Samarawickrama, Sumanthri, et al (eds), 2019, "Re-evaluating Space across disciplines": *Proceedings of the 12th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka, December 03, 2019 Colombo* pp. 202–209. ©

REVIEW OF SUITABLE PARAMETERS AND METHODOLOGIES TO DELINEATE THE TRAFFIC IMPACT AREA FROM A PROPOSED DEVELOPMENT IN SRI LANKAN CONTEXT

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Abstract
An upcoming development usually generates both vehicles in and out to the accessible and adjacent roads and junctions. Therefore, most countries have adopted different planning and building regulations and guidelines to manage them in advance. Although, there is a vast positive movement in guidelines in Sri Lanka as well, still doubtful areas could be observed in delineating the traffic impact area properly. A 500m buffer area from the proposed site is currently taken as the minimum study area at developing the traffic impact assessments which is mentioned under the Term of Reference (TOR) in Sri Lanka. The geographical extent of the traffic impact area is not a fixed boundary, which could be changed especially based on varieties of parameters. Therefore, a fixed boundary may misdirect the developers, consultants and planning authorities at the decision making in transport planning circumstances. Thus, many studies have gone wrong due this very subjective selection. Therefore, many scholars in the transportation field and its allied disciplines argue the importance of developing suitable parameters and methods to delineate the traffic impact area for each development uniquely. Only a few number of models, techniques, and algorithms would be observed on this subject from present assessments. Hence, the objective of this research is to review relevant methods and parameters from past studies and to select the most suitable parameters and methods for delineating the traffic impact areas for proposed developments in the Sri Lankan context. Most suitable parameters and methodologies were identified through the Snowballing technique and multi-criteria analysis for delineating the extent of the traffic impact area from a new development.

Keywords: *Delineate, Methodologies, Parameters, Proposed Developments, Traffic Impact Area*

1. Introduction

A proposed development automatically generates the vehicle demand to the main accessible and adjacent roads and connected nearby junctions (Weerasekera, 2011). Therefore, a new development or expansion of existing development or redevelopment influences on the extent of the traffic to the external environment (Land Transport Authority, 2011). If it is not properly managed, problems would be more and worse (Ponnurangama & Umadevib, 2014). Therefore, the traffic generation from an upcoming development should be properly identified and managed.

Once identifying this, different countries have adopted different planning and building regulations and guidelines in order to identify negative effects and avoid them in advance (Cooley, Gruyter, & Delbosc, 2016). A Traffic Impact Assessment (TIA) is a study that is required to conduct as per the guidelines to obtain the development permit for a new development. It determines the possible traffic impacts to the surrounding transport network from the proposed development and it acknowledges the developer by recommending the remedial measures to erase them (Teodoro & Regidor, 2005).

In Sri Lanka as well, mega-developments should be accompanied by Traffic Impact Assessments as stipulated in parking & traffic control (Regulation 34, Schedule III) under the City of Colombo Development Plan (Amendment, 2008) in order to obtain the development permits. Although there is a vast positive movement, doubtful areas still could be visible in some subject areas mentioned under the Term of Reference (TOR) (Director, Enforcement Division of Urban Development Authority, 2019). One of them is the delineating the traffic impact area properly, where it is currently taken as the 500m buffer area from the proposed site. Moreover, a fixed impact area is adapted by many countries (Ponnurangama & Umadevib, 2014) like Malaysia (Ministry of Public Infrastructure & Land Transport, 2015), Singapore (Land Transport Authority, 2017), Australia (Department of Planning, 2016), Mauritius (Ministry of Public Infrastructure & Land Transport, 2015), New Zealand (Abley, Durdin, &

Douglass, 2010), and United Kingdom (Department for Regional Development (DRD) & Department of the Environment (DOE), 2006) as the study area under own their TIA guidelines and Term of References (TOR). However, extent of the traffic impact area is not a fixed boundary, which varies in their range of parameters depending on the development types, size (Abley, Durdin, & Douglass, 2010), location of the development (Ponnurangama & Umadevib, 2014), surrounding land uses (Weller, 2007), road network, vehicle flow concentration (Wen T., Chin W., & Lai P., 2017), intersection performance (Cooley, Gruyter, & Delbosc, 2016), surrounding developments and considerable distance from the site (Land Transport Authority, 2017) etc. Therefore, a fixed boundary may misdirect the developers, consultants and planning authorities at the decision making in transport planning circumstances.

