International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-5, January 2020

Urban Freight Movement and Its Impact on Traffic Flow Pattern in Developing Countries

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Abstract*: Surat is one of the prime cities for the manufacturing of textile products in the country, having 40% of the man-made fabric production in the country. The city produces 30 million meters of raw fabric and 25 million meters of processed fabric daily. Textile industry in the city has witnessed tremendous growth in the last decade, which has led to much transportation related changes in the city. The textile industry of Surat has different segments such as weaving unit, processing unit, value addition and trading hub for carrying out various processes. The segments are located as clusters or pockets in different parts of the city or urban area. Due to the dis-integrated nature of the industry here, it produces a lot of internal goods movement. The present study is focused on analyzing the characteristics of textile fright trip generated in the city due to the initial unit of textile industry i.e. weaving unit. Stated preference survey was conducted for 122 weaving units located in different parts of the city. Multi-linear Regression model for trip generation and quantity of cloth produced is developed for estimation of textile freight trips and quantum of production. This study will definitely help the planner to identify the strategic location of the textile industry and allied supporting industry. This study further helps in understanding the trip generation and attraction in the city which affects on routine traffic as well.

Keywords: City logistics, goods movement, textile freight trip, urban freight

I. INTRODUCTION

Urban freight transportation is entirely different from passenger transport and its impacts on transportation system and environment are significant. Freight movement has gradually become top on the priority list for all major transport researchers and stakeholders across the world due to its unpredictable characteristic at city level. Though very good research studies have been carried out in various area of freight movement like urban, regional and international freight movement in the technologically advanced nations like the U.S., U.K., Germany, Netherland, Sweden and Japan etc., but it is still in a dormant stage in most of the developing economies of the world. India is considered as one of the fastest growing major economies in the world and it is expected to have at least 10 megacities by 2030. With high growth in industrialization and expanding city boundaries the movement of goods in the cities is becoming more and more complex. Cities in India, like most of the developing nations, have a highly heterogeneous traffic condition. Lane discipline and traffic sense is found to be in a dismal state in most of the Indian cities. In such a scenario the goods vehicle, whichever category are permitted in a given urban space, often result in overall speed reduction and acts as a hindrance to the other private and public modes. The current situation is bound to get worsened with increasing urbanization and cities getting denser.

Textiles manufacturing is the second largest industry after agriculture offering large scale employment to both skilled and unskilled workforce, with more than 35 million people in the country directly engaged in it. In India many cities like Surat, Kanpur, Ahmadabad, Mumbai, Banaras, Mysore, Kolkata, Coimbatore and Madurai etc. are the hub of the textile manufacturing. Cities in India, like most of the developing nations, have a highly heterogeneous traffic condition. The urban freight movement resulting out of the textile industry disturbs the city traffic operation and also has great impacts on the congestion and pollution levels. The quantification of this congestion and CO2 emission is need of the hour to control chaotic movement of goods traffic. In order to understand the quantum of trips generation due to this industry study has been carried out. Multi-linear Regression model for trips generated and quantity of cloth produced due to weaving unit in the study area are estimated.

II. LITERATURE REVIEW

The studies for achieving a harmonious freight flows started in the early 80's in Europe and the US. Brogan (1980) analyzed different stratification strategies for improving trip-end generation models, identifying land use as the most effective stratification scheme for improving model significance. Bartlett and Newton (1982) studied FTG using regression models based on four independent variables: total employment, site area, gross floor area, and non-office employment. The firms were grouped based on FG intensity. It was found that the model results matched very well with actual vehicle-trip counts. It was also found that haulage firms, fuel distributors, waste disposal firms, and ready-mix concrete/bulk distribution firms were the most intensive generators, while manufacturers and printers were the least intensive. Freight generation intensity, however, varies significantly within the same industry sector. Middleton et al.

Manuscript published on January 30, 2020.
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(1986) analyzed trip generation characteristics for special land use truck traffic in Texas; their study included an assessment of each special land use class in terms of FTG. Data collected included trip generation rates, trip length and vehicle type.

