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Independence and Interdependence of
Sustainable Spaces

ESTIMATE THE PASS-BY AND DIVERTED TRIP IMPACT GENERATED BY A SUPERMARKET IN COLOMBO, SRI LANKA

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Abstract: A new supermarket development will produce more trips, adding to the existing traffic and eventually leading to congestion and increasing clashes on nearby roads. One of the primary lands uses in the Colombo area is the supermarket. As a result, it will affect travel demand as well as other local transportation-related concerns. To accurately assess the level of congestion and the effects of the development on the network, it is essential to estimate the actual number of trips that a new supermarket will generate. All land use trips do not just trip to that destination and return (primary trips). Some of the generated trips (pass-by trips) are already in the existing traffic, but some of the generated trips are entirely new (diverted trips). These trips should be analyzed while planning development to determine the impact on the surrounding transport network. Therefore, this research objects to calculate the proportion of primary, pass-by, and diverted trips generated by a Supermarket in Colombo, Sri Lanka. Current vehicle trips attraction/generation of the supermarket, consumer trip chain pattern and vehicle volume of the access road are the primary research input. Five supermarkets in the Colombo area were selected as case studies, and descriptive analysis using SPSS software and Microsoft Excel was used for analysis. Results indicate that on average 43.7% of Pass-by and diverted trips will be generated by a new supermarket in the Colombo area. This paper leads to calculating the real traffic impact by a Supermarket on surrounding road network based on the pass-by and diverted trips in Colombo, Sri Lanka.

Keywords: *Pass-By Trip, Pass-By Trip Impact, Supermarket, Traffic Impact, Trip Generation*

1. Introduction

Traffic congestion is a major issue around the world (Khade, Khode, & Bhakhtyapuri, 2017). Vehicle demand has risen dramatically in recent decades, particularly in the Colombo Area (Thathsarani & Lanel, 2019). With the rise in vehicle consumption, traffic congestion has increased, resulting in a variety of harmful implications and it results in economic losses also (Wickramanayake, Jayasekara, Gamage, & Sharic, October 2021). Despite numerous efforts to reduce traffic congestion in Colombo, the majority of them have been ineffective (Weerasekera, 2011). As a result, the need for a better solution is both temporary and critical (Wickramanayake, Jayasekara, Gamage, & Sharic, October 2021) (Thathsarani & Lanel, 2019). Accordingly, an efficient and affordable transport system has become essential for the global economy to function properly (Dominic , Amar, & Vergel, 2013).

Land development and transportation planning are closely related because each new development in any location will result in more trips because of the growth in the population there (Khade, Khode, & Bhakhtyapuri, 2017). To measure the amount of traffic impact on the surrounding area, the number of trips created by a new development is an essential factor (Land Transport Authority, 2017). Therefore, trip generation is necessary for transport planners to make decisions about the transportation field (Dominic , Amar, & Vergel, 2013). The traffic that already exists will be increased by the development of a new development (Wen, Chin, & Lai, 2017). Since the supermarket is one of the major land uses in the Colombo area, it can cause congestion and other issues on nearby roadways (Ponnurangama & Umadevib, 2014). In order to ensure traffic efficiency and safety, new developments must often receive clearance from the Urban Development Authority, Road Development Authority, and local authorities (Urban Development Authority-Planning & Development Regulations, 2021) (Land Transport Authority, 2017). There are currently no specified trip generation rates in Sri Lanka that apply to new supermarket developments (Wickramanayake, Jayasekara, Gamage, & Sharic, October 2021). Therefore, to accurately analyze the amount of congestion and the consequences of the development on the network, transportation experts need have a good understanding of the trips that will be generated by new developments (Abley, Durdin, & Douglass, 2010). If not, it could lead the decision-makers to mislead (Dominic , Amar, & Vergel, 2013).

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Construction of new developments leads to a range of trips of various types. Not all trips on land include only travel there and back (primary trips) (ITE, Trip Generation Manual 10th Edition, 2017). Some trips may be the consequence of passing by or diverting to the land while ready to travel to another location (Steedman, Nairn, & Koorey, 2016). These trips must be taken into account while planning a development in order to fully understand the effects on the nearby road network (Albaz, 2018). Along with trips to land uses that essentially travel directly to that destination and return to their origin (primary trips), other trips may be as a result of passing by or actively diverting to the lands while travel to another destination (ITE, Trip Generation Manual 10th Edition, 2017) (Steedman, Nairn, & Koorey, 2016). These phenomena are examined in this research. This study aimed to examine the number of "pass-by" and "diverted" trips and their impact on roads in Colombo, Sri Lanka.

