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Reducing traffic congestion level of Dhaka City using policy based algorithm in SUMO

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CERTIFICATION

This thesis paper entitled "***Reducing traffic congestion level of Dhaka City using policy based algorithm in SUMO***" submitted by the group mentioned below, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science and Engineering on August 2017.

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DECLARATION

We hereby declare that the thesis titled ***"Reducing traffic congestion level of Dhaka City using policy based algorithm in SUMO"*** is the outcome of the investigation and innovation carried out by the following author under the supervision of Dr, Amitabha Chakrabarty. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

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ABSTRACT

In recent times, traffic congestion has grabbed attention of many researchers to come up with a solution and minimize enormous economic loss which incurs because of it. In this paper, we evaluate impact of road incidents and provide extensive analysis of vehicular travel time and traffic congestion level. After that, we propose a re-routing policy for Gulshan-Banani junction of Dhaka through the open source traffic simulator SUMO (Simulation of Urban Mobility) to bypass blocked road due to any incident. The proposed re-routing policy has been implemented and obtained results have proven its efficiency on reducing vehicular travel time and waiting time in case of incident compared to general SUMO.

Keywords -ITS, SUMO, Traffic Congestion, Re-routing Policy, Road Incidents, Travel Time

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Chapter 1

INTRODUCTION

Road traffic congestion is an irony of fate for the big cities. In big metropolitan, it remains one of the major problem caused by the amount of the traffic intimately move towards highest range for a road network, especially in the developing country in the world.

1.1 General

Due to urbanization people moved to the developing cities and more people are joining the in the road network topologies in the rush hour of a day. It is never sufficient for a government to initiate a road network enhancement program to an unrestricted inclination of traffic growth. It is a type of problem which individual faces everyday and the reasons behind this is road, intersections, common road, vehicle type, lane limitation, narrow and ruined road, unplanned stoppage, speed mismatch, unnecessary u-turns.

Current situation of the passenger transport of Dhaka metropolitan illustrates the obtainable facilities are insufficient to keep pace with the running population. Moreover, the traffic system of the city is non-sustainable. Large portion of roads are occupied because of the small vehicle which is responsible to amplify the road traffic congestion subsequently [1]. The total road network is 3000km (with only 450km primary and secondary/collector roads). The non-existence of qualified traffic engineering professionals is also a great barrier in this city traffic management. It is observed that bus traffic in Dhaka is on a level of baby compared with other cities. Today's bus operation in Dhaka is characterized with the existence of 750 individual bus owners [1]. By thorough observation the lack of synchronized control of vehicle and no route commitment can be understand which turns to be wastage of time, forceful competition, and violent activities of bus crews, risky driving practice, dodgy boarding and alighting by passengers in the middle of roads, nosing of buses etc. are the daily happenings of Dhaka city.

According to Meyers (1997) [18], congestion mitigation strategies can be broadly classified into three categories: Transportation System Management (TSM), Travel Demand Management (TDM) and Land Use Management. TSM techniques seek to improve the traffic flow through better management of existing facilities (Mobility 2020). Some of the TSM techniques adopted are reduction of delay of delay at intersections and freeways through better signalization procedures like coordination and traffic management measures to enhance the operation of roadways. The Travel Demand Management techniques focus on strategies to control the travel demand to reduce the peak hour travel time. Examples of TDM strategies are staggering the work hours, carpooling and encouraging the use of transit. Land Use Management strategies involve strategies like zoning and controlling land use which has a direct impact on the trip generation and demand distribution characteristics.

Technological strategies are increasingly booming over the last decades. This involves the integrated use of sensors, simulators, computers, electrical and communication technologies as a whole, collectively termed as Intelligent Transportation System (ITS) to mitigate the congestion and enhance mobility for a developing cites. Our policy based algorithm is the combination of these three categories. In this paper, the main focus it to incorporate the ITS with the major function of TSM and TMD, with the purpose of extending the microscopic traffic simulator (SUMO) by designing a re-routing mechanism that ensures real time update of the drivers routes (i.e. dynamic route update) upon detection of any abnormal increase in traffic congestion or as consequence of an accident or any other constraints. Our ultimate goal is to develop a model that will update a vehicle’s route when an incident occurs. For the time constrain currently we are working on policy based algorithm which is able to mitigate a huge percentage of congestion and improve the traffic situation.

1.2 Objectives

- Creating a road network of certain parts of a city
- Running a Policy-based algorithm from source to destination to ensure less travel time
- Providing traffic incidents as constraints
- Analyze Travel Time and Waiting Time on a rush hour of a day and Weekdays.
- Analyze Travel Time and Waiting Time for whole period of a day.

1.3 Motivation

Dhaka, Capital of Bangladesh, most densely populated city in the world. More than twelve million people live in Dhaka city. Day by day the number is increasing and most part of Dhaka is badly affected by huge traffic jam. Traffic jams have become intolerable in Dhaka. Although a modern city should have 25 per cent of its total area devoted to road use, Dhaka has only 7 per cent. Some other major reasons are the total absence of a rapid transit system; the lack of an integrated urban planning scheme for over 30 years; poorly maintained road surfaces, with potholes rapidly eroded further by frequent flooding and poor or nonexistent drainage; haphazard stopping and parking; poor driving standards; total lack of alternative routes, with several narrow and (nominally) one-way roads. The annual loss due to traffic congestion in only one city route [2], Airport-Postogola, is estimated at Tk 272.60 billion, giving an indication about how the problem is costing the country's economy.

It problem is not only the situation of the densely populated Dhaka but also a major issues for the many US cities past few decades. The 2002 Urban Mobility Study conducted by the Texas Transportation Institute states that in the year 2001, traffic congestion resulted in 5.7 billion gallons of wasted fuel and 3.5 billion hours of lost productivity costing the nation $69.5 billion. According to the report, a rush hour trip in 2001 takes thrice as long as a rush hour trip in 1982. In the same period, the annual hours of delay per person has increased by 19 hours [3].

1.4 Scope of Thesis

In our thesis, we are working with one of the major problem of our country which is traffic jam. Traffic congestion is considered as the biggest problem in present. This traffic congestion is not only wasting our time but also affecting our economy as well as on our health. In our research we are on the edge to get rid of this problem of our lovely city Dhaka by introducing policy to the road traffic network.

1.5 Thesis Outline

The dissertation is organized in six chapters and the outline of upcoming chapters is as follows:

- Chapter 1 describes the current situation of road congestion and its demerit as well as mitigation strategies.
- Chapter 2 represents the analysis of congestion criteria, sumo at ease of these congestion support and development of simulation models.
- Chapter 3 illustrates the environment and the platforms used it the research process.
- Chapter 4 concentrates on evaluation of the simulation of the road network pulled out from open street map, developing ideas for the mechanism and analyzing the impact of policy algorithm
- Chapter 5 shows the improvement brought by the proposed re-routing policy, through graphs and result comparisons
- Chapter 6 contains conclusion and discussion about the future aspects of our thesis and research.

References contain important citations which are used in this report.

Chapter 2

LITERATURE REVIEW AND BACKGROUND STUDY

In this section, we illustrate momentarily the key principle of the most significant proposed approaches to find out the congestion level and the techniques to mitigate the vehicle routing problem.

2.1 Congestion Criteria Analysis

Emergence of decisive congestion areas in a development country is a common feature across the road networks. This congestion area includes the areas where networks of road congregate and a large amount of traffic use that common junction. Though the arrival rates of the traffic depend on the time of the day, week and month varies significantly but thousands of vehicles are being delayed every day. As per free flow traffic theory [4], if the traffic exit rate is a function of the traffic road network topology, then a free flow traffic segment can be associated with the traffic curve. A free-flow road segment is known to exhibit a critical density point where any traffic input that pushes the density beyond the critical value can trigger a "spiralling effect" that results in the road segment operating at a low-capacity equilibrium point. Worse still, small traffic bursts over short time periods can potentially trigger the spiraling effect resulting in a congestion collapse.

