A REVIEW OF THE FREIGHT GENERATION MODELS AND DATA COLLECTION TECHNIQUES

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ABSTRACT

With the rapid development of the world economy after the Industrial Revolution, the freight transportation sector has evolved drastically worldwide. Both rural and urban roads of different developed and developing countries have seen a rapid rise in freight traffic movement. Transportation engineers and planners have been predicting present and future freight traffic movements to cope with the increasing demand. However, unlike four-step passenger transportation trip modelling, freight transport modelling steps include a variety of complexities. This includes the involvement of several stakeholders, variations in types of goods, and complex freight delivery systems in urban setups, among others. To encounter the complexities above, freight transport researchers must carefully consider different modelling techniques and relevant data collection processes for different economies, goods, shipment types, geographical areas, etc. This review paper aims to systematically analyze the existing body of literature on freight generation and freight trip generation models and associated data collection techniques across the world, focusing on evaluating their effectiveness, comparability, and real-world applicability. From a wide range of literature, we have meticulously analyzed 35 papers worldwide, including some developing economies, to understand the existing world and emerging trends in freight generation modelling and data collection techniques. The paper identifies strengths, limitations, and gaps in current research through a rigorous analysis of various methodologies, from traditional regression-based models to machine learning algorithms and data collection methods like commodity flow surveys, establishment surveys, carrier surveys, roadside surveys, GPS tracking and administrative records. Additionally, it highlights emerging trends and challenges such as data accuracy, privacy issues, and the integration of real-time analytics. Practical recommendations are offered for both practitioners and policymakers. This study is a comprehensive guide for future research and application in freight transportation planning.

Keywords: *Freight, freight generation, freight trip generation, freight transport model, survey techniques*

1. INTRODUCTION

Freight transportation plays a significant role in transportation engineering as it involves the movement of goods and materials across modes such as roads, railways, airways, and waterways. Its importance lies in its contribution to economies by ensuring the distribution of goods and influencing the development of infrastructure and environmental policies. The efficiency and reliability of freight transport systems directly impact growth and people's quality of life (Holguin Veras et al., 2011; Lawson et al.,2011). The scenarios surrounding freight transport differ significantly between developing countries. Developed nations generally have logistics networks and sophisticated infrastructure, whereas developing countries face challenges like infrastructure, unstable economies, and less efficient logistics systems. These differences call for customized approaches to planning freight transport and creating policies tailored to contexts (Puente-Mejia et al., 2020; Sánchez-Díaz et al.,2016). Various models, such as Freight Generation (FG) and Freight Trip Generation (FTG), estimate the movement and quantity of goods within a transportation network. These models involve data collection, analyzing transportation and economic variables, and applying statistical or machine learning techniques to predict freight flows. FG and FTG models are crucial for enhancing our understanding of logistics operations, planning infrastructure efficiently, and developing policies. Efficient freight movement reduces congestion and minimizes impact, especially in urban areas (Lim et al., 2022; Middela et al., 2022). Previous studies examining FG, FTG, and data collection techniques have highlighted the evolution of these models, the methodologies employed, and the significance of comprehensive data collection. These reviews emphasize the need to integrate data sources and advanced modelling techniques to tackle the complexities of freight systems (Malik et al., 2021; Novak et al., 2011).

The reason for choosing this topic for a review lies in the growing importance of efficient freight systems in an increasingly globalized and urbanized world. Effective data collection techniques are fundamental in FG and FTG modelling as they provide the foundation for accurate predictions and informed decision-making. Inaccurate or incomplete data can lead to suboptimal planning and policy decisions, affecting the overall efficiency of the transportation system. (Pani et al., 2018; Patel & Shukla, 2016). In conducting this review, 35 papers have been meticulously analyzed, focusing on modelling techniques, performance evaluations of different models, and the role of data collection in enhancing model accuracy and applicability. This review aims to present an understanding of practices and future directions in freight generation modelling and data collection techniques.

2. METHODOLOGY

A wide variety of literature regarding freight transportation is available online. Freight generation and freight trip generation are the most crucial domains of freight transportation research as they are considered the first stage of four-step freight transport demand modelling. Freight generation generally includes freight and freight trip generation, whereas freight trip generation generally indicates only vehicle trip generation. This research considers both freight and trip generation. The authors took an inclusive approach and considered studies from both developed and developing nations. The focus was also on the data collection technique, which is crucial for freight transport modelling, especially in developing countries with a lack of data and fewer sources of funds to carry out wide-scale surveys. This research incorporated studies from developed countries to benchmark against global best practices while also providing explicit recommendations for developing countries. These recommendations recognize developing countries' unique challenges and opportunities in freight transportation. Research papers were searched across various platforms, including Scopus, Web of Science, Academia, ResearchGate, etc. Initially, open-access articles were only considered; however, later, some papers were accessed through licensed users to enrich the review quality of the paper. Both journal articles and conference papers were considered for review. It was observed that more than six hundred (600) research articles related to freight generation are currently available online. Depending on the article title, keywords, and abstract, around seventy (70) papers were initially selected for review. After the secondary screening, a total of thirty-five (35) papers were reviewed for this paper, keeping in mind the page limit of the conference template.

