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EQUITY OF TRANSIT NEED IN BAGHDAD CITY

Summary. Public transportation plays a significant role in urban areas, transporting a large percentage of people. There is no existing study dealing with the balance between transportation demand and supply in Baghdad city; thus, there is a need to assess service equity before implementing any major services. The aim of the present research is to study the equity of transit need. The methodology uses geographic information systems (GISs) and spatial multi-criteria analysis to determine equity. Nine criteria were used in this study (land use, population density, commercial activities, medical locations, bus stops walkability, educational activities, bus terminal, and income) to determine a transit need map. Expert opinion surveys are conducted to determine pairwise comparisons between these criteria to estimate the weight of each criterion. Spatial analysis in ArcGIS 10.8 is utilized to apply methodology. The transit need map is obtained, and the need for transit service is represented by a value for each cell. In addition, the map output is important to public transit planning, as it maximizes the optimal transit route selection depending on the transit need. The output of this study (a transit need map) represents a powerful tool for the decision-makers to prioritize transportation programs and ranking alternatives. Gap analysis is used to measure equity between various zones. The results show that the transit supply provides higher service coverages in the Central Business District (CBD) and decreases as the distance to CBD increases.

1. INTRODUCTION

An urban area involves many origins and destinations with various traffic trends, which, in turn, result in complex transportation systems with multiple modes. Urban sprawl is a phenomenon that has arisen recently in cities and has been accompanied by the use of modern transport modes (e.g., metros, tramways) that travel over long distances [1, 2]. However, today, one of the challenges faced by cities is to transport between various urban opportunities without restrictions. Accessibility is a measurement between land use and transport, and it is a key measure to evaluate public transport performance and an indicator to assess transport policies [3]. In sustainable development, accessibility is of the utmost importance and is used as an indicator to measure spatial analysis of activities and people, urban policy, density, and urban form [4]. Due to concerns about traffic congestion and air pollution, which result from the full reliance on using a private vehicle, there is large interest today in increasing public transport efficiency and transit equity for different areas [5, 6]. Through recent accessibility studies, public transport accessibility by various modes has been an interesting issue in recent years [7].

Transportation is a demand that is heavily influenced by the surrounding environment and the environments of destinations, which creates an issue of how access a place from other locations [8].

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The desired destination depends on the spatial distribution of activities and the availability of transportation infrastructure around them. Public transportation systems serve two types of user groups. The first group is those who cannot own a car and do not have access to non-motorized modes; the second group is those who prefer using public transit to driving [9]. [10] measured transit need using spatial analysis by weighting socioeconomic factors and correlating them with a transit suitability map to create an index model. The transit accessibility was evaluated by an index model and was determined by aggregating transit and land use elements. After a comparison between the accessibility index and transit need was made, the equity of Boulder's public system was identified. The results demonstrate that Boulder's transit system is principally equitable, although there are a few inequitable high-need areas that lack accessible transit.

In other research, [11] developed a set of procedures for estimating transit need using secondary data sources and identified specific areas that have notable unmet needs that can be used to design actual services catering to the travel desires of residents. As stated by [12], "calculating employment accessibility identifies poor area with a high transit-dependent group that also suffers from inadequate service." Workers who use public transport to get to their places of work are mostly concentrated in the southwest part of the 10-county Atlanta region, which is comprised of predominantly low-income census tracts. To measure transportation equity, [13] studied the spatial distribution of public supply and public transport demand. Lyons and Choi (2021) [14] carried out a study that measured the transit equity of a multimodal network in the U.S. and developed an index that depended on travel speed to an assessment of work travel trips for all users. The results revealed that the transit system is equitable. Abdoli (2021) [15] analyzed the gap between the volume of demand and public transit supply at the traffic analyses zone (TAZ) level in Jefferson County. He concluded that transit supply is concentrated in the inner-city, while transit gaps appear on the west side of the city.

Equity is an important concept because, as the literature states, accessible transit is critical to long-term mobility and sustainability in the city. Public transportation accessibility provides easy access to different land uses, and its efficiency is represented by transporting a large number of people between different areas and balancing with economic scale. Public transit planning must be accomplished in an effective, advanced, and comprehensive way to make the service efficient, sustainable, and profitable. Locally, few transit system studies have been done, and there is no research concerning transit need, accessibility, and equity. Therefore, the current research combines all three topics into one measure model. Thus, this research fills the gap in the local literature; also, this approach can be utilized as a tool for transit service planning.