A part of our life, we cannot overlook the benefit of motor vehicles in our daily life and nonetheless its consequences. Inhabitant of urban areas spends their most of the time by roaming between workplace and home [6]. As a result of the failure of the authority to deal with the city area problem the go for unplanned solution initiates traffic problems. This situation has deteriorated for the developing cities like Dhaka for the following reasons:

Unplanned cities:

Roads have been constructed without any prior concern. Authorities do not bothered about the prerequisite scaling for a road need to be boarder enough thus creating bottlenecks congestion takes longer period to remove. Moreover, the traffic ratio is crossing the threshold vehicle capacities for the road and every developing country is facing the similar problem.

Lack of Discipline:

Amateurish driving style and disobeying the lane discipline depreciates the junction situation. When a vehicle stuck in a place for a long time it leads to the congestion [7]. Traffic congestion is the result of gap between transportation demand and supply [9]. A considerable amount of investment is required to setup this traffic management infrastructure which can scale with the increasing traffic.

The degree of road traffic congestion can be determined by the vehicle velocity and for smart competent traffic control and other TSM the reconstruction of traffic congestion is necessary at all the road network topology at which traffic measurement is unpredictable and unavailable [10]. Moreover 70 percent of trips in Dhaka are short trips; most of them is less than two kilometers [11]. In basis of a survey on Ireland based company named Bus Eireann, is losing €18 million annually only because of their improper adjustment of timetables due to the increased traffic congestion [12]. Congestion is creating immense prohibitive situation on all developing countries.

2.2 SUMO at ease of the congestion difficulties

Simulation of Urban Mobility, (SUMO) [13], open source, microscopic, multimodal traffic simulator. This assists the assessment infrastructure modification. Any algorithm and policy can be assessed before implementation in the real world scenarios [8]. As traffic congestion has become one of the aristocrat problem throughout the developing and developed world SUMO creates the environment to look how it works in different scenarios. The researcher [13] found no exact existing model as it is much complex and chaotic organization and established a common platform for traffic research. Being a traffic simulator, SUMO allows the user to create real world road topology pulling the road network from open street map. It allows the user to import a network using 'netconvert'. In a research paper by Vi Tran Ngoc Nha *et al* [5], the various routing algorithms that could be used in conjunction with SUMO or another traffic simulator were described and deeply analyzed based on their merits and limitations. This simulator gives the chance to investigate the congestion cause and refers anything that stops the traffic flow in the real world which can be considered as any incident as water clog, accident, road damage for a developing city like Dhaka. Creating incident in SUMO refers as a solution as then policy algorithm and re-routing mechanism could be availed.

2.3 An Illustration of Simulation Model Building

Given the confines of this chapter, we will illustrate the model development process by presenting the highlights of a sample problem, but avoiding exhaustive detail.

1) Define the Problem and Model Objectives - An existing microscopic stochastic simulation model of freeway traffic does not consider lane-change operations. It has been determined that this model's results are unreliable as a result. This addition should provide improved accuracy in estimating speed and delay; in addition it will compute estimates of lane changes by lane, by vehicle type and by direction (to the left and to the right).

2) Define the System -

a) A freeway of up to six lanes -- level tangent

b) Three vehicle types: passenger car; single-unit truck; tractor-trailer truck

c) Required inputs: traffic volume (varies with time); distributions of free-speed, of acceptable risk (expressed in terms of deceleration rates if lead vehicle brakes), of motivation to change lanes, all disaggregated by vehicle type

d) Drivers are randomly assigned an "aggressiveness index" ranging from 1 (very aggressive) to 10 (very cautious) drawn from a uniform distribution to represent the range of human behavior.

It must be emphasized that model development is an *iterative* process. For example, the need for the indicated input distributions may not have been recognized during this definition phase, but may have emerged later during the logical design. Note also that the problem is bounded – no grades or horizontal curves are to be considered at this time.

3) Develop the Model - Since this lane-change model is to be introduced into an existing microscopic stochastic model, using a procedural language, it will be designed to utilize the existing software. The model logic moves each vehicle, each time-step, starting with the farthest downstream vehicle, and then moving the closest upstream vehicle regardless of lane position, etc.

Chapter 3

PLATFORM AND ENVIRONMENT

For this paper we have used the platform and environment which are compatible with our research.

3.1 Simulation of Urban Mobility

Simulation of Urban Mobility (SUMO) is a microscopic Simulator.

3.1.1 About

"Simulation of Urban MObility", or "SUMO" for short, is an open source, microscopic, multi-modal traffic simulation. It allows to simulate how a given traffic demand which consists of single vehicles moves through a given road network. The simulation allows to address a large set of traffic management topics. It is purely microscopic: each vehicle is modelled explicitly, has an own route, and moves individually through the network. Simulations are deterministic by default but there are various options for introducing randomness.

If you download the SUMO package, you will note that it contains further applications besides SUMO. These applications are used to import/prepare road networks and demand data for being used in SUMO.

3.1.2 History

The development of SUMO started in the year 2000. The major reason for the development of an open source, microscopic road traffic simulation was to support the traffic research community with a tool with the ability to implement and evaluate own algorithms. The tool has no need for regarding all the needed things for obtaining a complete traffic simulation such as, implementing and/or setting up methods for dealing with road networks, demand, and traffic controls. By supplying such a tool, the DLR wanted to i) make the implemented algorithms more comparable by using a common architecture and model base, and ii) gain additional help from other contributors.

3.1.3 Features

- Includes all applications needed to prepare and perform a traffic simulation (network and routes import, DUA, simulation)
- Simulation
  - Space-continuous and time-discrete vehicle movement
  - Different vehicle types
  - Multi-lane streets with lane changing
  - Different right-of-way rules, traffic lights
  - A fast openGL graphical user interface
  - Manages networks with several 10.000 edges (streets)
  - Fast execution speed (up to 100.000 vehicle updates/s on a 1GHz machine)
  - Interoperability with other application at run-time
  - Network-wide, edge-based, vehicle-based, and detector-based outputs
  - Supports person-based inter-modal trips
- Network Import
  - Imports VISUM, Vissim, Shapefiles, OSM, RoboCup, MATsim, OpenDRIVE, and XML-Descriptions
  - Missing values are determined via heuristics
- Routing
  - Microscopic routes - each vehicle has an own one
  - Different Dynamic User Assignment algorithms
- High portability
  - Only standard c++ and portable libraries are used
  - Packages for Windows main Linux distributions exist
- High interoperability through usage of XML-data only
- Open source (GPL)

3.1.4 Usage Examples

Since 2001, the SUMO package has been used in the context of several national and international research projects. The applications included:

- traffic lights evaluation
- route choice and re-routing
- evaluation of traffic surveillance methods
- simulation of vehicular communications
- traffic forecast

3.1.5 Included Applications

The package includes [15]:

Application Name	Short Description
SUMO	The microscopic simulation with no visualization; command line application
SUMO-GUI	The microscopic simulation with a graphical user interface
NETCONVERT	Network importer and generator; reads road networks from different formats and converts them into the SUMO-format
NETEDIT	A graphical network editor.
NETGENERATE	Generates abstract networks for the SUMO-simulation

DUAROUTER	Computes fastest routes through the network, importing different types of demand description. Performs the DUA
JTRROUTER	Computes routes using junction turning percentages
DFROUTER	Computes routes from induction loop measurements
MAROUTER	Performs macroscopic assignment
OD2TRIPS	Decomposes O/D-matrices into single vehicle trips
POLYCONVERT	Imports points of interest and polygons from different formats and translates them into a description that may be visualized by SUMO-GUI
ACTIVITYGEN	Generates a demand based on mobility wishes of a modeled population
EMISSIONSMAP	Generates an emission map
EMISSIONSDRIVINGCYCLE	Calculates emission values based on a given driving cycle

Additional Tools	There are some tasks for which writing a large application is not necessary. Several solutions for different problems may be covered by these tools.

Several parties have extended the SUMO package during their work and submitted their code. If not being a part of the release, these contributions are usually not tested frequently and may be outdated. The following contributions are included; please note that not all of them are longer maintained.