The Federal Highway Agency Guidebook on State Travel Forecasting (FHWA 1999) uses land use and trip data from travel diaries and shipper behavior to estimate truck trips; these are then distributed using a form of gravity models that are calibrated with trip length frequency distributions obtained from trip diaries. Another trip-based model, the Quick Response Freight Manual (Cambridge Systematics Inc. 1996), calculates the number of commercial vehicle trips at the zonal level, commercial vehicle volumes at external stations, and commercial trips between zones, by applying trip generation rates using economic activity data for the traffic analysis zone. After the trips have been estimated, the model uses mode shares for each trip and then loads the O-D matrix to the network. The estimated vehicle kilometer traveled (VMT) were compared with control VMT for calibration. This model was implemented in a truck flow survey study that investigated the effects on traffic assignment when using different degrees of geographic resolution (Marker and Goulis 1998). The study showed that applying a much-aggregated model (e.g., the one suggested by the Quick Response Freight Manual) to a study area using extremely disaggregated Travel Analysis Zones (TAZs) results in no noticeable loss in model accuracy.

The ITE Trip Generation Manual, 8th Edition (Institute of Transportation Engineers 2008) contains a comprehensive compilation of estimated FTG rates for a broad range of land use types. Although the focus of the ITE Manual is on all vehicle types, some of the results can be applied directly to FTG, e.g., truck terminals. The ITE Trip Generation Hand-book, 2nd Edition, provides guidelines on how these rates (for all vehicle types) may be used for a given trip generation study. The most noticeable ones are related to the need to: use consistent definitions of trucks and truck trips; consider the age of the existing FTG data; avoid land use classes that are too broadly defined; and think carefully about the selection of independent variables.

Iding et al. (2002) estimated linear regression models of truck trip generation at industrial sites. The sample included 1,529 firms within the Netherlands with more than 5 employees. Parameters (slope and intercept) were obtained for two different classification types (18 sectors and 5 types of heavy industry site) and two independent variables (area and employment). The results indicate that which independent variable is better depends on the industry sector and on the direction of freight (in- or outbound). The logistics and transport services sector was found to have the highest average level of outbound trips produced.

Other vehicle trip models estimate FTG rates for productions and attractions using cross classification [Bastida and Holguín-Veras (2009) compared the use of cross classification and OLS for FTG modeling]. The authors estimated disaggregated freight trip delivery rates taking into consideration, company attribute. Using cross classification analysis, the authors identified the groups of company attributes that best explain FTG. When using linear regression models, the authors identified that commodity type, industry segment, and employment are strong predictors for FG. Tadi and Balbach (1994) estimated trip generation rates based on vehicle type stratification for non-residential land uses in Fontana, California; traffic counts were used on their estimations. Kawamura et al. (2008) took into consideration the supply chain decisions made by individual businesses in the estimation of FTG. Among other findings, the authors concluded that store floor space and the number of employees is poor indicators of truck trips at retail stores. At the city level, different freight models were developed in Europe that include some form of trip generation modeling (Taniguchi and Thompson (2002) and Patier and Routhier (2008). Models are generally linear and based on zonal aggregates or survey data. Examples are Russo and Comi (2002) for Italy, and Routhier et al. (2002) for France.

FTG models of various kinds have been developed for special facilities such as ports (Guha and Walton 1993; Wegmann et al. 1995; Holguín-Veras et al. 2002). Al-Deek et al. (2000) and Al-Deek (2001) used regression analysis and neural networks respectively to develop trip generation models. Wagner (2010) carried out an analysis of trip generation around the port of Hamburg, Germany. Regional warehouse trip production rates were published by DeVries and Dermisi (2008) for the Chicago metro area, and by Orsini et al. (2009) for France.

