ABSTRACT

Title of Dissertation: DEVELOPING AN INTELLIGENT DECISION SUPPORT SYSTEM FRAMEWORK FOR SCHOOL TRANSPORT MANAGEMENT

Ahmed H Almurshidi, Doctor of Philosophy, May 2019

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The current school bus stops along school bus routes in the UAE are based on requests from the parents, and most of them are in front of the main gate of each student's house. As a result, bus stops are generally placed so close to each other that in some cases the distance between two stops is just 40 meters. Moreover, a lack of school transportation planning often leads to having unnecessary bus stops, which increases the travel time of the school bus. In this research, GIS-based models were created to assist the Emirates Transport Authority and Ministry of Education in optimizing their bus stops. The main constraints were determined by the Emirates Transport Authority such as proposed location for stops, and average dwelling time for each student. The ArcGIS

network analyst extension was used to create optimum route models and assign each student to a new bus stop. These two models, new route model and location-allocation model, were used to identify redundant bus stops throughout the study area (Dibba al Fujairah- U.A.E). The result suggested 73% of the current bus stops could be eliminated, saving approximately 26% of the travel time. Eleven students live within 350 meters of the main gate of the school, so they are not eligible for free school transportation.

The models developed in this study can easily be transferred to other UAE school districts and re-run based on user-defined parameters. For sure, it will inspire the school transport and Ministry of Education officials to examine and apply the proposed systematic optimal route design approach to their current system. Finally, this study opens the door to further investigation for various aspects for improving the school transportation system in the UAE, such as reducing the number of bus fleets and carbon dioxide.

DEVELOPING AN INTELLIGENT DECISION SUPPORT SYSTEM FRAMEWORK FOR SCHOOL TRANSPORT MANAGEMENT

by

Ahmed H Almurshidi

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Chapter 1: Introduction

In the United Arab Emirates (UAE), education is mandatory by law for all citizens and provided for free from kindergarten until graduation from college. Also, school transport is free for all students up to the college level.

The school system in the UAE is like other countries, such as the USA, in regard to school level elementary, primary, and secondary school. In the UAE, school levels are kindergarten, primary school (grades 1-5), secondary (6-9), and high school (10-12). However, most of the schools have gender segregation. The gender segregation is also used on a school bus. The boys' schools start earlier than the girls' schools because the same school buses are used to pick up boys and girls at different times. The Emirates Transport Authority is responsible for providing schools and school buses. They also must provide transportation for female teachers to attend training courses, especially if those trainings are held outside the town, which creates a heavy load on the bus authority.

The UAE's government works toward applying all sustainability approaches at all governmental and private levels, to ensure the reduction of environmental pollution and energy consumption and raise social awareness of sustainability. The school transportation system in the UAE is one of the systems included in the 2021 government's agenda, which must be improved and work sustainably. This dissertation is the first dissertation that deals with active school transportation in the UAE, and one of the first in developing countries (Badri, Ustadi, Pierson, & Al Dramaki, 2012; Mehdizadeh, Mamdoohi, & Nordfjaern, 2017).

The aim of this dissertation is to examine the walking mode in the existing school transport system and evaluate its bus stops and bus routes.

1.1 Problem statement.

To understand the current situation, four questions were sent to the general director of the Emirates Transport Authority in the study area. The first question was: What are the criteria used to allocate the school bus stops? The second: How were the existing stops assigned? The third: What is the average travel time from home to school? The final question: What is the average distance between two bus stops?

The answers given for the questions illustrated that there are no guidelines, bus stops are assigned based on parent's request, the average travel time from home to school is 45 minutes, and the average distance between two stops is 0.049 miles (80 meters). Currently, the school bus system is used as a door-to-door service since the public considers it as a right for their child's comfort and safety.

Deeb et al. (2015), a research group from hospitals and universities in the UAE, studied dietary habits and lifestyle behavior in obese children in the UAE and found a significant relationship between child obesity and the absence of active travel in the UAE. Their finding is in line with McDonald (2008), who stated that obesity among children was rising in the USA in the past 30 years when walking to school was reduced by 75% among children. Therefore, the current practice of picking up pupils from the house's front door, which reduces physical activities of children, is a critical element of their deteriorating health. Also, the current situation leads to increased fuel consumption and air pollution (Albertsson & Falkmer, 2005). Adding a walking mode to the school transportation system would help to reduce usage of private cars (El-Geneidy, Diab, Jacques, & Mathez, 2013), since one of the central claims of using private cars is to reach the school faster than school buses. Promoting walking could reduce bus travel time

(Mehdizadah, Zavarch, & Nordfjaern, 2018). It is also essential to change children's travel habits. If children use walking as a school travel mode, walking will remain with them as a daily activity while they grow up. (Muromachi, 2017; Verplanken & Orbell, 2003). Changing that generation's habit to include excellent daily exercises will lead to achieving the central government's sustainability agenda.

1.2 Dissertation Objectives.

The dissertation has five main objectives:

1. Create a standard to allocate bus stops and routes
2. Minimize the number of bus stops
3. Reduce the load of operated buses in the fleet
4. Reduce home-to-school travel time in Dibba Al Fujairah, UAE.
5. Create a framework that could be used by the bus authority in the UAE.

Naturally, achieving those objectives will lead to other benefits such as reducing operating costs, reducing carbon dioxide emission, reducing the obesity rate in pupils (Hind & Burrows, 2007), and changing society's lifestyle.

1.3 Dissertation contributions.

Badri, Ustadi, Pierson, and Al Dramaki (2012) studied school travel in the UAE for the first time. Their primary objective was to understand the home to school travel context and understand the parents' point of view regarding children walking or cycling to school in Abu Dhabi. They distributed surveys with 28 questions to 1,344 parents, 1,145 of which returned the questionnaire. They found that 69.5% of parents were willing to allow their child to walk or cycle in a group, with boys more likely to be allowed to walk than girls (Badri, Ustadi, Pierson, & Al Dramaki, 2012).

To the author's knowledge, this is the first research study that examines the school transportation system using GIS as a spatial analysis tool in the UAE. In this dissertation many constraints will be combined and used to find the optimal location of school bus stops, and bus routes will be collected on one created analysis tool that could be used by a transportation authority in the UAE. Moreover, this study will raise awareness among officials of how proper planning could add many benefits to the country, society, and environment.

1.4 Dissertation organization.

The dissertation is divided into four chapters. The first chapter has the introduction, problem statement, dissertation objective, and dissertation contribution. The second chapter has a literature review which includes school travel planning, active school transportation, the impact of active school transportation on children’s health, optimization of school bus routes and stops, and the willingness to walk in the UAE. The third chapter includes methodology, which covered the study area, data collection, school bus data analysis, data preparation, and route analysis. The fourth chapter represents the results and discussion, and the conclusion, which includes recommendations.

Chapter 2: Literature Review

The literature review of this dissertation covers six sections. The first section includes school transportation planning, the school bus system, and active modes in the school transportation system. The second section provides the benefits of active modes in the school transportation system. The third section addresses factors influencing active modes such as social factors, safety, and urban forms. The fourth and fifth sections discuss bus route and bus stop specifications. The last part of the literature review introduces the geographic information system (GIS) and its implications for transportation planning. This chapter focuses on specific topics as mentioned to achieve the primary objectives of the dissertation.

2.1 School Travel Planning.

The school travel planning is a comprehensive plan that needs different entities to participate, such as educational organizations (schools, a board of education), the community (parents, students, teachers, bus drivers), and other governmental authorities (road safety, public works, bus authority). The engagement of all stakeholders would lead to establishing a successful sustainable plan, and the implementation of the action plan will be much more comfortable and productive.

School transport is one of the transportation systems that needs to generate sustainability (Goulias, 2003), and the school travel patterns among children are different from the general population travel patterns (Ermagun & Levinson, 2017). The transportation system as we know it moves people and goods from point to point safely and efficiently. Transportation literature addresses many related issues, such as safety, efficiency, access, comfort, and environmental contaminations. Besides, the transportation system directly influences society and the economy. Therefore, it is important to address an issue in a certain transportation system and analyze it to improve efficiency and maximize its benefits for society, the economy and the environment (Goulias, 2003).

Regarding sustainability, planners are expected to view school transportation systems from a wide angle and take into consideration the influence of the system on the students (reduce the obesity and diabetes rates), congestion, environment (reduce Co2 emissions), economy (reduce number of buses, gas consumption) and safety. Transport for London, 2008 established a school travel plan which supports and promotes active travel modes. Some benefits of active travel are suitability of travel and reduced air pollution and bus carbon dioxide emissions. A school transportation system has two main elements, social capital and physical capital. The human social capital is more important than the physical capital because all the systems are harnessed to serve human beings and improve their quality of life (Goulias, 2003). An active transportation mode is essential to increase the physical fitness of the students and reduce the diseases related to a lack of physical activity (Merom, Locke, Bauman, & Rissel, 2006).

2.2 Active School Transportation.

Active school transportation (AST) uses non-motorized modes to reach the school, such as walking, cycling, and running (Faulkner, Buliung, Flora, & Fusco, 2009). AST is an essential addition to the school transportation system because the lifestyle of the new generation has changed dramatically from the early 19th century. Children have been spending their time using electronic devices such as iPads, video games, and computers (Nelson, Neumark-Stzainer, Hannan, Sirard, & Story, 2006), which limits their physical activity level. Notably, most of the parents preferred their children to either commute to school by private car or school bus (Ferreira et al., 2006). Many studies have been conducted on active school travel all over the world, although mostly in developed countries, and researchers used many different methods to study influence parameters related to active travel and mode choice in school transportation systems.

Many factors limited the active travel among school children; for example, McDonald (2007) studied the trend of active travel among U.S. school children from 1969-2001 using national personal transportation survey (NPTS) data and found a 47% decline in active travel to school because of increased distance between home and school. Also, Nelson, Foley, O'Gorman, Moyna, and Woods (2008) used cross-sectional study for the different cohorts in 61 post-primary schools in Ireland from 2003 to 2005. Their study showed that active travel declined by 57% due to a long distance from home to school. Other researchers reported distance as the main reason for limited active travel among school children (Conlon, 2013; Curtis, Babb, & Olaru, 2015; Easton & Ferrari, 2015; McMillan, 2007; Mitra & Buliung, 2015; Loucaides, Jago, & Theophanous, 2010; Waygood & Kitamura, 2009). However, in Tirana, Albania, 78.9 % of the students in that city walk to school because most of them live near their school (Pojani & Boussauw, 2014).

In addition to the distance parameter, the built environment has a negative impact on children’s active travel (Rothman et al., 2015). The urban form of an area helps children feel safer when they walk to school (Curtis, Babb, & Olaru, 2015; Waygood & Kitamura, 2009; Wong, Faulkner, & Buliung, 2011).

Waygood and Susilo (2015) measured parents' perceptions of walking to school. The participants mentioned that the availability of local shops in the central city increases the amount of people in the streets, which in turn increases the feeling of safety because there are many eyes on the children who walk to school. That helps to increase active travel to school. Despite the importance of built environment influences, it differs in some regions; Loucaides, Jago, and Theophanous (2010) and McMillan (2007) found neighborhood safety and traffic safety more important than the urban form of the area.

Another factor found to influence travel by walking is car ownership. Families with high car ownership used cars to travel to school (Li & Zhao, 2015; Pojani & Boussauw, 2014; Van Goeverden & De Boer, 2013; Waygood & Susilo, 2015), and they mostly live in a suburb because those families have high incomes and owned single-family houses.

Many researchers found that boys traveled actively to school more than girls (Curtis, Babb, & Olaru, 2015; Easton & Ferrari, 2015; Nelson, Foley, O'Gorman, Moyna, & Woods, 2008), but Mitra and Buliung (2015) found no influence of child gender on active school travel.

Whereas there are many factors that influence walking to school, most of the research semi-agrees that walking is vital for children's health (Riddoch et al., 2009). The next section will address some of the benefits of AST.

2.3 The Impact of AST on Children's Health.

Much research was conducted to investigate the influence of AST (Martinez-Gomez et al., 2011) and physical activities on children's health (Merom, Locke, Bauman, & Rissel, 2006). Each investigator has a method for measuring the influence of physical activities on children's health. For instance, Martinez-Gomez et al. (2011) found that children who walked or cycled to school had higher mental concentration which was reflected in their academic achievement. Physical activities reduce the chance of having cardiometabolic problems, vascular diseases (Strong et al., 2005), and obesity (Jakicic, 2009). Also, walking to school allows children to acquire some critical skills such as independence (Hillman, Adams, & Whitelegg, 1990; Jackson, 2003; Tudor-Locke, Ainsworth, & Popkin, 2001). They recommended that walking should be a daily habit for children as a part of their lifestyle because it is so important for their health.

No doubt AST is beneficial for children, but there are some limitations and obstacles preventing children from walking or cycling to schools. Buliung, Faulkner, Beesley, & Kennedy (2011), conducted a study to promote AST. In their study, 1,489 parents participated in four Canadian provinces at 12 schools. Parents claimed weather as the main obstacle preventing children from walking to school, and it is more convenient for parents to transport their child to school using private cars while driving to work. Most of the AST studies were conducted in developed countries such as the USA, UK, and Canada, but some of the studies were performed in developing countries such as Iran. One of the latest Iranian studies on AST conducted by Mehdizadeh, Mamdoohi, and Nordfjaern, (2017), showed that the long distance between home and school is one of the main barriers to walking to school in Rasht, Iran.

A long distance from home to school remained an obstacle that reduced walking to school in many countries such as Australia (Timperio et al., 2006), the United Kingdom (Black, Collins, & Snell, 2001) and the U.S. (Schlossberg, Greene, Phillips, Johnson, & Parker, 2006). In addition to the long distance from home to school, Martin and Carlson (2005) found that the main concern among parents is safety.

To sum up, physical activities are crucial for children's health, and, therefore, walking barriers should be well addressed to change the children's current lifestyle.

2.4 Optimization of School Bus Routes and Stops.

In this dissertation, the study focuses on the school bus routing problem (SBRP) and rearranging the school bus system by adding a walking mode to the existing system, determining walking distance between homes and bus stops and between two stops, and re-determining the best route. Therefore, understanding the specification of bus routes and stops is important. This section discusses the school bus route problem in detail.

Newton and Thomas (1969), were the first researchers to address the school bus routing problem (SBRP). The primary target of the SBRP is to increase the efficiency of the school bus fleet in which each bus picks up pupils from different bus stops and drops them off at a school with respect to many variables, such as a full capacity of the bus and minimum riding time (Park & Kim, 2010). According to Desrosiers, Ferland, Rousseau, Lapalme, and Chapleau, (1981), the SBRP has five elements: data preparation, bus stop selection, bus route generation, school bell time adjustment, and route schedule.

The data preparation includes collecting required data such as each route, bus stops, school, and residential locations (Kim & Jeong, 2009). Bus stop selection consists of determining existing stops and rearranging them based on a reasonable walkable distance from houses to bus stops (Chapleau, Ferland, & Rousseau, 1985), and assigning each student to the bus stop nearest to his/her home (Dulac, Ferland, & Forgues, 1980).

The location of bus stops is a critical factor in the SBRP that should be chosen carefully to increase ridership and improve the efficiency of the system. Every user of transit buses or school buses must have proper access with a reasonable walking distance to the bus stops under normal conditions (Murray, 2003).

Although optimum stops spacing has received considerable attention in transit planning in developed countries (Furth & Rahbee, 2000) (Saka, 2001), it has not been studied in the developing countries as much as in the industrial ones. Some studies in Iran (Mehdizadeh, Mamdoohi, & Nordfjaern, 2017) are an example of the first school travel system studies in developing countries.

Optimization of stops spacing is an essential planning policy that should be addressed and chosen carefully based on many factors such as social aspect, topography, environment, and infrastructure condition. Stop spacing differs in dense areas (urban areas) and less populated areas (rural areas) (Demetsky & Lin, 1982). Providing good stop spacing results in providing the public with the best accessibility to transit services. Minimizing school bus stops in school transportation helps reduce ride time for pupils (Corberan, Fernansez, Laguna, & Marti, 2002) (Pacheco & Marti, 2006). Several studies have been conducted in optimizing bus stops (Galdi & Thebpanya, 2016; Schittekat et al., 2013; Ibeas, Olio, Alonso, & Sainz, 2010). An optimization of bus stops strategizes ways to delete redundant stops on the route (Delmelle, Li, & Murray, 2012). The methods used in the literature to limit unnecessary bus stops are geographical information system (GIS) and mathematical based algorithms; the walking distance is a primary constraint in most of them (Ceder, Prashker, & Stern, 1983; Ke, Aneja, & Caron, 2006).

Galdi and Thebpanya (2016) used GIS as the primary tool to help Howard County's officials choose the best locations for school bus stops and routes. They found that 30% of the existing bus stops should be eliminated, but, after reviewing the results with the officials, they reduced 15% of school bus stops. The constraints used to select optimal bus stops are distance between stops (0.25), sidewalk presence, safe roads, and distance from homes to bus stops (0.25) (Galdi & Thebpanya, 2016).

The stop spacing standards differ from place to place. Demetsky and Lin, (1982) stated that in some urban areas stop spacing reaches as high as 800 meters (0.5 miles). Furthermore, Ammons (2001) mentioned in his study that most routine stops spacing is between 200 meters (0.12 mile) and 600 meters (0.37 mile). For example, in the city of Belfast, the capital of Northern Ireland, the walking distance is 400 meters, and bus stop spacing is between 250 (0.15mile) -350 (0.21mile) meters (Translink, 2005). In Dubai, the stop spacing is 400 meters (0.24 miles) in the central business districts, 500 meters (0.31 mile) in residential areas, and 800 meters (0.49 miles) in rural areas (Roads and Transport Authority, 2016). It seemed most of the reports and studies built the walking distance and bus stop spacing based on best practices of previous work; there is no specific description or criteria of how those distances are determined. Few indicate the proper walking time.

In the UAE, no guideline was found for constraints related to school bus routing or bus stops. To encourage the students to walk to schools, and to have reduced bus stops without increasing parental anxiety, 350 meters (0.21 miles) is used as a bus stop spacing standard in this study.

Route generation is an essential element of the SBRP, which is classified into two categories based on the fleet size: heterogeneous – the fleet has different bus capacities (Hargroves & Demetsky, 1981), and homogeneous, which has one only bus capacity in all fleets (Newton & Thomas, 1974; Park, Tae, & Kim, 2012). Additionally, routes can be divided into two classes according to the type of load: mixed load (collect students of multiple schools in one bus) (Newton & Thomas, 1974), and single load (bus service for students of one school only) (Faraj, Sarubbi, Silva, Porto, & Nunes, 2014). The school bell time adjustment and route schedules are always used when one school bus transports students from multiple schools (Newton & Thomas, 1974).

