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ASSESSING THE IMPACTS OF CITY SPRAWL ON URBAN FREIGHT TRANSPORT IN DEVELOPING COUNTRIES

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Abstract

Introduction: In the 21st century, cities in developing countries have witnessed faster growth as compared with cities in developed countries. Countries like India, China and Brazil have one of the most densely populated cities in the world. The transport infrastructure in these cities struggles to deal with the increasing population and geographic sprawl. Though some efforts are made to improve the transportation systems in these cities, urban freight transport is largely overlooked as the focus remains on passenger transport. **Methods:** This study aims to assess the impacts of the city's geographic sprawl on urban freight transport using the example of the textile industry in Surat, India. The sprawl of the city and its textile industry is measured based on historical maps, Google imagery, and establishment surveys. Changes in urban freight trip lengths are determined using the data of a commercial vehicle drivers' survey. **Results:** In the last two decades, the city expanded geographically by almost three times. The relocation of textile manufacturing units led to a 40% increase in trip lengths and additional 56 tons of carbon dioxide generation per year. Due to the city sprawl, the overall efficiency of the urban freight transport system reduced. There is a need for a holistic planning approach towards urban freight movement and related urban infrastructure for sustainable freight flows. This can serve as a policy framework to decide on the location of a logistics hub or as guidelines to allocate manufacturing enterprises in the proximity of the urban area, thus enabling sustainable development of the city.

Keywords

Urban, freight, logistics, city sprawl, cities, developing countries.

Introduction

Rapid industrialization and mass urbanization in cities have generated a challenging situation for city managers to maintain a balance between the economic development of the city and a sustainable environment for its inhabitants. With city boundaries expanding over the years, trip lengths of passenger and freight transport have increased substantially. Urban freight trips generated by various industries largely depend on the type of industry, its geographic distribution in the city, and its supply chain requirements. The present study focuses on providing a technical background to the planners for considering the share of infrastructure requirements caused by industrial development. The textile industry of Surat is taken up as a case study. The supply chain of the textile industry is overly complex and freight-intensive in nature. Hence, the textile industry is selected for studying the impacts of freight transportation on city logistics.

The selected study area, Surat, has one of the biggest textile manufacturing hubs in the country. Surat is considered the economic capital of Gujarat state. It is a pivotal center on the Delhi–Mumbai side of the Golden Quadrilateral, having direct linkages with the industrial urban centers of Vadodara, Ankleshwar, and Vapi. Fig. 1 shows the location of Surat on the map of India. Surat has been a prominent mercantile node on the western coast of India since the 17th century and a contemporary industrial city, which today presents a mix of continuity and change in its social and economic character. The city is popular for its textiles and diamond manufacturing industry. Surat is known as the Silk City of India, the Textile Capital of India, and the Diamond City.

In addition to textile manufacturing and diamond polishing, Surat also has quite well-developed enterprises in the engineering, chemical, and IT sectors. The city witnesses migration of people seeking employment from other states of the country. The population of the city drastically increased from 2.8 million in 2001 to 4.6 million in 2011 (Directorate of

Census Operations, 2011). Though some surrounding areas were included within the municipal limits in the year 2006, the city is still one of the fastest-growing in terms of population (4.5% per annum). In terms of area covered, Surat is smaller than other major cities like Mumbai, Delhi, or Chennai; however, its population density is comparable to that in some of the most densely populated cities in the world. Table 1 presents such a comparison.

It can be seen that cities with the highest population densities are all located in Asia except for Lagos and Bogota (Table 1).

Table 1. Cities with the highest population densities

City	Country	Population	Area (km2)	Density (people/km2)
Mumbai	India	14.35	484	29,630
Kolkata	India	12.70	531	23,920
Karachi	Pakistan	9.80	518	18,920
Lagos	Nigeria	13.40	738	18,155
Shenzhen	China	8.00	466	17,160
Seoul	S. Korea	17.50	1049	16,685
Taipei	Taiwan	5.70	376	15,180
Chennai	India	5.95	414	14,360
Bogota	Columbia	7.00	518	13,515
Shanghai	China	10.00	746	13,410
Surat	India	4.46	326	13,680