Other methodologies that have been implemented for production and attraction include: time series models, Input-Output, and related models. Time series data have been used to develop models that range from growth factor models to auto-regressive moving average models (Garrido 2000). Sorratini (2000) estimated truck flows for the state of Wisconsin, using data from the 1993 CFS and IO coefficients. The authors derived production and attraction rates in tons for heavy truck mode for 28 economic sectors; the annual tons for the county level were converted to daily truck trips using aver-age tons-per-vehicle load factors. The trips were then assigned to the network and the results were compared to real counts. It was found that the production and attraction values were underestimated since not all truck trips were included.

III. STUDY AREA

Surat, located on the western part of India in the state of Gujarat as shown in figure 1. It is one of the fastest growing major cities in the country and is ranked as 9th biggest city in the country from population and economy point of view. The city of Surat is popularly known as “The silk city” or “The synthetic capital of India”. Surat city has area of 326.515 Sq. Km with population of 44, 66,826 (as per Census 2011). City has density of 13,680 persons/ Sq. Km. Decadal population growth of the city is 55.29% (2001-11). The city has seven administrative zones, 29 election wards and 101 census wards.

Fig. 1. Study area location

The major industries in Surat are Textiles, Diamond polishing, Engineering, Chemicals, etc. A report by Industrial Entrepreneur Memoranda (IEMs) (2006-07) on Surat district has shown that Textiles has the highest employment generation potential. Majority of population migrating to Surat for employment is involved in textile industry. Surat accounts for 40% of Nation's Man-made fabric production and 28% of man-made fibre production. It also accounts for 18% of total nation's man-made fibre export. As per the report of Vibrant Gujarat (2017) the textile industry of Surat produces 30 million meters of raw fabric and 25 million meters of processed fabric daily. The textile industry in the city has developed organically with different segments of production units located in different part of the city. The main segments of the industry, that are weaving unit, processing and dyeing unit and value addition are located in different parts of the city in the form of industrial clusters.

To understand the scale of operations and have basic understanding about the textile industry of the city secondary data regarding the numbers and location of the various units was obtained from Office of Textile Commissioner, Ministry of Textile, Regional Office. Various other associations and societies working in collaboration with the textile industry were approached and meetings with their officials were arranged to understand and device an effective and efficient methodology for obtaining primary data from the various units. This associations included Man-Made Textiles Research Association (MANTRA); Ved Road Art Silk Small Scale Co-operative Federation; Pandesara Weavers Co-operative Society; The Federation of Gujarat Weavers' Association (FOGWA); The Surat Art Silk Cloth Manufacturers Association (SASCMA); Federation of Indian Art Silk Weaving Industry (FIASWI), Southern Gujarat Chamber of Commerce and Industry (SGCCI) and District Industries Center (DIC), Ministry of Micro, Small and Medium Enterprises.

IV. METHODOLOGY

Methodology adopted for the present study is explained diagrammatically which is given in figure 2.

