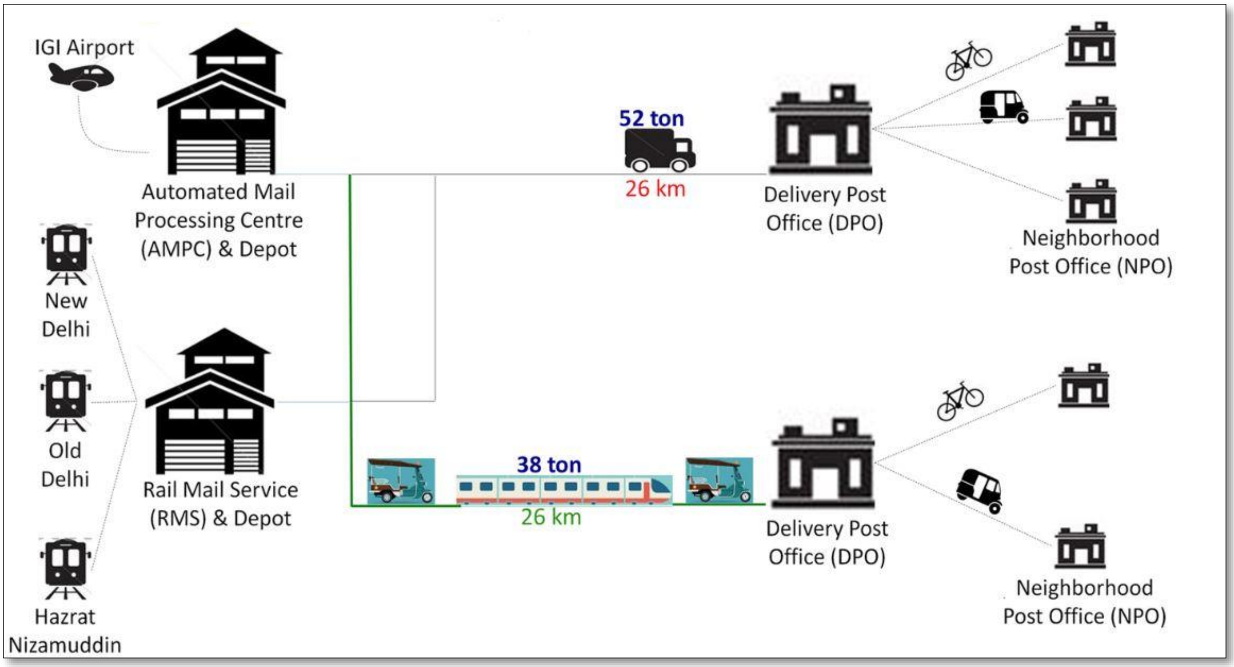

Figure 5. Scenario IV

8.2. *Evaluation*

All the scenarios are compared on the basis of three criteria, namely emission levels, handling time and energy (fuel consumption). Comparing all the factors across all the scenarios in base year, Scenario I is not feasible as it has values more than that of BAU, it is also because of multiple handling in the supply chain due to integration of Rail in first step movement in between AMPC/ RMS to Depot, whereas the Scenario II having improvisation in second step movement that is transfer of 42% of the case commodity which are lying within the one kilometre catchment of the urban rail corridors, there is a saving in vehicular movement (tonne km/ day),CO2 emissions and fuel consumption too. In terms of total handling time, Scenario IV is optimal as it has minimum time to accomplish the complete supply chain.

Table 7. Assumptions for Scenario Evaluation

	2016	2021	2026
Population (in millions)	18.85	21.93	25.34
No. of DPOs (@ 38000 persons/ DPO)	493	574	663
Metro Network Length (in km)	186	225	277
DPOs in 1km catchment of Urban Rail	213	367	577
Average Payload- LCV (tonnes)	1	1	1
Average Payload- MCV (tonnes)	4	4	4

The GHG emissions by the vehicles has been estimated on the basis of recommended average emission factor i.e., 62 gm CO_2/ tonne km (ARAI, 2011). Whereas, the carbon emission is calculated by the following method as shown in Table 8 by considering various factors like total number of freight vehicles estimated and assumed in the study, average load factor, total vehicle km, gross vehicle weight and average trip length (ATL).

Table 8. Carbon Emissions

Tonnes Handled/ day	No. of Vehicles (MCV)	Average Payload/ Vehicle (tonnes) (MCV)	Average Load Factor	GVW (Payload + Tare Weight) (tonnes)	ATL (km)	No. of Trips/ day	VU (km/ veh./ day)	Total km	Tonnes km	Tonnes CO_2 @62 gm CO_2/ tonne km
A	B	C	D= A/(B*C)	E= (C* D) +8	F	G	H= F*G	I= B*H	J= E*I	K=J* 0.062

It is observed that here is a reduction in GHG emission from vehicles across various scenarios when compared to BAU scenario (Table 9). In the long term, Scenario IV proves to be beneficial as there is distinct reduction on carbon emissions as it will be 2 per cent of the BAU scenario in the year 2026.

Table 9. Carbon Emissions

Scenarios	CO2 Emission (tonnes/ day)		
	2016	2021	2026
BAU	2571	3125	3605
I	2716	4256	5834
II	2015	2366	2701
III	2160	3497	4930
IV	2184	2689	78

It is seen that the there is a sizeable reduction in handling time in Scenario IV compared to BAU scenario (Table 10). The reduction in time in the base year 2016 is 29.4 per cent with comparison to Scenario IV, for the same scenario in year 2021 reduction in total handling time is observed to be 20 per cent and for the second horizon year 2026 it is estimated to be 14 per cent.

Table 10. Time in handling of commodity

Scenarios	Handling Time (in hours)		
	2016	2021	2026
BAU	319	406	448
I	280	274	254
II	282	258	235
III	258	234	210
IV	94	81	62

The fuel consumption too shows substantial savings in alternate scenarios in comparison between BAU (Table 11). The fuel consumption in comparison between BAU and Scenario IV is observed for base year 2016 has been increased by 21.5 per cent due to multiple intermediate handling but in long run this result into decline of fuel usage it was estimated to be 9 per cent of fuel consumption as what it will be for BAU scenario.

Table 11. Fuel Consumption

Scenarios	Fuel Consumption (litres/ day)		
	2016	2021	2026
BAU	2074	2614	3081

I	1686	2249	2737
II	1395	1687	1976
III	1007	1323	1632
IV	2521	3064	287

9. Conclusion

It is observed that in the present state-of-the art of city planning and practice in India there is very little importance attached to understanding the characteristics, problems and potentials of goods movement to, from and within urban areas. Alternate scenarios of distribution of case commodities through rail system were developed in this paper with varying distribution legs in supply chain networks to assess the usefulness of using rail system over the existing road system-based distribution practice with the reduced emission, handling time and fuel consumption. It was observed that there is a potential reduction in carbon emissions by 97.8% by 2026 compared by BAU scenario. In addition, there shall be substantial reduction in handling time as well as fuel consumed. The study concluded that in view of sizeable potential reduction in carbon emission and fuel consumption in alternate scenarios likely estimated when compared to BAU scenario and thus urban rail could be potentially seen as an alternative mode for distribution of goods in the city.

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