Although various national and regional TIA guidelines are available in most countries regarding the study area limits, there is a little understanding of the flexible extent of impact area in their guidelines and the practices for the traffic impact analysis (Cooley, Gruyter, & Delbosc, 2016). Moreover, a minimum study area is included in the guidelines based on the size and land use of the development in few cases such State of Utah (Utah Department of Transportation, 2015), Indiana (Indiana Department of Transportation, 2015), Arizona (Town Council Of Buckeye, 2012), Minnesota (New Prague City Council, 2010) and City of Visalia (Community Development Department, 2019) etc. in United States.
A minimum impact area or study area limit should be recommended in the TIA guidelines and TORs as a major component (Weller, 2007). Thus, it should be clearly defined the flexible study area limit for understanding how far a proposed development will impact (Cooley, Gruyter, & Delbosc, 2016). Otherwise, many studies will be gone wrong due to this very subjective selection. Hence, many scholars in the transportation field and its allied disciplines argue the importance of having a new method to identify the traffic impact area for each development uniquely.

Only few models, techniques and algorithms would be observed for identifying and delineating the impact areas from present assessments such as Flow-based PageRank (FBPR) and network modularity algorithms (Wen T., Chin W., & Lai P., 2017), V2V-based method (Wang R., Xu Z., Zhao X. & Hu J, 2019), GIS techniques, spatial multi-criteria analysis and fuzzy logic (Rashed & Weeks , 2003), GIS, GPS and Accelerometry (Yin , et al., 2011), GIS software, trajectory model, Multivariate cluster analysis model and Oil Spill Risk Analysis Model (OSRAM) (Guillen, Rainey, & Morin, 2001), GIS technology with GFLOW software, U.S. EPA's WhAEM software and Analytic Element Models (Raymond, et al., 2006) etc. But, all these studies were based on specific and subjective criteria, unique geographical locations and no general models or algorithms could be observed especially for developing countries. Hence, the objective of this study is to review the available methods and parameters from past studies and select the most suitable parameters and methods for delineating traffic impact areas for proposed developments in the Sri Lankan context.

2. Literature Review

Unplanned development is a serious issue, due to the unbalanced traffic congestion in most countries (Azra & Hoque, 2014). Therefore, TIA has become a necessity to implement in the most developed and developing countries. Vehicle attraction is habitually increased to the surrounding road network from each new construction activity (Khade, Khode, & Bhakhtyapuri, 2017). Therefore, traffic impact levels from every new development effect on the adjacent roads and intersections. Although a TIA is a proper tool for the decision-makers to make decisions on new developments, it is difficult to delineate the direct impact area from a new development in both developing and developed countries like Bangladesh (Azra & Hoque, 2014), Philippine (Teodoro & Regidor, 2005), Canada (Engineering and Capital Infrastructure Services Infrastructure, Development & Enterprise, April 2016), China (Weller, 2007) and United Arab Emirates (Department of Transport, November 2009) etc., as most them are adopted the TIA "recently or yet to be institutionalized" (Azra & Hoque, 2014).

Few cases have been adopted the fixed standards for delineating the direct impact area from the proposed development. The Land Transport Division of Ministry of Public Infrastructure & Land Transport in Malaysia under the Traffic Impact Assessment Guideline (2015) explains that the study area should be a 1km radius adjacent to the site (Ministry of Public Infrastructure & Land Transport, 2015). All the access roads, nearby roads and junctions within a 1km radius from the edge of the site should be studied as the direct traffic impact area under the guidelines in Mauritius (Ministry of Public Infrastructure & Land Transport, 2015). Although having a fixed impact area under the regulations, the consultants should discuss the extent of the study area with the approval agency.

The size of an impact area will vary on each development (Weller, 2007) and it is not a fixed boundary for each proposal (Abley, Durdin, & Douglass, 2010). The scale of the new development effects on the amount of traffic volume (Khade, Khode, & Bhakhtyapuri, 2017). Azra & Hoque (2014) explain that all new development generate adverse impacts such as traffic congestion, air pollution, and safety issues, etc. to the surrounding area and scope of the impact level depend on the size of the development. Thus, the Division of the Town of Caledon (2017) argues that the extent of the study area will depend on the size and nature of the proposed development. Accordingly, in some states of the United States, specific standards were defined clearly to demarcate the study area in their TIA guidelines based on the size and type of the development (Azra & Hoque, 2014). State of Utah (Utah Department of Transportation, 2015), Indiana (Table 1) (Indiana Department of Transportation, 2015), Arizona (Town Council Of Buckeye, 2012), Minnesota (Table 2) (New Prague City Council, 2010) and City of Visalia (Community Development Department, 2019) are real examples for it.