Application Name	Short Description
TraCI4J	A Java interface for connecting and extending information via TraCI by Enrico Gueli
TraCI4Matlab	A Matlab interface for connecting and extending information via TraCI Andres Acosta
TraaS	A SOAP(webservice) interface for connecting and extending information via TraCIby Mario Krumnow
Contributed/SUMO Traffic Modeler	A Java application for generating a demand based on mobility wishes by Leontios Papaleontiou (obsolete)

3.1.6 Software design criteria

Two major design goals are approached: the software shall be fast and it shall be portable. Due to this, the very first versions were developed to be run from the command line only - no graphical interface was supplied at first and all parameter had to be inserted by hand. This should increase the execution speed by leaving off slow visualization. Also, due to these goals, the software was split into several parts. Each of them has a certain purpose and must be run individually. This is something that makes SUMO different to other simulation packages where, for instance, the dynamical user assignment is made within the simulation itself, not via an external application like here. This split allows an easier extension of each of the applications within the package because each is smaller than a monolithic application that does everything. Also, it allows the usage of faster data structures, each adjusted to the current purpose, instead of using complicated and ballast-loaded ones. Still, this makes the usage of SUMO a little bit uncomfortable in comparison to other simulation packages. As there are still other things to do, we are not thinking of a redesign towards an integrated approach by now.

3.2 Ubuntu 16.04

Ubuntu releases are made semiannually by Canonical Ltd, the developers of the Ubuntu Operating System, using the year and month of the release as a version number. The first Ubuntu release, for example, was Ubuntu 4.10 and was released on 20 October 2004. Consequently, version numbers for future versions are provisional; if the release is delayed until a different month (or even year) to that planned, the version number will change accordingly [17].

Ubuntu releases are timed to be approximately one month after GNOME releases, which are in turn about one month after releases of X.Org, resulting in each Ubuntu release including a newer version of GNOME and X.

Every fourth release, in the second quarter of even-numbered years, has been designated as a Long Term Support (LTS) release, indicating that they are supported and receive updates for five years, with paid technical support also available from Canonical Ltd. However the desktop version of LTS releases before 12.04 were supported for only three years. Releases 14.04 and 16.04 are the current LTS releases. Non-LTS releases prior to 13.04 have typically been supported for 18 months, and have always been supported until at least the date of the next LTS release. This has changed, however, for 13.04 and subsequent non-LTS releases, with the support period being halved to 9 months.

Shuttleworth announced on 21 October 2015 that Ubuntu 16.04 LTS would be called *Xenial Xerus*. It was released on 21 April 2016.

The default desktop environment continues to be Unity 7, with an option for Unity 8. In May 2015, Shuttleworth indicated that Ubuntu 16.04 LTS would include Unity 8 and Mir, but that users have a choice of that or Unity 7 and X.org. He said, "Unity 8 will be an option for 16.04 and we'll let the community decide the default for 16.04."

The release adds support for Ceph and ZFS filesystems, the LXD hypervisor (using seccomp) for OpenStack, and Snappy packages will be supported. It will use systemd instead of Upstart as its init system. This release will replace the Ubuntu Software Centre with GNOME Software and eliminate Empathy and Brasero from the ISO file. Reviewer Jack Wallen said, "The truth of the matter is, the Ubuntu Software Center has been a horrible tool for a very long time. Making this move will greatly improve the Ubuntu experience for every user."

This release has online dash search results disabled by default in Unity 7. "None of your search terms will leave your computer", stated Ubuntu desktop manager Will Cooke. Reviewer Jack Wallen said about this, "I've never considered the inclusion of online search results to be spyware. In fact, I have always considered the online results to be an efficient means of searching for products through Amazon (etc.). That being said, with the release of 16.04, this feature is disabled."

Ubuntu 16.04 LTS does not support the AMD Catalyst (fglrx) driver for AMD/ATI graphics cards and instead recommends the free software radeon and amdgpu alternatives. These may not provide optimal graphics performance; however, AMDGPU-PRO is available for Ubuntu 16.04

The first point release, 16.04.1, was released on 21 July 2016. Release of Ubuntu 16.04.2 was delayed a number of times, but it was eventually released on 17 February 2017. Ubuntu 16.04.3 was released on 3 August 2017.

3.3 Python

Python is a widely used high-level programming language for general-purpose programming, created by Guido van Rossum and first released in 1991. An interpreted language, Python has a design philosophy that emphasizes code readability (notably using whitespace indentation to delimit code blocks rather than curly brackets or keywords), and a syntax that allows programmers to express concepts in fewer lines of code than might be used in languages such as C++ or Java. The language provides constructs intended to enable writing clear programs on both a small and large scale.

Python features a dynamic type system and automatic memory management and supports multiple programming paradigms, including object-oriented, imperative, functional programming, and procedural styles. It has a large and comprehensive standard library.[25]

Python interpreters are available for many operating systems, allowing Python code to run on a wide variety of systems. CPython, the reference implementation of Python, is open source software[26] and has a community-based development model, as do nearly all of its variant implementations. CPython is managed by the non-profit Python Software Foundation.

Python is a commonly used high-level programming language for general-purpose programming with a design philosophy that accentuates code readability and syntax allowing the programmers concept to implement in fewer lines of code [14]. All sorts of traffic network modification can be done by Python and to support such modification SUMO provides the Python tool *netdiff.py* [13]. Moreover, DLR-Institute of Transportation System- SUMO uses a client library written in Python when interfacing with the simulation. There are more than 150 additional tools which cover the topics from the traffic network analysis demand generation, demand modification to output analysis, are written in python [15]. A Python APIbesides a freely available Java API [16] are included with SUMO to support other programming languages may follow.

Chapter 4

ANALYSIS OF IMPACT POLICY-BASED ALGORITHM HOLD

As applying policies for whole Dhaka city is very difficult within a short period of time, we implemented our algorithms to Gulshan-Banani sector for experimental purposes. Road-network of this sector has been imported from OpenStreetMap and converted into an XML network file using SUMO NETCONVERT tool. Additional polygons have also been saved into a file named which are generated from SUMO docs. SUMO is a road-traffic simulator which only allows us to create various scenarios and compare or visualize their impacts to give us an assumption about what would happen if they are implemented on real world. To analyze re-routing we first need to create an incident.

4.1 Creating Incident

General definition of an Incident for traffic network is anything that stops the usual flow of traffic. For example, it can be collision between vehicles, road repairs, weather conditions or just high density of traffic. In order to create such an event, we are going to stop vehicles for a fixed period of time through defining a point along its route where we can set up for how long vehicle will stay halted. For this purpose, we first need to identify the edge id's, lane id's and specific position of the given edge that we want the vehicle to be halted on. This can be done through the help of NETEDITOR, a feature integrated with SUMO. Then, we need to find the edge list from the route file and include the following code in the vehicle definitions or route definitions.

<stop lane="edge id" endPos="position where the car is to be halted" duration="time in second"/>

Figure 1: Car causing traffic jam

Figure 1 shows the impact of implementing the above mentioned code in road network. However, we were facing difficulties while implementing this as it was unclear that how much time to halt a car would be realistic. From our own road experiences in Dhaka city, we thought 300 seconds for each car should be sufficient. Because as each car is halted for 300 seconds the car behind it would be halted for 600 seconds and so on. Thus, it is creating a massive traffic jam.

4.2 Way to Quantify Congestion

According to the review of various literatures and reports, the traffic congestion measures can be broadly categorized into six categories (NCHRP, 1997). These are as follows:

1. Early empirical concepts;
2. Highway Capacity Manual (HCM) related concept;
3. Lane occupancy rate and queues;
4. Travel time measures;
5. Miscellaneous measures (e.g. headway distribution);
6. Traffic flow per effective lane measures and congestion indices.
7. Measure of mobility level by peak hour volume-capacity ratio or peak hour average link speed.

Empirical measures (such as Green Shield's quality of transmission index) are difficult to visualize and comprehend, require extensive data collection and complicate any statistical analyses, relate specifically automobile and truck and thus lack applicability to several other modes of travel, (NCHRP, 1997).

HCM related measures are primarily based upon Level of Service determination. Such measures are easy to understand but require detail site and location specific input data and in some instances, the application of complex models. These measures are well suited to analyze intersections or short roadway section problems but not well suited for policy or large scale planning analyses (NCHRP, 1997).