3. FINDINGS

The findings regarding freight generation models and data collection techniques are divided into two separate sections as follows.

3. 1 Freight Generation and Freight Trip Generation Models

In most existing literature, linear regression models have been widely utilized to estimate freight generation, although there is evidence of non-linearity in the model parameters. Dhulipala and Patil (2020) demonstrated that the Generalized Additive Model (GAM) outperforms Multiple Linear Regression (MLR) in estimating agricultural freight in India with better prediction accuracy and can effectively handle the nonlinear effects of predictor variables. Dhonde and Patel (2019) used MLR to predict freight trips made by power loom units in Surat. They found a positive correlation between establishment area, employee count, and freight trips. In 2021, they found that the textile industry contributes 40% of the city's LCV traffic, affecting traffic dynamics. Key variables in the model included production machines, incoming goods quantity, floor area, goods production quantity, employee count, and distance from the textile market. Holguín-Veras et al. (2011) found that parameters of FG models and loaded vehicle trip distribution models show significant time-dependent changes. However, commodity flow-based freight distribution models remain stable over time. Park et al. (2012) conducted a study specific to industrial parks and showed that production area is superior to employment in freight trip generation. Bastida & Holguín-Veras (2009) identified company attributes like industry segment and commodity type, total sales and employment as significant predictors of freight generation using OLS and Cross-classification techniques. Lawson et al. (2011) applied Ordinary Least Squares (OLS) and Multiple Classification Analysis (MCA) to analyze the impact of land use and business size on freight trip generation. It was found that the local and standardized national land use classification code models (NYCZR and LBCS models) provide more accurate freight trip attraction estimates than ITE trip rates. Malik et al. (2021) proposed integrating the direct flow estimation models with conventional Origin Destination Synthesis (ODS) models and presented a methodological framework for running ODS models with limited data sources. Middela et al. (2018) provided friction factors that can be used to predict future freight movements when origin-destination data is unavailable. Net state domestic product and area were identified as significant in OLS regression models estimating FG. Pani et al. (2018) developed FG models for seven Indian cities and found that employment-based models are more appropriate for cities with dense commercial activities, while area-based models are better for medium urbanization levels. Patel and Shukla (2016) developed an MLR model with an explanatory power of 81.2% predicting daily truck trips in Mehsana GIDC based on factors like industry floor area, HCV ownership, and goods weight. B. V. Patel et al. (2017) developed an industrial freight trip generation model for Himatnagar, India, using several regression analyses using SPSS. The model had an R^2 value of 0.99, with industry area, employee income, travel distance, and raw material being the significant predictors.

Novak et al. (2011) concluded that the spatial regression model is preferable for modelling freight generation at the national level. The study also highlighted the growing use of Geographic Information Systems (GIS) in planning agencies and suggested that spatial regression techniques can significantly improve the quality of models that have traditionally been limited by insufficient data. Oliveira et al. (2017) developed an FTG model using simple linear regression, suggesting that it can be integrated into a GIS to enhance geographical analysis and decision-making. For many different commodities, Abate et al. (2019) introduced a new disaggregate stochastic model that predicts how different goods are shipped and the shipment size, giving insight into practical outcomes like the responsiveness of two specific commodities. Holguín-Veras & Patil (2008) introduced a model that significantly improves accuracy by including both loaded and empty truck trips in a multicommodity integrated freight study. Lim et al. (2022) compared eight regression models to predict industry-specific shipments (based on the NAICS code) using FG models. Support Vector Regression emerged as the most effective one in predicting shipments from different origins. On the other hand, both Support Vector and Gaussian Process Regression were found to be equally favourable in predicting shipments to various destinations. Future research should consider simpler Machine Learning methods unless they significantly outperform traditional models and explore different variables and settings. Table 1 summarizes a few more studies on FG and FTG modelling.