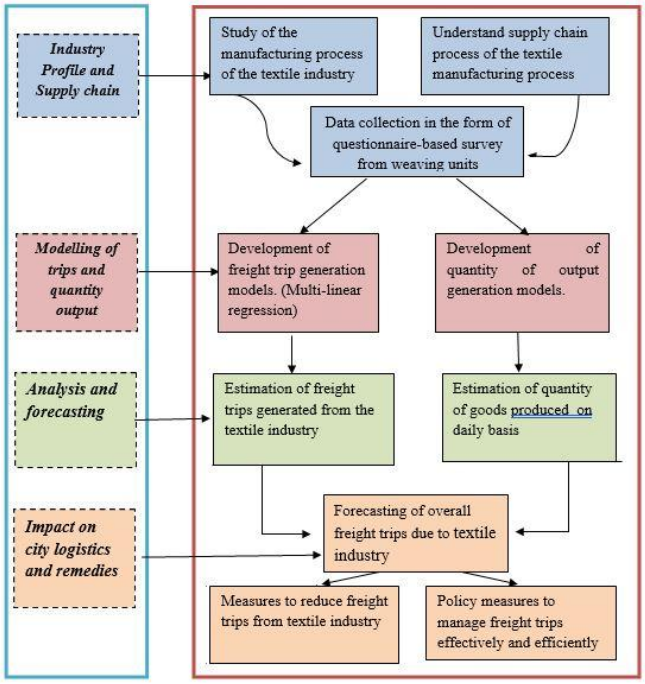

Fig.2. Methodology of the study

V. DATA COLLECTION AND ANALYSIS

As per the data registered with Office of Textile Commissioner for the year 2011-12 there are about 6.2 lac plain power loom machines, 513 processing units, 140 textile markets and 8 textile parks in Surat. There are more than 60,000 traders associated with the industry here. Recently value addition units like embroidery and laces have picked up well and it is estimated that there are more than 1.25 lacs of these machines currently installed in the city. Exact numbers of the machines or units is not available as the industry is highly segmented and small-scale operation makes it difficult to have exact data. The industry is not having any controlled manufacturing policy and hence the data obtained are only close estimates from the concerned authorities. It was understood that after every segment of textile, goods travel to ring road trading market area which cause unnecessary 3-4 trips of textile goods during the process of manufacturing of finished goods from grey cloth.

From literature review and meeting with the industry experts, factors were identified and questionnaire survey form was formed. Survey was conducted by visiting the weaving units located in different parts of the city. 250 weaving units were approached for out of which 122 owners agreed for the survey. Questionnaire survey form was divided into sub sections. The various subsections of the form are- Establishment information, Owner's information, Weaving machine details, building use and Area details, Cluster details, Employee details, work hours details, Parking facility, Cargo produced/ received details, Details of trip starting from the weaving unit, Details of trip ending at the weaving unit and Establishment related details.

From the data collected it was understood that different machines require different number of employees and area, production varies as per machine type, work time, method used for manufacturing, even some machines produced finished goods (e.g. jacquard machine produced sari). As owners were reluctant for sharing of data; some part of data was not obtained as required for establishing relation for trip generation while some data points were found outlying the other data points. Some data points were not within 95% confidence interval. As the outcome of textile industry is dependent on all these factors and deviation in these factors causes deviation in the outcome. Such samples were considered as outliers and relation was formed for data obtained for plain power loom machines only as plain power loom machines accounts for 96.57% of the total weaving machines in the study area. From 122 samples, 42 samples were used for trip generation model. It was observed from the overall information obtained from the survey that 3 factors could be very strongly related to the freight trip generation and quantity of cloth produced from a unit. These are

1. Number of weaving machines used
2. Number of employees in the unit
3. Total floor area of the unit.

Linear regression equations were derived for these factors for understanding the effect of these factors individually on trip generation and quantity of cloth produced by plain power loom machine. Figure 2 to figure 8 shows the linear regression results for trips generated and quantity of cloth produced.

A. Linear Regression for Trips Generated per month and Quantity of cloth produced

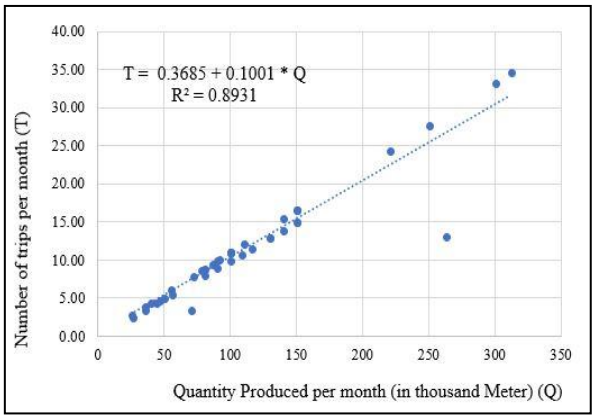

Fig. 3. Linear relation graph for Trips Generated per month and Quantity of cloth produced

In linear regression analysis trips generated per month is dependent factor and Quantity of cloth produced per month in 1000 m is independent factor.