All five of the SBRP's elements are essential, but just a few researchers dealt with all five (Park & Kim, 2010). For example (Desrosiers, Ferland, Rousseau, Lapalme, & Chapleau, 1981; Desrosiers, Sauve, & Soumis, 1988) used all five parameters, while (Chapleau, Ferland, & Rousseau, 1985) tested only three parts of the SBRP in an urban area.

Even though all five parameters of the SBRP are related, some researchers tried to examine them independently (Newton & Thomas, 1969; Park & Kim, 2010). Some researchers used the SBRP elements independently because of the lack of data, and because it allowed them to add more variables (Park & Kim, 2010).

Transit routes (in our case school bus routes) with fewer stops and optimal routes among all stops from origin to destination help reduce travel time and associated operational costs, as well as improve efficiency (Kinable, Spieksma, & Berghe, 2014; Saka, 2001) and bus routes (Park & Kim, 2010; Li & Fu, 2002).

One of the earlier studies in developing countries was done by Li and Fu (2002). The study was in Hong Kong with an objective of detecting school bus routing problems for kindergarten. They used a heuristic algorithm with selected variables such as the number of school buses, and bus stops pupils, the capacity of buses, travel time between two stops, average pick up time, and the number of pupils at each bus stop. The objective was to minimize the travel time and reduce the number of buses in the system. The result of the study showed a reduction of 29% in travel time (Li & Fu, 2002).

Schlossberg, Phillips, Johnson, and Parker (2005) used spatial analysis to study the relationship between school location and travel modes used to reach a school in a sprawling area in Bend, Oregon. The method used was a survey mailed to parents of middle school pupils with 104 responses, which were used in spatial analysis using GIS (Euclidean distance, Manhattan network distance) for local students' homes and school location. The study showed that 41% who lived within a 1.5-mile radius of school used private cars to travel to school, while 6% of students walked as a travel choice. Parents' main concerns were personal safety, school requirements (heavy school bags), and inadequate infrastructure (Schlossberg, Phillips, Johnson, & Parker, 2005).

Based on the literature, some cities don’t provide free school transportation to those living within a certain distance from the school, such as in London, where children ages 8-16 are eligible for free school transportation only if they live more than three miles from school. In this study Table 1 summarizes the criteria used in this framework. In detail, the walkable distance was determined as 3.5 meters, so those living within a 3.5-meter zone of the school gate will not ride the school bus.

The travel time is an important element that is used to evaluate the efficiency of the school system. Less travel time is more efficient and attractive, so the maximum travel time of each bus route should not exceed 35 minutes.

Table 1: Summary of school bus route and stop criteria.

Free School Transport	Age between 8-17	More than 3.5 meters from the school's gate
Travel Time	Primary, Secondary School	Max 35 Minutes
School Bus Stops	Low Traffic Volumes and Lower Speeds	
	Minimize or Avoid multi-lane roads	
	Select stops that provide enough visibility.	
	Minimize the need for students to cross a road	
	Enough space to wait at least 12 feet from the roadway.	
	Consider the surrounding environment (commercial, parks)	
	Consider the number of students in each stop.	
Student Route between Home to School bus stop.	Walking Distance 350 meters (0.21 miles)	
Distance between Stops	School bus stops assigned within 350 meters (0.21 miles).	

Street-side characteristics of bus stops matter; the bus stop should be located on a street with low speeds and less traffic, in our case on an arterial road. Determining stop locations includes avoiding having students cross multi-lane roads, selecting locations without curves or hills to provide sufficient visibility, and providing waiting areas that are at least 12 feet from the roadway.

To sum up, there are many studies conducted on AST with different objectives and methods, but most of the literature showed that the majority used statistical approaches, while very few researchers used spatial analysis. Thus, this dissertation used spatial analysis in optimizing bus stops and routes to reduce the travel time of pupils in Dibba, UAE.

Chapter 3: Methodology

3.1 Study area.

Dibba Al-Fujairah, the second-largest city in emirates of Fujairah, is located on the northeast side of the UAE, Figure 1. The coordination of the study area is latitude 25° 35' 32.86" N and longitude 56° 15' 42.34" E (Latitude, 2018). It is located approximately 350 Km from Abu Dhabi (Capital City) and 200 Km from the city of Dubai.

The study area has 43 districts with a total area of 2,754.65 square kilometers. According to the 2010 census, the total population was 29,387, which surely has increased in the last eight years.

The study focused on school transportation management, so Table 2 shows that the study area has four boys' schools serviced by 47 buses. The number of students is 1,265 and the bus stops number 1,055, so 83.4 % of the students are picked up from the front door of their houses. The sample in this study is a boys' school that was chosen by the Emirates Transport Authority as an example to build a management framework and test their operation's eligibility and efficiency.

It is notable that bus capacity is somehow not rationally chosen because the average number of students per bus is 27, while the majority (76.6 %) of buses have a student capacity of 60, and 10.6 % have a student capacity of 55.

Buses with a capacity of 35 students could be the best choice for the average of 27 students in a bus. In buses with a 35-student capacity, 27 students occupied 78% of seats compared to 45% of seats in 60-student buses.

Table 2: Summary of school transportation elements in the study area.

Item	**Total**
Schools	4
Students	1,265
Bus Stops	1,055
Bus	47
Bus Capacity 60	36
Bus Capacity 55	5
Bus Capacity 35	2
Bus Capacity 22	4

The study area was chosen because of two main reasons; the first reason is that this area is considered one of the functional areas included on a federal development master plan to serve rural areas. The second reason is that it has a unique distribution of houses on terrain with different elevations, which influences school bus transportation (Ministry of Infrastructure Developments, 2010).

However, the Emirates Transport Authority is responsible for providing all the schools in the study area with buses, including urban and rural areas, which creates a challenge to their daily operations compared to branches in other cities.

The study area is witnessing a growth in the housing sector toward the west toward the rural area. Therefore, the study of the school transportation system will contribute to knowing the geographical distribution of students for each school, which may help in the planning process for the location of a new school.

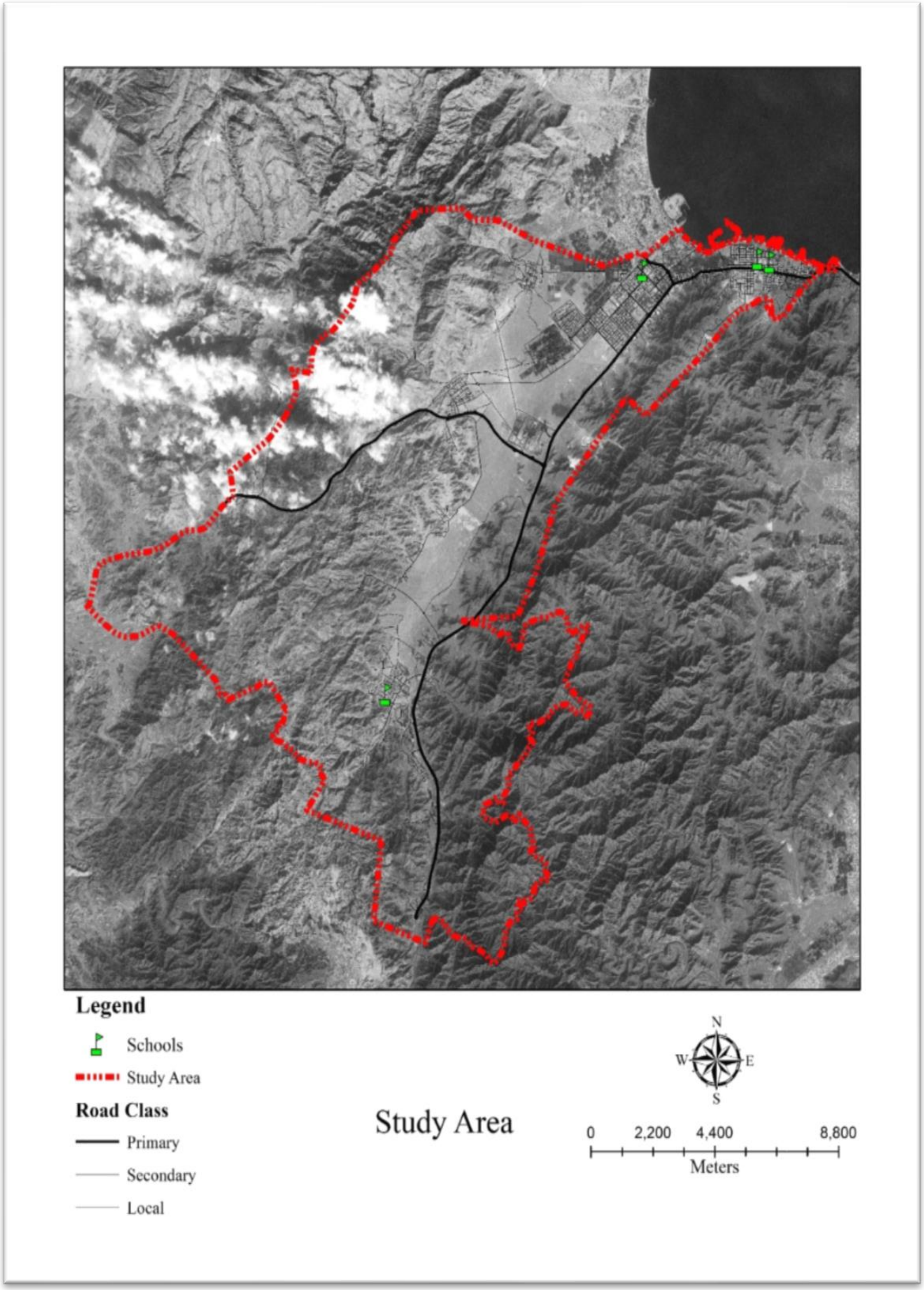

Figure 1: Map of the study area.

3.2 Methodology framework.

The methodology framework, Figure 2 gives a general idea of the structure of this study.

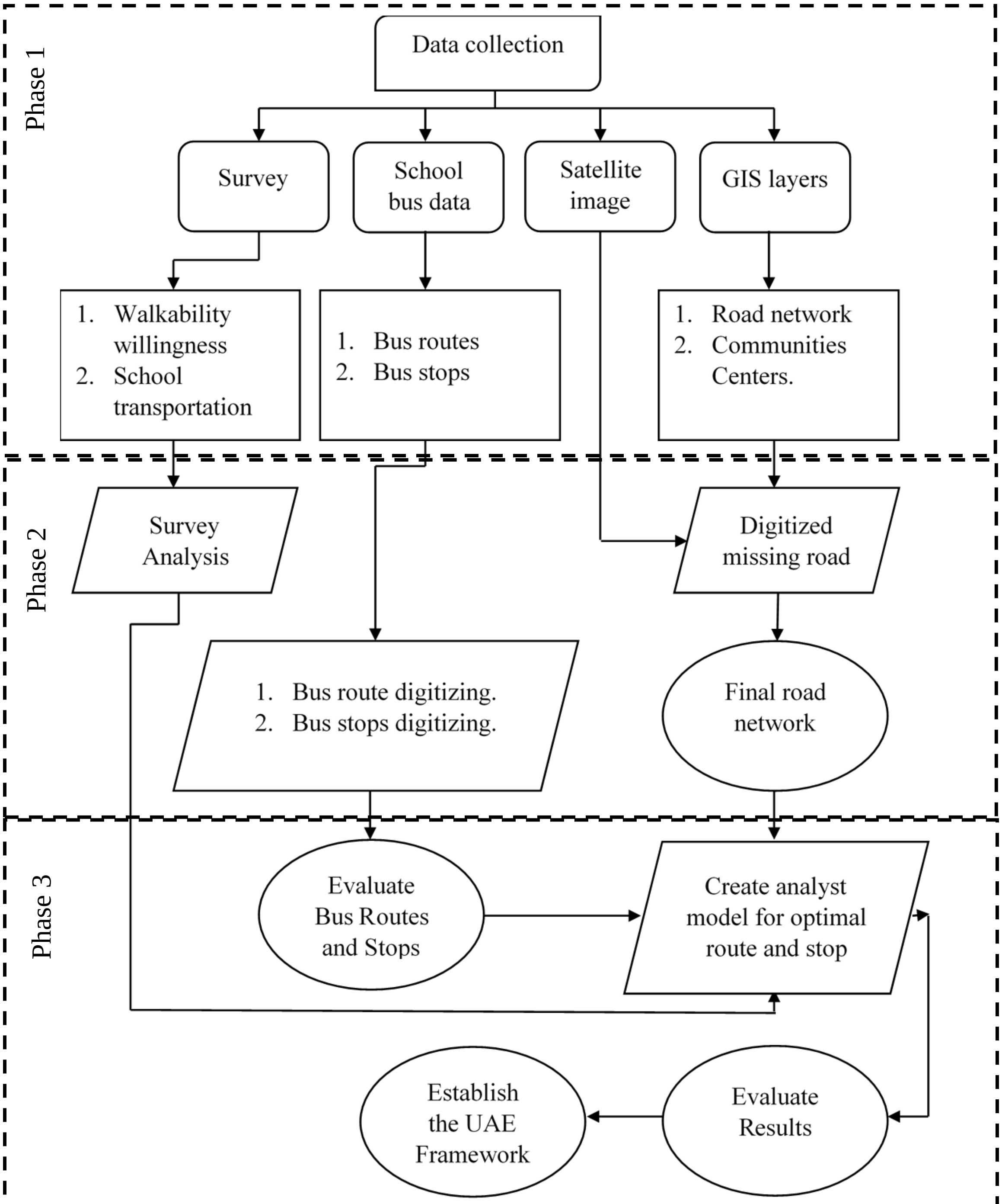

Figure 2: Methodology framework.

The framework has three phases; the first phase is for data collection, the second for data preparation, and the third phase covers data analysis.

The data was collected from different sources: the Dibba municipality, Emirate Transport Authority, and public questionnaire. The GIS layers collected from the municipality included road network, satellite image, district borders, and land-uses. The data collected from Emirates Transport Authority were a paper copy of bus routes, bus stops, and bus information such as buses' capacity and the number of students in each bus. A public questionnaire survey was distributed online to understand the willingness to walk among people, and their perspective of adding a walking mode to the school transportation system.

The second phase of the framework covered the data preparation after evaluating the collected data. The data preparation covered digitizing bus routes, bus stops, and road networks. Also, the preparation included adding the descriptive information to each layer, and the survey questionnaire was sorted out and completed forms selected to start the analysis.

The third phase of the methodology framework included all analyses and evaluation of the results plus creating the analysis models.

3.3 Data collection.

Collection of data is a vital process in this study because the collected data will represent the actual situation and the more data we can collect, the more accurate the results will be. However, it is the hardest part of the research. The bus authority in the study area uses all paper-based documents, so to computerize the analysis all the data must be converted into a digital form. The survey questionnaire has been commonly used in such study. In Britain, the transportation authority of London worked on a school travel plan focusing on active modes of transportation and it was approved by 2,400 schools (Transport for London, 2008). It used a questionnaire survey as an essential method to understand the real travel journeys and perceptions of parents.

Other data collected from governmental agencies includes school bus routes and bus stops. This data is collected by distributing a map to each bus driver for his/her service area with the request that s/he draws the bus route and bus stops. Moreover, the school bus schedules collected from the Emirates Transport Authority is in paper copy.

GIS data was obtained from the Dibba municipality (road network shapefiles, land-use shapefiles, and area boundary shapefiles). The 2017 satellite images were collected for the study area, and the school shapefile obtained from the Fujairah Statistic Center.

3.4 Willingness to walk in the UAE.

Survey questionnaires were developed in two parts to understand walking willingness in the UAE: demographic questions and walkability questions to investigate the perception of people willing to walk in the UAE's environment. The second part of the survey was directed to parents who have school-age children with questions related to school transportation. The survey was electronically distributed all over the UAE. Responses to each section and questions varied because participants have the option to answer or skip questions. On average, responses for the first part were 270 and for the second part were 170. The primary target of this survey was to gauge the willingness to walk among people in the UAE and factors impacting walking as a part of their travel decisions.

Even though walking promises sustainable travel and improved health, people have specific attitudes toward walking, and it is important to know their thoughts in order to make successful transportation planning choices (Shove, 2010).

For instance, the British government has been investing much money in the development of walking and cycling physical infrastructure since 2005, yet the level of using active modes in Britain compared to other European countries is still very low. Thus, knowing people's perceptions is an essential part of an analysis in planning (Pooley, et al., 2011).

The first section of the survey covered the demographic information; 63% of the participants were males while females were 37%, Figure 3.

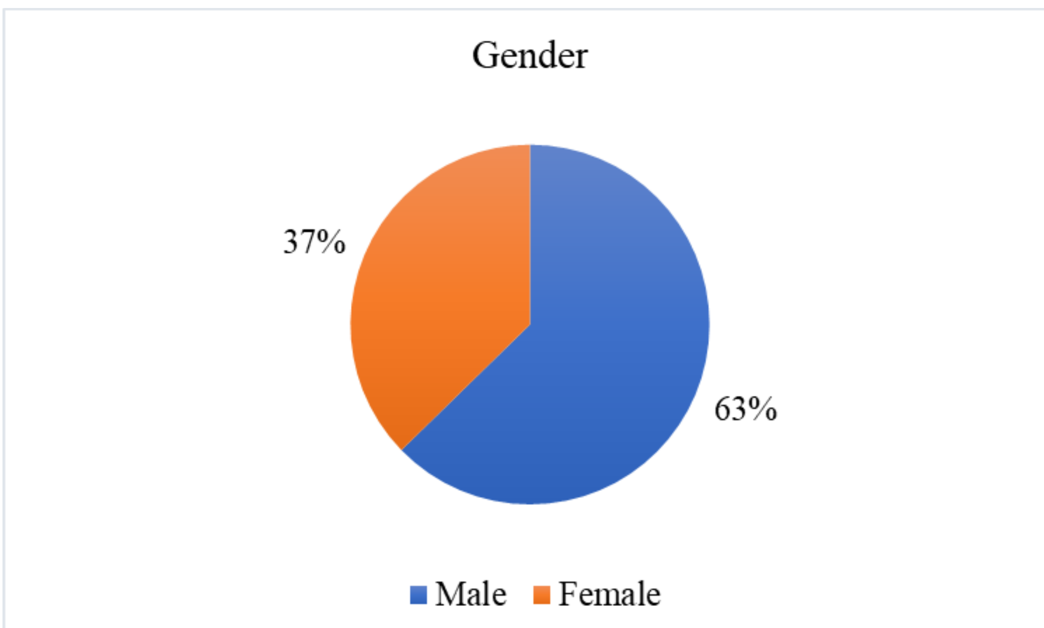

Figure 3: Gender distribution of survey participants.

The highest percentage of the participants was between 25 to 55 years old (84%), Figure 4. Since this group has school-age children, they have parental perceptions about adding a walking mode to the school transport system. Parent point of view is very important as it is considered a key element in the success of inclusion of the walking in the school transportation system.