In recent years, Baghdad city increased its population growth, which was accompanied by high car ownership, which reached 3.5%, meaning that transport across the city became associated with long travel times and high congestion [16]. The existence of major facilities and large economic activity zones led to significant travel needs in this area. Public transport, which is represented solely by buses, needs to become more efficient [17]. Transit equity is an important value, especially in Baghdad city, due to its increasing growth and various commercial activities. In this research, geographic information systems (GIS) and a spatial multi-criteria analysis represented by an analytical hierarchy process (AHP), are used to develop a systematic technique in public transit planning. In order to maximize the effective service area and serve as many transit-supportive areas as possible, thus making the service more sustainable. This methodology investigates inaccessible areas and tries to optimize transit planning through the creation of a transit need map consisting of a GIS analysis concerning demand, supply, and equity. This paper is intended to assess public transit equity by applying a spatial accessibility indicator.

2. STUDY AREA

The area of interest of this research is Baghdad city, which has faced a high level of urban sprawl because it is the capital political, administrative, and economics of Iraq's provinces. It ranks first among the governorates of Iraq in terms of population, with a population of about 8.4 million in 2016. The Baghdad region is grouped into two parts – Karkh and Rusafa – which are separated by the Tigris

River. Significant travel needs arise due to the high economic activity in this area and the appearance of major activities. Baghdad city has an extensive bus system, which consists of local and regional bus routes in the city. Bus networks represent the backbone of the transport system in this area, as the transit system represented by trains was not constructed due to political and financial issues over 20 years ago. Transport infrastructures do not highly change from the end of 1980 in the Baghdad country through until now, although large concentrations of populations, activities, and services have occurred alongside urban expansion towards the periphery. The highest population value is recorded in Sadar City, and the lowest population is recorded in the outskirts of the city. The bus network, which is the backbone of public transport through the city, has good coverage in some places but insufficient or weak coverage in other zones. Due to considerable population increases, these data were used to estimate accessibility to public transport. The population data were obtained by the central statistical organization [18]. Data related to highway and transport systems were collected from state company of private transport / ministry of transportation.

3. DATA COLLECTION

The current analysis uses the need gap method to identify equity gaps in terms of measured transit access by GIS and utilizes socioeconomic, demographic, and geographic information to spatially categorize groups concerning transit need infrastructure. The transit need was determined by a GIS spatial analysis.

Transit supply can be calculated by estimating accessibility that defines the ease of reaching land uses by the city transit system. After these measures were produced, the transit needs and accessibility maps were compared to determine transit equity.

The present research measured accessibility through transit stop access and access to destinations using public transport. Accessibility was estimated according to service area using network tools in ArcGIS. The bus stop service areas served as the independent variables, while transit accessibility was the dependent variable in the analysis. The bus stop service areas were used to calculate the access to transit infrastructure; this access was measured based on acceptable walking distances through the pedestrian network. The Federal Transit Administration (FTA) suggested a distance of 1/4 mile around bus stops to reach stops [19]. The service areas method better represents access to opportunities than other methods, such as methods based on a buffer. Data imported from various sources were collected to create the work database, which includes population and demographic information that was sourced from the Central Statistical Organization. Criteria that affect the equity of transit systems, such as spatially dispersed opportunities (education, job opportunities, business activity, or services) or factors, such as demographics or geographic factors, are considered when producing transit need maps.

The existing public transport network, which defines the transport supply along the entire study area, was defined using a field survey. All data were collected using ARC GIS 10.8, as follows:

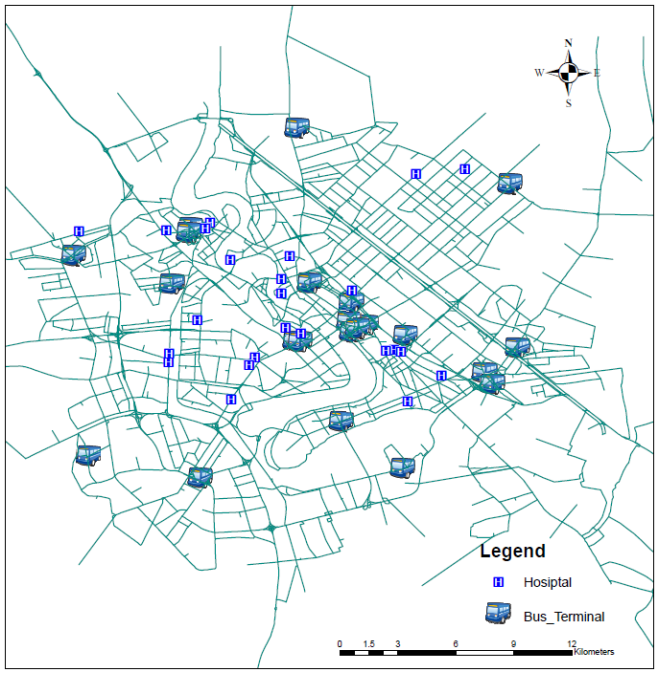
1. A layer of a highway network and its characteristics: length, travel time, speed, and type.
2. A layer of a public transport network consisting of route lines and their stops, which are connected to the pedestrian network.

All the required data were geocoded in a GIS environment. The data consisted of highway and public transport networks, which cover the whole area of study, as well as the links and nodes represented in the network. In the public transport network, the node is chosen to represent bus stops across the modelled network. For the GIS database, related attributes are represented by their length, type, and the time required to cross the link. In addition to the above geodatabase, the following data – including income, commercial centers, education facilities, hospital location, land use, public terminal point, and stops – were collected from different sources. All these data were created using the GIS database shown in Fig. 1.

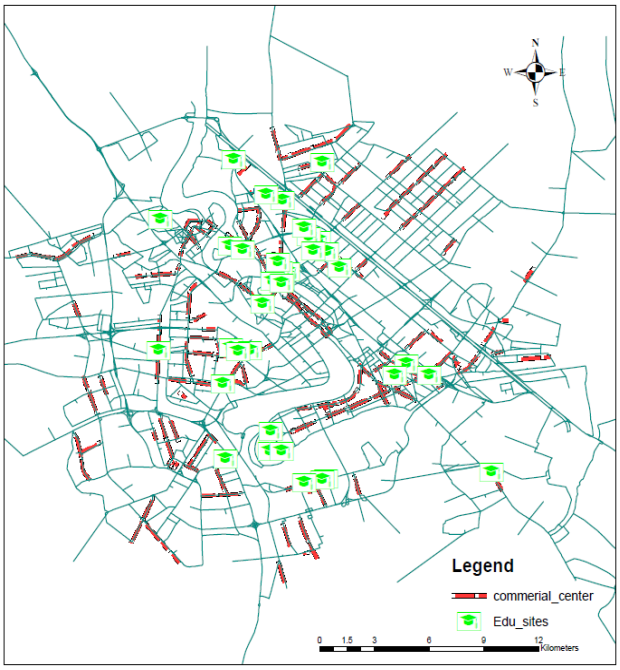
The transit need is measured by creating a GIS model that aggregates variables into a weighted map with an index score; a high score indicates a high transit need. The transit need was measured by spatially aggregating socioeconomic, geographic, and demographic factors related to transit need.

Afterward, variables associated with transit need were selected and exported into separate layer datasets. Each TAZ in the city was then classified in 10 quantiles and assigned the values of 1, 2, 3, 4, to 10 for each variable layer. The largest value (10) represented the highest quantile of the variable, and the lowest value (1) represented the lowest quantile of the variable. Higher quantiles were given higher values because they imply higher transit need (e.g., a TAZ with a higher percentage of individuals of low-income status are more likely to have high transit usage).