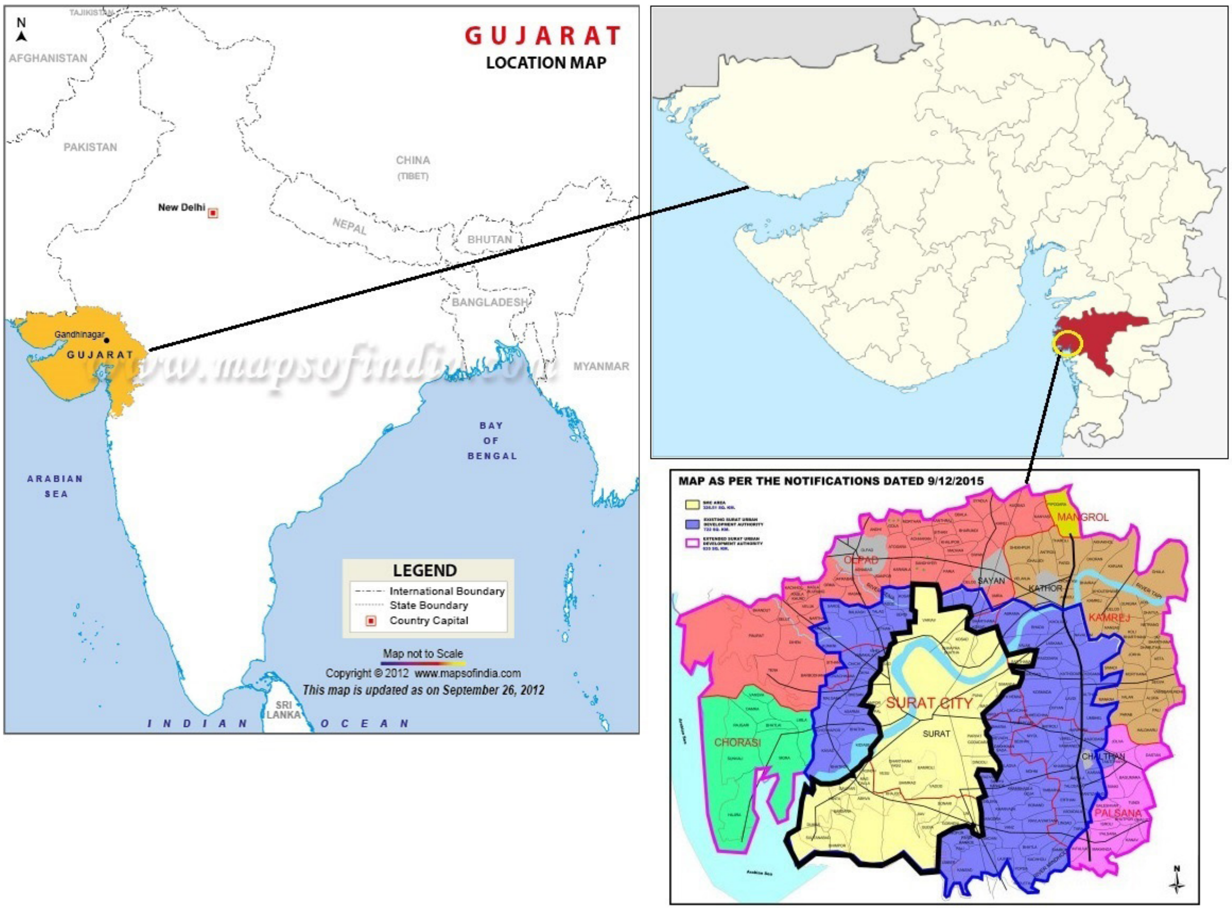

Figure 1. Location of Surat on the map of India
Source: Website of mapsofindia.com, suratmunicipal.gov.in

All the major cities in Europe and North America, which are more advanced in terms of urban freight transportation, do not have such high population densities. Proximity to Mumbai has helped various industries to prosper in Surat. It has two seaports, Hazira and Magdalla, for supporting overseas trade. It is well connected by national highways and railways with major cities like Mumbai and Delhi. The city has recently got an international airport providing direct flights to Indian and global cities, which boosts the business potential of Surat and leads to further growth of its textile industry.

City Sprawl of Surat

Surat witnessed a radial spatial expansion along five major corridors in the north, south, east, west, and south-west of the city till the end of the 1980s. Since then, the city has been growing rapidly in the eastern, southern, and south-western directions. Nearby towns are periodically included in the city's municipal limits by the Surat Urban Development Authority (SUDA). One of the major expansions was in the year 2006 when the city's area increased from 112.28 sq. km (2001) to 326.5 sq. km. It is proposed to expand the boundaries further, from 326.5 sq. km to 496.52 sq. km. The proposal is currently under consideration by the planning authorities. Fig. 2 shows the increase in the built-up area of the city. As per the mid-year estimates drawn by the Surat Municipal Corporation, the population of the city is believed to be around 6.63 million in the year 2020 and 6.93 million by the next official census in the year 2021.

The growth of the built-up area of the city is shown in five-year intervals from the year 2000 to 2018. The urbanized area in Surat city increased by almost three times between 1978 and 2004, with development mainly occurring within the municipal limits of the city. The metropolitan area has developed largely in terms of residential and industrial clusters (Surat Urban Development Authority (SUDA), 2018).

Textile Industry in Surat

Surat is one of the largest centers in the world to produce synthetic fibers, mainly nylon and art silk. Around 90% of polyester used in India comes from Surat. The city accounts for 40% of the total nation's man-made (synthetic) fabric production and 28% of man-made fiber production. It also accounts for 18% of the total nation's man-made fiber export. The textile industry in Surat produces 30 million meters of raw fabric and 25 million meters of processed fabric daily (Government of Gujarat, 2017). The textile industry has developed organically, and its manufacturing clusters are spread across the city. The major segments of the industry are weaving units, processing units, value-addition units, and the textile