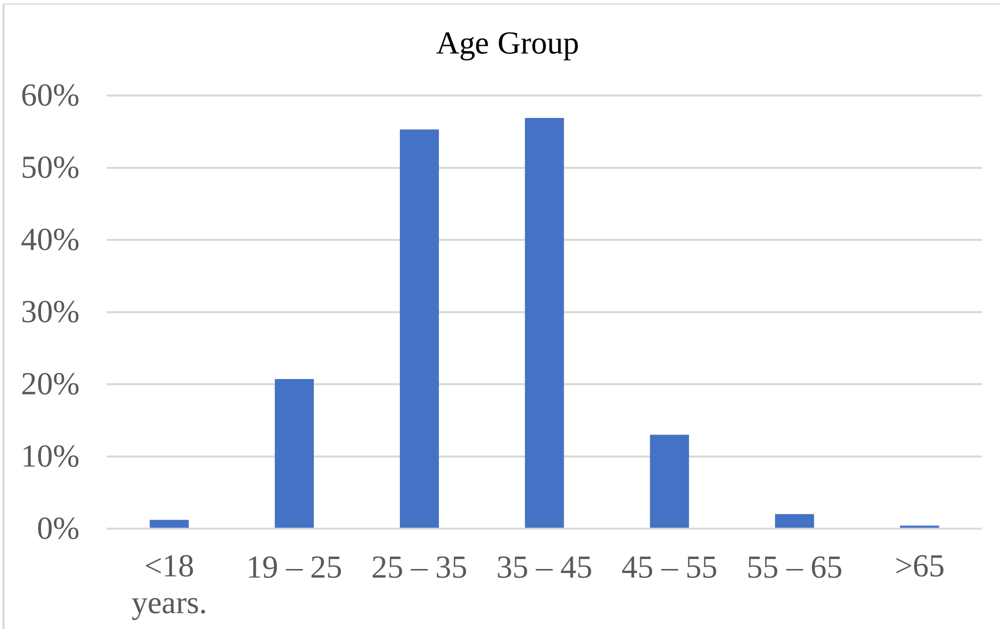

Figure 4: The percentage of participants distributed among age groups.

Ferreira, et al. (2006) studied the environmental correlations of physical activities in youth due to an increase in obesity among youth and found that young pupils have no freedom to travel alone. The school mode of travel is a choice made by parents (Mehdizadah, Zavarch, & Nordfjaern, 2018).

Most of the participants, 87.4%, were locals. Some 32% of participants had a high school education, 46% a bachelor’s degree, and 17% post graduate study, Figure 5. It is essential to know that most participants were educated, which gives this survey more validation and assumes they are going to answer questions more seriously. The point of view of educated parents is important in the process of incorporating sustainability as a part of the daily life of families.

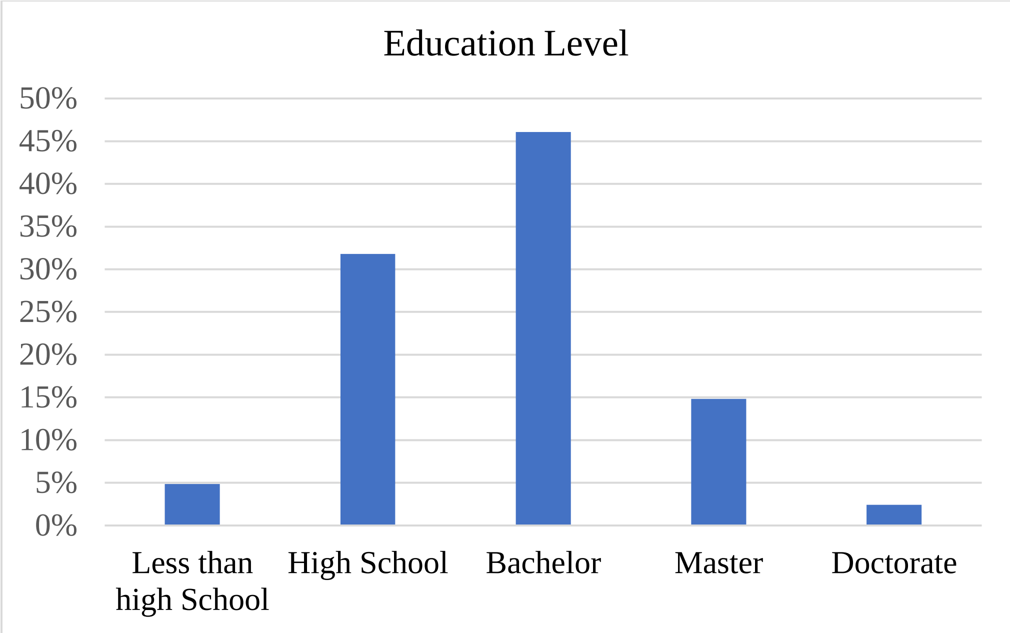

Figure 5: The percentage of participants distributed among education levels.

The questionnaire was distributed electronically all over the UAE to know in general the tendency of people to walk and the obstacles that prevent people from walking. Most of participants were from Fujairah, 52%; Sharjah, 13%; Abu Dhabi, 15%; Dubai, 9%; and other emirates, 11%. The study area is in Fujairah, which represents the highest percentage of the participants, Figure 6.

In the UAE, there are three governmental education authorities. Abd Dhabi, the capital city, has its own education authority, and Dubai has a local education organization. All schools and the education system for the rest of the five major cities are administered by the Ministry of Education. Therefore, the results of the survey show that the majority of participants of the survey are from the five cities, which gives the result more validation.

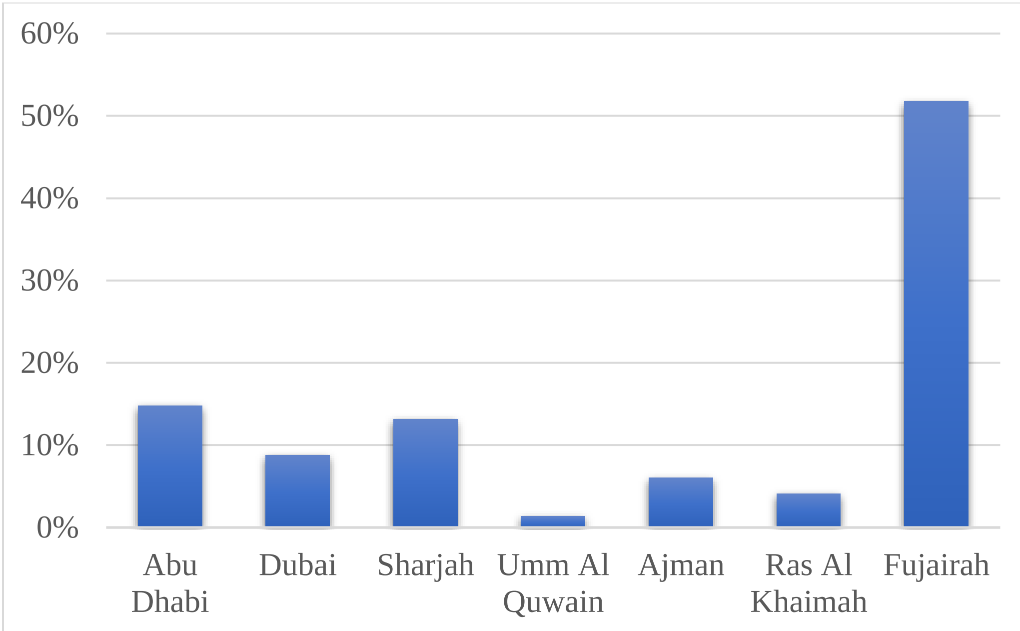

Figure 6: The percentage of participants in main cities in the UAE.

The participants were asked about their walking habits; 17% do not walk, 13% walk once or twice a month, and 70% walk every day or twice a week, which gives an indicator that walking is a popular mode in the UAE. That makes adopting the walking mode into the travel system more acceptable, Figure 7.

The majority of people in the UAE walk to mosques, so walking short distances is associated with their daily life, which makes people familiar with walking (Kim, Rasouli, & Timmermans, 2017; Kamargianni & Polydoropoulou, 2013).

The survey results showed that UAE residents are willing to walk for a fairly long distance. Table 3 presents the results.

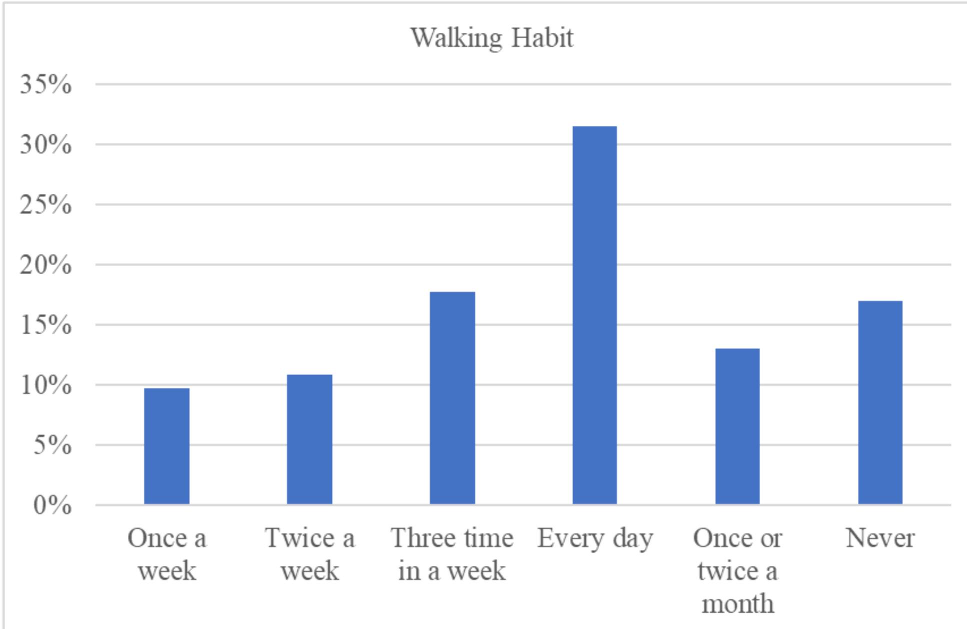

Figure 7: The percentage of usage of walking among the participants.

The willingness to walk for more than 1 Km (0.62 miles) gives us an indicator of the acceptance of applying walking as a travel mode in the school system.

Table 3: The percentage of people willing to walk to different destinations.

Distance / **Destinations**	<100m	100>300	300>500	500>800	>1Km	Not Applicable
Worship places	11%	15%	13%	18%	35%	9%
Schools and Colleges	9%	5%	8%	12%	35%	31%
Groceries and Restaurants	7%	8%	10%	12%	43%	20%
Visit Relatives	13%	16%	7%	15%	33%	16%
Work	9%	8%	8%	13%	38%	24%

The last section of the survey focused on parents who have school-age children. Some 68% of children used school buses and 32% private cars to go from home to school, Figure 8. No parents reported active modes such as walking or cycling for their children, which may be a cause of an increase in obesity in children (Deeb et al., 2015) at the school level (McDonald, 2008). Some 96% of parents believe that walking is suitable for children's health.

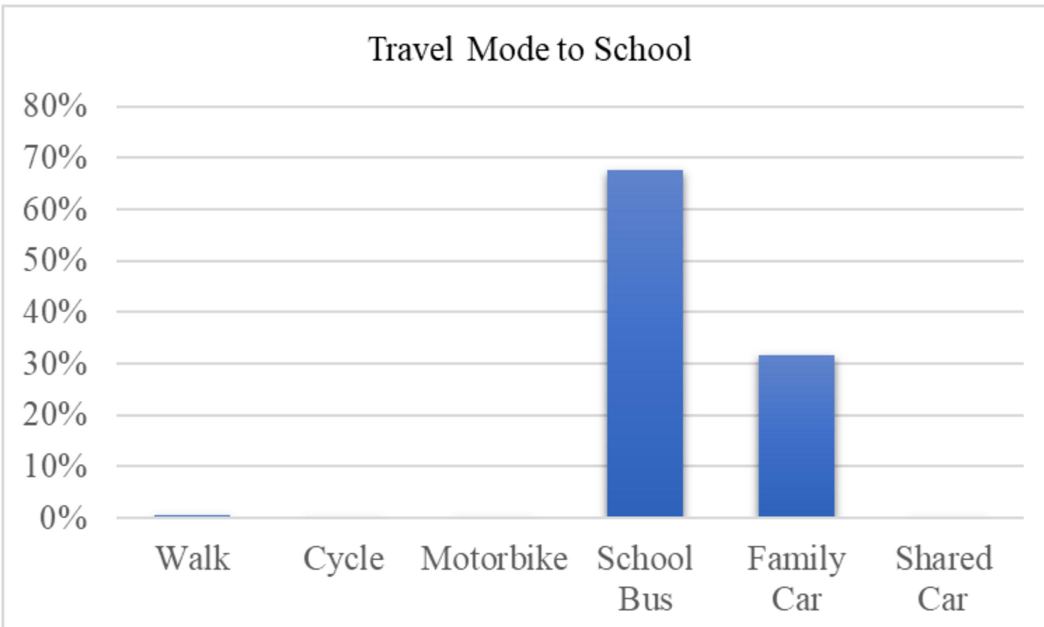

Figure 8: Used mode in school travel.

The percentage of travel mode used to travel from school to home is slightly different from travel from home to school; 71% used the school bus, and 28% used private cars. The difference is reasonable because some parents drop off their children at school but did not pick them up from school due to later working hours. The participants were asked the reason for choosing those modes of transportation for their children. Some 25% stated because it is the safest mode, 13% said the chosen mode is good for their child's health, 12 % said because it was the fastest mode, 10% had no other choice, and

9% stated that the school is too far away to use other modes. The parents preferred a school bus because it was considered the safest school travel mode.

In a TRB report (Transportation Research Board, 2002), the committee used national crash data in the USA from 1991 to 1999 to analyze the accidents that happened during school travel time, focusing on fatalities and injuries among children between the ages of 8 and 18. The result showed that the safest school travel mode is school bus. However, each year on buses around 800 school-aged children are killed in crashes during school hours, and 152,000 are injured. The study confirmed that the school bus is the safest mode compared to private cars, cycling, and walking; however, it ignored that other travel modes are not the only solution. Transportation planners must reconsider the risk of other modes, work to improve their safety and come up with new solutions to raise their efficiency.

To sum up, adding walking mode to a school's travel is beneficial for children's health, and it is accepted by parents, too. In term of walking distance, the majority of participants accept walking more than 1 km (0.62 miles), which gives the researcher room to apply the best applicable walking distance between homes and bus stops, and between two bus stops. Indeed, safety is one of the main factors that may cause a reduction in walking or cycling to school. It is essential to focus on all factors that influence children's school journeys, such as the traffic speed of school routes, the distances between home and bus stops, environment, quality of infrastructure, and social factors (University of North Carolina Highway Safety Research Center, 2010).

3.5 School Bus Data.

The school bus data was collected from Emirates Transport Authority, a governmental entity responsible for providing all government organizations with cars, buses, and transportation services. Their primary client is the Ministry of Education, so school bus operations is their responsibility. They provided the data for this study in a paper format, such as bus routes, bus stops, and bus operations data.

The number of buses used in this study is 47 for only boys' schools. The average odometer from the first stop to school is 15 Km, average bus stops is 22 per bus, and the average time is 41 minutes. The organization works hard to improve their level of service, especially reducing the student home to school travel time as one of the government's priorities. Improving the services would lead to an increase in ridership rate (Ceder, Butcher, & Wang, 2015; Murray, 2003).

3.6 Data preparations.

Data needed to be converted to a digital format to be used efficiently in digital analysis. Each bus schedule was converted to a cumulative Excel sheet with all buses' data. Bus routes and stops were switched to shapefiles in the GIS platform.

Some significant steps should be used to prepare the road network to ensure all road topology is correct, such as intersection nodes; each road segment should have correct speed and length (George, Kim, & Shekhar, 2007). After having all network maintained, the connectivity and walkability analysis should be performed (Poulsen et al., 2018). An example of the hard copy data collected from the Emirates Transportation Authority is shown in Figure 9.

Figure 9: Example of paper map of bus routes and stops.

The main layer of this study is the road network dataset. This study mainly focuses on the school transportation system to create a model that simulates reality and creates maps for the current operation routes and proposed final stops with bus routes. In this manner, the road network dataset should be completed and created with all the required information for each road segment such as road length, speed limit, one-way and name; this information is required to run the network analysis in ArcMap.

Network attributes are important to create the cost attributes that are used as impedances, restrictions such as one-way roads, and directions. ArcGIS Network tools look for the most common features to use such as meter, minutes, speed limits, and one-way. The tool automatically generates analysis based on user parameters.

In this study the following impedances and restrictions were used: meters as a cost for route length, and pedestrian time and travel time as a travel time cost. One-way road restrictions also are used to avoid the simulated route going in the wrong direction, Figure 10.

The travel time equation is {road segments length in meter / average bus speed * 60}. The walking time equation is {road segments length in meter / average walking speed (1.4) * 60 / 1000}.

After setting up the impedance, the final layer of the proposed route as an example will calculate the travel time of buses, and walking time on the pedestrian layer.

Moreover, the system is going to navigate the simulated routes to the specific constraints that have been added to the network dataset. For example, if the cost was meter, the system is going to find the route with smallest distance from origin to destination.

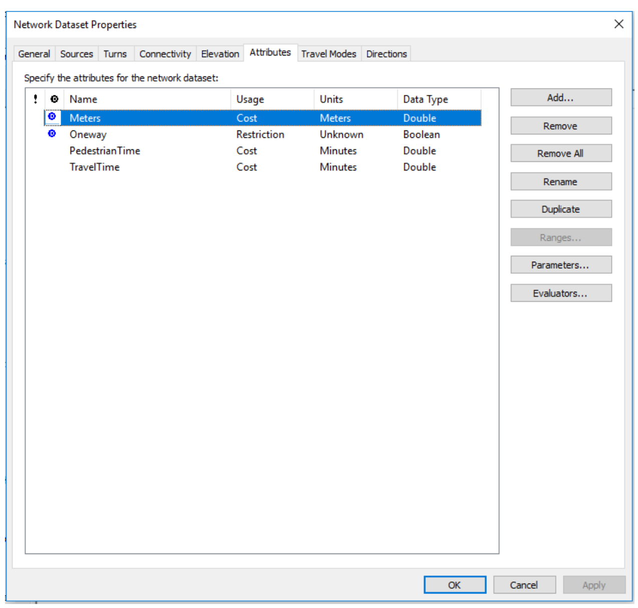

Figure 10: The properties of network dataset.

3.7: Methods.