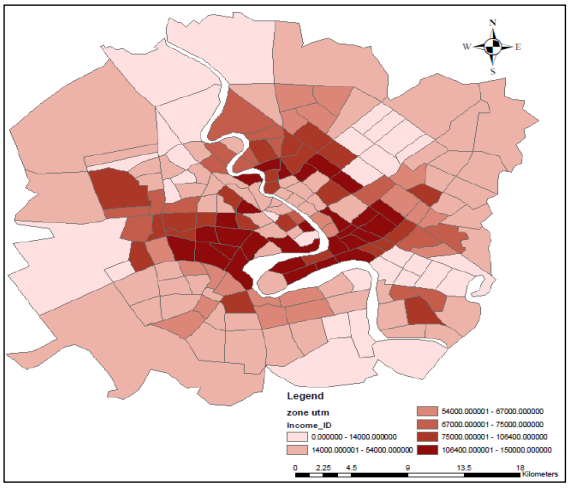
After each variable was quantified, they were each allocated a different weight, with higher weights signifying a higher correlation with transit need. The field calculator tool was used to aggregate the values and weights of each variable into one dataset model and index score, which illustrated the overall transit need of Baghdad city on a TAZ-level basis.



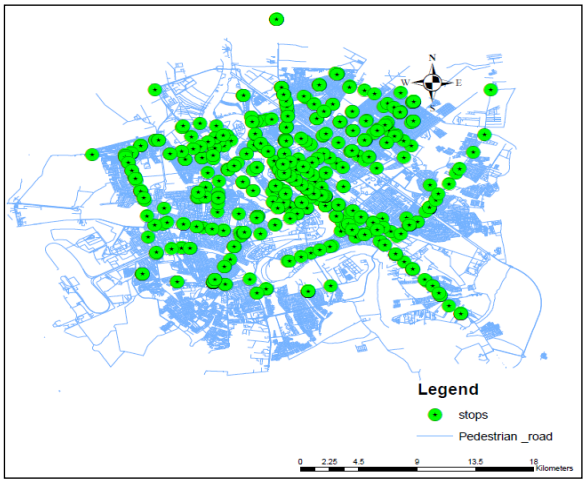
A: Spatial Distribution of Hospital Facilities and Bus Terminals



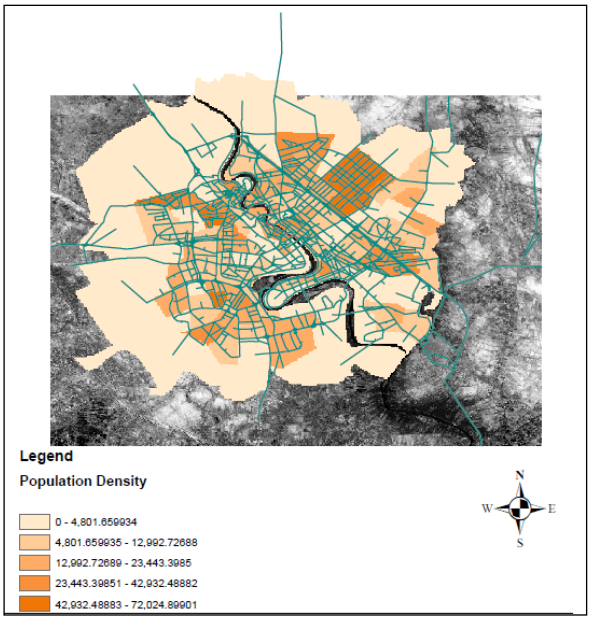
B: Spatial Distribution of Commercial Centers



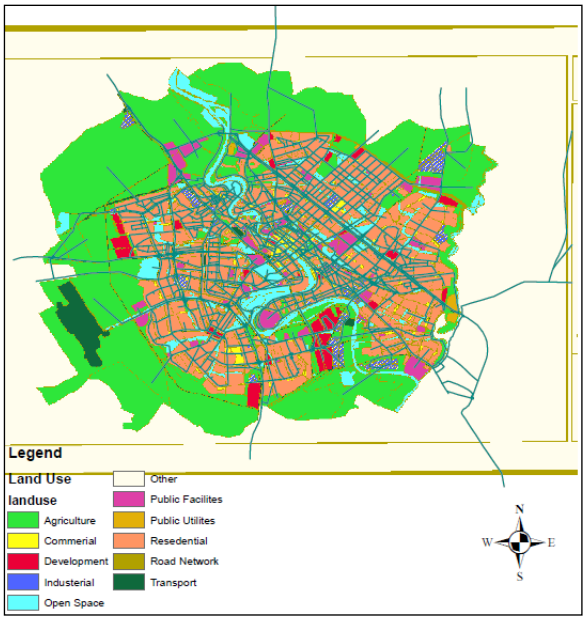
C: Spatial Distribution of Income per Zone