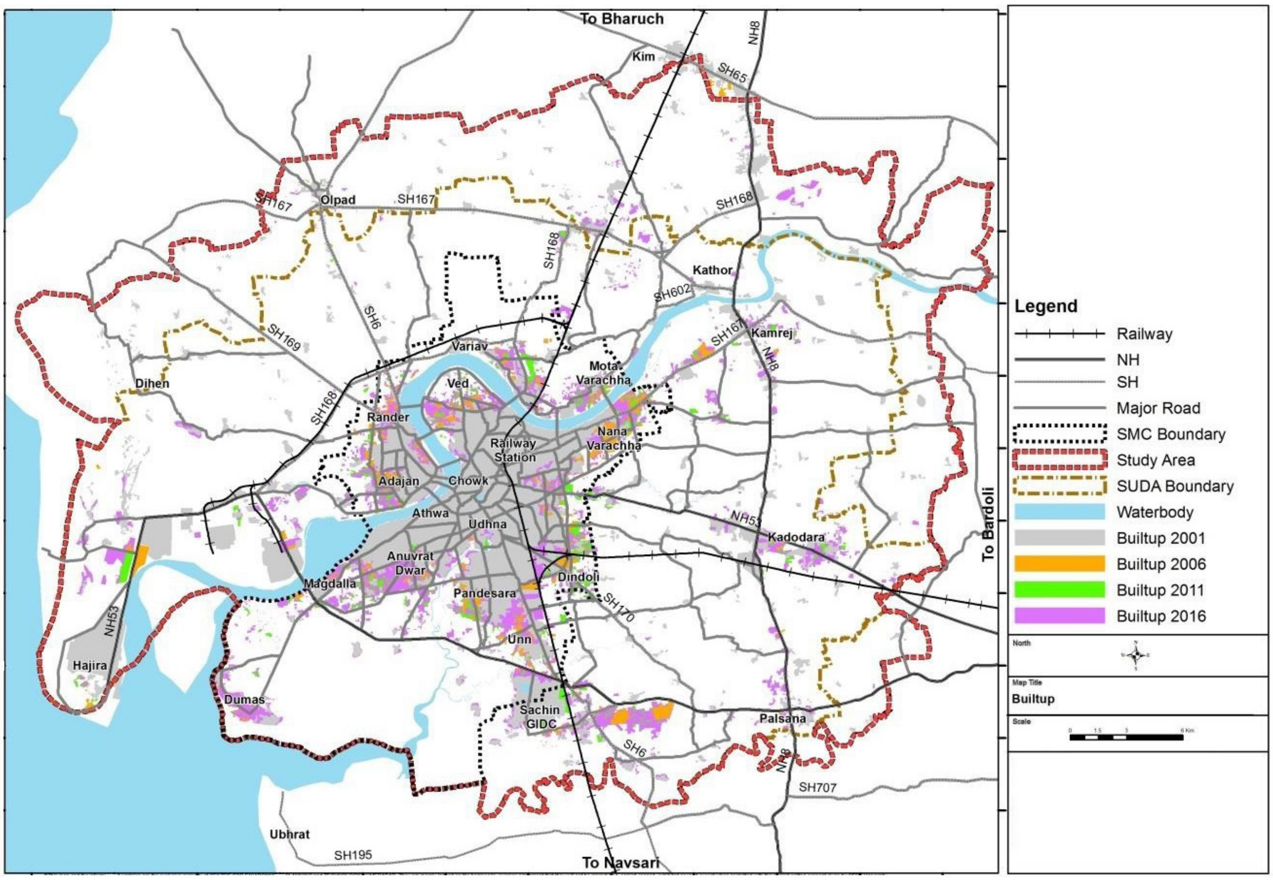

Figure 2. Growth of Surat city over time
Source: Comprehensive Mobility Plan Surat 2046 (Surat Urban Development Authority (SUDA), 2018)

market. The manufacturing segments in the form of industrial clusters are spread all over the city. The textile market is located in the ring road area of the city. The textile market also serves as a distribution center for textile raw materials and semi-finished goods. Table 2 shows characteristics of various production facilities of the textile industry established in the city. Since 1956, the Indian Government's policy of providing incentives and protection to small-scale enterprises has given a major boost to power loom weaving in the city. The industry has grown rapidly owing to the huge demand from the domestic market as well as the Middle East countries. Exports to other parts of the world have also increased gradually.

Table 2. Characteristics of the textile industry in Surat

Type of units	No. of units	No. of clusters	Approximate area occupied
Weaving units	25,000	24	3,000,000 sq. m
Processing units	400	5	743,000 sq. m
Value-addition units	11,000	12	1,200,000 sq. m (approx.)
Trading	75,000	2	3,300,000 sq. m (approx.)

As stated above, there are four major manufacturing segments in the textile industry in the city: weaving units, processing units, value-addition units, and a distribution hub (textile market). Some weaving units are small-scale with only 12 weaving machines (power looms) in a single unit. The total number of weaving units operating in the city is 25,000. The same is the case with embroidery work units. Dyeing, printing, and sizing of raw fabric are done at processing units. These units require large investments in machinery, labor, and land. Therefore, in most cases, they are managed by private or public limited companies. Trading units are represented by shops for bulk sales and purchase of raw, semi-finished, or finished textile products. The textile market occupies an area of approx. 3 sq. km, where 160–170 building complexes house more than 75,000 textile trading units or shops.

The number of power looms in the city increased from approx. 25,000 in 1980 to approx. 650,000 in 2018. As per the data obtained from the above sources, the city currently has approx. 650,000 power looms and approx. 50,000 shuttleless looms in 25,000 weaving units, nearly 120,000 embroidery machines in 11,000 value-addition units, 400 processing units, 160–170 wholesale complexes with approx. 75,000 trading units. The textile industry employs (directly and indirectly) around 1.5 million people in the city.

Literature Review

Urban sprawl (city sprawl) is traditionally studied with reference to the entire logistics or warehouse industry in the city or metropolitan region. The effects of urban sprawl with regard to industries and their freight flow patterns have not been sufficiently explored. Urban sprawl has an impact on the warehouse industry, which affects the overall freight trip characteristics in a broader sense as compared with a particular industry. Though the present study is focused on the sprawl of the textile industry in the city and its effects on freight flow patterns, we review the existing studies on urban sprawl to gain an in-depth understanding of various methodologies used for curbing uncontrolled sprawl and/or mitigating congestion impacts.