No precise data is known regarding how a new supermarket will influence the vehicle traffic flow in Colombo, Sri Lanka (Wickramanayake, Jayasekara, Gamage, & Sharic, October 2021), despite the presence of international literature about the traffic generation rates for various land use patterns specially for developing nations (Cooley, Gruyter, & Delbosc, 2016). Thus, this is a valuable research area as there are very lack of past studies and findings internationally and locally on this research background (Steedman, Nairn, & Koorey, 2016) (Trips Database Bureau , 2015). Additionally, since Sri Lanka is a developing nation, the need for trip generation estimation has become more crucial over time (Wickramanayake, Jayasekara, Gamage, & Sharic, October 2021). Furthermore, there are no reliable sources to find the proportion of pass-by trips and diverted trips generated by a supermarket in the international or local context to apply to Colombo areas (Steedman, Nairn, & Koorey, 2016) (Wickramanayake, Jayasekara, Gamage, & Sharic, October 2021). Therefore, the objective of the research is to estimate the percentage of pass-by trips and diverted trips generated by a Supermarket in Sri Lanka. This provides an opportunity to discover a matter that hasn't been thoroughly studied in Colombo, Sri Lanka. This review presents encouragement to generate accurate predictions to make the correct transportation decisions. The variety of researchers indicates that this kind of research is necessary (Wickramanayake, Jayasekara, Gamage, & Sharic, October 2021) since people's shopping habits are changing quickly and the impacts of these changes on the transportation networks need to be examined (Steedman, Nairn, & Koorey, 2016) (Weerasekera, 2011).

2. Literature Review

Trip generation is the first of four steps model in the transportation planning process (Papagostus, 1981), which is primarily used to calculate travel demand (Ben-Edigbe & Rahman, 2010). According to earlier researches, numerous authorities and organizations have carried out trip generation investigations and established trip generation rates and equations for a range of land uses, primarily in highly urbanized regions of developed countries (Mustafa & Al-sahili, 2016) (Miller, Hoel, Goswami, & Ulmer, 2006). Estimates of total trips entering or departing a land plot are based on socio-economic, geographic, and land use criteria (Al-Masaeid, Al-Omari, & Al-Harahsheh , 1999). Trip generation depends on different parameters such as development type, development scale, location or setting, time (ITE, Trip Generation Manual 10th Edition, 2017), surrounding land uses, modal share, the economic condition of the region (Ahmed T. et al., 2020), travel mode, trip purpose, population density (Dominic , Amar, & Vergel, 2013), distance from the site (Land Transport Authority, 2017), intersection performance (Cooley, Gruyter, & Delbosc, 2016), road network, vehicle flow concentration (Wen T., Chin W., & Lai P., 2017) (Mustafa & Al-sahili, 2016) etc.

When traveling between an origin and a primary destination, "pass-by" trips are taken (Steedman, Nairn, & Koorey, 2016). A primary trip is one that travels directly from its beginning point to its ending point (ITE, Trip Generation Manual 10th Edition, 2017). According to the Trip Generation Handbook, a pass-by trip is a stop in between an origin and a primary trip destination without detouring (ITE, 2014). A development attracts passing motorists (pass-by trips) by driving on a nearby road where they decide to stop and watch (ITE, Trip Generation Manual - 9th Edition, 2012). Pass-by trips are popular for retail-type developments located near busy roads, and they attract drivers who are moving through traffic (Mousa, 2013). For a diverted tour, vehicles need to travel off the road to see a location on their way to their final destination. This means that the path taken from the beginning to the end is not the shortest (Abley & Douglass,2011). Therefore, supermarkets attract a portion of nearby road's traffic and those pass-by trips are not considered as new traffic to the current traffic stream (Mousa, 2013). The location of the supermarket, the daily traffic volume of the access road, proximity to the supermarket from roads, time of day, size of the supermarket, type of the supermarket (Albaz, 2018) and proximity of competitors (ITE, Trip Generation Manual 10th Edition, 2017) have an impact in the proportion of primary, pass-by and diverted trips (Steedman, Nairn, & Koorey, 2016).