D: Spatial Distribution of Pedestrian Networks and Bus Stop Locations



E: Spatial Distribution of Population Density



F: Spatial Distribution of Land Use

Fig. 1. Criteria used for Generating the Transit Need Map

4. METHODOLOGY OF THE STUDY

Transit spatial equity is an important subject. It points out current spatial coverage of city areas and places that are difficult to reach, thus highlighting these places to improve access to them. Previous studies have used the gap analysis method [20]. This method highlights the difference between transport supply represented by accessibility and transit need represented by demand and helps to examine potential problems associated between land use and a transportation system. It is an effective tool that decision-makers can use to inspect the deficiency between land use and transport integration. It also identifies inaccessible places depending on the accessibility criteria and recommends improvements by extending and enhancing the transit network to it.

After the transit need and accessibility models were created, the equity of the transit system was evaluated by overlaying the two datasets. Zones were considered inequitable when the transit need outweighed the available transit supply, while zones with an available transit supply that exceeded the transit need were deemed equitable. After the inequitable zones were identified, solutions to improve the accessibility and, subsequently, the equity of these zones were established. These solutions were determined by examining the individual raster maps for each service area, which spatially summarized areas lacking access to bus stops or land use that should be accessible by transit.

Accessibility to public transport was measured by a GIS-based accessibility model that measures accessibility to different activities. Standard ArcGIS network analysis approaches were used to create the service areas where the trip origin and destination were assumed to be bus stops associated with its coverage area. A pedestrian speed of 4 km/h was assumed. A model builder in ArcGIS was used to build a transit need map around the city, and the various criteria mentioned above were used to create a transit need map as shown in Figs. 2 and 3. AHP is used to find the weights of the criteria, and a questionnaire was designed and given to decision-makers to obtain their opinions about pairwise comparison between different criteria used. Tab. 1 below shows the results of the pairwise comparison used in the weighted overlay to create a transit need map. Finally, the results are transit supply and transit need maps, which are used to evaluate transit equity around the city.

Table 1

Weight of criteria using AHP

Criteria	Income	Population	Commercial center	Hospital	Education	Terminal point	Stops	Pedestrian network	Land use
Weight	20	20	14	3	20	3	5	5	10

5. RESULTS AND ANALYSIS

The clear measurement of accessibility is reflected in a clear illustration of transit equity analysis. Once a transit need map is created, the deficiency in the spatial distribution of transit service can be measured [20, 21]. The results of the data analysis show that the zones with the highest transit need in the city are located centrally in the densest areas of the city. These areas have high to very high levels of transit need. The zones with the lowest levels of transit need are located along the edges of the city boundary. These areas have the lowest level of transit need because they are largely open spaces and, thus, have low-density populations that have little need for transit. Additionally, transit accessibility in the city gradually decreases as one moves outwards from the center of the city. Areas that have the lowest levels of transit accessibility are situated on the outer edges of the city but are largely low population and, therefore, are not served by bus routes, bus stops, and business/commercial land use. The results show that the transit supply provides higher service coverages in the central business district and decreases as the distance to downtown increases. The results from the GIS analysis show that the Baghdad transit system is equitable because areas of high transit need have high levels of transit accessibility. However, a few inequitable areas in the city contain high levels of transit need.

Bus routes, bus stops, and transit-accessible land use serve the majority of locations that have high transit need, particularly in central location CBD. However, there are locations along the perimeter of the city that encompass relatively lower transit accessibility than transit need and, therefore, are inequitable. Solutions to improve the equity of these areas are by the implementation of additional transit infrastructure, as well as increased access by transit to desirable land use (e.g., business, commercial, public, and parks). As shown by the transit need map in Fig. 3, the blue area experiences the highest levels of transit need in the area. Due to these results, it appears that areas with high transit need must be provided with transit systems with the highest transit capacities (such as metro), while the orange areas require light rail transit to meet the mobility needs of the region. Due to the high population of Baghdad city, especially in Al-Sader city, Al-Kadhimiya, Shuala, and the center of Baghdad, these places must provide high-capacity transit routes such as metro routes. In addition, existing public transport needs to be made more efficient through the use of modern buses with high capacity, giving this service priority in an intersection, and locating specific stops along routes.