Linear Regression equation is given as:

$$T = 0.3685 + 0.1001 * Q \quad (R2 = 0.8931) \ldots\ldots\ldots (1)$$

Where,

T= Trips generated per month (in number),
Q= Quantity of cloth produced per month in 1000 m

B. Linear Regression for Trips Generated per month and Total floor area at the unit

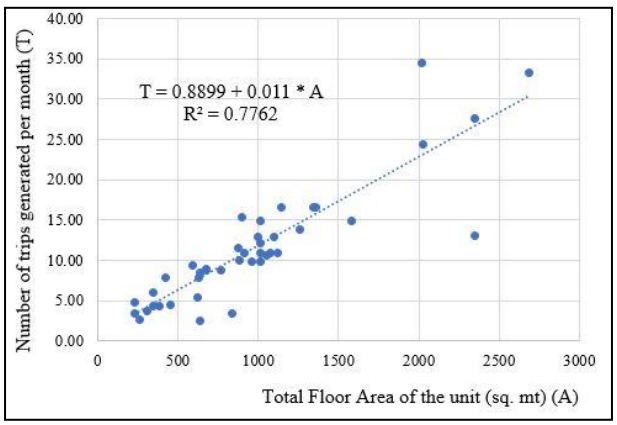

Fig. 4. Linear relation graph for Trips generated per month and Total floor area at the unit (sq. mt.)

Linear Regression equation is given as:

$$T = 0.8899 + 0.011 * A \ (R2 = 0.7706) \ldots\ldots\ldots\ldots (2)$$

Where,

T= Trips generated per month (in number),
A = Total floor area at the unit (in sq. mt.)

From discussion with owners of weaving units it was understood that power loom machines are mostly placed on G + 1 floors. In rare cases they are placed on upper floor; on upper floors other activities of manufacturing (TFO or worping etc.) are carried out or use for storage purpose (warehouse) or used as office or even used by embroidery units. Owners were not able to provide the specific area details (i.e. area under manufacturing of grey cloth), which is the main reason for variation of points from trend line as shown in figure 4.

C. Linear Regression for Trips Generated per month and Number of machines at the unit

Linear Regression equation is given as:

$$T = 1.5918 + 0.1351 * Npm (R2 = 0.8115) \ldots\ldots\ldots (3)$$

Where,

T= Trips generated per month (in number),
N_{pm} = Number of power loom machines at the unit (in number)

As shown in figure 5 points are away from trendline, the reason for this is this work hours of the unit and type of vehicle used for transportation of goods. For same number of machines there is variation in number of trips generated. Working hours of the unit and type of vehicle play an important role in this context.

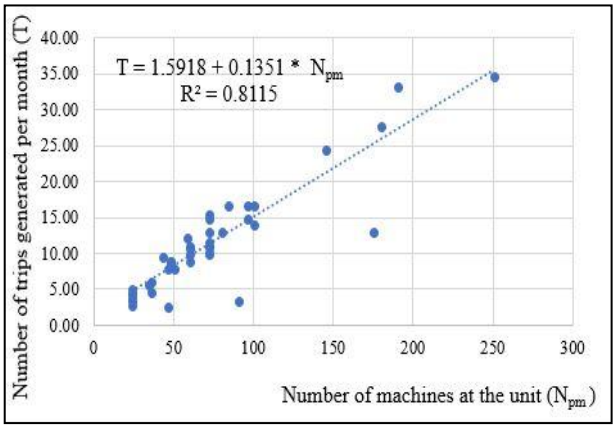

Fig. 5. Linear relation graph for Trips generated per month and Number of machines at the unit

D. Linear Regression for Trips Generated per month and Total number of employees

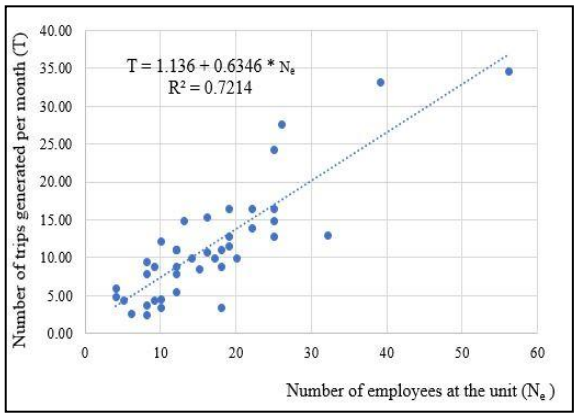

Fig. 5. Linear relation graph for Trips generated per month and Total number of employees