In this section, the modeling concepts adopted are described in detail: how to model the existing bus routes and stops, assign each student to the new proposed stops, and create the final proposed route. The critical point to start manipulating data is to create a set of standards that will be used as a primary guideline for GIS analysis. The main parameters elements used in such study are bus stops and bus routes. Thus, all constraints of bus stops and routes should be clear. For example, determining the spacing distance between two bus stops (Braca, Bramel, Posner, & Simchi-Levi, 1997) is important to figure out the travel time; also for the safety aspect determining location of stops as either in mid of block or at the corner of the block is important (Desrosiers, Ferland, Rousseau, Lapalme, & Chapleau, 1981), as is determining the distance of stops from the roadway.

Bus routing constraints should also be selected carefully such as the shortest route (Bowerman, Hall, & Calamai, 1995; Chapleau, Ferland, & Rousseau, 1985) and avoiding busy routes (Krenn, Oja, & Titze, 2014). The slope of route (Navarro, Ribera, LIario, & Terroso, 2018) influences the performance of buses.

In this dissertation, the geographic information system (GIS) is used as the main analytic tool to find the optimal bus routes, and bus stops. Abkowitz, Walsh, Hauser, and Minor (1990), mentioned that over last two decades, the GIS technology has become inseparable from the transportation field because of its efficiency and productivity transportation applications. Also, Goodchild (2000) stated that GIS is one of the most influential applications in transportation analysis. The common GIS' applications used in transportation are determining vehicle routing, service areas, and shortest routes (Alivand, Malek, & Alesheikh, 2008; Cova, 1999; Panahi & Delavar, 2008).

The following Figure 11 summarizes the GIS analysis of the SBRP.

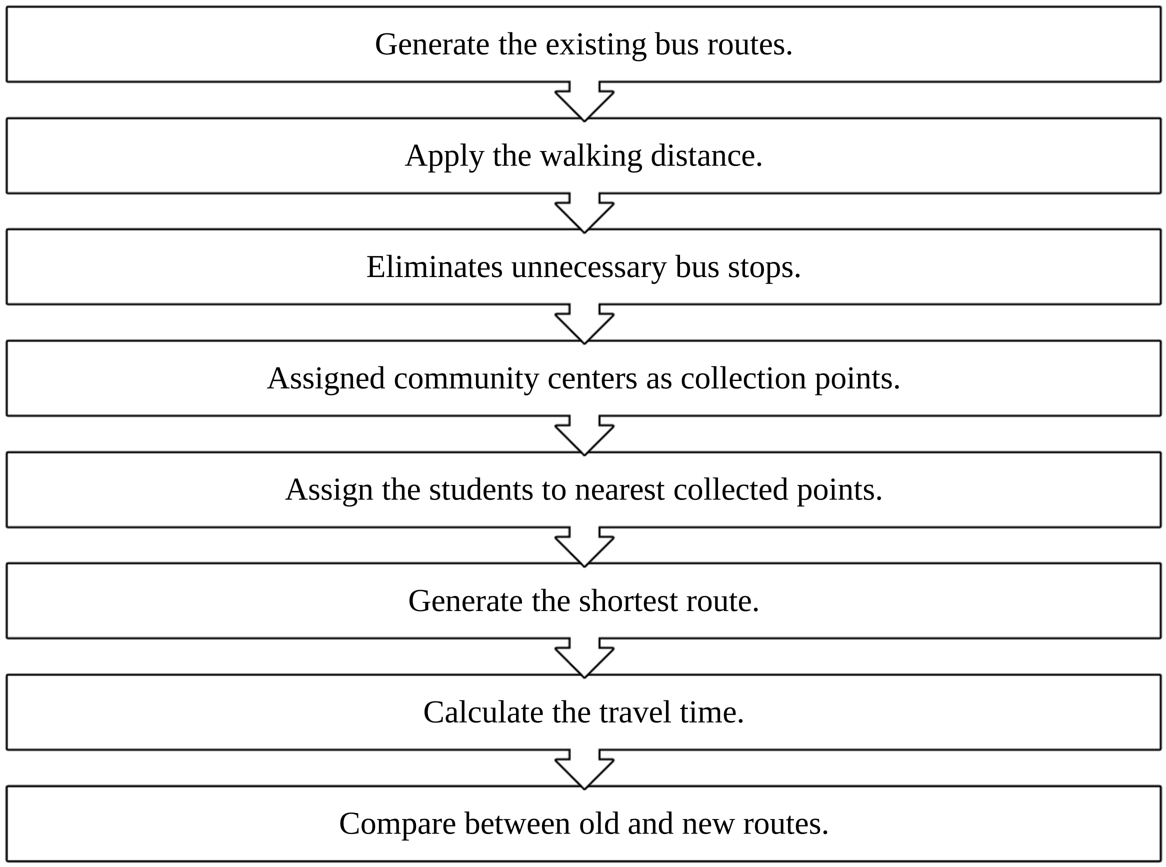

Figure 11: Summary of GIS analysis.

For example, the stop spacing analysis used by a tool called "service area" in network toolbox in ArcMap (A GIS Software) is used to find the coverage area of any service such as finding walking distance using a time constraint. The optimal route and shortest path from origin to destination, using a Dijkstra’s algorithm (ESRI, n.d.), is considered one of the most famous algorithms used to solve shortest path problems

(Sadeghi-Niaraki, Varshosaz, Kim, & Jung, 2011), so it will be used in this study with a combination of constraints to solve school routing issues.

The community centers were chosen to be the collection point due to many reasons. First, the community center in the UAE is always the area which has the mosques (worship place). People have to visit the mosque five times a day, which makes the route and walking paths to the community center safe and familiar to everyone in the community, including the students. The second reason is that most of the community centers have a community park with big empty lots in front of the mosque, which makes maneuvering the buses easy, and provides a comfortable area to have more students gather.

The two main network analyses used in this study are finding new route and location-allocation. The main reason for using the suitable tools for a study are the type of data available and target of the study. The first model created finds the existing bus route and is used to find the optimum route with some setting changes. Moreover, the model is used to calculate the length and travel time of the existing and proposed routes.

The solving route model was created to find the existing route based on the sequences of a series of bus stops, Figure12.

This model also is used to find the optimum route with some changes on parameters. While the aim of this study is to reduce the travel time, and so the main impedance is time, it also focuses on finding the quickest route with the lowest cost. Moreover, using different accumulated impedance attributes in the analysis, such as distance, does not affect the main impedance that has been chosen to find the best route, which in our case was travel time.

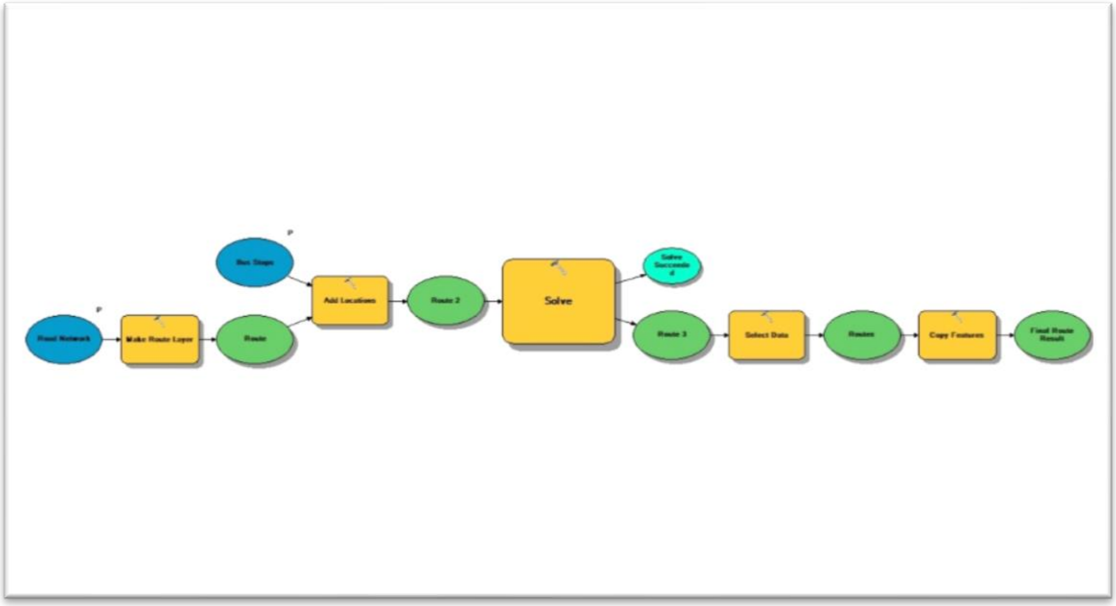

Figure 12: Make new routes model.

Before describing the second model that was used in this study, knowing the difference between a service area analysis tool and a location-allocation tool is essential to find the best result.

In the ArcGIS network analyst extension, there are five different analysis tools. The famous tool that is used in literature to reduce the redundant stops is service area, so finding service areas is a tool used to find the service area around any location or facility on the network within a specified impedance such as distance or travel time. Mostly, service area is used to evaluate accessibility. When the service area is created, it is easy to know the total coverage area of a facility, number of people in the area, or anything within the coverage region. The location-allocation tool is a network analysis extension which is useful to locate demand points such as stops.

The location-allocation tool is also one of the powerful accessibility tools used by private and public sectors. It finds the best location to provide the greatest services to the community at a low cost. In this study, as an example, the school considers a facility that provides a service to a set of demand points (student pickup points), so knowing the nearest stops to the school using a road network within a distance impedance, the location-allocation works much better and more accurately than finding the service area. The differences between the two tools (service area and location-allocation) is clearer in Figure 13.

The result of the service area is confusing because if the coverage polygon around the school is used to eliminate stops within 350 meters of the school, there are 10 stops that should be deleted. But in reality, by using the road network and assuming walking paths are parallel to roads, not all the 10 stops are located within 350 meters of the school, which is clearly noticeable (bold road segments inside service area) on the service area result map Figure13. However, the second map in Figure 13 shows the result of the location-allocation tool, which is more accurate, and it automatically chose the stops that are located within 350 meters of the school, just nine stops. To make sure that the difference is true the manual measurement tool was used and the distance between the main gate of school and surrounding stops measured. The result confirmed that the location-allocation is the more appropriate tool for this study, so the location-allocation model was created to assign the students to the nearest collected stop in the study area.

The location-allocation model was created to make the analysis automatically generated as Figure14.

The main three parameters in the model are road network, facilities (community centers) and demand points (students' stops). In the location-allocation analysis tool there are seven different functionalities. In this model the minimize impedance is used because the walking distance (350 meters) is considered in the cost analysis, which means the tool used to locate bus stops can only access the part of the road network that is within 350 meters of the community centers.

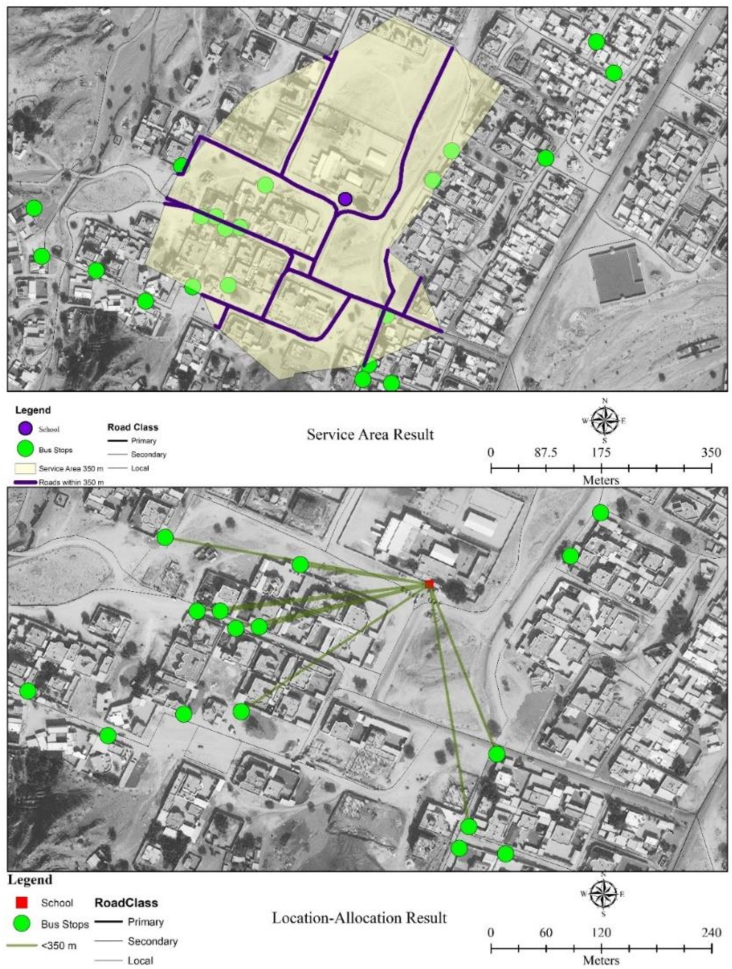

Figure 13: Maps show the differences between two analyst tools: service area and location-allocation.

The location-allocation analysis was applied to the four schools in the study area to determine the stops within walking distance of the school. All such stops were deleted from the bus route.

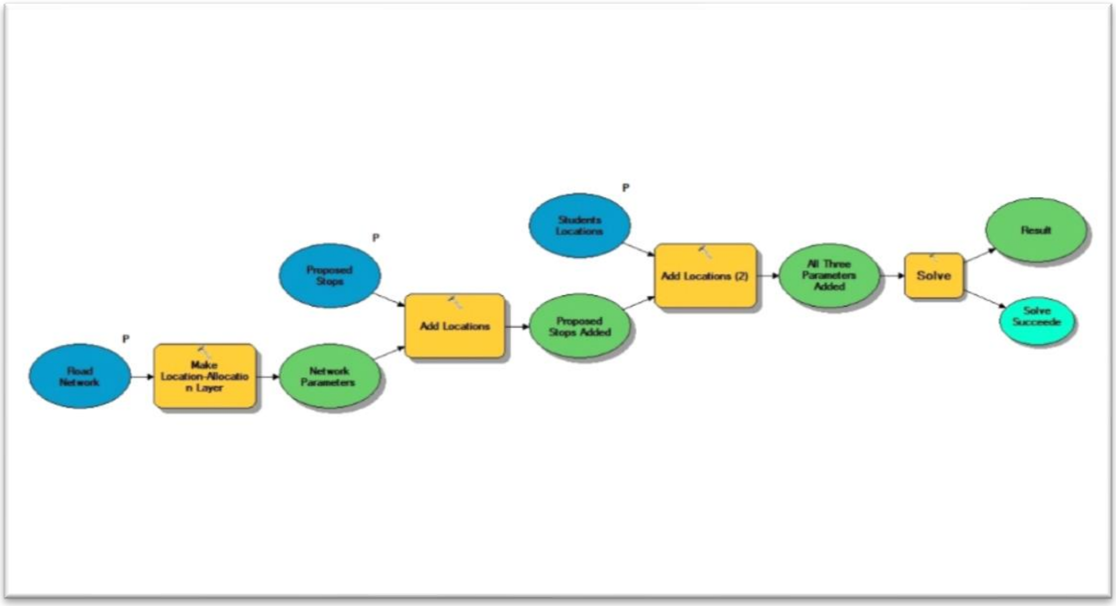

Figure 14: Location-allocation model used to assign students to new collection stops.

The final proposed stops were chosen carefully based on many different categories. In some cases there are only two students assigned to one designated community center, and those students are neighbors, so in this case if the community center is farther than 150 meters from their house, the proposed stop is assigned between the two students.

Next, when all the students are assigned to the new collected stops, the new route is created in the model as an existing route. The changes that were made to the first model were reordering the stops sequences to the optimum arrangement while minimizing the travel time for the proposed route.

Chapter 4: Result and Discussion.

The result of this study is a geodatabase for a school transportation system with four schools. The study creates and builds a road network for the study area, creates a geodatabase for each school's transport system, creates an optimal route-finding model, proposes new bus stops, assigns each student to the nearest collected stop with a location model, and finds the optimum bus route.

However, the focus of the research is minimizing the travel time from the first stop in each bus route to the school, so the created model is capable of finding walking time from the houses to the proposed stops, along with the bus travel time to the destination. Also, the model can add other costs, such as distance, and the users of the model can add more stops or delete from the route and regenerate the model to find updated costs.

One of the main outputs of this research is the creation of road network for the study area. It was noticeable that the road network layer, which came from the municipality, is not complete and missing a lot of existing road segments and information. Such important data was missing because the municipality used AutoCAD for their daily work, and they are too far away from using GIS for planning analysis and modeling.

After digitizing the existing bus route from the paper maps received from the bus authority, most of the missing road segments were added to the municipality road layer, and the difference was huge, as shown in Figure15. The layer from the municipality has 530 road segments, and the final created road network has 3,760 road segments.

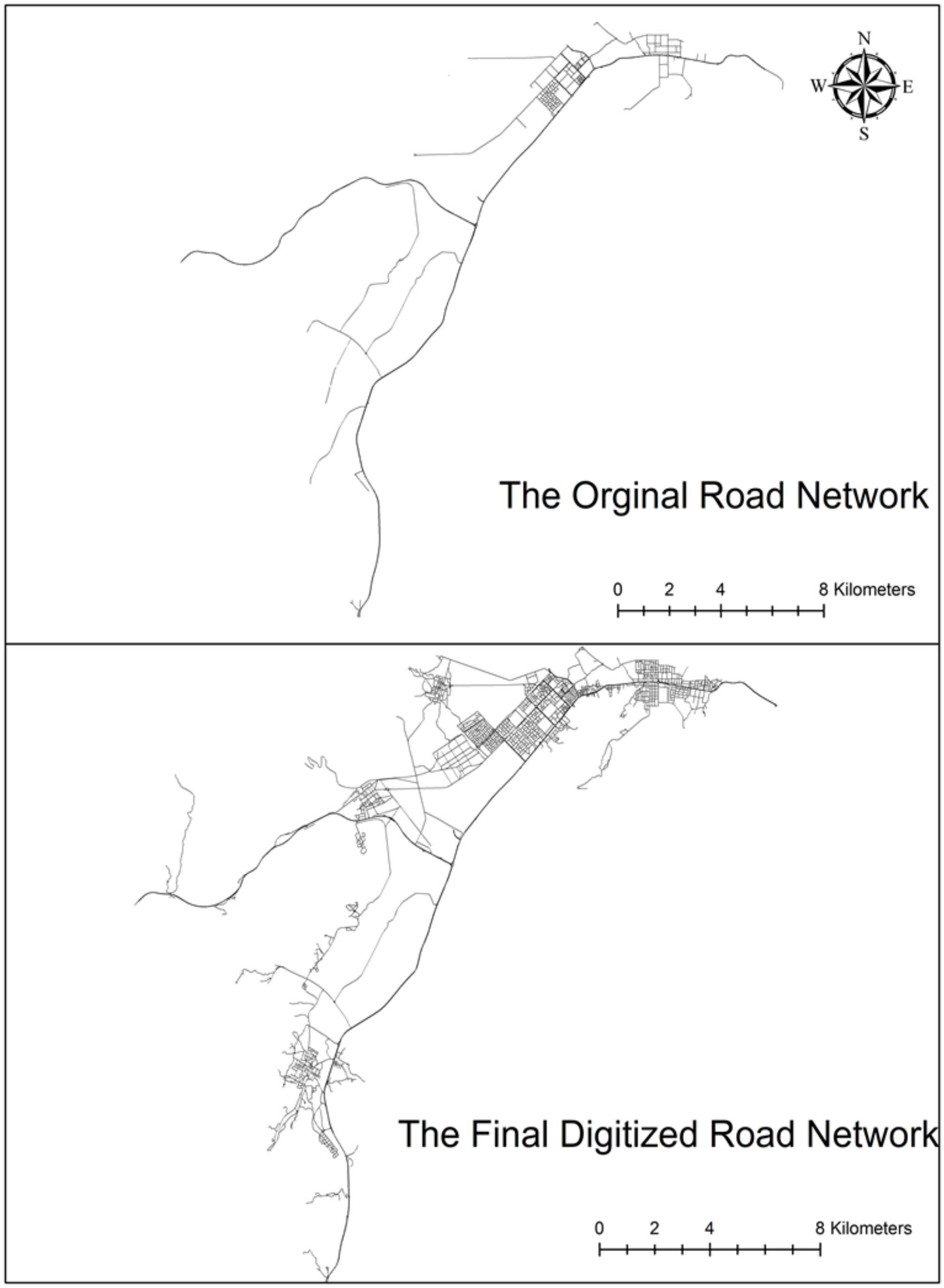

Figure 15: Map shows the differences between initial road network layer and the final digitized road network.