Table1: Summary of Reviewed Articles on Freight Generation and Freight Trip Generation Models

Paper	Establishment/ Type of Goods	Variables Considered	Model Type	Techniques Applied
Middela & Ramadurai (2022)	Mixed	Establishment Characteristics, Establishment Types and Spatial Factors	Spatial Seemingly Unrelated Regression (SpSUR) Models	Lagrange-multiplier tests for spatial specifications, non-spatial and spatial SUR models for FTA and FTP analysis.
Focus: FTG **Year:** 2021 **Location:** Chennai, India	**Key Findings**: FTG was influenced by vehicle types and establishments. As per the LM test, spatial dependence is absent in FTP; spatial lag specification is more appropriate for FTA. The approach combined error terms with spatial correlations for better analysis.			
De Bakshi et al. (2020)	Mixed	Population Density, Employment Density, Land Use Mix (Dissimilarity) Index	Ordinary Least Square (OLS) Models	Socio-economic indices were used to express the urban form, and the impact was assessed through OLS regression analysis.
Focus: FTG **Year:** 2019 **Location:** New Delhi, India	**Key Findings**: The sectoral employment-based model outperformed the combined model with urban forms. For non-motorized modes, the combined model performed better. Employment in the retail sector worked as a significant factor in estimating FTP and FTA.			
Bac & Viet (2019)	Mixed	Spatial factors such as geographic location and regional characteristics.	Spatial Autocorrelation Analysis	Moran's I index for spatial autocorrelation analysis and Moran's scatter plot.
Focus: FG **Year:** 2019 **Location:** Vietnam	**Key Findings**: At the regional level, the spatial correlation was found to be less significant or absent, but it was significant at the national level. On a national scale, there was a clear pattern of clustering in freight volumes, suggesting similarities in high and low-volume provinces throughout Vietnam.			
Gonzalez-Calderon et al. (2021)	Mixed	Vehicle Types, Commodity Types	Empty Trip Model	Utilized OLS regression to establish a connection between the transportation of empty and loaded trips based on vehicle and commodity categories as an expansion of the Noortman and Van Es' empty trip model.
Focus: FTG (Empty Trips) **Year:** 2021 **Location:** Columbia	**Key Findings**: Various goods result in different percentages of empty trips, with commodities that necessitate specialized equipment exhibiting higher rates of empty trips. The improved model offers more precise estimations of empty trips, especially by considering the influence of cargo type volumes, suggesting similarities in high and low-volume provinces throughout Vietnam.			

Table1 (Continued)

Paper	Establishment/ Type of Goods	Variables Considered	Model Type	Techniques Applied
Venkadavarahan & Marisamynathan (2022)	Mixed	Employment, Industrial Segment, Mode of Commercial Vehicle, Type of Delivery, Number of Suppliers, Gross Floor Area	Binary Logit (BL), SVM (Support Vector Machine), and ANN (Artificial Neural Network) models	Employed binary logit (BL) for traditional methods, while ML techniques are represented by support vector machine (SVM) and artificial neural network (ANN) for establishment classification.
Focus: FTG **Year:** 2022 **Location:** Tamil Nadu, India	**Key Findings**: The ANN model using hyperbolic tangent and dropout activation (ANN tanh) performed the best in terms of accuracy and precision compared to SVM methods in classifying establishments as pure receivers or intermediate establishments. The study emphasizes the classification of establishments as an initial step for estimating freight activity.			
Patil et al. (2021).	Restaurant Sector	Seating Capacity, Gross Floor Area, Number of Vehicles Owned, Number of Employees, Interaction Variables	Linear Regression Poisson Regression	Employed linear regression and Poisson regression. Evaluated the model fit using R squared values, McFadden's rho squared value, Pearson's residuals and Deviance residuals.
Focus: FTG **Year:** 2021 **Location:** Mumbai and Delhi-NCR, India	**Key Findings**: This study models freight trips in Mumbai and Delhi-NCR's restaurant sector using Poisson regression with R-squared values of 0.70 and 0.60, outperforming linear models (R-squared 0.50). Conclusively, Poisson regression better explains freight trip variation in these regions' restaurant sectors.			
Oliveira et al. (2022)	Commercial Establishments	Area (Size of the Establishment) Number of Employees	Ordinary least squares (OLS) regression model	Data analysis: Ramsey RESET test, Cook's distance for outliers, Pearson correlation for variable associations. Model evaluation: T-test, F-test, R-squared for fit, AIC and BIC for comparison.
Focus: FTG **Year:** 2022 **Location:** Brazil	**Key Findings**: Utilizing different OLS regression approaches enhances parameter estimation and accuracy. It highlighted the notable influence of employee count on generating freight trips, with a more pronounced impact in smaller cities compared to medium-sized ones.			