Linear Regression equation is given as:

$$T = 1.136 + 0.6346 * Ne(R2 = 0.7214) \ldots\ldots\ldots\ldots (4)$$

Where,

T= Trips generated per month (in number),

N_e = Total Number of employees (in number)

Survey showed that there are different categories of worker working in weaving unit. The different workers are power loom unit worker, TFO worker, winding worker, etc. It was understood that one worker can handle 12 power loom machines for one shift. Number of workers depend on number of machines at the unit and work hours of the unit which being the reason for point lying away from trendline as shown in figure 5. Numbers of workers are different for same number of machines reason being the work hours of the unit. Staff scenario is different for different units. At some unit owner himself plays the role of staff, at some places staff worker work for 2-3 units at different time of the day, whereas for some unit staff work for single unit. Number of staffs depends on need and quantum of working of the unit.

E. Linear relation for Quantity of cloth produced per month and Number of machines

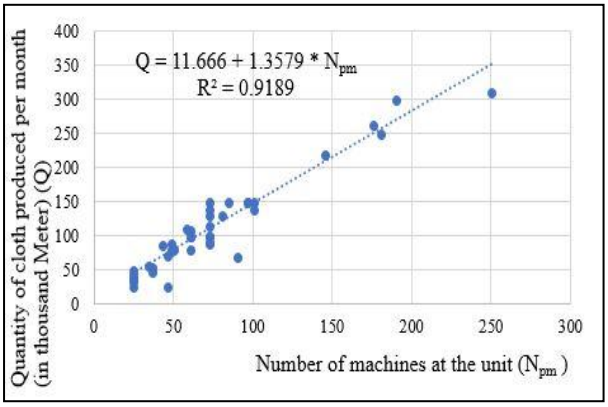

Fig. 6. Linear relation graph for Quantity of cloth produced per month and Number of machines

Linear Regression equation is given as:

$$Q = 11.666 + 1.3579 * Npm(R2 = 0.9189) \ldots\ldots (5)$$

Where,

Q = Quantity of cloth produced per month in 1000 m,

N_{pm} = Number of power loom machines at the unit

Linear equation implies that one machine can produce 1.35 thousand meters of cloth per month. From figure 6 it can be observed that same number of machines produce different amount of cloth. Production is dependent upon the quality or raw material, manufacturing techniques used for production and work hours of the machine. From graph it is observed that same number of machines have a variety of amount of cloth production. As stated by the owners of the weaving unit quantity of production varies from unit to unit due to the method of production adopted by the unit.

F. Linear relation for Quantity of cloth produced per month and Total floor area at the unit

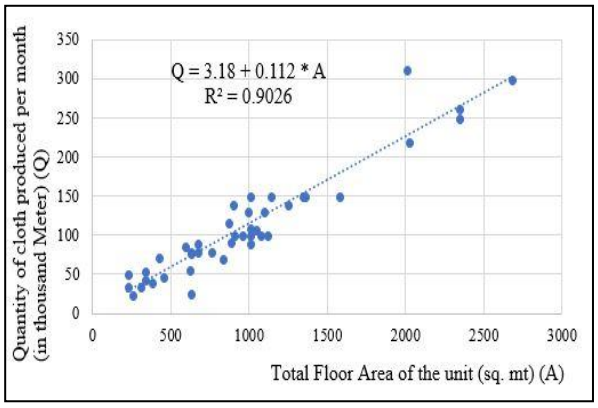

Fig. 7. Linear relation graph Quantity of cloth produced per month and Total floor area at the unit

Linear Regression equation is given as:

$$Q = 3.18 + 0.112 * A(R2 = 0.9026) \ldots\ldots\ldots (6)$$

Where,

Q = Quantity of cloth produced per month in 1000 m,

A = Total floor area at the unit (in sq. mt.)