Table 1, Study Area Limits for Transportation Impact Analysis in Indiana, United State *(Source: Indiana Department of Transportation, 2015)*

Development	Study Area
Fast – Food restaurant Service station with or without fast-food counter Mini-mart or convenience grocery with or without gas pumps Other development with fewer than 200 trips during any peak hour	Adjacent intersection if corner location Adjacent intersection if corner location 600 ft. from access drive 1,000 ft. from access drive
Shopping center less than 70,000 sq.ft. Or Development w/peak-hour trips between 200 and 500 during peak hour	All signalized intersections and access drives within 0.5 miles from a property line of the site and all major un-signalized intersections and access drives within 0.25 miles
Shopping center between 70,000 and 100,000 sq.ft. GLA Or Office or industrial park with between 300 and 500 employees Or Well balanced mixed-use development with more than 500 peak-hour trips	All signalized and major un-signalized intersections and freeway ramps within 1 mile of a property line of the site
Shopping center greater 100,000 sq.ft. GLA Or Office or industrial park with more than 500 employees Or All other developments with more than 500 peak-hour trips	All signalized intersections and freeway ramps within 2 miles of a property line and all major un-signalized access (street and driveways) within 1 mile of a property line of the site
Transit Station	0.5 mile radius
ft = feet, sq.ft.= square feet, GLA=Gross Leasable Area	

Table 2, Minimum Study Area Guidelines in Minnesota, United State *(Source: New Prague City Council, 2010)*

Development Characteristics	Minimum Study Area
Small Development (100-499 peak trips)	Site Access Drives, Adjacent signal controlled intersections within ¼ mile and/or major street intersections without signal control and driveways within 500 feet.
Moderate Development (500-999 peak trips)	Site Access Drives, All signal controlled intersections within ½ mile and/or major street intersections without signal control and major driveways within ½ mile.
Large Development (1,000-1,500 peak trips)	Site Access Drives, All signal controlled intersections within 1 mile and/or major street intersections without signal control and major driveways within 1 mile.
Regional Development (>1,500 peak trips)	Site Access Drives, Key signal controlled intersections and major street intersections without signal control within 3 miles.

In case of Singapore, still within 400m & 800m walk radius and 2km cycling radius are used for the study area delineation of TIAs (Land Transport Authority, 2017). Further, the Land Transport Authority also is to revise the standard based on the use and scale of the development. However, the same standards in other contexts are unable to apply as it is, due to the differences in travel characteristics, locational and geographic characteristics, socio-economic conditions, and cultures, etc (Azra & Hoque, 2014). The below table shows the traffic impact area standards of TIA guidelines.

Table 3, Case Studies of Standards and Methods for Traffic impact area delineation

ID	Country	Suggested Minimum Study Area / Impact Area	Classification on Development Characteristics	Source
01	Sri Lanka	Yes	No	(Urban Development Authority, Sri Lanka , 2018)
02	United Arab Emirates	No	No	(Department of Transport, November 2009)
03	Canada	No	No	(Engineering and Capital Infrastructure Services Infrastructure, Development & Enterprise, April 2016)
04	Malaysia	Yes	No	(Ministry of Public Infrastructure & Land Transport, 2015)
05	Singapore	Yes	No	(Land Transport Authority, 2017)
06	Australia	Yes	No	(ACT Government & Transport Canberra and City Services (TCCS), August 2016) (Department of Planning, 2016)
07	Mauritius	Yes	No	(Ministry of Public Infrastructure & Land Transport, 2015)
08	Bangladesh	No	No	(Azra & Hoque, 2014)
09	State of Utah, United State	Yes	Yes	(Utah Department of Transportation, 2004) (Utah Department of Transportation, 2015)
10	Indiana, United State	Yes	Yes	(Indiana Department of Transportation, 2015)
11	Arizona, United State	Yes	Yes	(Town Council Of Buckeye, 2012)
12	Minnesota, United State	Yes	Yes	(New Prague City Council, 2010)
13	Wisconsin, United State	No	No	(Bureau of Traffic Operations, 2019)
14	City of Norwalk, California, United State	Yes	No	(Norwalk Transportation Management Plan)
15	City of Visalia, California, United State	Yes	Yes	(Community Development Department, 2019)
16	City of Aspen, Colorado, United State	Yes	No	(City of Aspen)
17	Hong Kong, China	No	No	(Weller, 2007)
18	New Zealand	Yes	No	(Abley, Durdin, & Douglass, 2010)
19	Philippine	No	No	(Teodoro & Regidor, 2005)
20	London, United Kingdom	No	No	(Department of Transport, March 2007) (IBI Group and City of London, 2012) (Weller, 2007)
21	Northern Ireland, United Kingdom	Yes	No	(Department for Regional Development (DRD) & Department of the Environment (DOE), 2006)

It is vital to review and amend the TIA guidelines by understanding the operational requirements in a city (Cooley, Gruyter, & Delbosc, 2016). Without a proper standard or method, the consultants are unbaled to develop a proper TIA study (Azra & Hoque, 2014). Hence, this research purpose to identify the suitable parameters, existing standards, models and techniques to assess the direct traffic impact area from a proposed development.

