# Location-Allocation Model-Based Approach for Sheltered Bus Stops Site Selection in Port Arthur City, Texas

*Ratul Debnath, Sam Houston State University, Huntsville, Texas*




Port Arthur City Location

## INTRODUCTION

In this study, we propose a location-allocation model-based approach for the optimal selection of Sheltered Bus Stop Site, aiming to improve the efficiency and accessibility of public transportation systems in Port Arthur City, Texas. The methodology integrates geographic information systems (GIS) and advanced optimization techniques (location-allocation model) to identify the most suitable locations for transit stations while considering multiple factors such as population and demographics. The proposed approach is designed to enhance the overall effectiveness of public transit networks by minimizing travel times, reducing walking distances, and promoting the equitable distribution of bus transit stations across urban areas. With proper design, lighting, and security measures in place, transit stations can offer a safe and secure environment for passengers, reducing the risk of accidents or crime. In this study, we propose a minimum of fifteen transit stations to optimally cover most of the population, thereby improving safety, efficiency, and comfort for passengers.

## STUDY AREA

The study area for this research is Port Arthur City, located in southeastern Texas, along the Gulf of Mexico. This mid-sized city is characterized by a diverse topography that includes urban centers, residential neighborhoods, and industrial zones, alongside significant water bodies and wetlands.

## METHODOLOGY

The formula used in this study is referred to as the network-ratio formula (O'Neill et al.,1992).

The formula for calculating the population with access to transit using the network-ratio method is as follows:

$Ai=(Wi)/(Mi)*Pi$

where:

Ai = The population in analysis zone i with access to transit

Mi = The total length of street network in analysis zone i

Wi = The length of the street network within walking distance to transit in zone i

Pi = The total population of zone i.

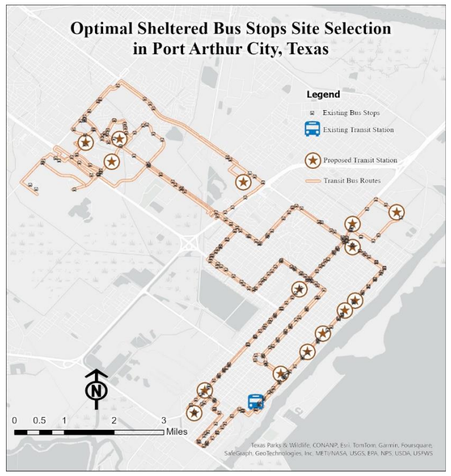
The methodology consists of four steps

**Step 1: Assigning demographic attributes to block centroids (Figure 3)**

A specific point must be selected as the initial location from which a pedestrian would depart the parcel to reach the bus route. Using the parcel's centroid serves as a reasonable approximation of this starting point. Consequently, the initial step in the parcel-network method involves generating centroid points for all parcel polygons (census block polygons) within the area under study. While various attribute information (population of employees or students) can be employed to examine the features of the population that has (or lacks) access to public transportation, the goal of the research discussed in this context was to determine the overall residential population with access to transit services. Using the "add join" function, population and other demographic attributes were assigned to the block centroids.

**Step 2: Creating a pedestrian network (Figure 4)**

As the street network does not connect with the parcel centroid points that currently possess associated attribute data, it is necessary to create new links within the network to identify the walking routes that pedestrians would take. In order to do so, first step is to prepare origin-destination points to create a pedestrian network.



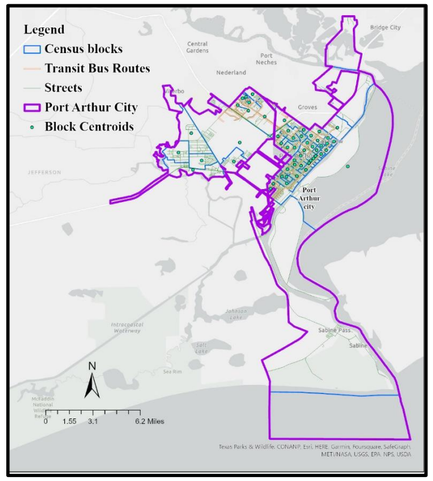




Figure 3: Port Arthur City Map along with block centroids and transit bus routes

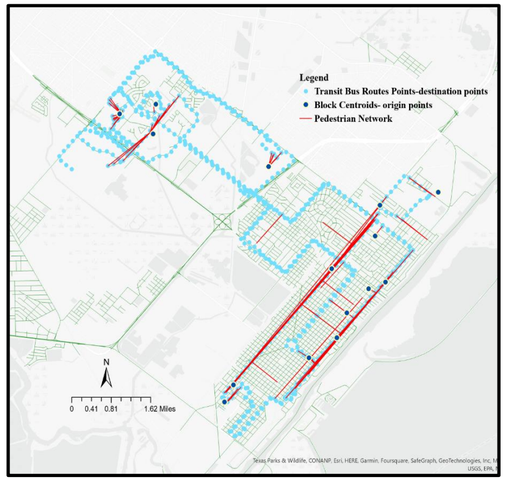



Figure 4: Create pedestrian network by origin-destination cost matrix analysis

Initially, the "Generate Points Along Lines" geoprocessing tool was employed to create various points along bus routes at regular intervals of 200 meters. These points function as destination points for the analysis, with the previously generated block centroids serving as origin points. Next, the "Network Analysis" function was used, utilizing the Port Arthur Street network as the network dataset. Following this, an "origin-destination cost matrix" index was created. The block centroids were then imported as origin points, and the bus route points were designated as "destination" points. Running the "origin-destination cost matrix" analysis produced a set of parcel centroids . with population attributes and network connections to the pedestrian walkway system. This pedestrian network was used to determine walking distances.