Table1 (Continued)

Paper	Establishment/ Type of Goods	Variables Considered	Model Type	Techniques Applied
Günay et al. (2016)	Mixed	Logistical Site Type, Actively Used Area, Employment and Activity Type	Conditional Modelling (Binary Logit Model and a Multiple Linear Regression Model)	Analysis of covariance (ANCOVA) - for segmentation of logistical site; binary logit modelling - the probability of tractor-trailer trips; and multiple linear regression - for estimating FTG.
Focus: FTG **Year:** 2016 **Location:** Kocaeli,Turkey	**Key Findings**: The new conditional modelling method, when applied to a specific segment of logistical sites for tractor trailers, performed better than the regular regression modelling approach, reducing RMSE and MAE. This approach enhanced the understanding and modelling of tractor-trailer trips, especially for segments that had a significant number of cases where no trips were made.			
Sahu & Pani (2020)	Mixed	Annual Freight Production (FP) and Freight Attraction (FA), Employment and Area (Measured as Gross Floor Area)	Linear Regression Models and Multiple Classification Analysis (MCA).	FG was measured using linear regression based on the size of establishments, estimated through data cross-tabulation using multiple classification analysis (MCA). ANCOVA was used to investigate locational impact and geographical variations.
Focus: FG **Year:** 2020 **Location:** Kerala, India	**Key Findings:** Employment is a more accurate indicator for estimating FP, whereas area is a better measure for assessing FA. Compared to New York, Kerala had lower rates of employment-based freight production. The study emphasizes the significance of acknowledging geographical differences in freight generation and suggests that policymakers and planners in Indian cities should consider these disparities when formulating policies and strategies.			
Holguín-Veras et al. (2021)	Mixed	FTA, FTP, Establishment Characteristics (Employment, Annual Revenue), and time	Econometric Models	Comprehensive modelling - two variable combinations, two-time effect methods, and OLS technique to test linear, exponential, logarithmic, and power forms.
Focus: FTG **Year:** 2021 **Location:** New York City, USA	**Key Findings**: 66 final models; 51 had a time-dependent effect significant at 95%, and 5 had a 90% confidence level. Most effects interact with employment, which indicates marginal FTA and FTP changes at the establishment level. When annual revenues were considered as a factor, the number of time-dependent effects decreased, but it was clear that other factors, like e-commerce, still played a role in shaping FTG temporal patterns.			

Table1 (Continued)

Paper	Establishment/ Type of Goods	Variables Considered	Model Type	Techniques Applied
Pani et al. (2019)	Mixed	Trips per Day, Freight Tonnage per Day, Zonal, Industrial, Economic Land and Locational Characteristics	Hierarchical Linear Models (HLMs)	Employed ad-hoc geographical clustering and automated zone design procedures (AZP) for zoning systems, Moran's I spatial autocorrelation for assessing zoning systems. Used hierarchical linear modelling for the analysis of FG/FTG patterns.
Focus: FG and FTG **Year:** 2019 **Location:** Jaipur, India	**Key Findings**: This research underscores MAUP's impact on freight demand models, emphasizing the importance of wisely choosing spatial units and using industrial aggregation to mitigate it. Accurate zoning systems are crucial for effectively capturing freight travel patterns and making informed policy decisions.			
Kulpa (2014)	Mixed	Number of Inhabitants, Number of Companies and Employment.	Multiple Regression, Artificial Neural Network (ANN)	The ANN models that were tested include linear multi-layer perceptron (MLP), radial-based functions (RBF), and general regression (GRNN). In evaluating the impact of variables, the analysis took into account factors like error quotient and standard deviation quotient.
Focus: FTG **Year:** 2014 Location: Poland	**Key Findings**: Both models developed to estimate freight truck trips show high errors in verification. The limitation of the study lies in the small sample size and the risk of using ANN as a "black box" model.			
Sánchez-Díaz et al. (2016)	Mixed	Land-Use Variables, Economic Attributes, Network Characteristics	Ordinary Least Square (OLS) Regression, Spatial Econometric Models	Models FTA impact on employment, land value and street width using OLS and nonlinear methods. Spatial econometrics (Moran's I, Thiessen polygons, LISA) and GIS. Validation with literature benchmark using MAPE.
Focus: FTG **Year:** 2016 Location: New York City, USA	**Key Findings**: Establishment location, land value and front street width are crucial and including these enhance FTA estimates, particularly in areas with a high concentration of retail businesses. Nonlinear models provide the best representation of how FTA varies across different sectors, demonstrating that as employment increases, the rate at which FTA rises slows down.			