The geodatabase of school transport was created for four schools, Figure 16. Each geodatabase has four datasets with existing bus routes and stops features, and proposed bus routes and stops.

This dataset constitutes considers the first digital form of bus routes and stops in a school transport system in the UAE, which helps to identify the system's weakness and development opportunities.

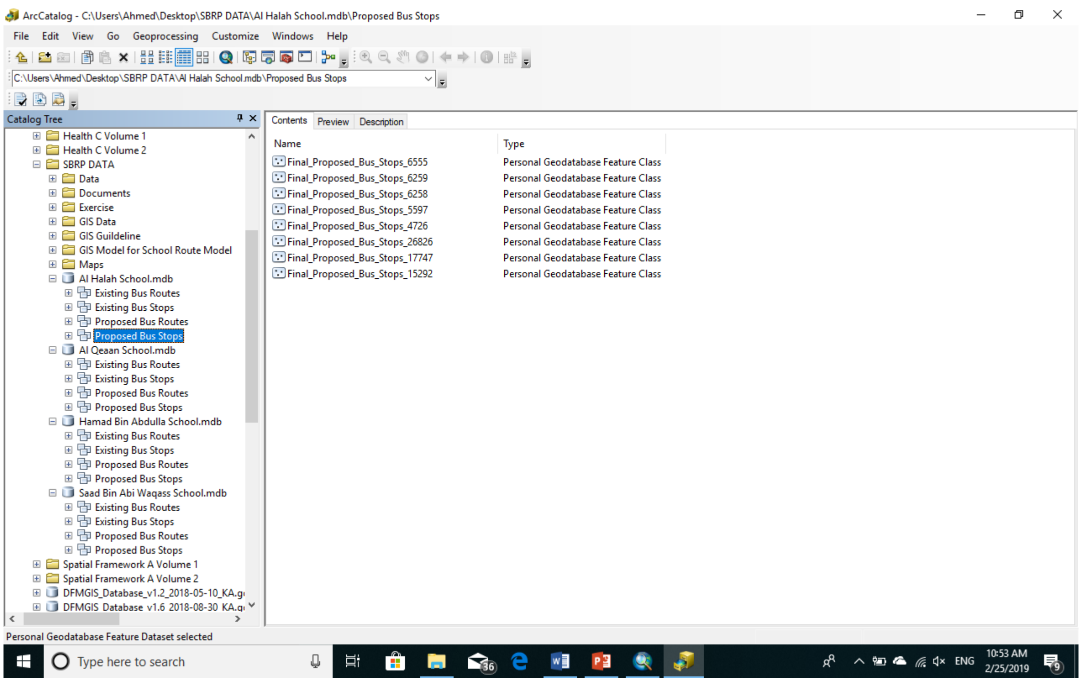

Figure 16: The geodatabase of bus routes and stops in a study area.

In the study area there are three different transport scenarios. The first scenario is that the bus serves students in the same community where the school is located. The second scenario is the bus transports students from a different community farther away from the school, but the students' homes are near each other. The third scenario is the bus collects students from houses in scattered locations to transfer them to a school in a different village.

In the first scenario, applying the walking distance from school to the nearest stops resulted in eliminating some of the stops, figures 1-2. Bus 4726 picks up 30 students from 30 bus stops, Figure17, while the school is in same community.

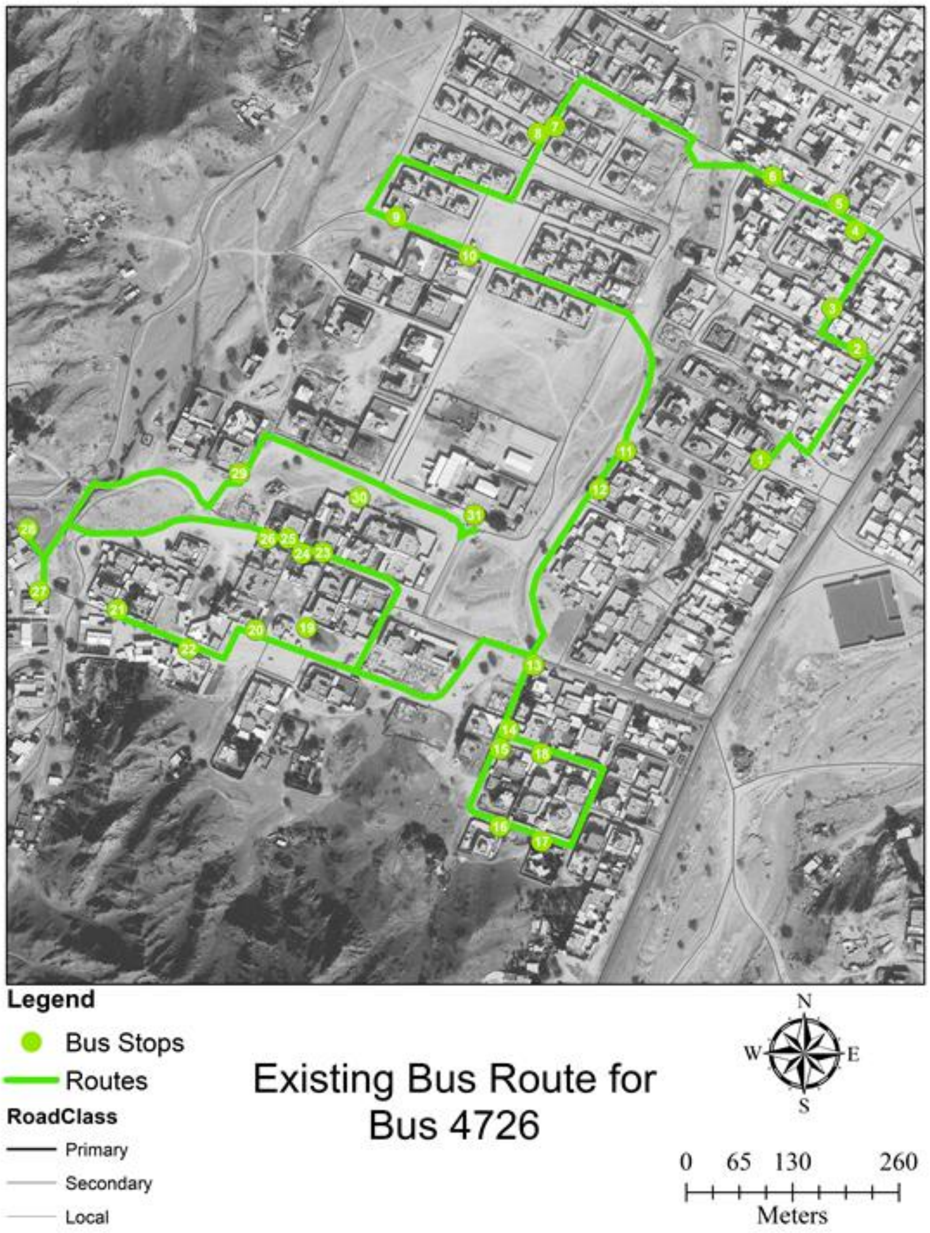

Figure 17: Map shows proximately distance to designated school.

After applying a location-allocation analysis, using 350 meters from the main gate of the school, nine stops were eliminated, so the total number of students was reduced to 21. Then the remaining students were assigned to seven proposed stops; the travel time in the existing route was 31 minutes but dropped to 16 minutes for the new proposed route, Figure 18. Finally, since the bus now only carries 21 students, instead of using the existing bus with a capacity of 60 students, a smaller, 22-passenger bus is all that is needed.

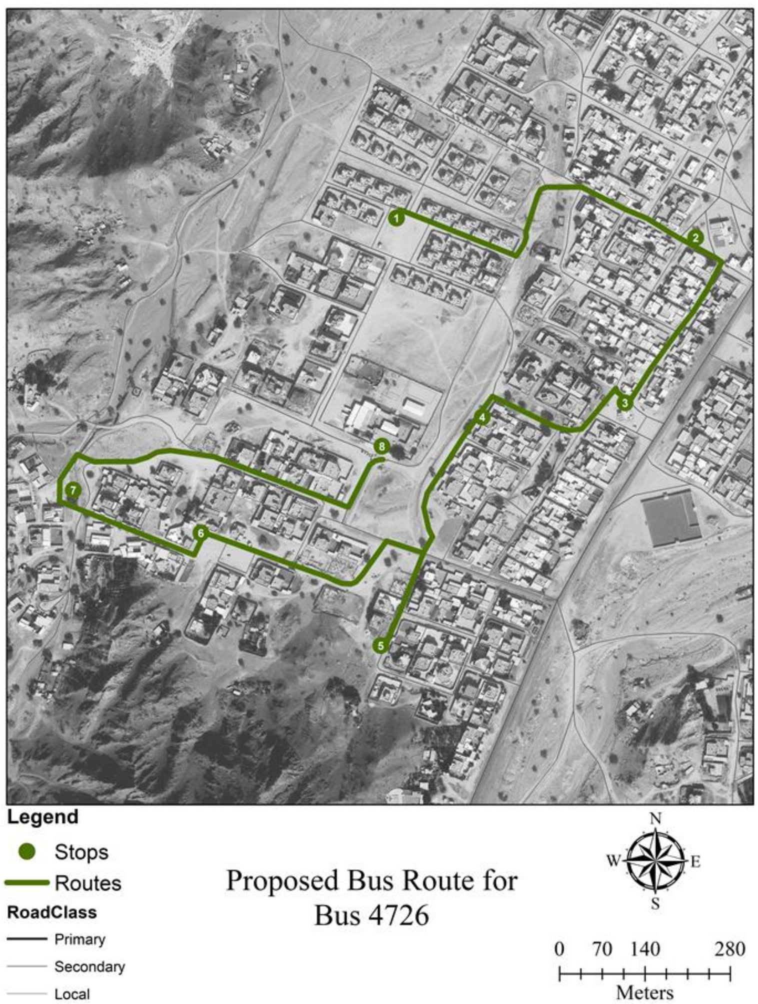

Figure 18: Map shows final proposed bus route and stops.

The second scenario is the bus transports student from a different village farther away. In this case, the bus should transport all the students, unlike the first scenario in which the students who live near the school do not have to be transported. However, all the students are assigned to new collected stops, Figure 19. So instead of 29 stops on the current route for Bus 6555, the stops are reduced to five collection points. The travel time drops from 42 minutes to 31 minutes.

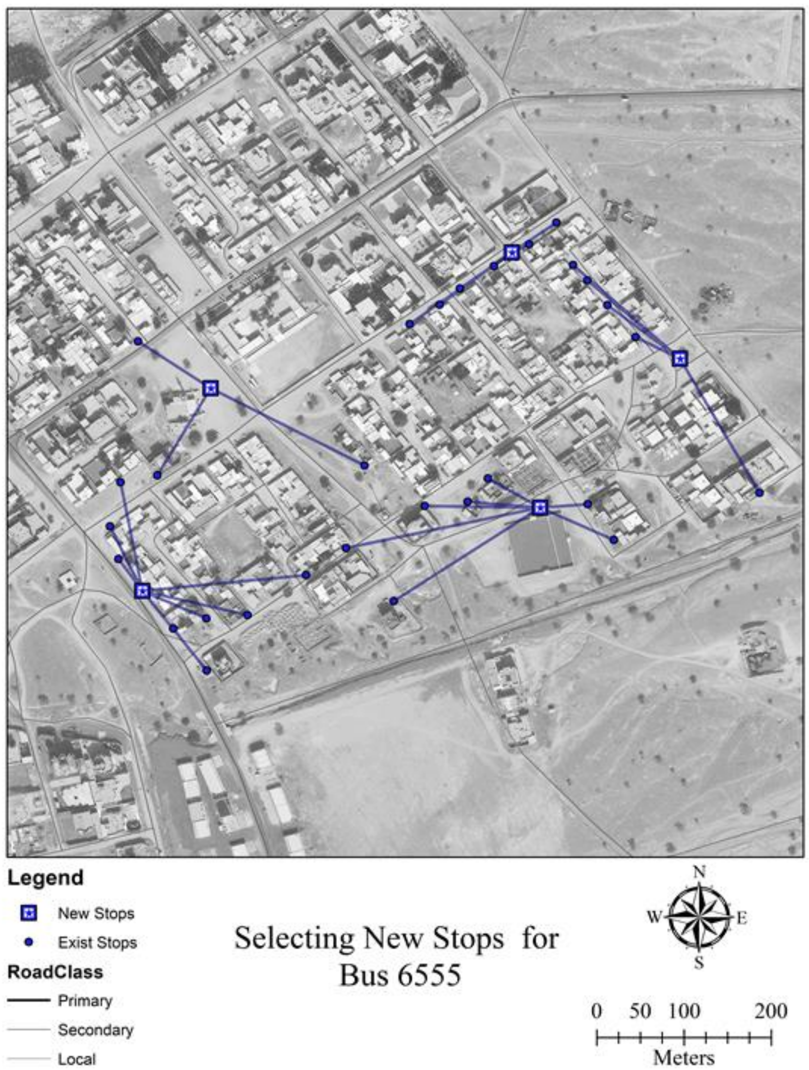

Figure 19: Map shows the result of location-allocation analyst.

The third scenario is the bus transporting students from villages with scattered houses, so the number of stops and travel time do not decrease much. Figure 20 shows the existing bus stops on the existing route for Bus 6259. Compared to the second Figure 21 with proposed stops and route, it does not change much. The travel time drops by just 7 minutes, and bus stops are reduced from 19 to 12 stops.

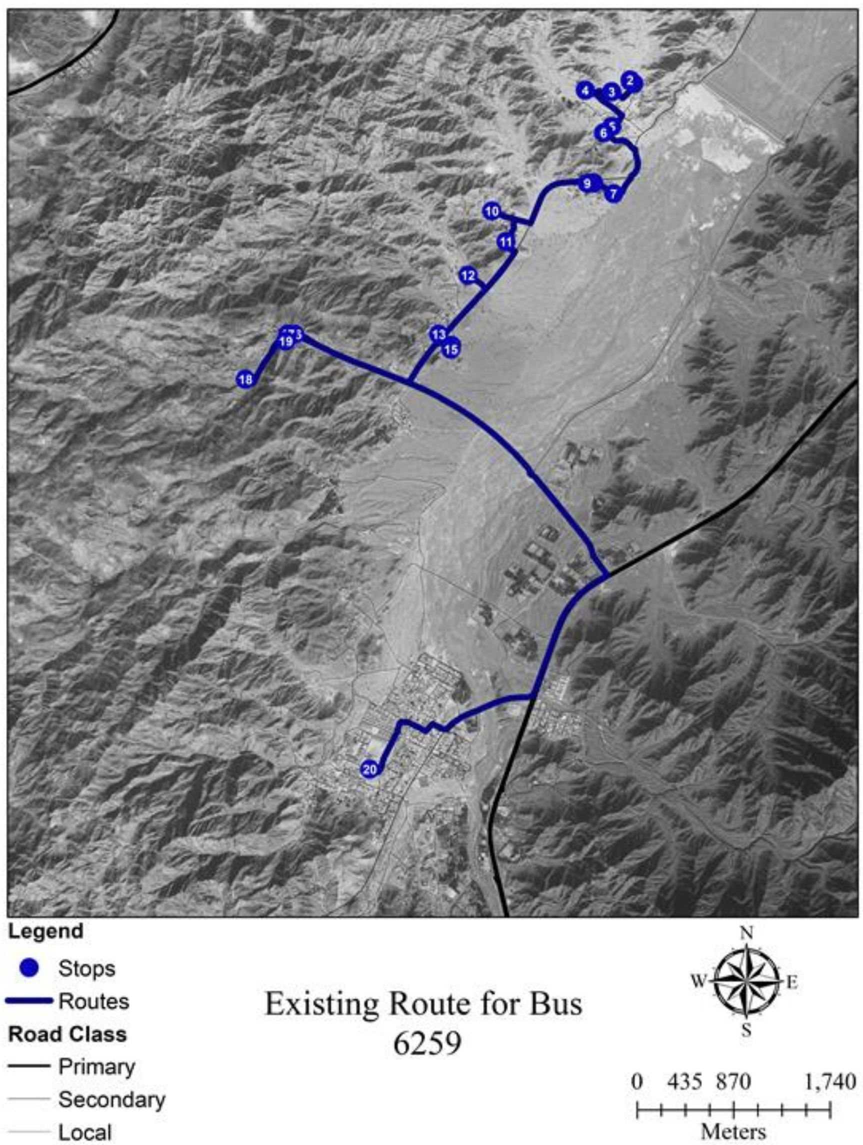

Figure 20: Map shows the existing bus route in a rural area.