Linear equation implies one sq. mt. of area produces 112 meters of cloth per month. As explained before it is difficult to find the exact area under machine which results in variation in the results. At the same time for the same area working hours play an important role in estimating the quantity of cloth produced.

G. Linear relation for Quantity of cloth produced per month and Number of employees

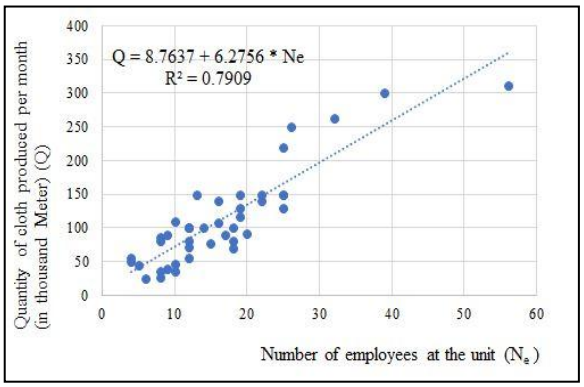

Fig. 8. Linear relation graph Quantity of cloth produced per month and Number of employees at the unit

Linear Regression equation is given as:

$$Q = 8.7637 + 6.2756 * Ne \ (R2 = 0.7909) \ \ldots\ldots\ldots(7)$$

Where,

Q = Quantity of cloth produced per month in 1000 m,
N_e = Total Number of employees

Linear equation implies one employ produces 6.27 thousand meters of cloth per month. Linear Regression derived for trips generated per month and quantity of cloth produced per month in 1000m shows results for individual factors. Results for trip generated per month and quantity of cloth produced per month in 1000m by individual factors is summarized in the table I.

Table-I Summary of Linear Regression for Trip generated per month and Quantity of cloth produced per month in 1000m

Linear Regression Equation for Trip Generation per month	Remark
T = 0.3685 + 0.1001 * Q	1000 m generates 0.1 trip per month
T = 0.8899 + 0.011 * A	One sq. mt. of area generates 0.01 trip per month
T = 1.5918 + 0.1351 * N_{pm}	One machine generates 0.13 trip per month
T = 1.136 + 0.6346 * N_e	One employee generates 0.6346 trip per month
Linear Regression Equation for Quantity of cloth produced per month (in 1000m)	**Remark**
Q = 3.18 + 0.112 * A	One sq. mt. of area can produces 112m of cloth per month
Q = 11.666 + 1.3579 * N_{pm}	One machine can produce 1357m of cloth per month
Q = 8.7637 + 6.2756 * N_e	One employee can produce 6275m of cloth per month

In order to find combined effect of these factors on trip generation and quantity produced multi-linear regression is to be derived. Multi-linear Regression model was prepared for estimation of trips generated per month and quantity of cloth produced per month based on the independent factors such as number of power loom machines, area of the unit and number of employees. This multi-linear regression model gives combined result of the independent variable on dependent variables. Hence multi-linear regression model for both trip generations per month and quantity of cloth produced per month was derived.

VI. FREIGHT TRANSPORT MODELS

A. Trip Generation Model

Number of trips generated is dependent variable in the multilinear regression model. Total number of power loom machines at the unit, total floor area of the unit and total number of employees employed at the unit in all shifts are the independent variables in model.

Multilinear Regression model for trip generation per month is given as:

$$T = 0.6438 + (0.0652 * Npm) + (0.0044 * A) + (0.1120 * Ne) \quad (R2 = 0.8293) \quad \ldots\ldots\ldots\ldots (8)$$

Where,
T = Trips generated per month (in number),
N_{pm} = Total number of machines at the unit (in number),
A = Total Floor Area of the unit (in sq. mt.),
N_e = Total number of employees at the unit (in number)

As per the data collected there are 6.2 lac power loom machines, 25,000 weaving units and the average area of one unit from survey is obtained as 970 sq. mt. number of employees are considered as per thumb rule that one worker can handle 12 machines for one shift of 12 hours. From this data magnitude of trips generated per month due to weaving unit can be estimated.