3. Methodology

The first step of this research was the identification of the parameters to change the extent of the impact area, due to a new development by reviewing the past studies. The second step identified the available models/algorithms/methods/techniques/ standards for delineating the traffic impact area from a proposed development by considering the present planning and building regulation guidelines and the published past studies and evaluated them by case studies. The final step identified the most appropriate methods and parameters by using the snowballing technique and multi-criteria analysis. Here, the proposed study area is the Western Province of Sri Lanka, which presents a high correlation between land-use change and existing transportation issues in Sri Lanka as the commercial capital of Sri Lanka. Hence, this paper will support decision makers to use it easily and effectively for generating accurate decisions in the planning process further.

4. Analysis and Results

New traffic will be generated due to construction around it. Thus, Yayat K.D., Kombaitan B., Pradono & Purboyo H.P.H. (2015) explain that the size of the building also affects the road network and intersections around the development. The high number of development could be generated huge traffic (Yayat K.D., Kombaitan B., Pradono, Purboyo H.P.H., 2015). The size of the catchment area from a proposed development will depend on the surrounding transport network, modes of transport facilities, intersections and road link performance and scale of the activity and trip generation of the new development (Cooley, Gruyter, & Delbosc, 2016). Thus, Sarkar, Maitri, & Joshi (2015) illuminate that topographical barriers, connectivity of road network, nearby trip attraction points and population density around vary on the traffic impact area limits.

Trip generation from a new development, existing traffic condition on the nearby roads and junctions (Ministry of Public Infrastructure & Land Transport, 2015), access points to the site (Indiana Department of Transportation, 2015) and distances from the site (Land Transport Authority, 2017) also may depend on extent of the traffic to delineate the study boundary. The availability of bare land or vacant land and its changes can be used as an indicator to change the traffic impact area (Chen Y. & Liu A., 2019). Further, road classification, width, and the number of lanes of the access road effect on the extent of the traffic generation (PMK Associates, Inc., July 2006). Thus, walking distances to public transport connections may determine the extent of the traffic impact area from a new development (National Roads Authority, 2014). Transport related infrastructure developments such new developments or alterations or improvement of roads and intersections, shared paths, crossovers, pedestrian routes, cycle routes, public transport routes, bus routes or bus stop locations (Department of Planning, 2016) and intersection control type which means signalized or un-signalized (Department of Transport, March 2007) would be affected to enlarge or reduce the boundary of the traffic impact area of a new development.

Partition of traffic zones is an important indicator to analyze and predict the traffic flow on the surround road network in a city (Zheng, Zhao, & Liu, 2015). Accordingly, a traffic distribution model with simulation have been developed by the Yang, Wang, & Chen (2007) to analyze and predict the micro and macro traffic flow on the road network for TIAs by using Geography Information System (GIS) and Voronoi diagrams for detecting the traffic analysis zone (TAZ) and the Multiplicative Competitive Interaction (MCI) model for estimation of new OD matrix.

Cluster methods are used as the traditional method for the division of traffic zones through the location points in past studies. Zheng, Zhao, & Liu (2015) have developed a Novel grid-based K-Means cluster method to identify the clear and accurate traffic zones based on the simple cluster analysis. However, Taxi GPS data is the only parameter taken for this research for traffic zone divisions. Although the four-step forecasting and sketch-level forecasting are common two delineating methods of Transit Traffic Analysis Zone (TTAZ), Wang, Sun, Rong, & Yang (2014) have proposed the Thiessen Polygon to divide the study area into TTAZs. Thus, Shen, Liu, & Chen (2017) used geospatial statistical methods to analyze location-based data through the Thiessen Polygon, Moran's I index, Hot spot analysis and Global Positioning System (GPS). The Thiessen Polygon has been used to divide the study area into small plots to detect the spatial distribution of vehicle pickup and drop-off points. The Moran's I index was to identify the spatial correlation of the distribution of vehicle pickup and drop-off points. Hot spot analysis was used to find the spatial clusters of pickup and drop-off location points. And, pickup and drop-off locations were recorded by the GPS. But, this research has been adopted only taxi-based Floating Car Data (FCD) and ignored the holidays and positional error of vehicle pickup or drop-off plots to identify the human spatial pattern in the city. Thus, land uses such as rivers, lakes, and mountains in the study area were not considered to build the Thiessen polygon. However, GIS can be used to demarcate the traffic impact area by adapting the location-specific characters (Shen, Liu, & Chen, 2017).