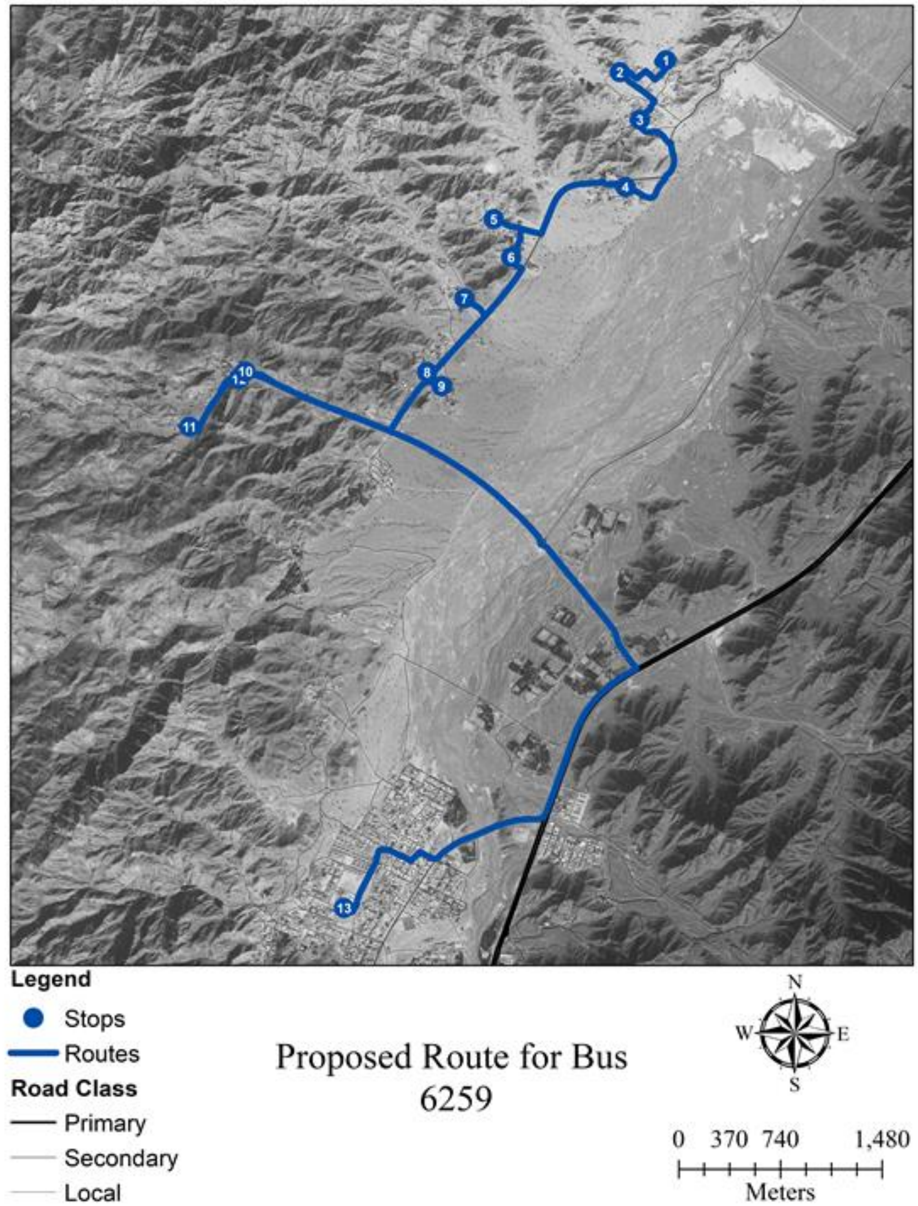

Figure 21: Map shows the proposed bus route and stops in a rural area.

To conclude the three scenarios, the distribution of land use (residential area) and the bus route influence the travel time. The first scenario reduced travel time by approximately 48%, while the second scenario saw a 26% reduction, but in the third scenario travel time was reduced by only 15%.

4.1 Bus Capacity Result.

In the study area, the school transport system was evaluated in four schools. Hence, the result of each school is discussed separately, which includes the current number of bus stops, travel distance and travel time compared to the proposed result.

Exploiting the maximum capacity of buses in a fleet is a sign of good quality management and optimal utilization of resources. The following Figure 22 shows that the existing system could get rid of all buses with 60 student capacity because the average number of students in each bus is 30, and buses with 55 seats have an average of 22 passengers for each bus. Reconsidering the buses' capacity in the study area is important to save money and reduce fuel consumption.

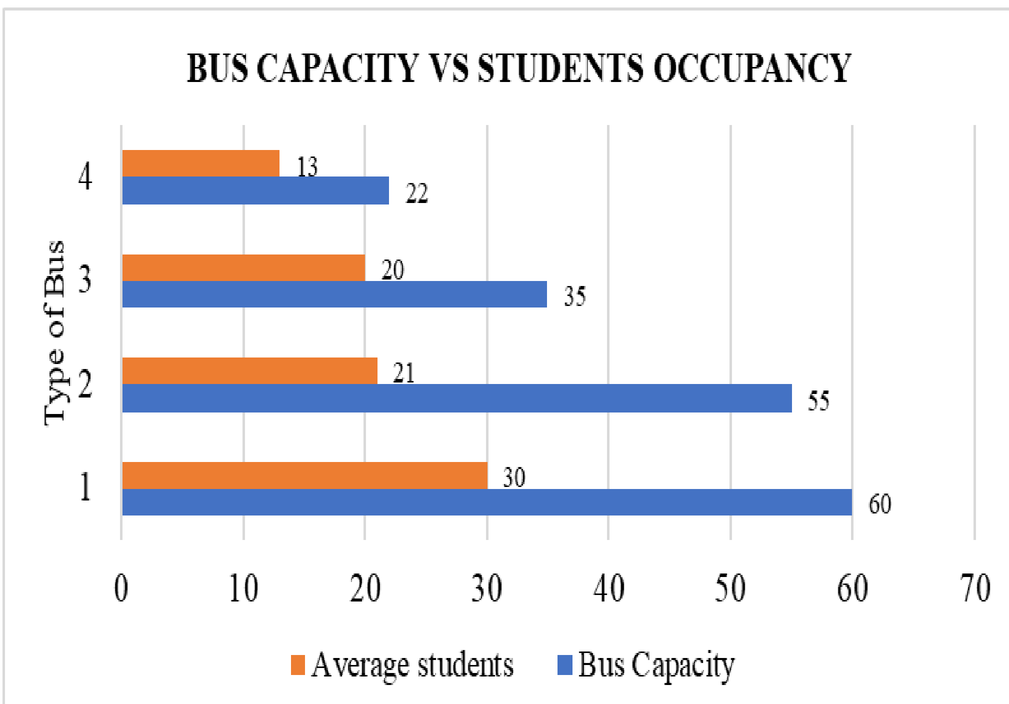

Figure 22: The chart represents the total buses occupancy rate.

4.1.1 Al Halah School.

Only one school is in a suburban area, the other three schools in the study area are in the city. The school is served by eight buses – five of them with 60-student capacity, one bus that can carry 55, and two with 22 seats. The five 60-passenger buses cost more to operate than the smallest buses, but all the buses have an average occupation rate of less than 50% of the total capacity.

The percentage of stops eliminated is 71% when compared to the existing condition. From Figure 23, it is noticeable that Bus 6's route only cuts out two stops. That's because Bus 6 serves a rural area with scattered houses, where each family has its own separate area. Most of Bus 1's stops were deleted from the bus route because they were close enough to the school to be within the walking distance of 350 meters.

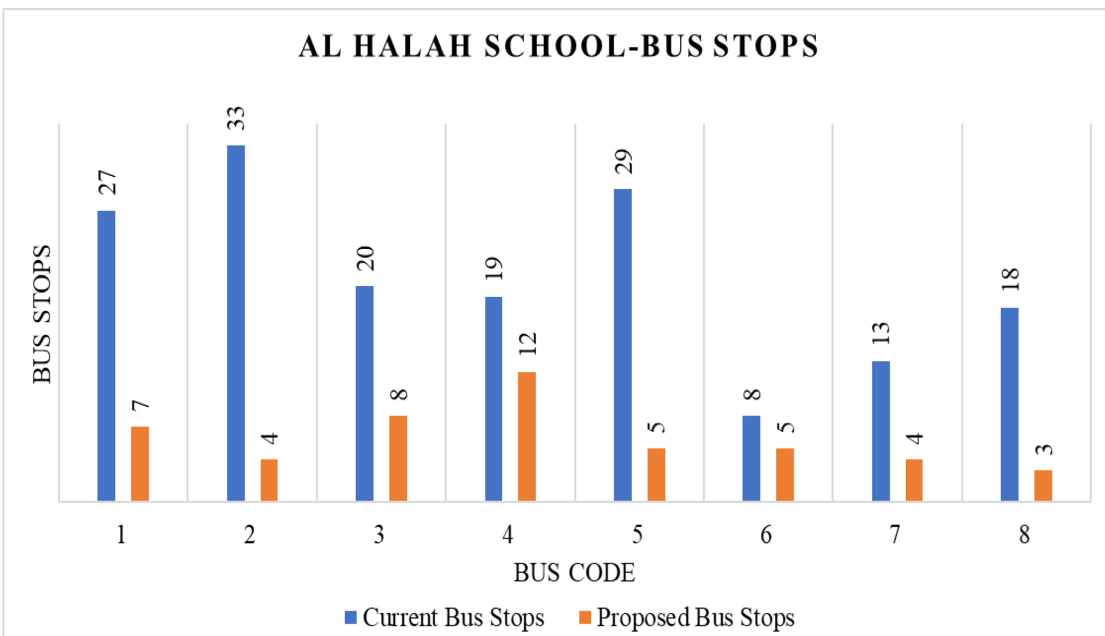

Figure 23: The differences in bus stops numbers between current and proposed conditions for Al Halah school.

The travel distance dropped by 8%, not much change, because the buses have nearly the same route with the proposed new stops, Figure 24. The main influence of the collected stops is that the waiting time for the bus is reduced.

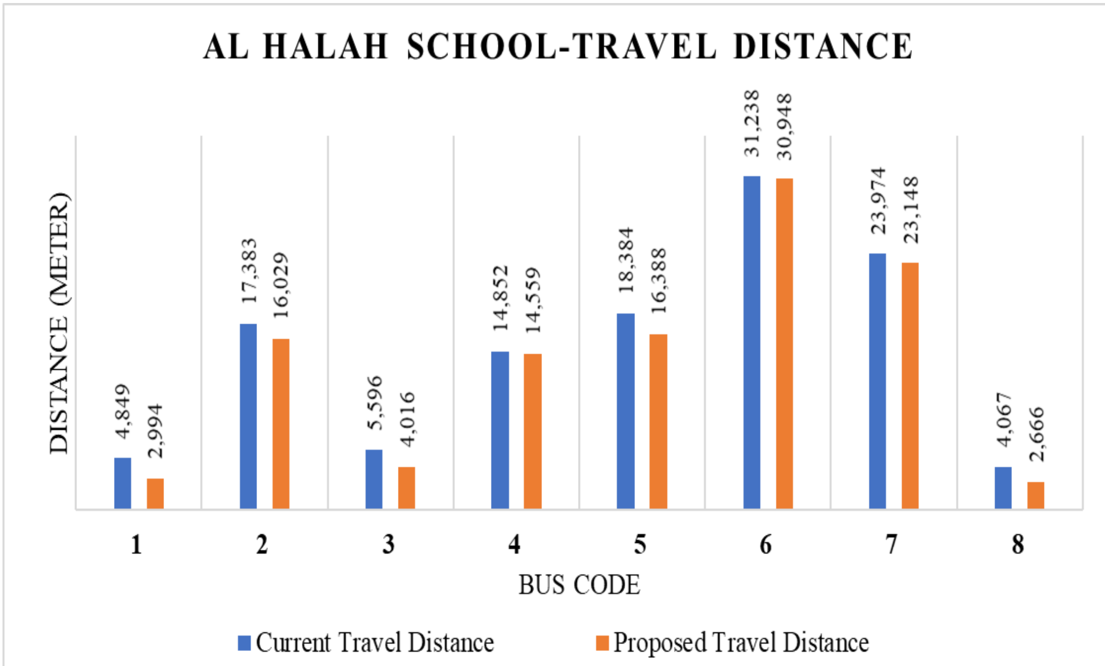

Figure 24:The differences in buses travel distances between current and proposed conditions for Al Halah school.

The total reduction in travel time is 23%. Adding walking time to the school transport system positively impacts total travel time – an average of 9 minutes is saved. From Figure 25, remarkably all the buses of the school saved travel time.

The walking time of each student is calculated from the students' houses to the proposed stops, Figure 26. The maximum distance walked by a student is 319 meters, and maximum walking time is 3.8 minutes. In general, the average walking distance is 109 meters, with an average walking time of 1.3 minutes.

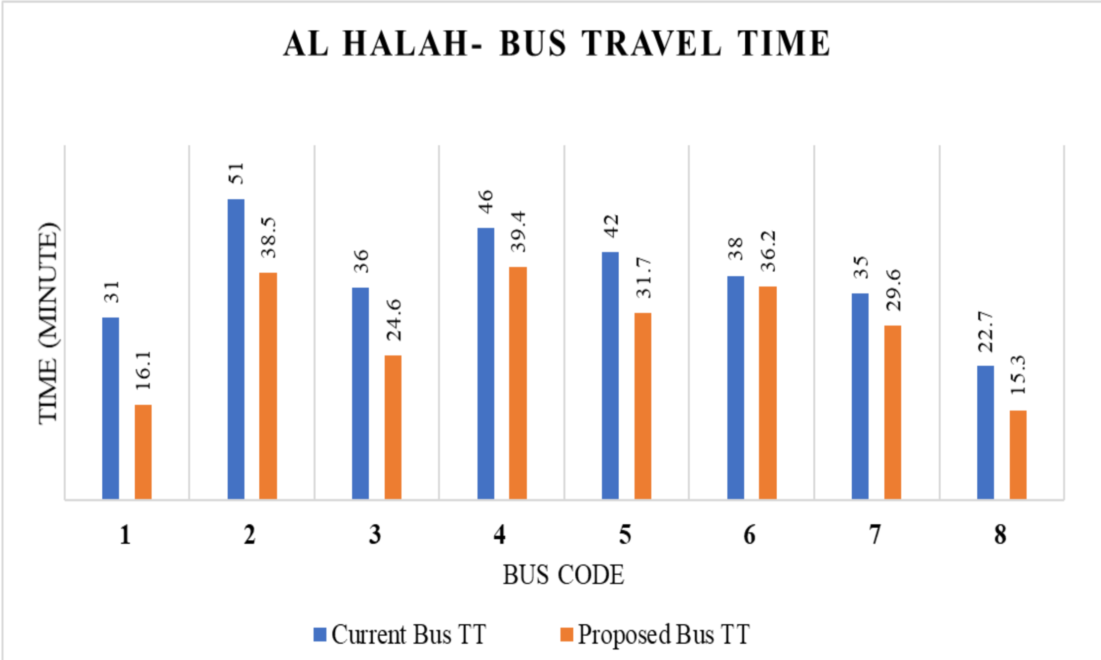

Figure 25: The differences in buses travel time between current and proposed conditions for Al Halah school.

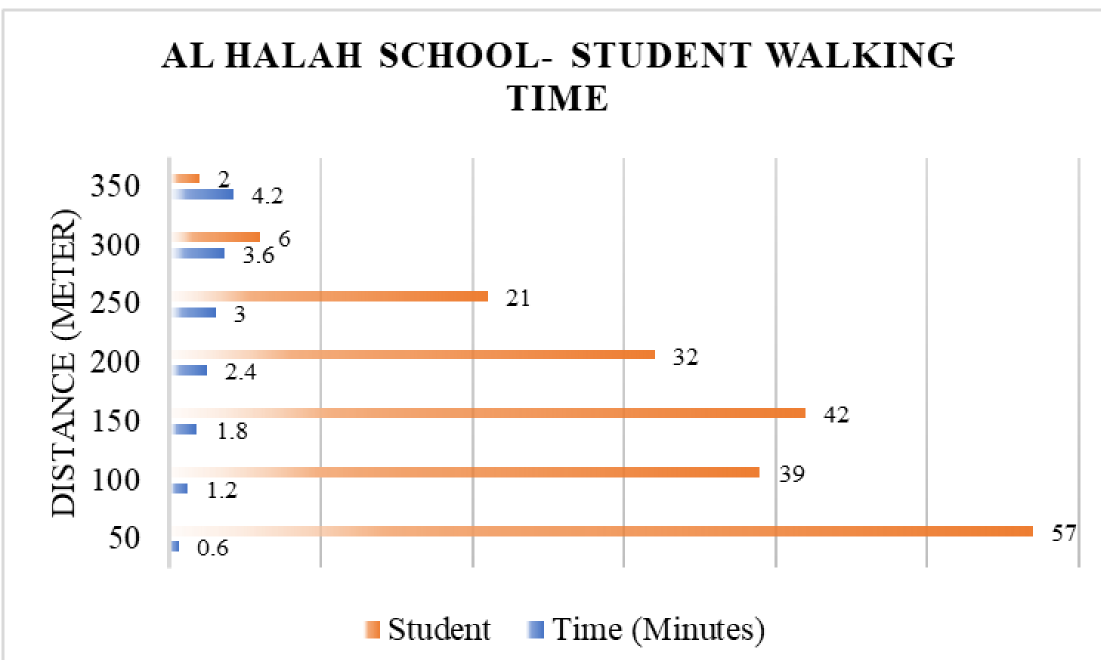

Figure 26: The students walking time and distance from their house to proposed stops.

4.1.2 Al Qiaan School.

Al Qiaan School is in the city center. It has 15 buses in service to pick up 340 students from all over the city and suburban villages. In the existing condition, the average travel time is 35 minutes for an average distance of 14,687 meters. However, in the proposed condition the average travel time is 26 minutes, and average travel distance is 12,102 meters.

Currently 307 bus stops serve the students in the Al Qiaan school, while the proposed stops are 87, Figure 27. The total percentage of eliminated stops is 72%, a change which will greatly affect the system's operation.

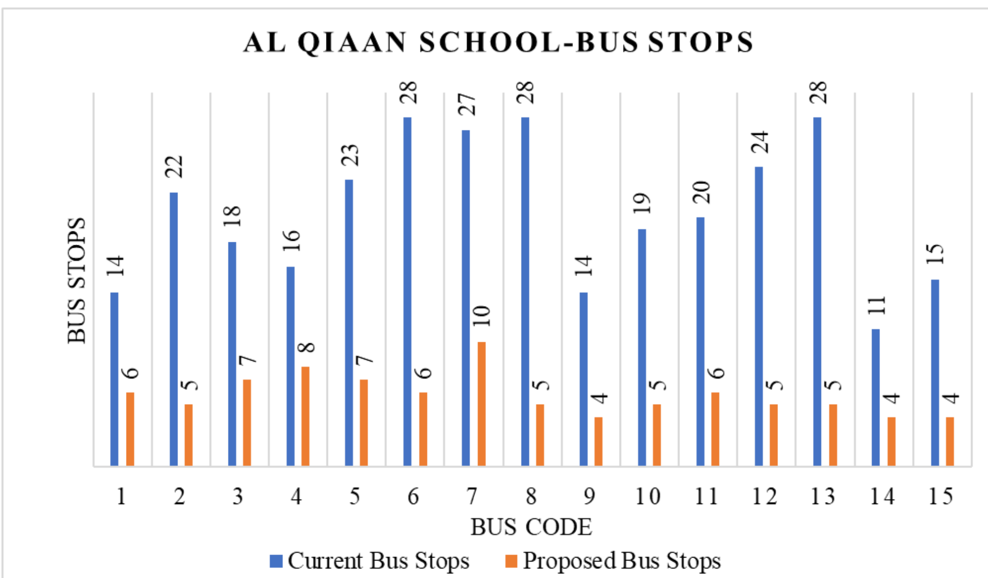

Figure 27:The differences in bus stops numbers between current and proposed conditions for Al Qiaan school.