The location of logistics facilities significantly affects not only the urban goods movement but also the urban environment since such facilities are major originators and receivers of freight. The freight industry appears to have contradicting issues in urban areas, as it is required to operate efficiently and sustainably and adjust to the increasing urban freight activities (Aljohani and Thompson, 2016). The mega-region concept is particularly well-suited to the analysis of freight transport systems because freight transport's market areas, driven by global supply chains, are largely disconnected from a single city and spatially organized on a regional and multicity basis (Dablanc and Ross, 2012). Some recent research focuses on the megaregional scale, showing its significance for the understanding of freight flows and the increasing interconnection of facilities. Megaregions, as they contain both urban and suburban environments, have a higher share of road transport, which significantly adds to severe congestion issues. In the future, this will threaten the country's logistics performance.

Dablanc et al. (2014) compared the growth in geographic distribution of warehouses in the Los Angeles, California, and Seattle, Washington, metropolitan areas during 1998–2009. To measure sprawl, the barycenter, or geographic center of warehousing establishments, was determined, as was the average distance of warehouses to that center. Warehousing in Los Angeles sprawled considerably, with the average distance increasing by 6 miles, while in Seattle, the region locations remained relatively stable. Dablanc et al. explained that logistics sprawl characteristic of exceptionally large metropolitan areas, which serve both as trade nodes to the entire region and country as well as enormous consumer markets. Differences in land prices are also considered as an important factor in the large metropolitan areas (Dablanc et al., 2014; Woudsma et al., 2016). According to Sakai et al. (2015), from the year 1980 to 2003, logistics facilities in the Tokyo Metropolitan Area migrated outward, although on a much smaller scale as compared with some U. S. and European cities. Besides, the authors' analysis of the shipment data confirmed that logistics sprawl increases truck travel. Furthermore, they found that, regardless of their age, logistics facilities tend to increase shipping distances as their distances to the urban center increase, due to the spatial mismatch between the locations of the facilities and the shipment origins and destinations. According to Lindholm and Behrends (2012), the common challenge for the cities is that freight transport is growing. Freight transport is needed for the cities to be liveable as well as functional, but at the same time citizens perceive it as a disturbing factor for local sustainability. On the other hand, local authorities recognize freight transport as an important factor for the economic development of their region. The NCHRP Report 739 and NCFRP Report 19 state the following: in short, the freight transportation system will need to do more with less. This adds pressure to state transportation agencies and metropolitan planning organizations to balance the conflicting objectives of the stakeholders involved and impacted by freight. The lack of research and data concerning freight affects all facets of transportation demand analysis: generation of cargo, distribution, mode choice, and traffic assignment (Transportation Research Board of the National Academies, 2012).

In their study, Dablanc and Rakotonarivo (2010) discussed that the Paris (Ile-de-France) region had witnessed deconcentration of parcel transport terminal locations over the period of 1974–2008. The centrographic analysis, performed by them, showed an increased mileage resulting from those more distant terminals, which they translated into net added CO2 emissions of 15,000 tons per year. According to Diziain et al. (2012), the Ile-de-France region has concentrated its action on real estate and land use, with an objective of counter-acting logistics sprawl phenomena. The region has worked with private partners and identified five levels of markets for the emerging urban logistics real estate, ranging from large multi-story facilities to small-scale urban logistics service depots. Toilier et al. (2016) described methods to gather data on the urban goods movement in the Paris region occupying a territory of 12,000 sq. km. They used multidimensional data analysis methods to gather data on such a huge scale. According to Taniguchi et al. (2016), city logistics requires a range of data and information to define problems, develop models and evaluate schemes. Recent developments in ICT allow the performance of urban freight systems to be monitored more extensively and accurately. This provides opportunities for enhancing efficiency and reducing the impacts of goods movement in cities. Recent developments in alternative fuel vehicles and advanced manufacturing have good potential for reducing the impact of freight in urban areas.

Methods

The textile industry in Surat got a major boost in the 1980s when the textile industry in Mumbai witnessed a downfall due to labor union issues and bankruptcy. At the time, the city's boundaries were limited by the current ring road, which was considered the outermost road of the city. It enabled entry into the city from the railway station and the state transport bus terminal, which were then located on the outskirts. The textile market developed along the ring road due to easy access from those transport terminals. Over the years, the city expanded, and the ring road area became denser. The city grew rapidly and sprawled over an area of 326.5 sq. km. This expansion brought the transport terminals and the textile market area to the city center. Due to an increase in land prices, narrow streets, and lack of parking spaces, the industry gradually shifted to new locations on the outskirts. Since background data are limited, we consider only 20 years of the geographic expansion (sprawl) of the textile industry (from the year 2000 to 2019). The sprawl of the industry is estimated based on the data obtained from an establishment survey conducted at several textile manufacturing units and a map study using historical maps available from the Surat Municipal Corporation (Surat Urban Development Authority, 2017) as well as Google Maps. The sprawl of the textile industry in Surat can be divided into two processes: the sprawl of the manufacturing clusters and the expansion of the textile market area. To understand the characteristics of freight trips generated by the textile industry, we conducted an establishment survey at weaving units in various textile manufacturing clusters of the city. Its results are presented in detail in the section dedicated to the analysis of freight trips generated by the textile industry.