3.2 Data Collection Techniques

Table 2 represents the data collection techniques and corresponding sample sizes from some of the reviewed studies.

Table 2: Summary of Reviewed Articles on Data Collection Techniques

Paper	Data Collection Techniques	Sample Size	Paper	Data Collection Techniques	Sample Size
Bac & Viet (2019)	Statistical Yearbook; GADM (Database of Global Administrative Areas)	63 Prefecture Level Units	Bastida & Holguín-Veras (2009)	Establishment Survey	700 Establishments
De Bakshi et al. (2020)	Establishment Survey Demographic Statistics Employment Census	1800 Establishments	Holguín-Veras & Patil (2007)	Road Side Interview	5276 Trucks
Dhonde & Patel (2019)	Establishment Surveys Commercial Vehicle Drivers' Survey Traffic Volume Study	250 Samples 1137 LCVs 5 Screen Points	Gonzalez-Calderon et al. (2021)	Freight Origin-Destination Survey	135,564 Trucks
Dhulipala & Patil (2020)	Secondary Sources (Directorate of Statistics and Economics, Census of India, etc.)	210 District-Level Data	Patel & Shukla (2016)	Company Travel Diary Survey Roadside Interview Survey	210 Company Owners
Günay et al. (2016)	Establishment Survey Interviews with Drivers Vehicle Counts Screen and Cordon Line Counts	337 Establishments 5873 Interviews 17 Stations on 4 Screen Lines	Pani et al. (2019)	Establishment Survey Zonal Level Data Collection	Sampling Frame of 31,725 Establishments (Final 184)
Holguín-Veras et al. (2011)	Freight Origin–Destination Survey (FODS	70 Survey Stations	Sahu & Pani (2020)	Establishment Survey	432 Establishments
Lawson et al. (2011)	Establishment Survey, Dun and Bradstreet (D&B) Database	362 Establishments	Puente-Mejia et al. (2020)	Establishment Survey	607 Establishments
Malik et al.(2021)	Traffic Volume Counts Secondary Digital Source (Map API)	72 Locations (5184 Data Points for Each Vehicle Type)	Abate et al. (2019)	Commodity Flow Survey	2,897,010 Outgoing Shipments
Kulpa (2014)	Trip Diary	100 Firms	Rwakarehe et al. (2014)	Census Data	448 Internal TAZ

Data collection procedures adaptable to the unique characteristics of different study zones can help in urban planning, supporting stakeholders, and anticipating future urban logistic scenarios (Puente-Mejia et al., 2020). A significant majority of the reviewed studies are based on establishment-based surveys, which underscores the value placed on direct and detailed data collection from businesses and establishments in the field (Iding et al., 2002; Sánchez-Díaz et al., 2016; Patil et al., 2021; Oliveira et al., 2022; Venkadavarahan & Marisamynathan, 2022; Bastida & Holguín-Veras, 2009; Oliveira et al., 2017). The sample sizes in these studies vary greatly, ranging from 150 (Patil et al., 2021) to 31,725 (Pani et al., 2019), reflecting the wide range of study scope. Holguín-Veras et al. (2021) used multi-year establishment-level data and stated the importance of periodically collecting FTG data to understand and predict time-dependent patterns in FTG. Several studies (Park et al., 2012; Abate et al., 2019; Novak et al., 2011) focused on commodity flow surveys, which offer vital insights into freight logistics. Middela et al. (2018) highlighted the need for comprehensive data collection programs, like the Commodity Flow Survey in the United States, as there are limited studies due to data scarcity and complex interactions among stakeholders, especially in developing countries.

Some of the reviewed studies have employed other methods like roadside interviews, trip diaries, and freight origin-destination surveys. The trip diary method involves direct documentation of freight trips, and the roadside interview technique gathers data directly from transporters, and they both provide on-the-ground insights into freight movement (Kulpa, 2014; Holguín-Veras & Patil, 2007; Holguín-Veras & Patil, 2008). The freight origin-destination survey deals with estimating the freight flows between the origin and destination zones, and the existing studies provide improved and developed methods for evaluating policies and infrastructure investment (Gonzalez-Calderon et al., 2021; Kalahasthi et al., 2022). Holguín-Veras and Patil (2007) contributed to the FODS literature by incorporating empty trip and distribution models. Truck trip-based studies have large sample sizes that range from 5,276 (Holguín-Veras & Patil, 2007) to 135,564 (Gonzalez-Calderon et al., 2021), indicating extensive efforts in collecting data due to trucks' crucial role in freight transportation. Kulpa (2014) highlighted the importance of wider truck surveys like TIUS (Truck Inventory and Usage Survey) made in the USA while developing a freight truck trip generation model in Polish condition. A noteworthy number of the reviewed studies were conducted based on various secondary sources alone or along with primary data sources, highlighting a resource-efficient strategy in freight transportation research. By combining readily available data from public sources with borrowed model parameters, Rwakarehe et al. (2014) contributed to fostering innovation within Canadian highway agencies by reducing the cost associated with developing provincial FDMs. Economic Census/Country business pattern, Traffic Count Data, and Census Data each featured in individual paper as the secondary data sources within the review indicate more specialized applications in freight generation studies (Bac & Viet, 2019; Dhulipala & Patil, 2020; Rwakarehe et al., 2014; Middela et al., 2018).