The travel distance is reduced by 18%. In the following Figure 28, all the buses' travel distance drops except Bus 14 because the impedance that was used in the analyst model is travel time, not shortest distance, so the model searches for a quicker route rather than the shortest route. The existing route for Bus 14 includes many obstacles such as roundabouts and speed humps.

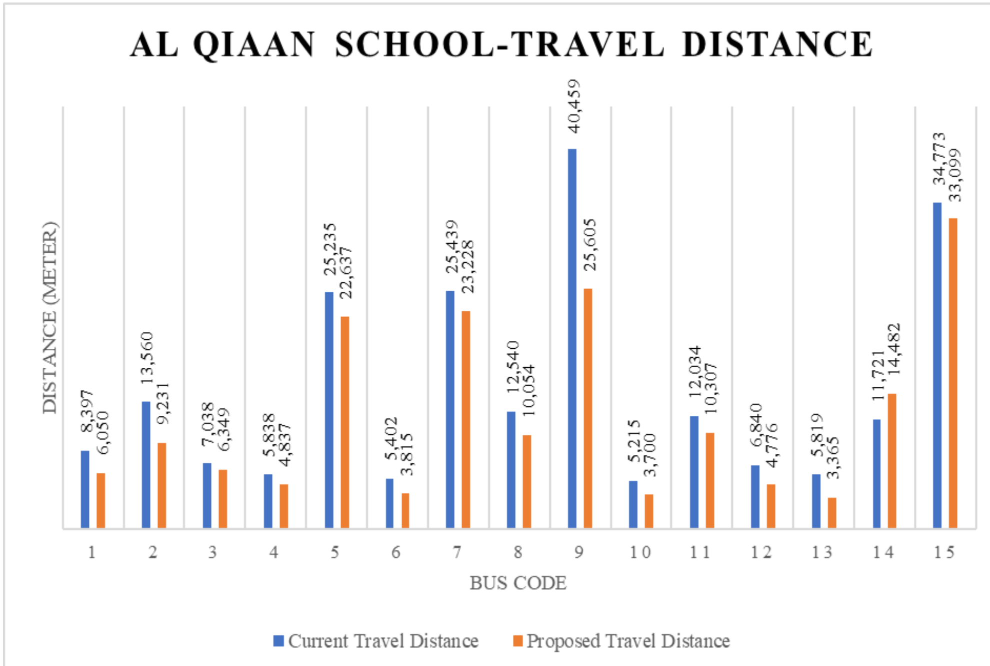

Figure 28:The differences in buses travel distances between current and proposed conditions for Al Qiaan school.

The total reduction in travel time is 27%, with an average of 9 minutes saved. All 15 buses have reduced travel time. Bus 9 has the most dramatic reduction, from 50 minutes to 32 minutes, Figure 29. This bus has 14 stops and picks up students from their houses' main gates in residential neighborhoods, which made for a crooked bus route. The new route with proposed stops for Bus 9 is almost straight.

Knowing the walking time of the student from the house to the proposed stop is essential as part of the total travel time to school Figure 30. The maximum distance walked by student is 344 meters, and maximum walking time is 4 minutes. In general, the average walking distance is 134 meters, and average walking time 1.6 minutes.

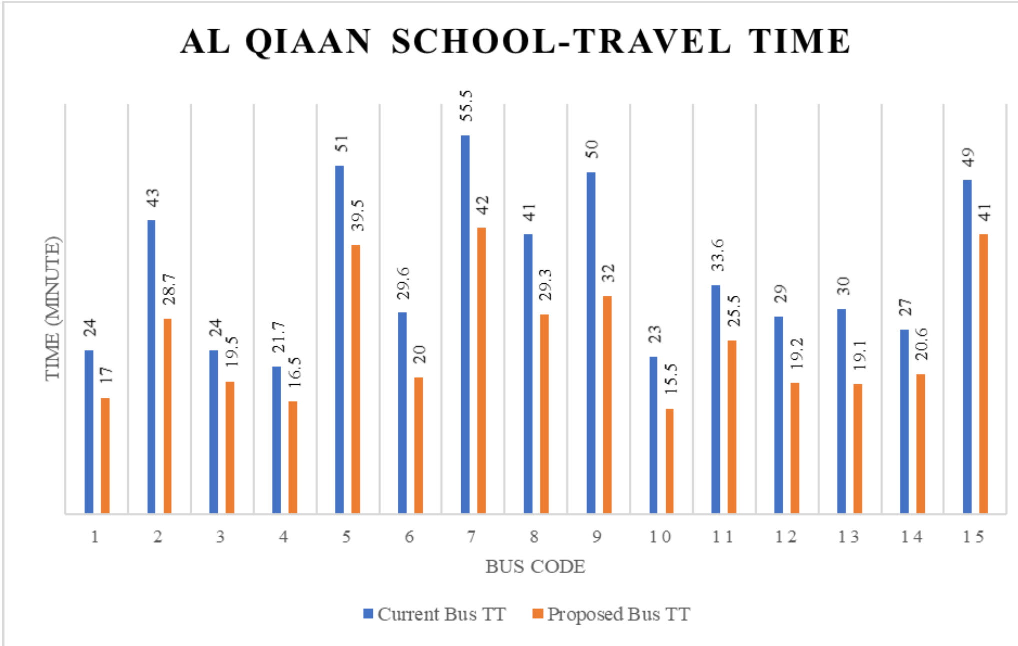

Figure 29: The differences in buses travel time between current and proposed conditions for Al Qiaan school.

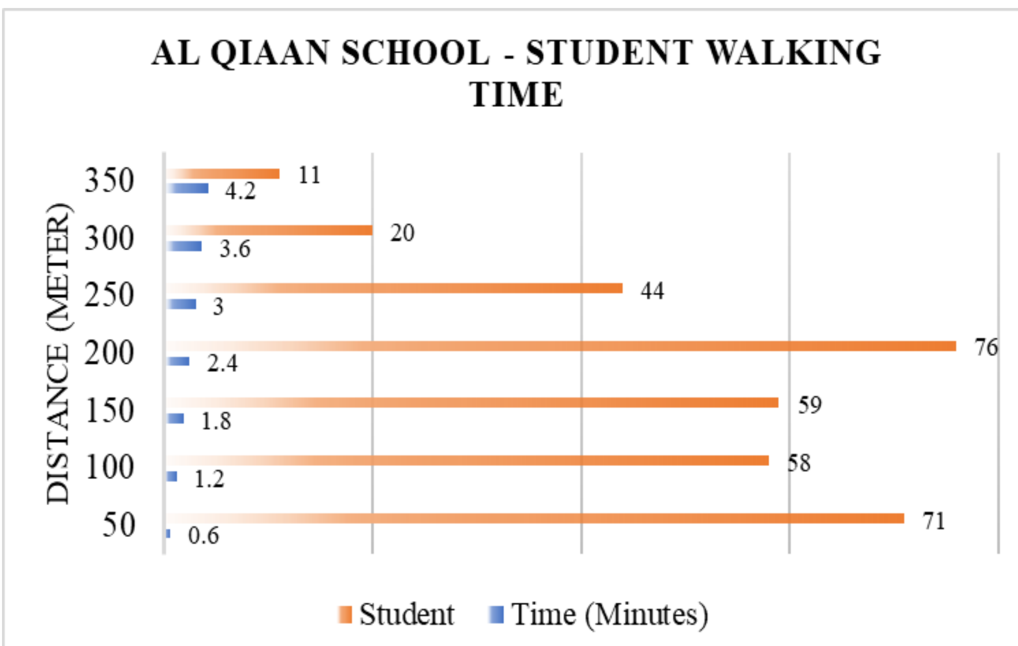

Figure 30: The Al Qiaan school's students walking time and distance from their house to proposed stops.

4.1.3 Hamad Bin Abdulla School.

Hamad bin Abdulla school is located on the east side of the study area near to Saad school. The school has 11 buses serving 322 students. The school has 248 bus stops for the students, so 74% of the stops are at the front gate of a student's house. Figure 31 illustrates the difference between the current and proposed bus stops. In the proposed condition, 70% of the existing bus stops are eliminated because of unnecessarily stops spacing.

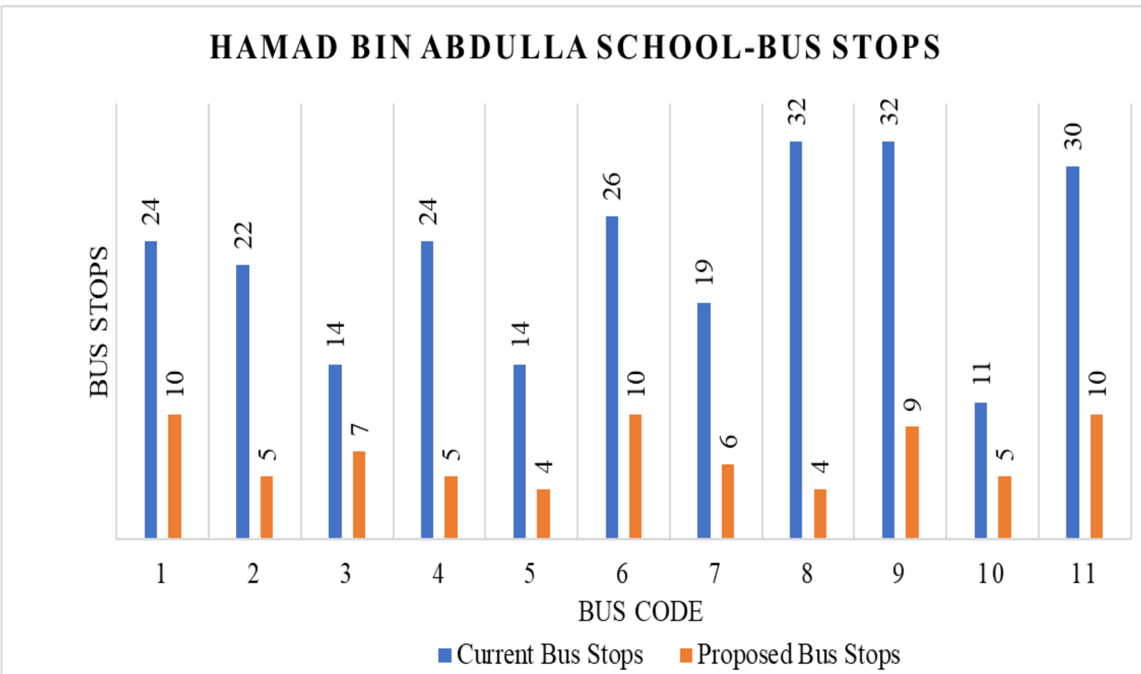

Figure 31: The differences in bus stops numbers between current and proposed conditions for Hamad Bin Abdulla school.

While the distance on all routes for the Hamad Bin Abdulla school decreased, Figure 32, two buses, Bus 3 and Bus 5, had little decrease in travel distance. That's because both serve rural villages with small residential density, so the proposed stops are close together.

The travel time of all buses was reduced, Figure 33. The average decrease in time on all routes was 11 minutes. The maximum travel time was 63 minutes for Bus 1, and it drops to 52 minutes with the new proposed stops and route. The lower proposed travel time is for Bus 2. Overall, the framework works well in reducing travel time.

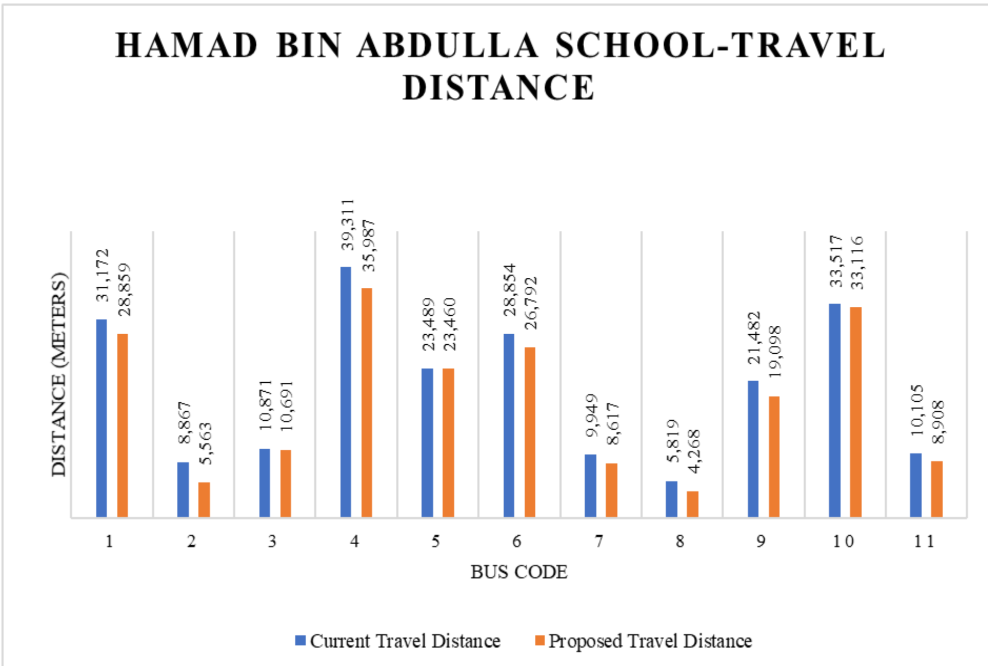

Figure 32: The differences in buses travel distance between current and proposed conditions for Hamad Bin Abdulla school.

The maximum walking distance of the students of Hamad Bin Abdullah school is 348 meters with a maximum time of 4.2 minutes walking. As is clearly shown in Figure 34**,** most of the students (75%) walk 197 meters for 2 minutes.

However, 10 students walk more than 300 meters for approximately 4.2 minutes, and 26 students walk more than 250 meters with 3.6 minutes. So, most of the students, nearly 89%,walk less than 250 meters and they spend 3 minutes or less walking to the proposed stops.

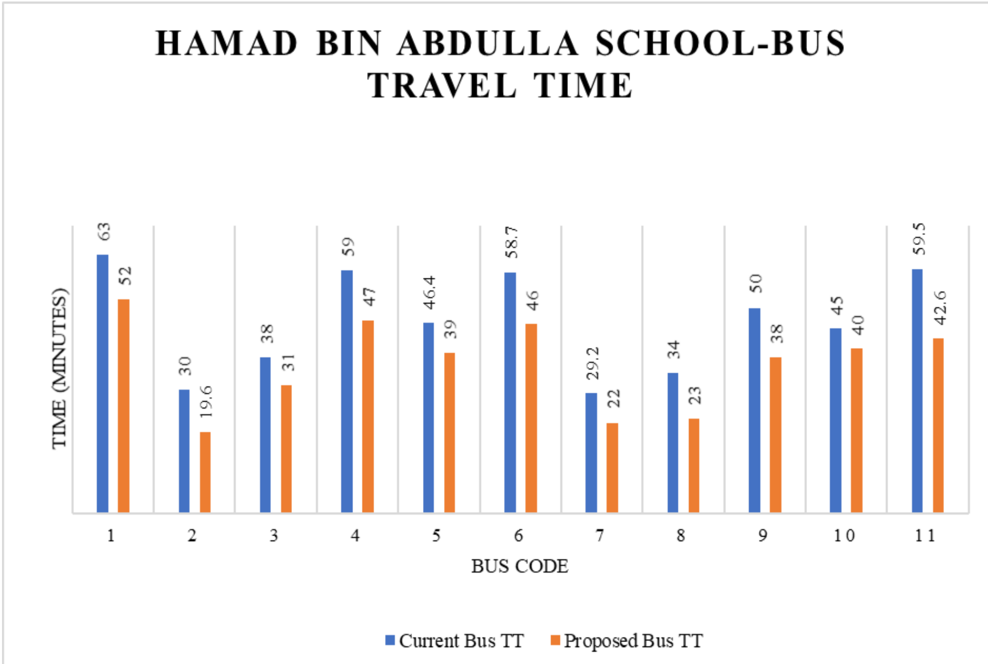

Figure 33: The differences in buses travel time between current and proposed conditions for Hamad Bin Abdulla school.

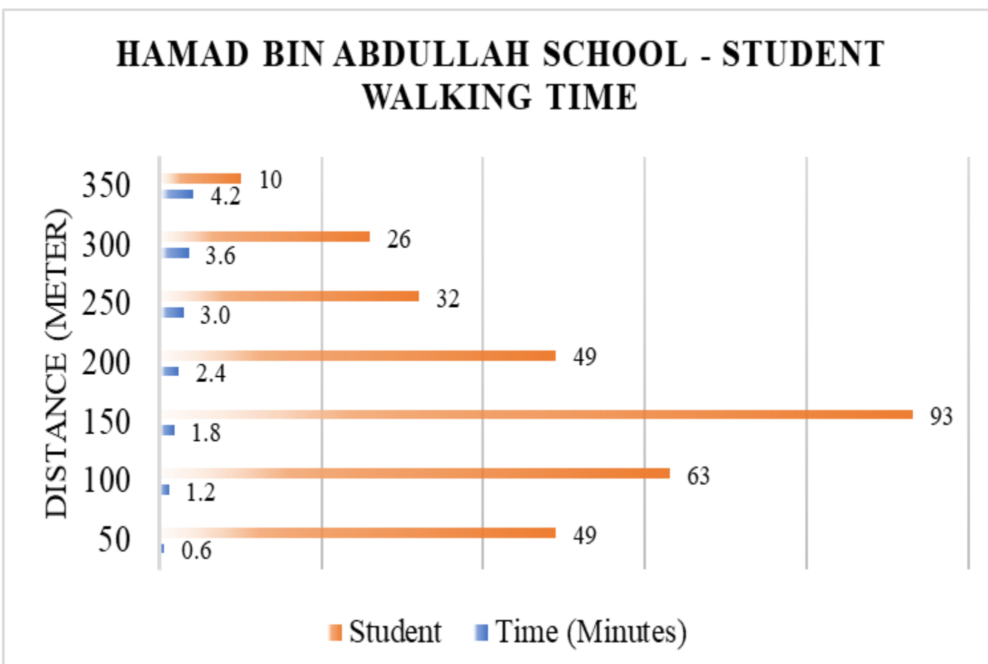

Figure 34: The Hamad Bin Abdullah school's students walking time and distance from their house to proposed stops.