Lane occupancy rates, travel time, headway distribution etc. are direct measures and need real-time traffic information. The primary problems with these direct measures are that, they are difficult to use in predicting future congestion levels. Again it is difficult to address non-technical audiences without meaningful summary of congestion statistics. These difficulties have led many to suggest the need for a Surrogate measures called congestion indices (NCHRP, 1997).

A number of studies have been carried out by a number of researchers and professional organization to develop Congestion Indices. Pioneers of such studies are National Cooperative Highway Research Program (USA); Texas Transportation Institute (TTI), and Federal Highway Administration etc. A number of indices have also been proposed but they are mainly for freeways, corridor analysis or arterial roads etc. For regional or area wide analysis such type of indices cannot be used directly but the theme can be translated from a particular scope to a broader perspective.

4.3 Mobility Level

Sometimes the mobility level of an individual link is measured by volume-capacity ratio. Such type of measure is proposed by Houston-Galveston Council of Traffic Modeling (HGAC, 1998), which is shown in Table 3.2.

Level of Mobility	Volume / Capacity
Tolerable	< 0.85
Moderate	>= 0.85 < 1.00
Serious	>= 1.00 < 1.25
Severe	>= 1.25

Table 1: Scale of Different Mobility Levels

4.4 Evaluation Results

When the simulation is run through "randonTrips.py" without any given incident, a fixed travel time would be generated. To get some evaluation metrics, a separate python file was run to procure statistical data and the file was saved as an XML file. Within the output file there were several metrics such as departure time, travel time, arrival duration, waiting time etc.

Figure 2: Traffic density during rush hours

Primarily, the simulation was run with no incidents and the trip duration data was written to a file, then an incident was introduced and that new trip duration was written into another file. This way the no-incident data could remain the same whilst various additional tests could be run, such as modifying the number of incidents. Only the vehicles that returned an increase in travel time of more than 2 minutes were considered, this was done to reduce the error rate. Some random vehicles would have a reduced travel time and other vehicles had a minimal change of less than 2 minutes, while some other vehicles had seemingly impossible times, so any times above 4000 seconds were discarded. These were chosen as cut off points because on the lower end it is 10% of the incident time, and 4000 seconds sets the upper bound high enough to eliminate outliers, which proved to be a more realistic representation of what could be seen on the network when running the simulation. These bounds returned a subset of the most affected vehicles, and these were the ones taken into account for the results.

As it was nearly impossible to find out the actual volume of traffic during the rush hours in Gulshan-Banani sector, we had to do our research based on assumed data. From realistic point of view, we have made an assumption about the density of vehicles in the network during rush hours. Here by rush hours, we basically mean volume of traffic from 8 A.M. to 10:30 A.M. and from 4 P.M. to 6.30 P.M during working days. Also, we have simulated the same time frame for weekdays meaning Friday and Saturday as well. The graph below illustrates volume of traffic in Gulshan-Banani sector in the mentioned time frames.

The overall travel distance in Gulshan-Banani sector is approximately 7.8 Kilometers. Average length of vehicles in Dhaka city is 4.3 meter. Hence, by dividing the travel distance with length of each vehicle we can assume the total volume of vehicles present in the network during rush hours. Assuming that it will be the maximum capacity road can accommodate, the number of vehicles we will be simulating for rush hours (8 AM to 10.30 AM) on working days are 1813. The figure below gives an idea about the mass traffic jam (Yellow dots are vehicles) people have to face during rush hours.

However, on weekdays most of the vehicles do not approach that road network so early in the day. Hence, numbers of vehicles in the same time-frame (8 AM to 10.30 AM) on weekdays are assumed to be around 700. On the other hand, evening rush hours (4 PM to 6.30 PM) have a significant difference in the traffic density with morning rush hours.

Figure 3: Re-routed path

As some people leave the area before our assumed evening rush hours, the volume of traffic is not as high as morning rush hours but still considerably high. On average, we have assumed around 1500 vehicles moves in the network during evening rush hours on working days. However, evening rush hours in weekdays sees an increase in volume of traffic than morning rush hours of weekdays. The reason being, on weekdays people tend to go out with their families or friends during evening time which gives a rise in volume of traffic in network. We have assumed this density to be around 900 vehicles. It should be mentioned that number of vehicles are considered as total number of vehicles in the network at the same time. Figure 4 shows the percentage ratio between Total Travel Time and Total waiting time for all time-frames that are considered in the simulation.

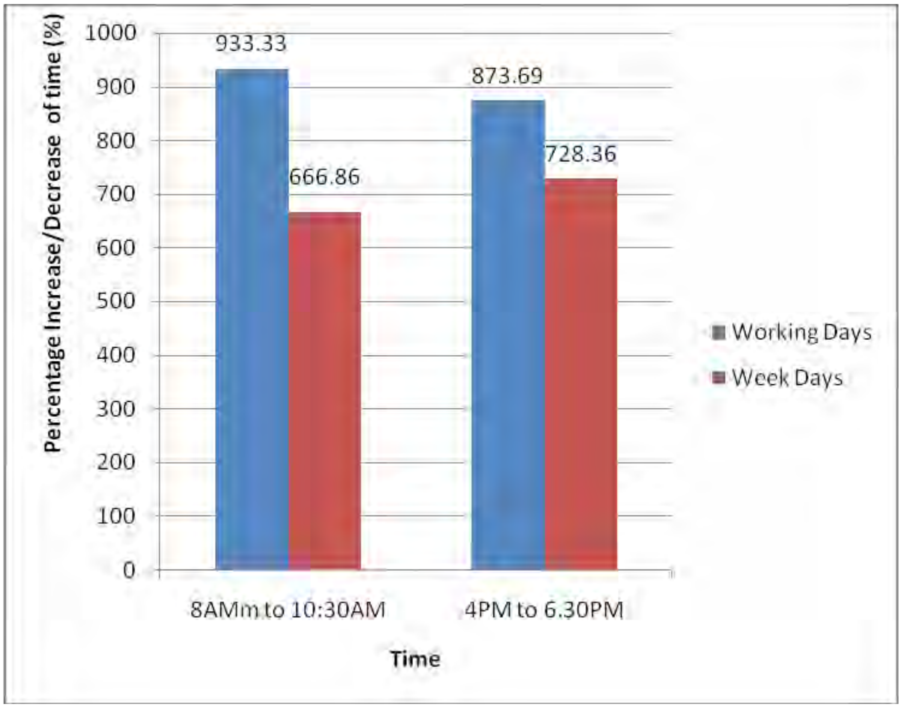

Figure 4: Ratio between Total Travel Time and Total Waiting time

Ratio TTT vs. TWT		
	8AM to 10:30AM	4PM to 6.30PM
Working Days	933.33	873.69
Week Days	666.86	728.36

Table 2: Ratio between Total Travel Time and Total Waiting time

Morning rush hours had increasing ratio as density is high in the morning. For working days the ratio in percentage is calculated to be 933.33% during morning rush hours (8AM to 10.30AM). On the other hand, it is 666.86% for weekdays. Similarly, for evening rush hours (4PM to 6.30PM) working days have 873.69% as percentage ratio of total travel time and total waiting time. Whereas, weekdays have 728.36% at that same time-frame. Figure 5 illustrates the impact of traffic density on travel time for both morning and evening rush hours during working days and weekdays.