4. RECOMMENDATIONS

Based on the literature review, it is evident that the freight transportation industry in developing countries, such as Bangladesh, can significantly benefit from adopting more sophisticated and regionally tailored models, improved data types, and enhanced data collection methods. The data types and collection methods require a shift towards a more granular level. Middela et al. (2018) used a grid-based method to collect freight data for more detailed insights and avoid the limitations of pre-aggregated units. The study suggested that finer-level Traffic Analysis Zones (like districts) can be considered with extensive data collection efforts like the USA's Commodity Flow Survey for better freight movement forecasting. Puente-Mejia et al. (2020) and Lawson et al. (2011) discussed the use of both observational and declarative data for a more comprehensive understanding of freight dynamics, which is a major limitation in the freight transportation sector of our country due to the scarcity of data. Lim et al. (2022) anticipated that advanced models like Random Forest, Gradient Boosting, and Multi-layer Perceptron regressions could outperform Ordinary Least Squares (OLS), particularly with larger training datasets or more detailed geographical levels. They suggested that future research in freight modelling could explore the application of the proposed framework to disaggregate freight data into finer geographical levels, incorporate additional external or private data sources to uncover relationships

between economic activity and specific freight shipments at the individual business level and expand the model framework to forecast future freight demand based on industry type.

Additionally, incorporating spatial autocorrelation analysis can provide deeper insights into freight volume patterns, aiding in the development of more efficient transportation networks (Novak et al.,2011; Bac & Viet, 2019). In the context of developing countries like India and Bangladesh, Sahu and Pani (2020) emphasized the necessity of taking locational variables into account when modelling FG, where changes in transportation costs have a substantial impact on freight movements. Some studies (Günay et al., 2016; Pani et al., 2019) underscore the need to design zoning systems that accurately reflect physical, economic, and industrial attributes to capture freight travel patterns effectively. Emphasis should also be placed on understanding the influence of urban form on freight trip generation, which is crucial for planning in rapidly urbanizing areas. More disaggregate studies were suggested incorporating a wider range of economic and urban forms of variables addressing the limitations in this sector in developing economies, including Bangladesh (De Bakshi et al., 2019). Malik et al. (2021) developed an ODS model that can easily be adaptable to the informal sector in a developing country like ours. In developing countries like Bangladesh, where commodity flow survey practice is mostly absent, the combined modelling approach by Pani et al. (2018) is of major importance and can benefit planners and policymakers in decision-making regarding infrastructure investment and operation strategies. The study suggested that future research could enhance FG models by exploring additional variables like annual turnover, sales volume, stock-keeping units, and transport cost share to improve predictive accuracy. Overall, these insights can help in developing a more efficient, sustainable, and responsive freight system in Bangladesh and similar developing countries.

5. CONCLUSION

This study focused on FG/FTG modelling and data collection techniques at national and regional levels. Several models have been analyzed, and it can be said that there is still room for improvement in freight/freight trip generation modelling in terms of approaches, variables considered, and data collection techniques. City planners have started to realize the underlying logistics of freight transportation, and that has paved the way for emerging trends in FG/FTG modelling. Comprehensive data programs are needed in developing countries to drive the number of studies in this sector that have been inhibited by data scarcity and complex interaction among stakeholders.

REFERENCES

Abate, M., Vierth, I., Karlsson, R., De Jong, G., & Baak, J. (2019). A disaggregate stochastic freight transport model for Sweden. *Transportation*, 46(3), 671–696. https://doi.org/10.1007/s11116-018-9856-9

Bac, T. C., & Viet, P. Q. (2019). THE SPATIAL AUTOCORRELATION ANALYSIS FOR VOLUME OF FREIGHT IN DIFFERENT REGIONS: A CASE OF VIETNAM. *International Journal of Engineering Sciences & Research Technology*, 8(12), 35–44.