**Step 3: Calculating walking distances**

Following this, the parcel-network method's next step involves selecting the shortest walking network distances for each parcel centroid by using the "summary statistics" tool. In this research, we opted to identify centroids with a walking distance of 400 meters (1/4 mile) or less to the bus stops along each unique route using the "definition query" tool. Finally, 15 census blocks centroids were found, which are equal or less than 400-meter walking distances.

**Step 4: Estimating the population with access to transit (Figure 6)**

Based on this selection, a summary of the population associated with routes can be made. Again, Using the summary statistics tools, information were calculated for these final 15 census blocks.

The method selects census block centroids located within 400 meters of bus routes. One of the advantages of using this method is that it avoids census blocks with very few transit users, low residential or commercial areas, thereby reducing the overestimation of the population with access to transit.

| | | |
|---|---|---|
| **Mi** | **Total Street Length (meter)** | **148405.27** |
| **Wi** | The length of the street network within walking distance to transit | 2376.17 |
| **Pi** | The total population of census blocks with census tracts within 400 meters | 16359 |
| **Ai** | The population in analysis zone i with access to transit | 262 |
| | Percentage of the overall population | 1.60% |

| | | |
|---|---|---|
| | **Total Population (44 census blocks across bus routes)** | **45758** |
| | The population in study area with access to transit | 733 |

Figure 5: Demographic Information about selected 15 census blocks

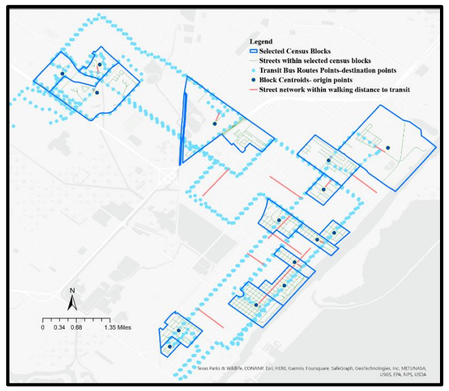



Figure 6: Street network within walking distance to transit along with the corresponding census blocks

| Attribute name | Total number in the census block | Estimated number covered by bus routes | Percentage covered |
|---|---|---|---|
| **Population** | 16359 | 262 | 1.60% |
| **Limited English spoken household** | 6842 | 98 | 1.43% |
| **Poverty** | 15940 | 227 | 1.43% |
| **Housing Unit** | 8214 | 117 | 1.43% |
| | | | |

Figure 7: Estimated attributes covered by bus routes

| | |
|---|---|
| **Census blocks across bus routes** | **44** |
| Total Population | 45758 |
| Covered Population | 32718 |
| Percentage Covered | 71.50 % |
| Census blocks across bus routes | 44 |

Figure 8: Population served by these fifteen sheltered bus stops




Port Arthur Transit Logo

## RESULTS

Result shows that minimum fifteen transit stations were required along the bus routes to cover maximum population within 400 meters.

Figure 7 displays the percentage of the population served by these fifteen transit stations.

The significant population served by these transit stations provides evidence that the model will have a considerable impact on accessibility and enhance the opportunity for multimodal transportation.

In the network-ratio method, the length of the streets within walking distance of the route is compared to the total length of streets in the analysis zone. Thus, this method can provide an estimation of the total population and related attributes served by the route. Figure 8 shows the total population served by these fifteen transit stations along 44 census blocks across bus routes.

## DISCUSSION

The network-ratio method can effectively resolve commonly documented problems in identifying the population with access to a transit route. This method is especially useful in analyzing disaggregated population data (parcel data). While data availability may still pose challenges in some areas, this method can be executed using increasingly available cadastral data, in conjunction with GIS and network analytic techniques. The network-ratio method can be extended to examine not just physical access to transit but also various other demographic characteristics (such as car ownership, income, age distribution, etc.) that may impact ridership patterns and, consequently, route optimization. By summarizing attributes by the bus stop identifier, it is easy to determine the population served by each bus stop. This data could be beneficial in determining bus stop placement and amenities.

## CONCLUSION

In this research, the maximum accessible walking distance was set at 400 meters (1/4 mile). Models predicting transit utilization might also take into account the quality of transit service and walking distances up to 1.6 km (1 mile). A dataset created using the network-ratio method can be conveniently integrated into transit use models that use a distance decay formula for estimating transit usage, rather than focusing on transit accessibility. The inclusion of highways, along with their related frontage roads and off-ramps, can result in significant inaccuracies in population estimates. Research has indicated that these constraints of the network-ratio method consistently led to an overestimation of the population having walking access to transit. However, the magnitude of these errors is not as substantial as those observed with the buffer method (Zhao et al. 2003). The network-ratio method can offer a more precise starting point for use in other transit utilization models as well.

## REFERENCES

Aslan, H., & Kocaman, H. (2018). GIS Based Bus Stop Optimisation for Sakarya Public Transportation System. Sakarya University Journal of Science, 22(5), 1298-1308.

Dallas Area Rapid Transit, 2002. Service planning five year action plan. Dallas, TX, p. 69.

O'Neill, W.A., Ramsey, R.D., and Chou, J., 1992. Analysis of transit service areas using geographic information systems. Transportation Research Record, 1364, 131–138.

Zhao, F., et al., 2003. Forecasting transit walk accessibility – regression model alternative to buffer method. Transportation Research Record, 1835, 34–41

**ACKNOWLEDGEMENTS**
Dr. Yaping Xu