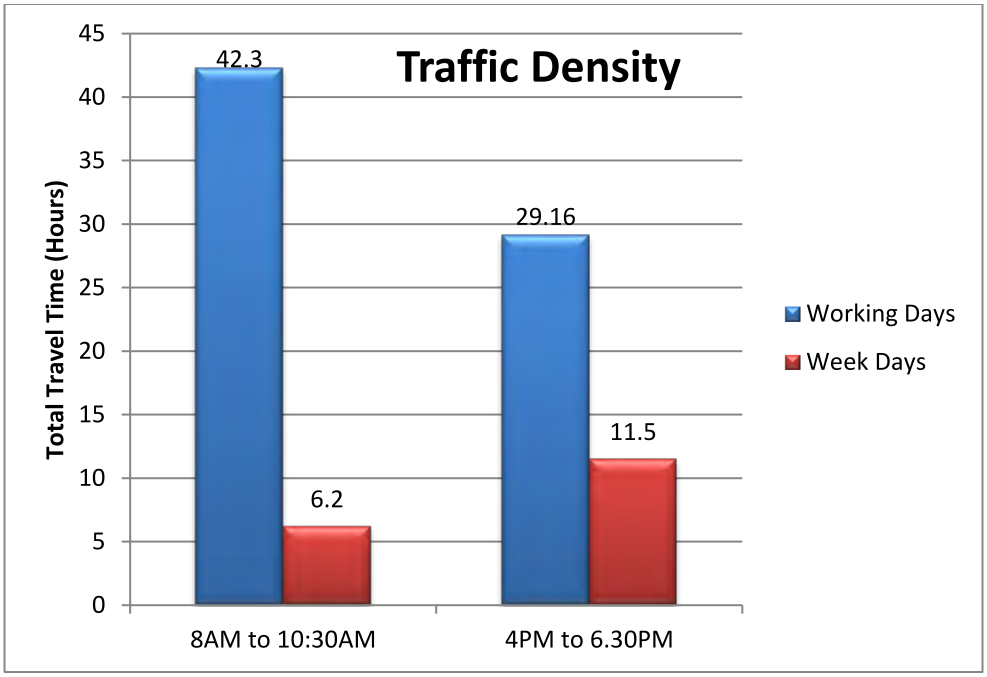

Figure 5: Impact of Traffic Density on Travel Time

	8AM to 10:30AM		4PM to 6.30PM	
	Traffic Count	Travel Time for all cars	Traffic Count	Travel Time for all cars
Working Days	1813	42.3	1500	29.16
Weekdays	700	6.2	900	11.5

Table 3: Impact of Traffic Density on Travel Time with Traffic Count

From the figure it is clear that weekdays travel time is considerably lower than working days. Working day's morning rush hours have 42.3 hours of total travel time with a traffic density of 1813. However, weekday morning rush hours have 6.2 hours of total travel time where the traffic count is 700. Conversely, evening rush hours on working days have 29.16 hours of total travel time while the density is 1500 and weekdays having 900 density resulted in having 11.5 hours of total travel time. Although vehicle density was not equal in simulations, after calculating average travel time we have been able to see how vast the difference is between working days and weekdays. Morning rush hours of working days and weekdays have average vehicular travel time of 84 seconds and 32 seconds which means that on an average, the vehicle that required 84 seconds to travel a particular distance on working days needs only 32 seconds to travel that same amount on weekdays. We have seen similar impact on evening rush hours as well. During working days evening rush hour average vehicular travel time is 70 seconds and weekdays have 46 seconds at that same time. Our goal is to reduce the working days rush hour's travel time with comparison to weekday's rush hour's travel time.

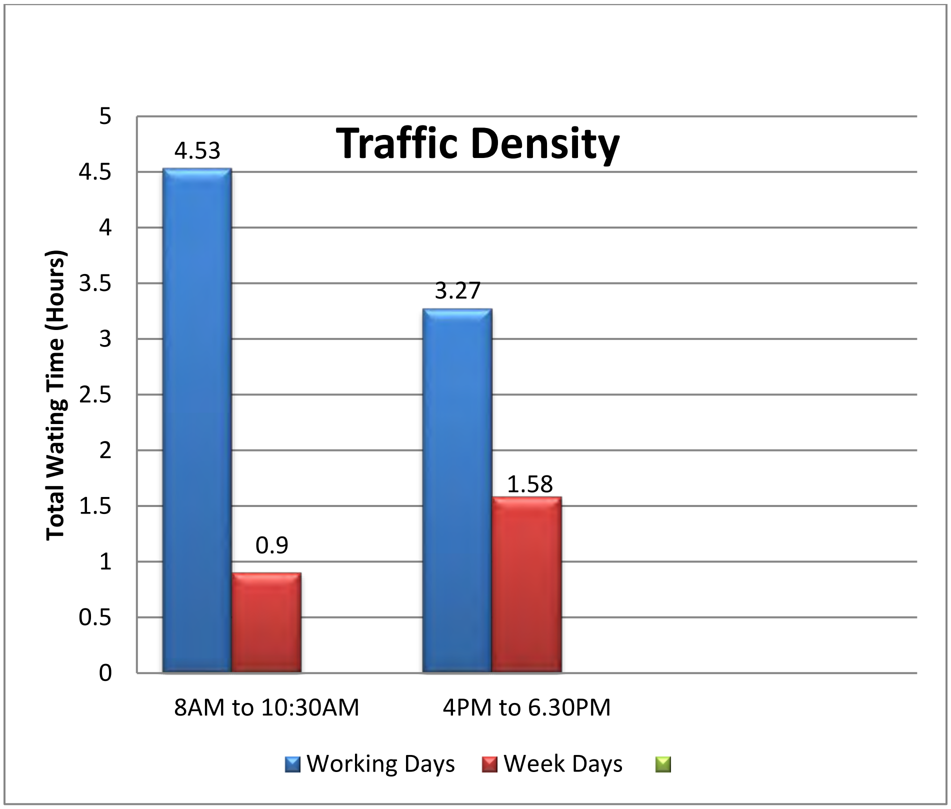

Figure 6: Impact of Traffic Density on Waiting Time

	8AM to 10:30AM		4PM to 6.30PM	
	Traffic Count	Waiting Time for all cars	Traffic Count	Waiting Time for all cars
Working Days	1813	4.53	1500	3.27
Weekdays	700	0.9	900	1.58

Table 4: Impact of Traffic Density on Waiting Time

Figure 6 explains total waiting time for different time frames with different traffic density. Morning rush hours during working days have 4.53 hours of total waiting time with density 1813 and evening rush hours have 3.27 hours of waiting time with a density of 1500. On the other hand, weekdays morning rush hours have 0.9 hours waiting time with 700 traffic and evening rush hours have 1.58 hours of waiting time while the density is 900.

Chapter 5

RE-ROUTING POLICY DESIGN

In this chapter, we are concentrated on the improvement brought by the proposed re-routing policy, through graphs and results.

5.1 Key Principal

There were little options to reroute vehicles in SUMO. We can use statically defined routing mechanism provided by SUMO. This static method is deployed by adding a re-routing file to SUMOs configuration. All vehicles that need to be re-routed have to be listed in this file prior to simulation runtime. This method was tested using very small scale scenarios in which it worked well. However, it is difficult to measure efficiency of large scale scenarios with this mechanism. Therefore, we had to consider only vehicles that are traveling from Mohakhali to Badda via Gulshan 1 in this paper.

Once there is an incident it is not feasible to try and clear out traffic that are already in the congestion segment. However, we can prevent other vehicles to enter that congestion if they are re-routed. The solution for it is to list the lane ID's that are being affected by incidents, and then comparing each vehicle's route list which can become affected by the incident. After that, only reroute the vehicles that have the accident lane in their route definition. In order to deploy this approach, the routes of all the vehicles have been written in a list, and then the vehicles for which the route contains the incident lane have been identified by running a manual look up. State transition diagram of rerouted vehicles is as below.