Although trip generation rates were developed by the Institute of Transportation Engineers (ITE) for urban, suburban and rural applications by classifying the land uses to meet the all user requirements, there are no detailed locational classifications for supermarket development and it is generational for all locational features such as center city core, dense multi-use urban, general urban/suburban and rural. Trip generation standard for the supermarket is 9.24 trips per 1,000 ft^2 of gross floor area. In addition, if gross floor area is less than 50,000 ft^2 and equal or greater than 50,000 ft^2, it is 50ntitled to a 60% and 40% of pass-by trip reduction respectively (ITE, Trip Generation Manual 10^{th} Edition, 2017). ITE Trip Generation Manual has been developed based on the data in different type of locations in United State (ITE, Trip Generation Manual 10^{th} Edition, 2017) . According to Dr. Michael Schrader, ITE rates are perfectly matched for developed countries to predict the potential impact of a new development but not perfectly

matched for developing countries (Khaled , Eisheh , & Fawz, 2018). Most past studies explain that there is no proper manual like ITE for developing countries (Ben-Edigbe & Rahman, 2010) (Dominic , Amar, & Vergel, 2013)(Khaled , Eisheh , & Fawz, 2018)(Wickramanayake, Jayasekara, Gamage, & Sharic, October 2021) (Miller, Hoel, Goswami, & Ulmer, 2006). Therefore, follow the methodology of ITE and apply for the local areas is a better to take correct decisions makings (Khaled , Eisheh , & Fawz, 2018).

3. Method of Study

Traffic congestion is a major issue around the world (Abley, Durdin, & Douglass, 2010) and traffic congestion has a significant negative impact on Colombo city in Sri Lanka (Wickramanayake, Jayasekara, Gamage, & Sharic, October 2021). The number of vehicles traveling to Colombo is growing by the day. As a result, most of the time, the roads are congested (Thathsarani & Lanel, 2019). The study area was selected based on several factors such as congestion level, growth of population and vehicles, building density, travel patterns and public and private modes of transport, and urbanization level, (ITE, Trip Generation Manual 10th Edition, 2017) land use spatial distribution, road capacity and infrastructure development (Mahmud, Gope, & Chowdhury, 2012). The highest congestion, population, building density, vehicle demand and urbanization and the transport hub in Sri Lanka is Colombo. Therefore, five similar scaled supermarkets were randomly selected with the range of 8500 ft^2-1200 ft^2 as the research case study within the Colombo City area.

Inputs of this study are current vehicle trip attraction/generation of the supermarket, consumer trip chain pattern (ITE, Trip Generation Manual - 9th Edition, 2012) (ITE, Trip Generation Manual 10th Edition, 2017) (Dominic , Amar, & Vergel, 2013) (Mousa, 2013) (Miller, Hoel, Goswami, & Ulmer, 2006) and vehicle volume of the access road (Khade, Khode, & Bhakhtyapuri, 2017) (Albaz, 2018) to estimate the pass-by and diverted trip impact generation of a supermarket in Colombo. A number of vehicles entering and leaving the supermarket at gate location/s were collected to identify the current vehicle trip attraction/generation of the supermarket. Vehicle traffic flow of the access road/s were counted in front of the supermarket to study the present traffic condition of the access road. All traffic counts were done under a normal traffic flow condition during business operational hours from 8.00 am to 10.30 pm (nearly 14 hours). Traffic data were manually counted based on vehicle classification and simunitately recorded via a CCTV camera in each store to avoid the double counting. Manual data collection was conducted at entry & exit points near the access road by using data collecting devices such vehicle counters machines for an interval of 15 minutes. Only motor vehicle trips were examined in order to streamline the study.

On-site interviews were conducted to understand the consumers travel behaviour in each supermarket. Accordingly, 100 customers were interviewed to identify the origin, destination and trip chain of their journey to classify the primary, passing and diversion trips separately. Most past studies have been used descriptive statistic of SPSS software applications for research purpose (ITE, Trip Generation Manual - 9th Edition, 2012) (ITE, Trip Generation Manual 10th Edition, 2017) (Mousa, 2013) (Thathsarani & Lanel, 2019) (Mousa, 2013). Accordingly, descriptive statistics from SPSS software and Microsoft Excel applications were used to calculate number of primary, passing and diversion trips generated by a supermarket and its separate traffic impacts.