Sprawl of the Manufacturing Clusters

The manufacturing clusters of the textile industry are spread all over the city. The number of clusters gradually increased from 16 in 2000 to 26 in 2019 due to the sprawl of the city and the growth of the textile industry. Fig. 3 presents sprawl maps showing the expansion of the textile industry clusters from the year 2000 to 2019. The maps were developed using ArcMap software.

New clusters developed on the outskirts in the north, east, and south directions. Over the years, some clusters expanded in size while others became denser as the other types of land use were reduced. The sprawl of the manufacturing clusters shown in Fig. 3 is presented in 5–6-year intervals considering the periodic expansion of city limits. The maps were developed using information collected during the field survey and satellite imagery from Google Earth Pro. It should be noted that the size of a couple of industrial clusters located in the central area reduced

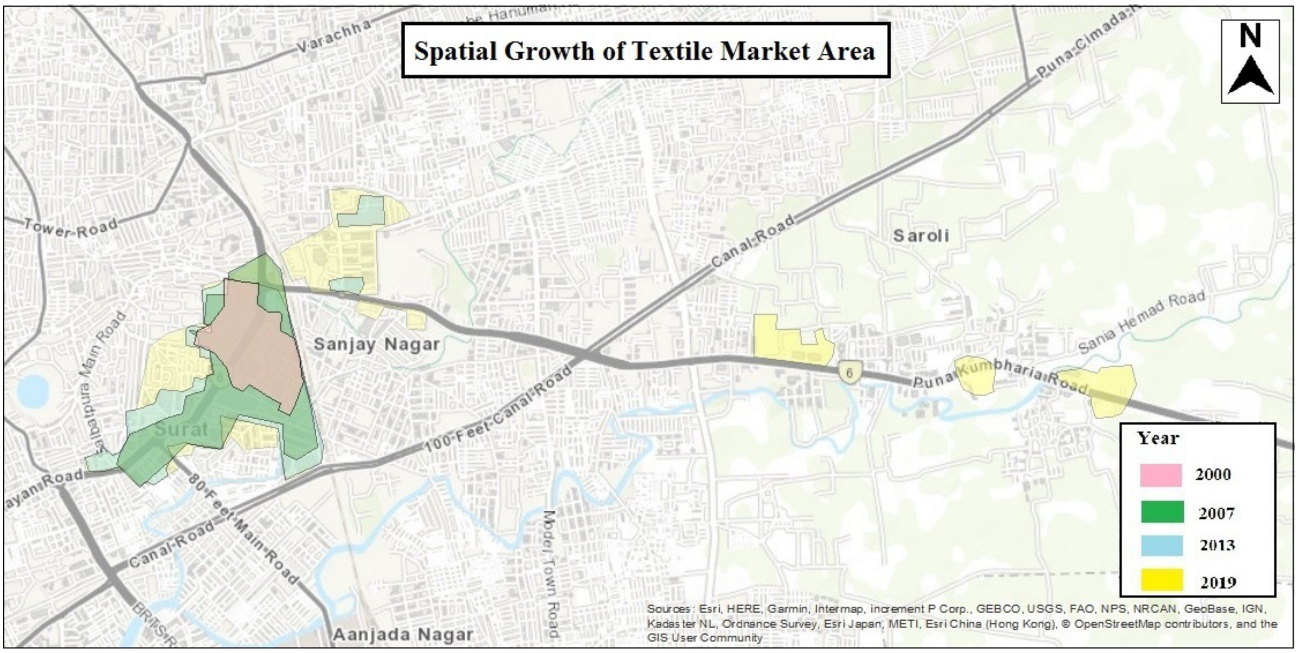

Figure 3. Spatial growth of the textile manufacturing clusters in 2000–2019
Source: Own work