Bastida, C., & Holguín-Veras, J. (2009). Freight Generation Models: Comparative Analysis of Regression Models and Multiple Classification Analysis. *Transportation Research Record: Journal of the Transportation Research Board*, 2097(1), 51–61. https://doi.org/10.3141/2097-07

De Bakshi, N., Tiwari, G., & Bolia, N. B. (2020). Influence of urban form on urban freight trip generation. *Case Studies on Transport Policy*, 8(1), 229–235. https://doi.org/10.1016/j.cstp.2019.04.004

Dhonde, B., & Patel, C. (2019). An Impact of Decentralized Small Scale Industry on Intra-City Freight Trips in Developing Nation. *Journal of Eastern Asia Society for Transportation Studies*, 13, 908–928.

Dhonde, B. N., & Patel, C. R. (2021). Estimating urban freight trips using light commercial vehicles

in the Indian textile industry. *Transportation Research Interdisciplinary Perspectives*, 11, 100411. https://doi.org/10.1016/j.trip.2021.100411

Dhulipala, S., & Patil, G. R. (2020). Freight production of agricultural commodities in India using multiple linear regression and generalized additive modelling. *Transport Policy*, 97, 245–258. https://doi.org/10.1016/j.tranpol.2020.06.012

Günay, G., Ergün, G., & Gökaşar, I. (2016). Conditional Freight Trip Generation modelling. *Journal of Transport Geography*, 54, 102–111. https://doi.org/10.1016/j.jtrangeo.2016.05.013

Gonzalez-Calderon, C. A., Holguín-Veras, J., Amaya, J., Sánchez-Díaz, I., & Sarmiento, I. (2021). Generalized noortman and van es' empty trips model. *Transportation Research Part A: Policy and Practice*, 145, 260–268. https://doi.org/10.1016/j.tra.2021.01.005

Holguín-Veras, J., Ramirez-Rios, D., & Pérez-Guzmán, S. (2021). Time-dependent patterns in freight trip generation. *Transportation Research Part A: Policy and Practice*, 148, 423–444. https://doi.org/10.1016/j.tra.2021.03.029

Holguín-Veras, J., & Patil, G. R. (2007). Integrated Origin–Destination Synthesis Model for Freight with Commodity-Based and Empty Trip Models. *Transportation Research Record: Journal of the Transportation Research Board*, 2008(1), 60–66. https://doi.org/10.3141/2008-08

Holguín-Veras, J., & Patil, G. R. (2008). A Multicommodity Integrated Freight Origin–destination Synthesis Model. *Networks and Spatial Economics*, 8(2–3), 309–326. https://doi.org/10.1007/s11067-007-9053-4

Holguín-Veras, J., Sarmiento, I., & González-Calderón, C. A. (2011). PARAMETER STABILITY IN FREIGHT GENERATION AND DISTRIBUTION DEMAND MODELS IN COLOMBIA. *Dyna*, 78(166), 16–20.

Iding, M. H. E., Meester, W. J., & Tavasszy, L. (2002, August 27). Freight trip generation by firms. 42nd Congress of the European Regional Science Association: "From Industry to Advanced Services - Perspectives of European Metropolitan Regions," Dortmund, Germany. https://doi.org/handle/10419/115840

Kalahasthi, L., Holguín-Veras, J., & Yushimito, W. F. (2022). A freight origin-destination synthesis model with mode choice. *Transportation Research Part E: Logistics and Transportation Review*, 157, 102595. https://doi.org/10.1016/j.tre.2021.102595

Kulpa, T. (2014). Freight Truck Trip Generation Modelling at Regional Level. *Procedia - Social and Behavioral Sciences*, 111, 197–202. https://doi.org/10.1016/j.sbspro.2014.01.052

Lawson, C. T., Holguín-Veras, J., Sánchez-Díaz, I., Jaller, M., Campbell, S., & Powers, E. L. (2011). ESTIMATION OF FREIGHT TRIP GENERATION BASED ON LAND USE. Transportation Research Board (TRB) 91st Annual Meeting.