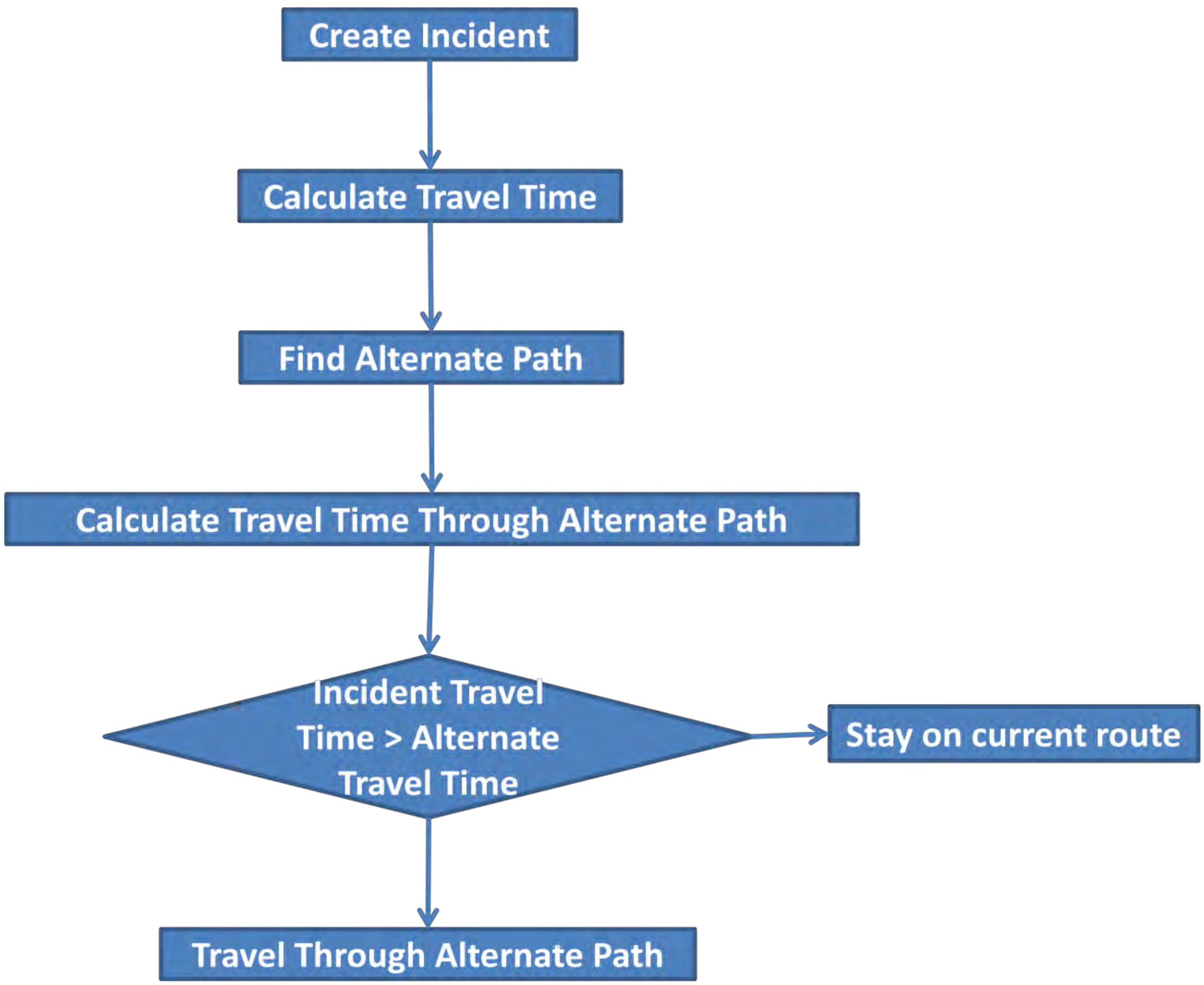

Figure 7: Workflow Diagram of Proposed Model

Once the vehicles have been identified, we updated their route according to our need to maximize efficiency while also considering that other routes in the network do not have any ongoing incidents. To update the route definition starting edge and destination edge of the any specific vehicle need to stay same while changing edges in between must have viable connection with one another in the network map.

5.2 Performance Evaluation Results

Multiple scenarios and test have to be run to evaluate our proposed re-routing policy efficiency. For each scenario there have been individual simulation tests on given traffic density. These simulations involved: simulation with no incident (morning and evening rush hours), simulation with incidents (rush hours both working days and weekdays) and simulation with our re-routing policy (both rush hours of working days and weekdays). Despite being easier to manipulate the parameters of the tests using python and NetEditor, the test runs took longer than just simulating an incident as to comprehend a real world idea, scenarios had to be simulated for real rush hour time (2 hours and 30 minutes). Our implementation was of O(N) complexity (i.e. N = number of vehicles on the network), so when running more complex tests the simulation time increased.

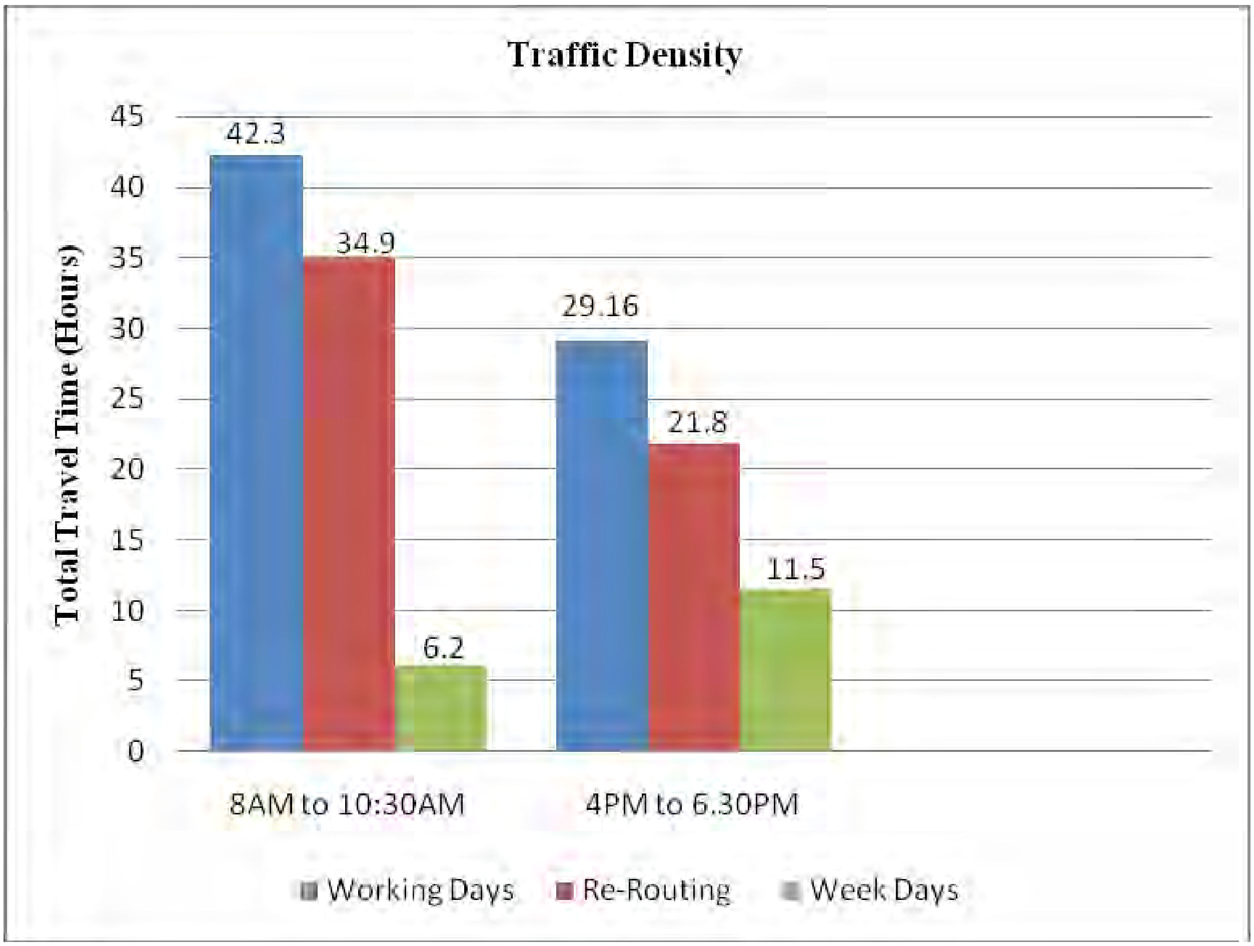

Figure 8: Our Proposed Re-routing Policy Efficiency in Total Travel Time

	Traffic Density	
	8AM to 10:30AM (Traffic Count 1813)	4PM to 6.30PM (Traffic Count 1500)
Working Days	42.3	29.16
Re-Routing	34.9	21.8

Table 5: Proposed Re-routing Policy Efficiency in Total Travel Time

From figure 8 we can observe the improvement brought by our re-routing policy in case of both morning and evening rush hours, which is mainly due to one incident that have been introduced. However, our policy still works well if there are more than one incident in the network for the given Gulshan-Banani sector. For time constraints, we will be focusing on only one incident here. The total travel time for morning rush hours have been reduced to 34.9 hours where it was 42.3 hours previously. This average travel time for morning hours have been reduced by 17.4% by our policy based algorithm. Meaning a 60 minute travel has been reduced to 49.56 minute per vehicle upon applying our re-routing policy. In case of evening rush hours, total travel time reduced to 21.8 hours from 29.16 hours, resultant a reduction by 25.27%. This means a 60 minute travel reduced to 44.84 minute per vehicle.