Table 1: Site Locations

Site	GPS Location	Address
Location 1	6°58'09.3"N 79°52'25.1"E	No: 854, Aluthmawatha Road, Mattakkuliya
Location 2	6°56'54.3"N 79°51'39.5"E	No: 01, Bonjeang Road, Colombo 13
Location 3	6°55'18.1"N 79°51'22.0"E	No: 199, Union Place, Colombo 02
Location 4	6°54'50.4"N 79°52'51.9"E	No: 85, Cotta Road, Borella
Location 5	6°53'13.0"N 79°51'51.4"E	No: 228, Havelock Road, Colombo 05

4. Analysis and Results

The primary, pass-by, and diverted trip proportions for each location were plotted and can be seen in Figure 1. All locations except location 3 have a large proportion of primary trips compared to other trips. Location 3 follows a different type of trend. Location 1,2,4,5 have a low similar proportion of pass-by trips compared to location 3. Location 2,4 and 5 have similar proportions, location 1 has a less proportion and location 3 have a large proportion of diverted trips.

The proportion of primary trips is larger than the pass-by trips and diverted trips except location 3. A larger proportion of diverted trip generation will happen in location 3. Further, the proportion of pass-by trips is lesser than the primary trips and diverted trips. As per the statistics, on average 56.3% proportions of primary trips, 19.2% proportions of pass-by trips and 24.5% proportions of diverted trips will be generated by a supermarket in Colombo, Sri Lanka. The findings of this study clearly show that a high proportion of diverted trip generation is at supermarkets in Colombo than the pass-by trip generation.

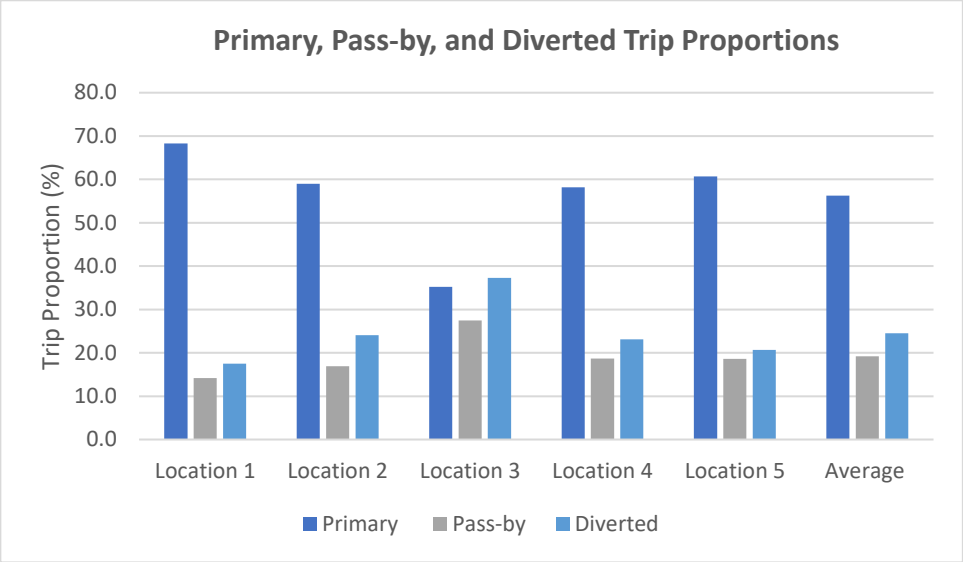

Figure 1, Primary, Pass-by, and Diverted Trip Proportions

Table 2: Primary, Pass-by, and Diverted Trip Proportions

Location	Primary (%)	Pass-by (%)	Diverted (%)
Location 1	68.3	14.2	17.5
Location 2	59.0	16.9	24.1
Location 3	35.2	27.5	37.3
Location 4	58.2	18.7	23.1
Location 5	60.7	18.6	20.7
Average	56.3	19.2	24.5

The primary, pass-by, and diverted trip impacts on the exiting traffic flow in each location were plotted and can be seen in Figure 2. All locations except location 3 have a high primary trip impact. Location 3 has a high diverted trip impact on the existing network and it has a different type of trend.