Fig. 4 shows transit supply overlaid by the transit need map. Transit equity is measured by the difference between the transit need map and the transit supply map. It appears that the area around the downtown area is quite transit-accessible because public transit routes are laid out in a way that can connect CBD, which is the major activity in the city, with other locations provided to maximize accessibility and ridership.

6. CONCLUSIONS

The main conclusions of this work are as follows:

1- The transit need map was generated using GIS spatial analysis to maximize the population need (ridership).
2- Variables such as population, education, and income represent a high weight value and affect the transit need.
3- The area around the CBD area appears to be quite transit-accessible, but transit accessibility in the city gradually decreases as one moves outwards from the CBD.

4- The output of this study can be used by decision-makers to establish transit alternatives and prioritize transportation projects.
5- According to the transit need map, areas with high transit need should be provided with high-capacity transit systems, such as metro systems, to maximize transport efficiency.

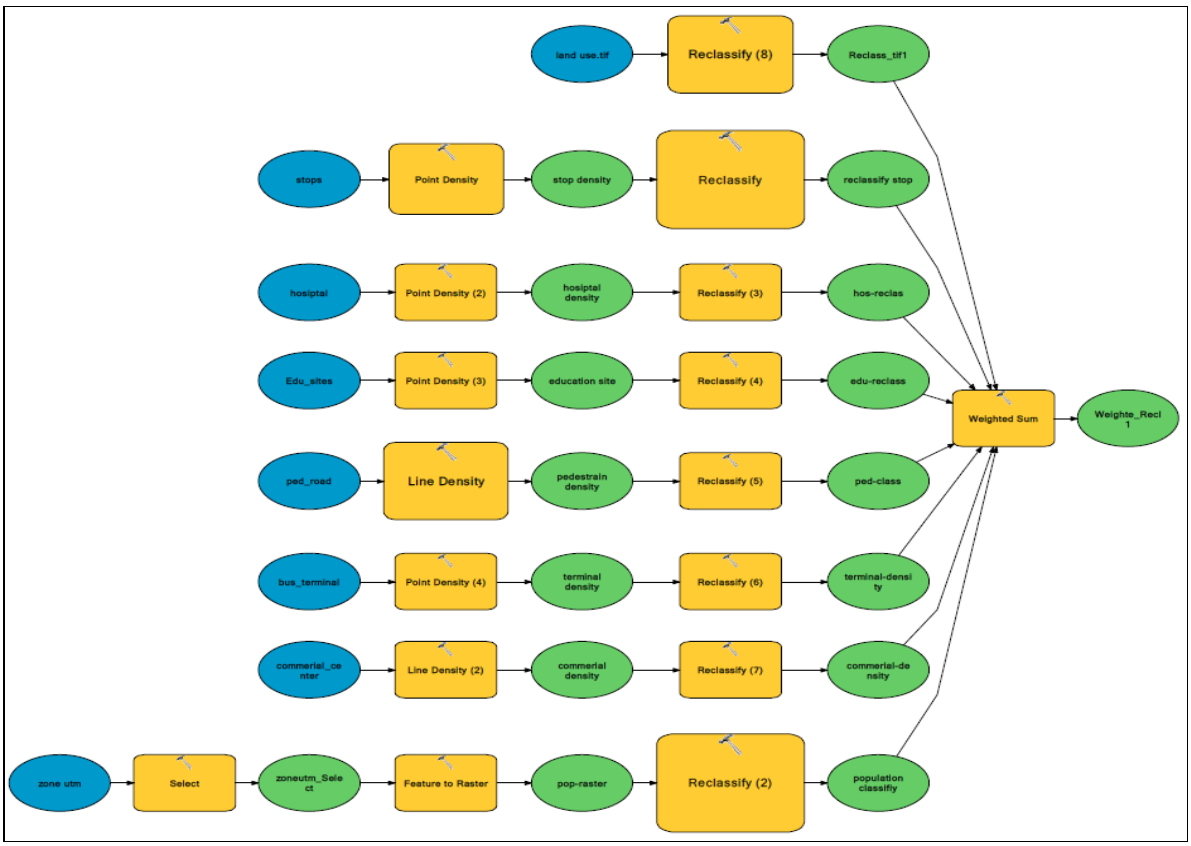


Fig. 2. Model Used to Generate Transit Need Map

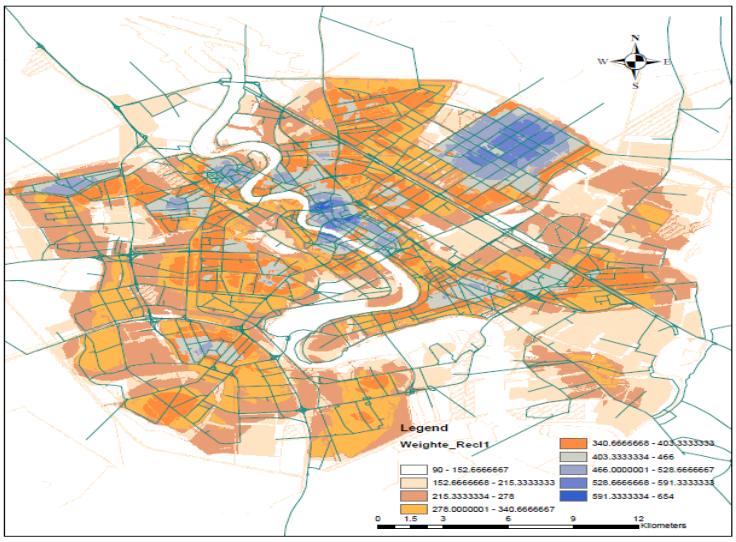
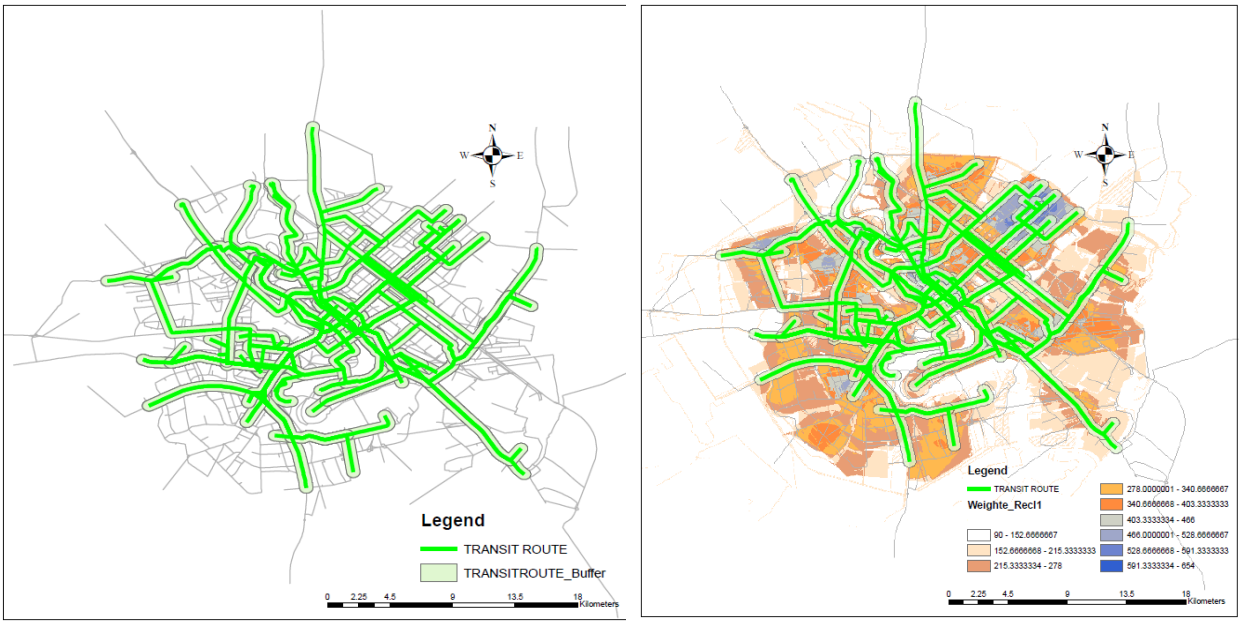


Fig. 3. Transit Need Map



a) Transit Supply b) Overlay of Existing Transit on Transit Need Map

Fig. 4. a) Transit Supply, b) Overlay Existing Transit on Transit Need Map

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