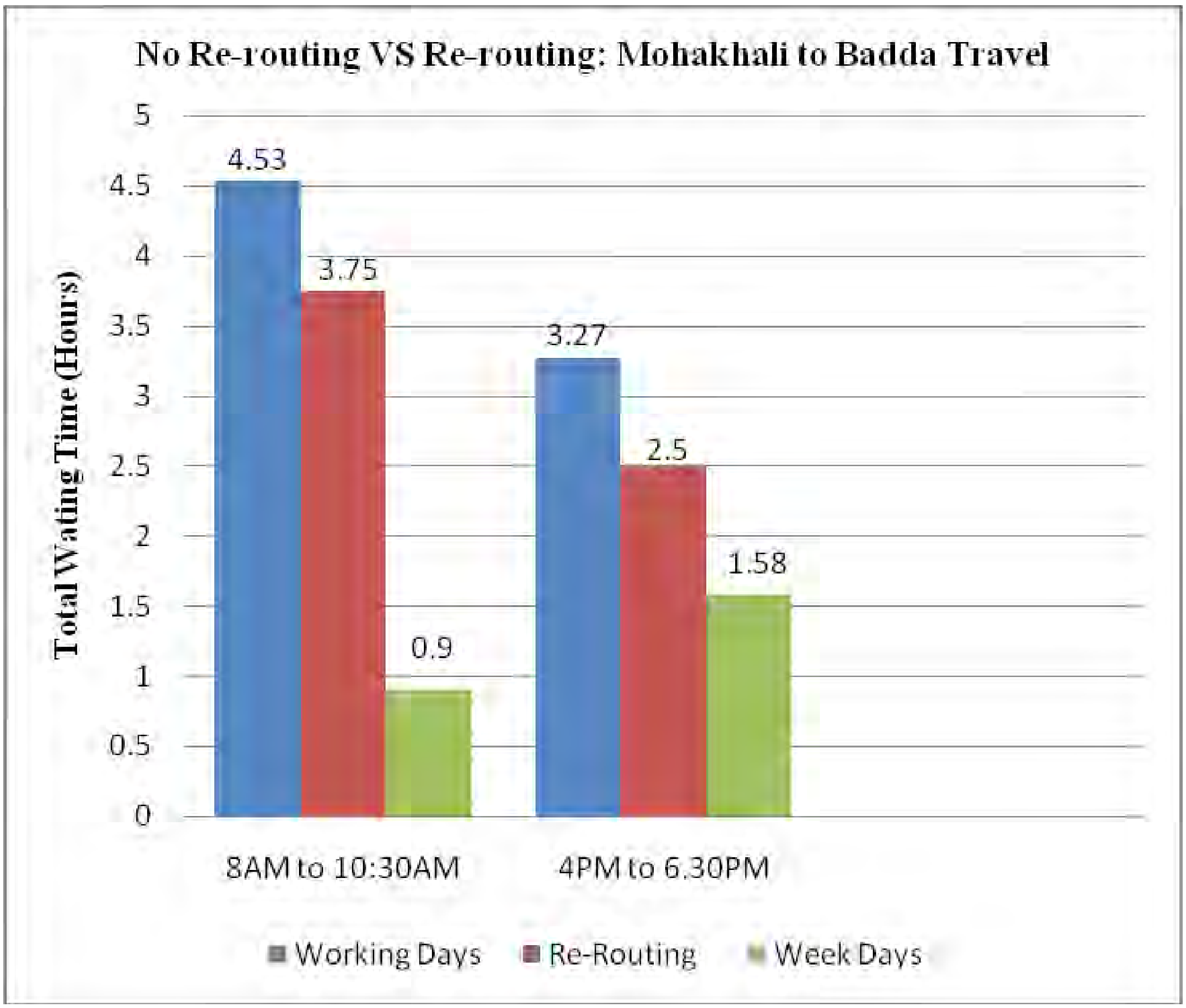

Figure 9: Our Proposed Re-routing Policy Efficiency in Total Waiting Time

	8AM to 10:30AM (Traffic Count 1813)	4PM to 6.30PM (Traffic Count 1500)
Working Days	4.53	3.27
Re-Routing	3.75	2.5

Table 6: Proposed Re-routing Policy Efficiency in Total Waiting Time

Figure 9 gives us the total waiting time in the network with respect to No Re-routing vs. Re-routing which was generated for Mohakhali to Badda Travel. Total waiting time of morning rush hours have been reduced to 3.75 hours from 4.5 hours, giving a reduction by 17.2% of total waiting time because of our re-routing policy. Meaning if a vehicle had to wait for 60 minutes previously, it waits for 49.68 minutes after implying our policy. Similarly, evening rush hours total waiting time becomes 2.5 hours from 3.27 hours generating a reduction by 23.8%. As a result, a vehicle waits for 45.72 minutes whereas it waited for 60 minutes before our policy was implemented.

Although a reduction by 17.4% of total travel time and 17.2% of total waiting time seems very little, it is for the highest possible density. For the purpose of better illustration of our proposed policy's efficiency, we then ran total of 8 simulation with different traffic density dividing the time-frame to 8 segments of a day which generated reduction by 24.22% of total travel time. Meaning if a vehicle had 60 minute travel time before, it has 45.46 minute after implying our policy. Figure 9 shows the travel time without re-routing policy and reflects the reduction of travel time by our re-routing policy.