Lim, H., Uddin, M., Liu, Y., Chin, S.-M., & Hwang, H.-L. (2022). A Comparative Study of Machine Learning Algorithms for Industry-Specific Freight Generation Model. *Sustainability*, 14(22), 15367. https://doi.org/10.3390/su142215367

Malik, L., Tiwari, G., Biswas, U., & Woxenius, J. (2021). Estimating urban freight flow using limited data: The case of Delhi, India. *Transportation Research Part E: Logistics and Transportation Review*, 149, 102316. https://doi.org/10.1016/j.tre.2021.102316

Middela, M. S., & Ramadurai, G. (2022). Spatial Seemingly Unrelated Regression Models for Freight Trip Generation by Vehicle Type: Application to the Chennai Metropolitan Area in India. Transportation Research Record: Journal of the Transportation Research Board, 2676(4), 380–392. https://doi.org/10.1177/03611981211060035

Middela, M. S., Pulipati, S. B., & Prasad, C. S. R. K. (2018). Modelling Freight Generation and Distribution for Nationwide Interstate Freight Movement. *Transportation in Developing Economies*, 4(1), 6. https://doi.org/10.1007/s40890-018-0059-z

Novak, D. C., Hodgdon, C., Guo, F., & Aultman-Hall, L. (2011). Nationwide Freight Generation Models: A Spatial Regression Approach. *Networks and Spatial Economics*, 11(1), 23–41. https://doi.org/10.1007/s11067-008-9079-2

Oliveira, L. K. D., Araújo, G. G. F. D., Bertoncini, B. V., Pedrosa, C. D., & Silva, F. G. F. D. (2022). Modelling Freight Trip Generation Based on Deliveries for Brazilian Municipalities. *Sustainability*, 14(16), 10300. https://doi.org/10.3390/su141610300

L. K. D., Nóbrega, R. A. D. A., Ebias, D. G., & Corrêa, B. G. E. S. (2017). Analysis of Freight Trip

Generation Model for Food and Beverage in Belo Horizonte (Brazil). *REGION,* 4(1), 17. https://doi.org/10.18335/region.v4i1.102

Pani, A., Sahu, P. K., Chandra, A., & Sarkar, A. K. (2019). Assessing the extent of modifiable areal unit problem in modelling freight (trip) generation: Relationship between zone design and model estimation results. *Journal of Transport Geography*, 80, 102524. https://doi.org/10.1016/j.jtrangeo.2019.102524

Pani, A., Sahu, P. K., Patil, G. R., & Sarkar, A. K. (2018). Modelling urban freight generation: A case study of seven cities in Kerala, India. *Transport Policy*, 69, 49–64. https://doi.org/10.1016/j.tranpol.2018.05.013

Patel, A. D., & Shukla, R. N. (2016). Freight Truck Trip Generation Model for Mehsana GIDC. 2(12).

Patel, B. V., Kadiya, D. K., & Varia, H. R. (2017). Developing Industrial Trip Generation Model for Himatnagar Industrial Area. *International Journal of Engineering Research*, 6(04), 768–775. https://doi.org/10.17577/IJERTV6IS040670

Patil, G. R., Thadoju, S., Sahu, P. K., Mondal, A., & Bajpai, V. (2021). Data Collection and Modeling of Restaurants' Freight Trip Generation for Indian Cities. *Transportation in Developing Economies*, 7(1), 9. https://doi.org/10.1007/s40890-021-00114-7

Park, M., Sung, H., & Chung, S. (2012). Estimation of Freight Trip Generation Rates based on Commodity Flow Survey in Korea. *International Journal of Railway*, 5(4), 139–143. https://doi.org/10.7782/IJR.2012.5.4.139

Puente-Mejia, B., Palacios-Argüello, L., Suárez-Núñez, C., & Gonzalez-Feliu, J. (2020). Freight trip generation modeling and data collection processes in Latin American cities. Modeling framework for Quito and generalization issues. *Transportation Research Part A: Policy and Practice*, 132, 226–241. https://doi.org/10.1016/j.tra.2019.10.013

Rwakarehe, E. E., Zhong, M., & Christie, J. (2014). Development of a Freight Demand Model for the Province of Alberta Using Public Sources of Data. *Procedia - Social and Behavioral Sciences*, 138, 695–705. https://doi.org/10.1016/j.sbspro.2014.07.263

Sahu, P. K., & Pani, A. (2020). Freight generation and geographical effects: Modelling freight needs of establishments in developing economies and analyzing their geographical disparities. *Transportation*, 47(6), 2873–2902. https://doi.org/10.1007/s11116-019-09995-5

Sánchez-Díaz, I., Holguín-Veras, J., & Wang, X. (2016). An exploratory analysis of spatial effects on freight trip attraction. *Transportation*, 43(1), 177–196. https://doi.org/10.1007/s11116-014-9570-1

Venkadavarahan, M., & Marisamynathan, S. (2022). Development of urban freight trip generation models concerning establishment classification process for a developing country. *International Journal of Transportation Science and Technology*, 11(3), 603–618. https://doi.org/10.1016/j.ijtst.2021.08.001