The Regression Model (Khade, Khode, & Bhakhtyapuri, 2017) and the scorecard approach (Cooley, Gruyter, & Delbosc, 2016) are applied to evaluate the traffic growth rates at present and future scenarios. Analogy Method, Gravity Model Method, Market Area Analysis and Origin-Destination Method (Bureau of Traffic Operations, 2019) estimate the trip distribution based on land use and locational characteristics to delineate the traffic influence area of the surround transport network.

Different impact delineation models and techniques could be observed in not only the transport-related but also in other subject areas. Meanwhile, as same the TIA studies, the boundary of the study area for an Environment Impact Assessments (EIA) have been delineated through the different methodologies under own their Terms Of Reference (TOR). The legal requirement in India is based on the Environment (Protection) Act, 1986, the Environmental Impact Assessment Notification, 2006 (amended 2009), and it has clearly mentioned the 10km radius from the site is the catchment area to be studied by the consultants (Government of India Ministry of Environment & Forests, New Delhi, India). Accordingly, an EIA study for a proposed bridge in Bihar, India has been taken a 2 km buffer area as the direct impact area and up to 10km buffer area as the indirect impact area (Bihar State Road Development Corporation Limited, Government of Bihar for the Asian Development Bank, 2016). Thus, the minimum study area has been delineated within 3 km radius from the proposed site under the TOR of the EIA for the proposed resort development at Big and Little Pelican Cay Portland Bight, St. Catherine in Jamaica (Terms Of Reference for an Environmental Impact Assessment for a Proposed Resort Development at Big and Little Pelican Cay Portland Bight, St. Catherine, Jamaica, 2011).

Flow-based PageRank (FBPR) and network modularity algorithms (Wen T., Chin W., & Lai P., 2017), V2V-based method (Wang R., Xu Z., Zhao X. & Hu J, 2019), GIS techniques, spatial multi-criteria analysis and fuzzy logic (Rashed & Weeks , 2003), GIS, GPS and Accelerometry (Yin , et al., 2011), GIS software, trajectory model, Multivariate cluster analysis model and Oil Spill Risk Analysis Model (OSRAM) (Guillen, Rainey, & Morin, 2001), GIS technology with GFLOW software, U.S. EPA's WhAEM software and Analytic Element Models (Raymond, et al., Using Analytic Element Models to Delineate Drinking Water Source Protection Areas, 2006) etc.

A GIS methodology has been developed by Rashed & Weeks (2003) using spatial multi-criteria analysis and fuzzy logic to assess the spatial vulnerability to the earthquake hazards in urban areas. Raymond et al (2006) used the GIS technology with GFLOW software, U.S. EPA's WhAEM software and Analytic Element Models to delineate the size and shape of the drinking water source protection areas. Guillen, Rainey, & Morin (2001) have used the GIS software, trajectory model, Multivariate cluster analysis model and Oil Spill Risk Analysis Model to delineate the common oil spill risk area. GPS, GIS, and Accelerometry are used to identify the physically active land areas within the neighborhoods in Erie County, New York (Yin, et al., 2011). Nelsona, Long, Laberee, & Stewart (2015) used GIS and GPS technologies to detect the slow-moving areas of grizzly bears in Alberta, Canada. Pelot & Plummer (2009) applied to delineate the marine protected area by using the GIS technique.

5. Conclusion

The objective of this study was to recognize the most suitable parameters and methods for delineating the traffic impact areas from a new development. The findings of the study indicated that the Geography Information System (GIS), Global Positioning System (GPS), Thiessen Polygons, Regression Models, Multivariate cluster analysis model, Hot spot analysis and Spatial Multi-Criteria Analysis could be identified as the most adopted spatial distribution methodologies to delineate the extent of the traffic impact area from a new development. Further, the findings emphasized the development type and the scale, location, lands use pattern around, modes of transport facilities, nearby trip production points, population density, and prevailing traffic conditions on the road network have a high correlation with the extent of the traffic impact area from a new development. However, the reliance on the results and assumptions and the homogeneous of parameters are the problems associated with available models and techniques in past studies, when directly adapting them to the local context. Thus, many researchers in the transportation filed argue the importance of having a new technique to delineate the traffic impact area for each development uniquely. Hence, this study direct to develop a spatial and dynamic model to demarcate the traffic impact area from a new development at the decision making in transport planning circumstances.

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