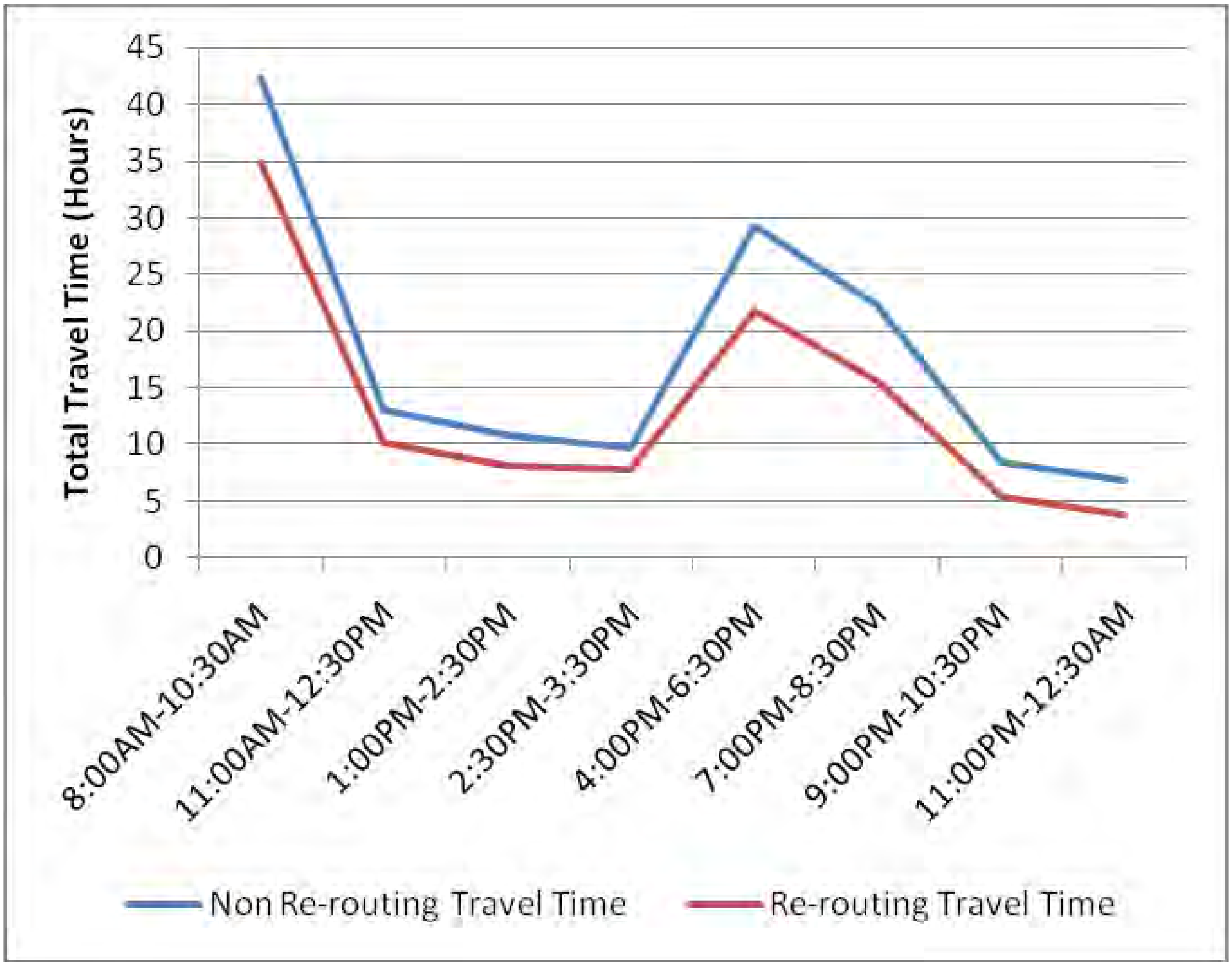

Figure 10: Non Re-routing VS Rerouting (Travel time) in all time frames

Time of Day	Traffic Count	Non Re-routing Travel Time (Hour)	Re-routing Travel Time (Hour)
8:00AM-10:30AM	1813	42.3	34.9
11:00AM-12:30PM	1200	12.9	10.2
1:00PM-2:30PM	850	10.7	8.1
2:30PM-3:30PM	800	9.6	7.8
4:00PM-6:30PM	1500	29.16	21.8
7:00PM-8:30PM	1300	22.25	15.6
9:00PM-10:30PM	765	8.34	5.4
11:00PM-12:30AM	500	6.75	3.8

Table 7: Non Re-routing VS Re-routing (Travel time) in all time frames

Furthermore, we have achieved a reduction by 20.55% of total waiting time which means a vehicle has 47.67 minutes of waiting time which was previously 60 minute. Figure 10 displays total waiting time of all 8 time frames and presents aftermath of our policy in vehicular waiting time.

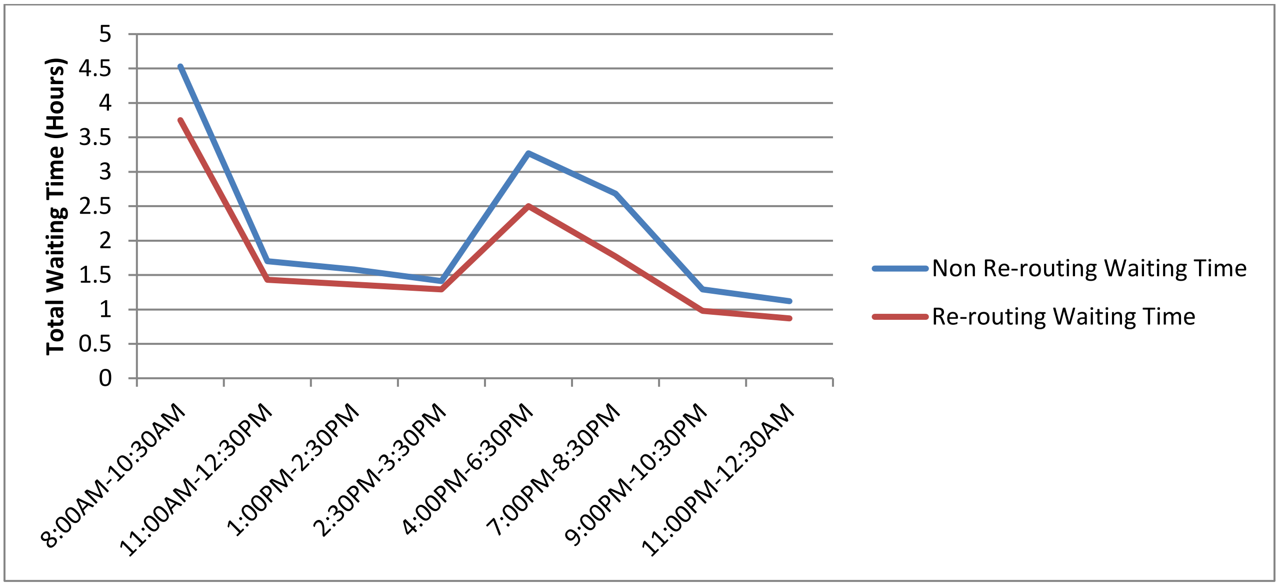

Figure 11: Non Re-routing VS Rerouting (Waiting time) in all time frame

Time of Day	**Traffic Count**	**Non Re-routing Waiting Time (Hour)**	**Re-routing Waiting Time (Hour)**
8:00AM-10:30AM	1813	4.53	3.75
11:00AM-12:30PM	1200	1.7	1.43
1:00PM-2:30PM	850	1.58	1.36
2:30PM-3:30PM	800	1.41	1.29
4:00PM-6:30PM	1500	3.27	2.5
7:00PM-8:30PM	1300	2.68	1.77
9:00PM-10:30PM	765	1.29	0.98
11:00PM-12:30AM	500	1.12	0.87

Table 8: Non Re-routing VS Rerouting (Waiting time) in all time frame

Time duration of incident plays a vital role in this policy. If a traffic jam would last half an hour, it would be much better off to follow another route that may add 20 minutes to the journey. The only thing that is uncertain is whether or not an incident has occurred on the detour road that has been chosen.. This is what leads to further increases in travel time, which often happened in our simulations. To overcome these errors, we ran the incident for a longer duration, to illustrate the effectiveness of our solution. The main flaw with re-routing traffic is that the detour must take less time than the incident. If the incident is too short (e.g. less than ten minutes), more often than not the vehicle will end up worse off than if it decided to wait in the traffic jam. From all the results discussed above, it is clear that the road network topology play a major role in the effectiveness of our re-routing solution. The more one way streets, single lane, 2-way streets, traffic lights and junctions means the more complex a detour becomes. Even with a small sample of different topologies, major differences can be seen in the effectiveness of re-routing.

Chapter 6

CONCLUSION

The proposed re-routing policy has been implemented and obtained results have proven its efficiency on reducing vehicular travel time and waiting time in case of incident compared to general SUMO.

6.1 Discussion

The main goal of this paper is to extend SUMO by proposing policy based algorithms to mitigate traffic congestion of Dhaka City. However, due to lack of time, real data and also many bugs and missing features in the simulator, we could complete Re-routing policy for vehicles traveling to Badda from Mohakhali via Gulshan 1 junction. After running many tests to highlight the effect of incidents in the network has on vehicular travel time, our proposed policy for re-routing was developed. Then, further tests were run to prove its efficiency. These results indicated that our proposed policy can reduce overall travel time by 17.4% and total waiting time by 17.2% during morning rush hours. Also, overall travel time by 25.27% and total waiting time by 23.8% during evening rush hours. However, multiple tests gave us an increase in reduction of travel time by 24.22% and 20.55% in waiting time. Further tests can be run if real data is applicable to find out impact of our re-routing policy on real traffic demand.

6.2 Future Work

Future implications of SUMO are vast. We want to elaborate our work by applying dynamic route update system in simulation for various networks in Dhaka city. Also, as traffic is unpredictable and ever changing incidents may arise in different sectors of the city, we want to apply different policies based on better efficiency for specific junctions and analyze each policy’s efficiency. To achieve real life application, we propose a collaboration of SUMO with image processing to receive real data on real time to calculate congestion level and vehicle to vehicle communication protocol to send data to all vehicles registered in the system. Although this particular objective is very difficult to reach considering our country’s current situation, we believe it will be a prime necessity in the near future as both population growth and vehicle growth is very high in Bangladesh in recent times.

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