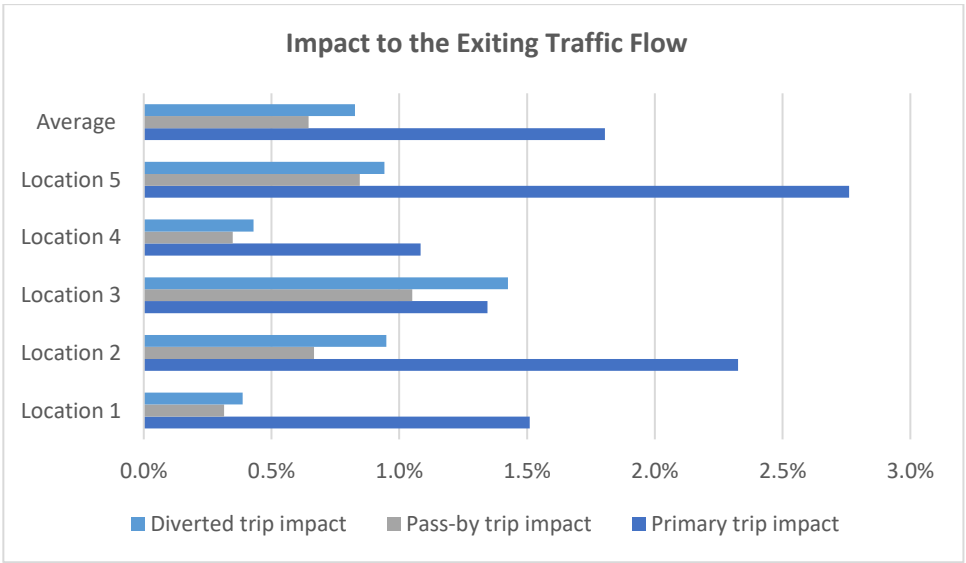

Figure 2: Primary, Pass-by, and Diverted Trip Impact to the Exiting Traffic Flow

Table 3: Primary, Pass-by, and Diverted Trip Impact on the Exiting Traffic Flow

Location	Primary Trip Impact	Pass-By Trip Impact	Diverted Trip Impact
Location 1	1.5%	0.3%	0.4%

Location 2	2.3%	0.7%	0.9%
Location 3	1.3%	1.1%	1.4%
Location 4	1.1%	0.3%	0.4%
Location 5	2.8%	0.8%	0.9%
Average	1.8%	0.6%	0.8%

Location 1,2,4,5 have a low pass-by trip impact on the adjacent road than location 3. Locations 1 and 4 have a low impact, Locations 2 and 5 have a high similar impact and location 3 has a height impact from the diverted trip generation to the supermarket. The primary trip impact on the road network is high than the pass-by trips and diverted trips except in location 3.

A high diverted trip impact will happen in location 3. Further, the pass-by trip impact is lesser than the primary trips and diverted trips. As per the statistics, on average a 1.8% primary trip impact, 19.2% pass-by trip impact and 24.5% diverted trip impact will be happened to the existing road network by a supermarket in Colombo, Sri Lanka. The findings of this study clearly show that diverted trip impact is high at supermarkets in Colombo than pass-by trip impact.

To gather information on supermarket customers' travel habits, face-to-face interviews were conducted. The primary, pass-by, and diverted trips made by five supermarkets in Colombo were examined using this data. The survey findings in numerous supermarkets indicated that a variety of factors influence the primary, pass-by, and diverted trip rates of various spots. It was shown that the survey time also affected the findings. Pass-by trips were found to be the highest during the weekdays (evening). The peak of the weekend days showed that the top tours made were the primary trips. The number of trips that are diverted was seen to be influenced by the distance between supermarkets and the closest major road. The number of diverted trips was observed to decline as the distance to the closest alternative route rose. Distances to competitive supermarkets also affected diverted trips. It was found that the type and size of the supermarket affect the travel rate. The number of primary trips would increase as the supermarket's floor area rose.

5. Conclusion

The objective of this study is to figure out what percentage of primary, pass-by, and diverted trips are created by a supermarket in Colombo, Sri Lanka. Pass-by or diverted trips accounted for 43.7% of trips on average. Supermarkets in Colombo, Sri Lanka, will generate an average of 56.3% primary trips, 19.2% pass-by trips, and 24.5% diverted trips, according to statistics. The outcomes of this study reveal that supermarkets in Colombo generate a higher proportion of diverted trips than pass-by trips. Statistical analysis has identified several factors that may contribute to the type of trip.

The location of the supermarket was found to have a significant impact on the proportion of primary, pass-by, and diverted trips. The proximity of the supermarket to roadways with high daily traffic volumes had a significant impact on the trip generation. Further, the time of day, the size of the supermarket, the type of supermarket, and the proximity of competitors are other factors to influence trip generation. This study examines and anticipates probable transportation and traffic problems. Since there hasn't been a thorough investigation of this topic in Colombo, this study is useful transport decisions travel demand forecasting of a new development. Further, it is recommended to use same methodology to calculate trip rates for locational-specific sites to better decisions makings. Finally, it is recommended that primary trip rates, pass-by trips rates and diverted trip rates of a supermarket in Colombo should be validated by application of enough case studies and adjustments could be done accordingly in future for better accuracy level, as this study is limited to five case studies.

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