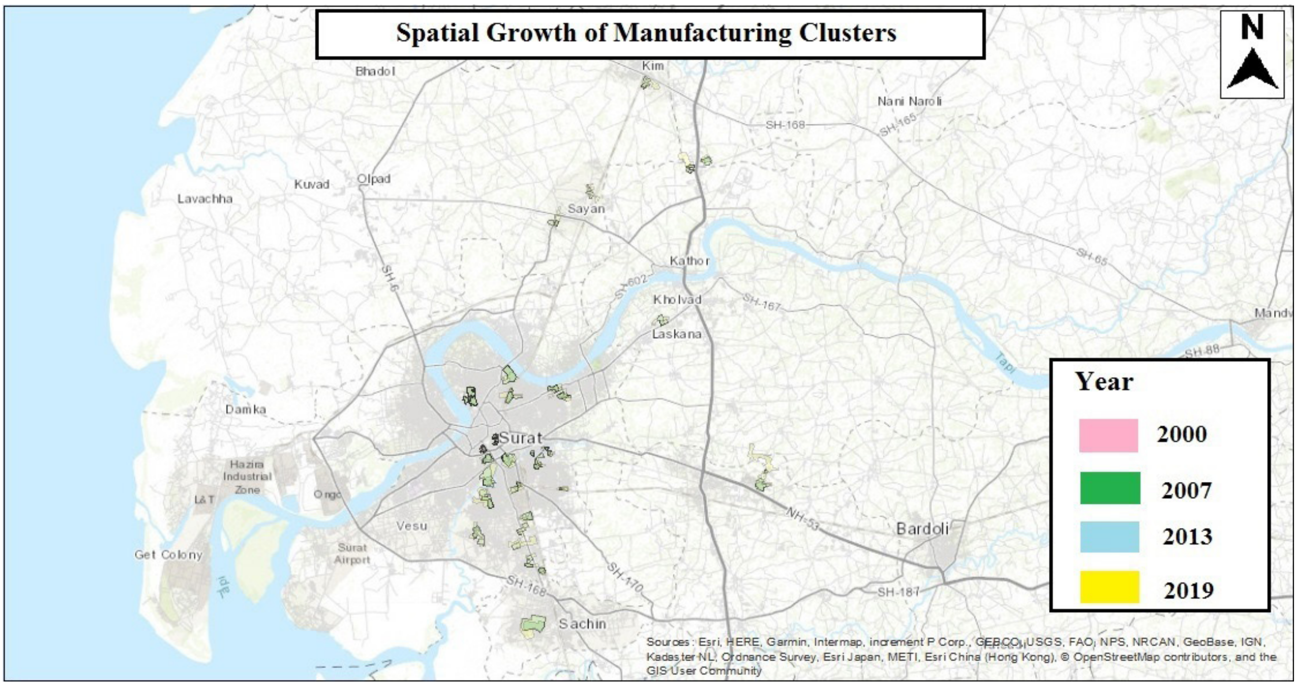

Figure 4. Spatial growth of the textile market area in 2000–2019
Source: Own work

over the years. This is due to the expansion of the textile market located nearby.

Sprawl of the Textile Market

The textile market developed along the ring road of the city, and its latest extension was in the direction of Surat–Bardoli Road. Over the years, more building complexes were constructed in the area solely for textile business purposes. Currently, there are around 160 functional textile market complexes in Surat along the ring road and almost 20 new complexes along the Surat–Bardoli Road, which are, however, sparsely located. Fig. 4 shows the expansion of the textile market area.

The textile market area can be considered the heart of the entire industry. Its location along the ring road is very strategic for the business due to its proximity to the Surat railway station and the central bus terminal of the city. In Fig. 4, the sprawl of the textile market area in 2000–2019 is shown with different color codes. The textile market area in Surat is one of India's largest trading districts with thousands of shops crammed into multiple malls or commercial building complexes. Traders sell silk and cotton fabric, saris with intricate jari embroidery, and suits to local buyers and visitors. Along the ring road, the market is also lined with simple restaurants, banks, and offices of mobile service providers. These units are basically to cater to the requirements of those involved in the textile market. Since 2011, the market has witnessed eastward sprawl along Surat–Bardoli Road. Some sparsely located building complexes have become functional while many more are under construction or designed.

Increase in average distances in the textile industry

Our study of the geographic expansion of the textile industry included the temporal sprawl of the manufacturing clusters and the textile market area. Due to the limited data available, we analyzed only the last two decades. Over the years, the number and size of the manufacturing clusters increased and the clusters became quite dense. In fact, their number increased from 16 to 26 due to new clusters forming on the outskirts of the city. The textile market area has witnessed an increase in density as well as sprawl in the eastward direction with new complexes forming on Surat–Kadodara Road. Based on the study of the temporal growth of the manufacturing clusters and the textile market area, we determined that the average distance between a manufacturing cluster and the textile market area (considering the center-to-center distance) had increased from 5.9 km in 2000 to 10.17 km in 2019. This is due to new manufacturing clusters developed away from the city center as well as the growth of the clusters in size.

Analysis of Freight Trips Generated by the Textile Industry

It is difficult to obtain the exact data on the number of machines or units because the industry is highly segmented and characterized by small-scale operations. The industry also does not have any controlled manufacturing policy. Hence, the data obtained are just estimates provided by concerned authorities. It is assumed that the manufactured goods, leaving a segment, are delivered to the ring road trading market area, which causes 3–4 unnecessary trips during manufacturing of final products from grey cloth. We conducted a survey by visiting weaving units located in different parts of the city (250 weaving units were approached, and 122 owners agreed to participate in the survey). We cautiously supervised data collection at manufacturing units of different types and sizes to get an overall idea about freight trip generation characteristics. The data on the number and locations of various textile establishments in the city for the year 2008 were obtained from a local municipal body (Fig. 5). The details on the textile clusters for the corresponding year were obtained from the interviews carried out during the study. In total, 122 respondents shared information and knowledge about the industry and its spread in the city. The data obtained from various textile establishment owners were again sufficiently verified with the Regional Office of the Textile Commissioner.

Based on a freight carrier survey, we obtained data on the origins/destinations of trips of commercial vehicles during business hours of the ring road market. Table 3 shows results obtained for the origins/destinations of 1137 trips of commercial vehicles carrying textile goods. In order to quantify textile units, we represented graphically their dispersion around the center for the trading of textile goods in the city (i.e., the ring road market area) and performed a spatial analysis of the geographic data on the textile clusters. The row “Others” mentioned in Table 3 includes such areas as Kapodra, Karanj, Kosad, Olpad, Parvat Patiya, etc. The number of trips to these areas is less than the number of trips to other areas mentioned in Table 3. The trips within the ring road market area are characterized by the highest numbers. It can be seen from Table 3 that, in terms of the number, the trips within the ring road market area are followed by the trips to such clusters as Varachha, Pandesara GIDC, Kadodara, Sachin GIDC, and Palsana. The maximum trip length is 34.4 km to Kim followed by 21.8 km to Palsana. The minimum distance traveled is 2.6 km to Anjana. The average trip length is 11.17 km. Based on the data on the locations of the textile clusters in the city for the year 2008, we established that the farthest one was Kamrej (in 18.2 km), while the majority of the enterprises were in the area of Bhatena, Ved Road, Sagrampura, and Salabatpura located very close to the ring road market center. It is not quite possible to analyze the origins/destinations for the year 2008 now, but if we assume the same freight flow frequency, then the average freight trip length will be 6.73 km. It can be inferred that the average freight trip length increased by 4.44 km in the last decade. If the assumptions are true and the industry gains momentum within the government’s campaign, trade experts expect the industry to grow by 12–15% percent annually. With the expansion of the city, freight trip lengths are also bound to increase.