Trips generated per month = 158698.052
Trips generated per day = 5289.935

As per the model approximately 5300 trips per day will be generated due to power loom unit. The Ring Road Textile market has work timing from 10 a.m. to 8 p.m. with lunch break from 1 p.m. to 3 p.m. every day except Sunday. If considered average peak work hours of 5-7 hours in a day then there will be approximately 1060-750 trips per hour respectively as per the estimation from the model developed.

B. Quantity Produced Model

Quantity produced in thousand meters per month is dependent variable in the multilinear regression model. Total number of power loom machines at the unit, total floor area of the unit and total number of employees employed at the unit in all shifts are the independent variables in model.

Multilinear Regression model for Quantity produced in thousand meters per month is given as:

$$Q = 2.6282 + (0.6836 * Npm) + (0.0528 * A) + (0.4615 * Ne) \quad (R2 = 0.9461) \quad \ldots\ldots\ldots\ldots (9)$$

Where,

Q = Quantity of cloth produced in 1000 meters per month,
N_{pm} = Total number of machines at the unit (in number),
A = Total Floor Area of the unit (in sq. mt.),
N_e = Total number of employees at the unit (in number)

As per the data collected there are 6.2 lac power loom machines, 25,000 weaving units and the average area of one unit from survey is obtained as 970 sq. mt. number of employees are considered as per thumb rule that one worker can handle 12 machines for one shift of 12 hours. From this data magnitude of trips generated per month due to weaving unit can be estimated. The huge number of trips generated by the textile industry creates traffic congestion at the ring road area. The estimated trips are only trips for carrying grey cloth from weaving unit to ring road trading area. Further trips are not estimated in this study. The set-up of different segments of textile industry in different parts of the city attracts textile freight movement within the city.

VII. RESULTS AND CONCLUSIONS

City sprawl played an important role in increase and mixed traffic flow condition of urban traffic and textile freight movement. Initially textile segments were located at the outskirts of the city, which did not create traffic problem in the city. Slowly city sprawl took place and segments came near to the city boundary, which increase traffic problems. Impact of textile industry internal freight movement on the city roads is summarized in table II below.

Table II: Details of freight traffic generated due to textile industry in Surat city

Decription	Unit
Quantity produced per month (in thousand meters)	1751923
Quantity produced in thousand meters per day	58398
cloth production per day will be generated due to power loom unit	58.39 million meters
Generation of freight trip per day (due to powerloom industry)	5,300 trips per day
LCV trips per hour during peak hours	1060 trips
Average length of freight trip (in kms) based on estimate from survey data	9.9 kms/trip
Estimated vehicle kilometers travel (VKT)generated	50,880 kms /day
Total freight trip generation (approximately)	37,100 trips per day
Total freight vehicle kilometer travel due to entire textile industry	356,160 kms/day

Now due to further sprawl of city majority of segments of the industry are within city limits. This result in Ring Road Textile Market area acting as central trading hub located centrally within the city limits for the industry. Linear regression model for trips generated and quantity of cloth produced showed linear relation between dependent and independent variables satisfying value of R2. Multi-linear regression model for Trips generated and quantity of cloth produced by plain power loom machine was formed. The estimates of multi-linear regression model for quantity of cloth produced showed 58.39 million meters of cloth production per day and generation of approximately 5300 trips per day (approximately 1060-750 trips per hour for average peak work hours of 5-7 hours). That too these trips included trips from weaving unit to ring road market or export (i.e. single trip); further trips or the trips attracted for delivery of raw material to weaving unit are not included. There is lacking in data availability in this sector due to is highly decentralized nature, otherwise there is wide scope for study of the trips generated and attracted by this setup of textile industry in the city.

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