4.1.4 Saad School.

The school is located on a residential area at the east side of the study area. A total of 385 students use the bus in the current situation, while in the proposed condition the total students would be 368; two students live in front of the school at less than 350 meters. The school uses 13 buses.

Looking at Figure 35, there is a big difference between the existing and proposed situations, so that in the proposed condition the number of stops drops significantly.

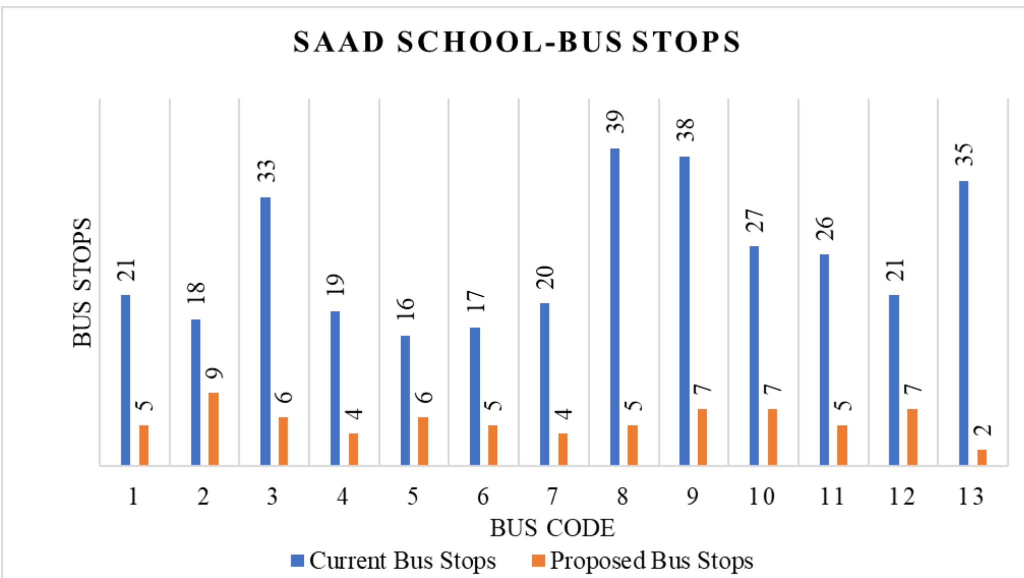

Figure 35: The differences in bus stops numbers between current and proposed conditions for Saad school.

In total, the travel distance decreased by 21%. The maximum existing travel time is approximately 12 km; however, the proposed maximum distance is 11 km. In the analysis chart of distance traveled, all routes decrease in distance between the existing and proposed conditions, but Bus 3 experiences the highest drop in distance, Figure36.

Travel time is reduced by a total of 30%. An average of 10 minutes of travel time is saved, and all 13 buses see a reduction, Figure 37. Bus 11 dramatically decreases travel time from 42 minute to 22.9 minutes. This bus used to pick up students from 26 bus stops, while in the proposed condition it has just five stops.

The reduction of the bus stops benefits the whole school transportation system. There are many advantages in reducing travel time, including reducing fuel consumption, reducing carbon dioxide emissions from bus exhausts, and easing the burden of traveling on students.

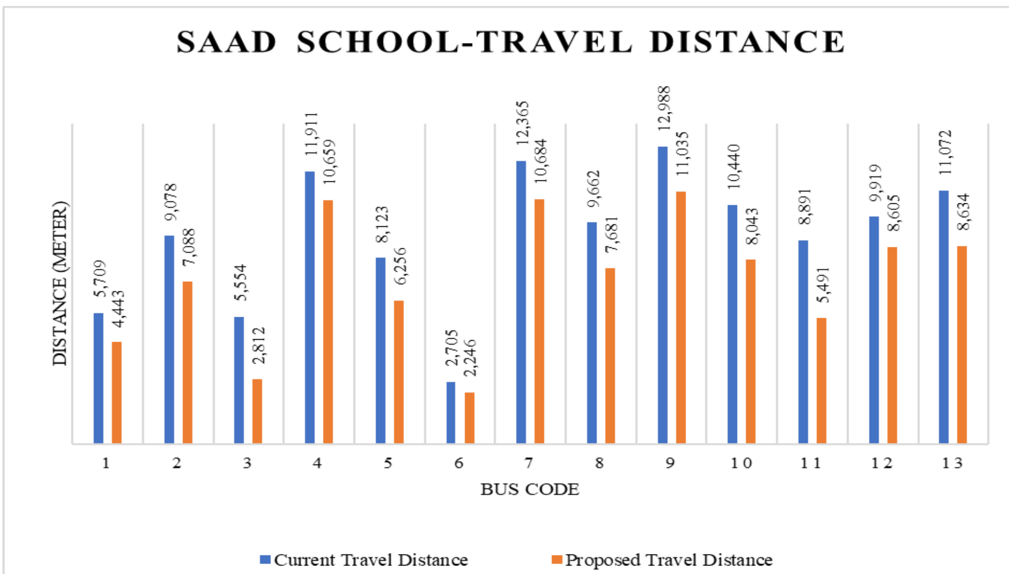

Figure 36: The differences in buses travel distance between current and proposed conditions for Saad school.

The significance of the walking time for students from the house to the proposed stop should not be underestimated; it is an essential consideration. The maximum distance walked by student is 344.7 meters, and maximum walking time is 4.1 minutes. In general, the average walking distance is 163.7 meters, and average walking time is 0.8 minutes, Figure 38.

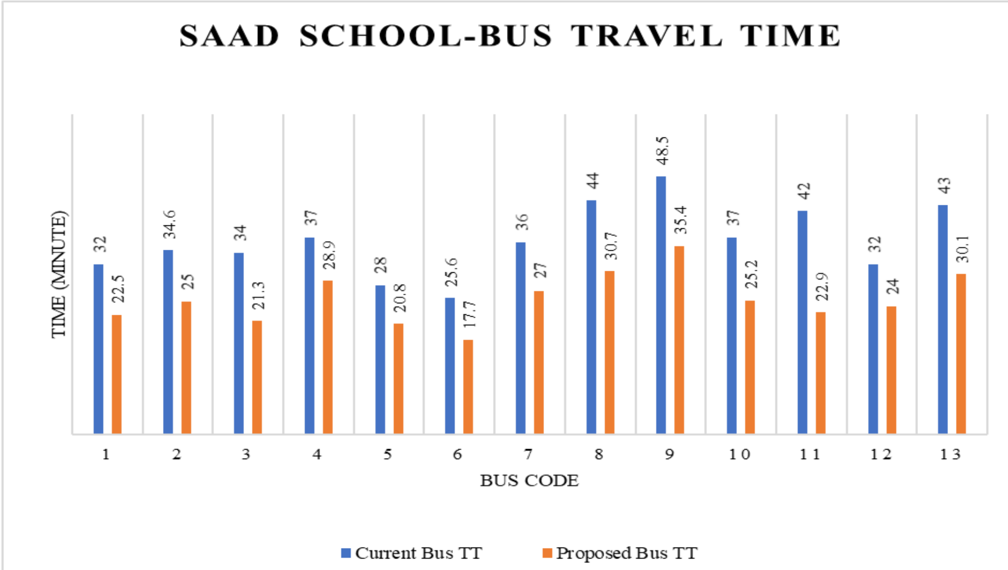

Figure 37: The differences in buses travel time between current and proposed conditions for Saad school.

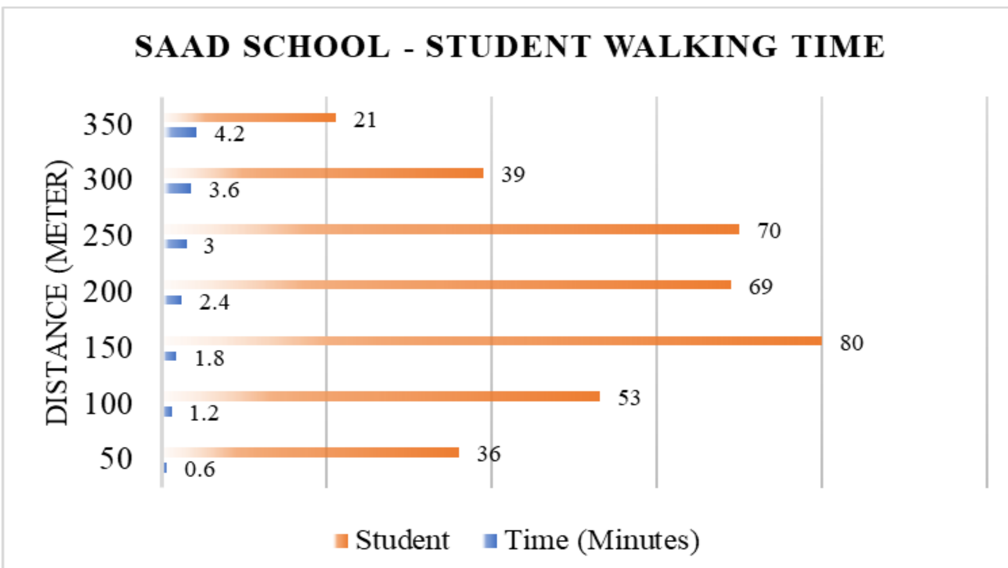

Figure 38: The Saad school's students walking time and distance from their house to proposed stops.

4.2 Worst Scenario for first students.

The following table 4 represents the worst scenario (the longest travel time) for students in all bus routes. The first column is for the number of buses that service the school. The second column represents the current travel time from the first stop to school. The third column is the average walking time for students at the first stop. The fourth column is the travel time for proposed bus routes, and the fifth column represents the total proposed travel time for the first student picked up at the first stop for both walking from home to the stop and the total bus travel time. The sixth column shows the difference between the current travel time from the first stop on the bus route to the destination (schools), and the new proposed bus travel time with the new route plus the average walking time for students at the first stop.

The entire existing buses' travel time is 1,820 minutes while the proposed bus travel time in a new route is 1,351, so the total travel time is reduced by 469 minutes (7.8 hours). The average travel time for all 47 buses in the current situation is 38.73 minutes; however, in the proposed routes the average bus travel time is 28.75 minutes, saving almost 10 minutes per route. The maximum travel time in an existing route is 63.4 minutes, and the minimum is 21.7 minutes, while in the proposed routes the maximum travel time is 51.9 minutes and the minimum is 15.62 minutes.

The walking mode is added to the school transportation system, so the walking time from the house to a bus stop is additional travel time for the proposed routes. It is essential to now notice the worst scenario (longest time on the bus) for students' travel time from the first stop to the school. Therefore, the column five was created to add the average walking time of students at the first stop to the proposed travel time for new routes. And the final column represents the differences between both the current bus TT and proposed bus TT plus walking TT. Of significance is the difference in travel time between the current bus TT and new proposed bus TT with walking time; currently it is 409 minutes but adding average walking time to the proposed route creates a TT of 469 minutes. So, 60 minutes is the total average student walking time from the first stop.

Table 4: The comparison between current bus travel time and proposed bus travel time plus average student walking time at the first bus stop.

Buses	Existing Travel Time (minute)	Average Walking TT (minute)	Proposed Bus TT (minute)	Walking TT + Proposed Bus TT (minute)	Change (minute)
1	43	2.47	30	32.47	10.53
2	32	0.45	22.4	22.85	9.15
3	34.6	0.3	25	25.3	9.3
4	34	2.21	21.3	23.51	10.49
5	37	1.24	28.9	30.14	6.86
6	28	2.31	20.8	23.11	4.89
7	25.6	0.68	17.7	18.38	7.22
8	36	2.4	26.9	29.3	6.7
9	44	2.4	30.6	33	11
10	32	1.1	24	25.1	6.9
11	42	1.97	22.9	24.87	17.13
12	37	1.88	25.2	27.08	9.92
13	48.5	2.73	35.4	38.13	10.37
14	31	2.27	16.13	18.4	12.6
15	22.7	0.3	15.32	15.62	7.08
16	35	0.06	29.64	29.7	5.3
17	38	0.3	36.16	36.46	1.54
18	51	1.62	38.49	40.11	10.89
19	36	0.3	24.63	24.93	11.07
20	46	0.2	39.39	39.59	6.41
21	42	1.82	31.7	33.52	8.48
22	45	0.3	40.5	40.8	4.2
23	59.5	0.05	42.6	42.65	16.85
24	63.4	0.3	51.9	52.2	11.2
25	29.8	1.34	19.6	20.94	8.86
26	38.4	0.04	30.89	30.93	7.47

Buses	Existing Travel Time (minute)	Average Walking TT (minute)	Proposed Bus TT (minute)	Walking TT + Proposed Bus TT (minute)	Change (minute)
27	59.1	2.12	47.35	49.47	9.63
28	46.5	0.91	39.15	40.06	6.44
29	58.7	3.41	46.36	49.77	8.93
30	29.2	2.8	22.28	25.08	4.12
31	50	0.31	38.15	38.46	11.54
32	34	2.32	23.02	25.34	8.66
33	51	0.06	39.5	39.56	11.44
34	21.7	3.54	16.48	20.02	1.68
35	24	1.44	19.4	20.84	3.16
36	43	1.18	28.7	29.88	13.12
37	24	0.19	16.98	17.17	6.83
38	49	2.51	41.7	44.21	4.79
39	27	1.12	20.57	21.69	5.31
40	30	0.15	19.12	19.27	10.73
41	29	0.97	19.2	20.17	8.83
42	33.6	0.29	25.53	25.82	7.78
43	50	0.3	32.1	32.4	17.6
44	41	1.81	29.34	31.15	9.85
45	55.5	0.21	42.8	43.01	12.49
46	29.6	1.6	19.87	21.47	8.13
47	23	1.72	15.5	17.22	5.78
Total	**1,820.4**	**60**	**1,351.15**	**1,411.15**	**409.25**
Average	**38.73**	**1.28**	**28.75**	**30.02**	**8.71**
Max	**63.4**	**3.54**	**51.9**	**52.2**	**17.6**
Min	**21.7**	**0.04**	**15.32**	**15.62**	**1.54**

As can be seen from Table 4 the maximum travel time difference between the new proposed bus TT plus walking TT and existing bus TT is 17.6 minutes and the minimum is 1.54 minutes, and the average change is 8.71 minutes. In general, there is a reduction in travel time on total bus travel time even though the walking travel time of the student is added to the bus travel time.

Chapter 5: Conclusion.

The main objective of the study is to create a planning framework for the school transportation system in Dibba, U.A.E. GIS modelling was adopted in this study to achieve the main objective and reduce the travel time in bus routes, eliminate redundant bus stops in the system, and create a geodatabase for school transportation systems. The process of developing a GIS model required some important entities such as main model parameters like road network. In this study, the main modeling is created for school transportation routing, so it is essential to have a complete built road network of the study area with all important attributes such as speed limit, direction of roads, number of lines and length of each road segment.

The developing countries have a lot of problems that are not studied yet, such as developing efficient infrastructure and, transportation systems and other issues in different fields. That is because developing countries have a few researchers, and most professionals move to developed countries. The developed countries have promising opportunities for professionals, and researchers, especially the main grounded infrastructure for researchers was built. For example, researchers can get funding for their research, the developed countries have a solid data infrastructure, and these data are completed and available to use. However, one of the most important issues facing researchers in developing countries is data limitation, which has led to having big gaps in research in many fields.

The UAE is not an exception and has a lot of data limitations. Developing the road network took a long time, almost six months, because the study area did not have a complete network layer, so digitizing the existing bus routes helped to identify the missing road segments. In addition to digitizing the existing bus routes, satellite images were used to compare the digitized road with real roads. The complete road network was created in the ArcGIS platform.

However, after creating the road network, some other limitations were found. For example, the school buses' speed limit was not the same as the road's posted speed limit. The school buses' speed on highways was set by the Emirates Transport Authority to 75 km/h (rather than the posted speed limit of 120 km/h), which was added to the road network separately, and that is important for time cost. Moreover, the dwelling time (the time spent for a bus to pick up a student from a stop) is added as a component of overall bus travel time. The two dwelling times were estimated by the Emirates Transport Authorities. The first dwelling time used was 45 seconds for each student in the current condition because the bus takes the student from their houses, where they were waiting inside the house, which takes longer than waiting at a collected stop. The second dwelling time was 30 seconds on proposed stops for each student. Those variables were collected from the Emirates Transport Authority and added to the road network and bus stops as a new field to be used to calculate travel time in the model.

Then the bus stops were digitized, which considered the location of students because the buses picked up each student from their houses except for two stops in the city center area where the students lived in an apartment building. The new location of collected bus stops was determined to be community centers; in this case the community center is the mosque, locations suggested by the Emirates Transportation Authority due to two main reasons: First those locations have big parking lots which makes it easy for the bus maneuver and second, the route to the mosque is familiar to all students and parents because they walk to the mosque five times a day. Walking distance played a significant role in the school transport system as public transit. The most used walkable distance and stop spacing distance is 400 meters, but in this study the walking distance was determined to be 350 meters. That's because this is the first time the walking mode was added to the school transportation system in U.A.E, which needs to be acceptable to parents and students.

After finishing building the road network and digitizing bus stops, the GIS models were created. The first model is used for both existing and proposed routes; the model used two main parameters: road network and stops in bus routes. The second model makes location-allocation to assign each student on any route to the nearest proposed stop; the model used three parameters: the road network, existing bus stops, and proposed bus stops. Since the two models can perform the analysis, they should be easily used by others and applied to any number buses or stops; the users need only to change the main parameters.

The model output estimated that 73% of the total bus stops were eliminated in the study area. The existing bus routes were reduced by 93,465 meters. Moreover, the new proposed framework saved 469 driving minutes in a bus route but adding the walking time to the proposed route travel time changed the saved time to 409. However, saving time in bus routes is important to reduce the operating costs. The models work well, and it is an important for the Emirates Transportation Authority to apply it to increase their system efficiency.

5.1 Future study.

The research focused on travel time as the main cost for each existing bus route, so useful additional analyses could combine some of the buses routes to reduce the fleet size.

The study has some limitations that affect its scope; the traffic data is not available in the study area, which is an important element of transportation study. Changing all the buses so that their occupancy rate improves from the current less-than-half-full status would involve short-term cost. In this study the rental cost of buses is not added because it was not provided by governmental authorities.

On of the main additions to future study that should be investigated more is the travel time of each student from his house to the school. That can be found by adding each student’s walking time to the bus travel time from students stop to the school.

The spatial correlation between the student distribution and schools should be investigated as well, to help planners and school authorities to find the optimal locations for future schools.

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