Table 3. OD survey count in the textile market area

Origin location	Destination location	Distance (km)	Percentage
Ring road market	246 (internal)	-	21.64
Amroli	6	9.3	0.53
Anjana	23	2.6	2.02
Bamroli	10	8.9	0.88
Bhatar	41	6.8	3.61
Bhatena	13	2.6	1.14
Bhestan	10	6.9	0.88
Chowk Bazar	6	2.7	0.53

Dindoli	20	4.9	1.76
Gadodara	16	6.7	1.41
Kadodara	83	11.1	7.30
Kamrej	34	18.2	2.99
Katargam GIDC	28	5.7	2.46
Kim	10	34.4	0.88
Limbayat	12	3.3	1.06
Palsana	58	21.8	5.10
Pandesara GIDC	130	9	11.43
Sachin GIDC	73	14.9	6.42
Saroli	44	4.8	3.87
Sayan	16	21	1.41
Udhna	46	7.6	4.05
Varacha	139	14.2	12.23
Ved Road	24	5.1	2.11
Others	49	-	4.31
Total	1137		

Reduction in the number of freight trips by directly transporting goods from one phase of production to the other without transporting goods to the market area is an ideal solution to reduce the overall goods movement in the city. Several attempts have been made in this regard by a local municipal body. It discouraged the delivery of goods to the market area by increasing parking charges for commercial vehicles. Strict time frames for the movement of medium and heavy commercial vehicles were established in many areas of the city by the traffic control department. A special transportation hub was created in the periphery of the city for the collection and distribution of textile goods. Though these steps were taken to improve the efficiency of city traffic and transportation facilities, they were not welcomed by the stakeholders of the textile industry. Weavers, processors, and traders' associations jointly opposed this move as their business was adversely affected. Since the industry is highly unorganized and there

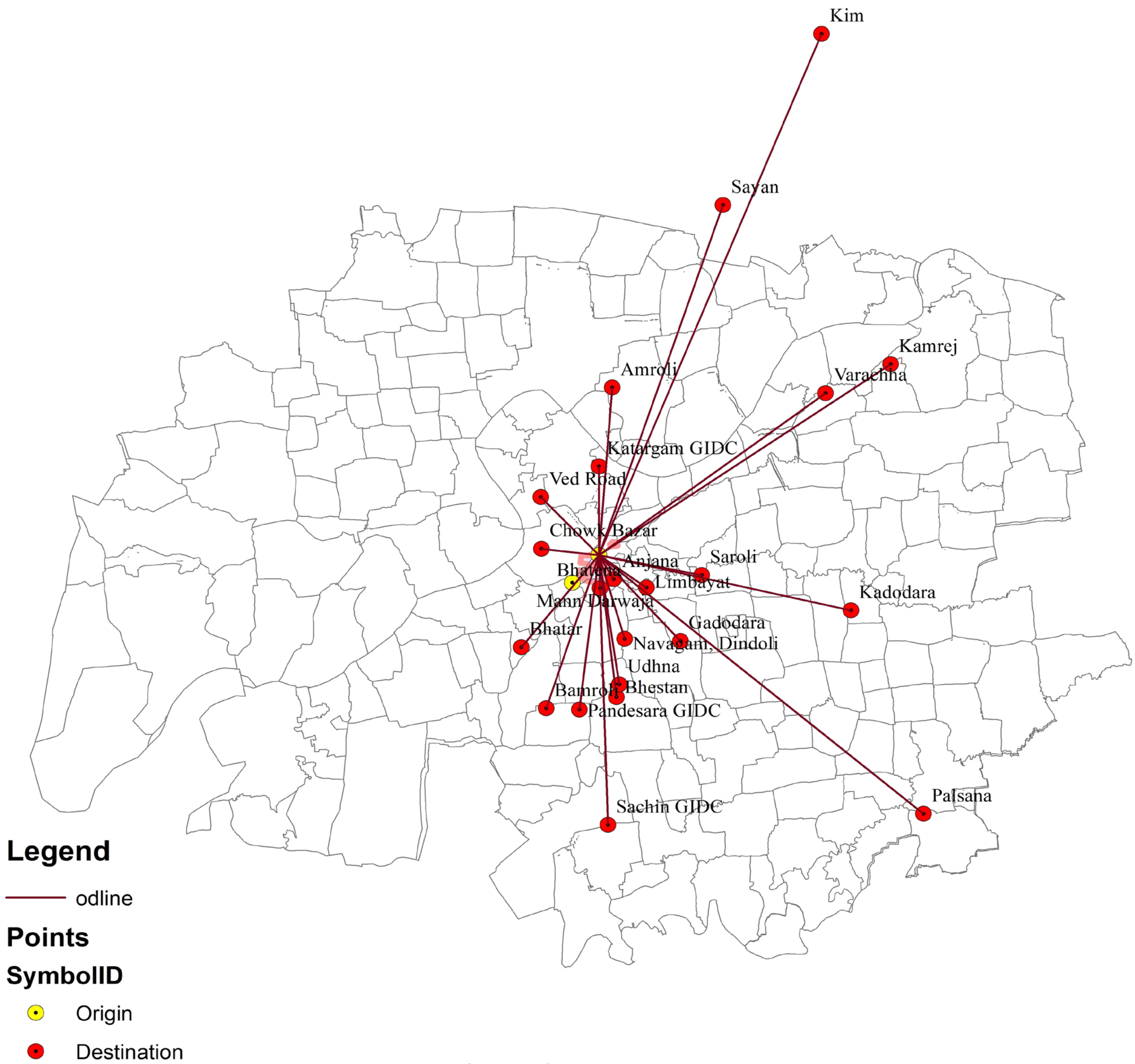

Figure 5. Spread of the textile industry in the city
Source: Own work

are thousands of people involved at various stages of production and distribution of goods in the textile industry, it is quite difficult to change the pattern of goods movement in the industry. Due to continued protest by the textile industry community, parking charges were gradually reduced. In the interest of the growth and development of the textile industry, which is one of the biggest economic forces in the city, regulatory measures related to inhibiting the goods movement, which might affect the functioning of the industry, were discouraged.

To estimate the reduction in freight trips due to sharing, trips are calculated based on the factors affecting trip generation. The number of trips generated depends on the total number of weaving machines, the total floor area, and the total number of employees at the unit, as well as the type and capacity of the vehicle used for freight transportation. Using the data collected, we developed a multi-linear regression model for freight trips based on the above dependent variable. The trip generation model for a power loom unit is as follows:

$$T = 0.6438 + (0.0652 * N_{pm}) + (0.0044 * A) + (0.1120 * Ne), \quad \left(R^2 = 0.8293\right), \tag{1}$$

where:

T = trips generated per month (ea.),

N_{pm} = total number of machines at the unit (ea.),

A = total floor area of the unit (sq. m),

Ne = total number of employees at the unit (people).

Considering the aggregate data in the power loom industry obtained from various sources, we found that there are 650,000 power loom machines installed in the city. Based on the survey data, the average area of one unit is 970 sq. m and the number of employees calculated as per the thumb rule is 1 per 12 machines per shift of 12 hours. The number of the generated freight trips estimated using the above equation is approx. 8850 if all freight trips are shared and freight vehicles are used at their full capacities only. Such trips are generated only for transporting raw fabric to processing units or to the market. According to the survey results, at least 4 internal trips are generated during the manufacturing phase. Hence, a minimum of 35,000 trips is expected due to the internal goods movement during their manufacturing. Considering 4.44 additional km to deliver goods in the city of Surat due to its sprawl, a net addition of CO2 emissions is calculated below. Yet again, these are just the bare minimum addition considering the textile industry alone. There would be other trips generated due to service and maintenance requirements, which are not considered in this study. The calculation is based on unitary emissions (g/km) from vans and trucks, provided by the Indian Emissions Regulations (Automotive Research Association of India (ARAI), 2018). According to the Bharat Stage VI (BS-VI) Emission Standards, the threshold value of CO emissions for a diesel vehicle is 1 gm/km. For 35,000 freight trips with extra 4.44 km (on average), CO2 emissions are supposed to increase by 56,210 kg (56.21 tons) per annum.

Results

As a result of the in-depth industry analysis in terms of the pattern of goods movement, we found that the manufacturing process and supply chain in the textile industry are overly complex due to scattered locations of processing units in the city. Different manufacturing phases are carried out at different clusters specialized in a particular value addition process, and each independent phase increases the movement of semi-finished goods manifold, thereby increasing the overall number of trips per unit of goods manufactured. According to estimates, a unit of fabric makes 7 internal trips before reaching its final distribution point. For 4–5 of the above trips, the wholesale market (ring road) area is either the origin or destination location, while the other point (destination or origin point, respectively) is located across the city or, in some cases, is in the city area. Besides, due to trading activity in the market area, many internal trips are generated here.

Hence, the ring road area occupying approx. 3 sq. km experiences an exceedingly high number of incoming and outgoing freight trips. Due to the municipal restrictions imposed on heavy commercial vehicles' movement in the major residential and commercial belts of the city, most of the internal goods movement in the textile industry is carried out by LCVs and three-wheeler carriers. This can also be confirmed by the category-wise vehicle count carried out in the ring road area. It was found that the average trip length for freight vehicles had increased from 6.73 km in 2008 to 11.17 km in 2018. This is basically due to the relocation of production units to the outskirts and suburban areas due to the urban sprawl.

Conclusions

There is a need for a holistic planning approach towards urban freight movement and related urban infrastructure for sustainable freight flows. This can serve as a policy framework to decide on the location of a logistics hub or as guidelines to allocate manufacturing enterprises in the proximity of the urban area. An incentive mechanism can also be added as a corresponding cost-effective measure. However, according to the early estimates of approx. 30% of the city's textile-related freight trips taking place within the ring road market area, it is advisable to provide a central warehousing facility for the area through collaborative efforts of the industry and the Municipal Corporation. We calculated the net additional emissions of CO_2 generated by an increase in the distances traveled by vans and trucks to reach their final destinations. However, our calculations are quite general, and more accurate estimates are required with account for particular transport organizations and temporal changes. This research is ongoing. We have reached a general conclusion regarding the approximate amount of CO_2 generated by urban sprawl. More detailed research is needed with regard to the industry and its ancillaries sprawling in metropolitan areas and sprawl impacts on the distance traveled. The location patterns of textile manufacturing facilities and corresponding temporal changes should be closely compared with those in other major industries in the city.

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