Development of a Traffic Microsimulation Tool with the Incorporation of Variations in Driver Behaviors

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Abstract: - Traffic simulation is a field that is gaining popularity among researchers and practitioners due to various benefits and applications. This research aims to develop a traffic microsimulation model using an object-oriented approach. The proposed approach will also consider variations in driver behavior. The approach was applied as a prototype on a busy four-leg intersection in Bahrain. The available data consisted of turning movement counts on the intersection at three different times of the day. The tool applied the movement to simulate the flow in each lane of the said intersection. It was observed that the proposed tool could simulate the flow with reasonable accuracy without any evidence of bias which could result in under or over-estimation of results. These encouraging results pave the way for further use of the tool for application on other types of road segments and intersections. It is expected that this tool will provide valuable insights for road safety analysis.

Key-Words: - Traffic, Bahrain, Intersection, Error, Standard deviation, Simulation tool.

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1 Introduction

Simulation refers to the replication of a real-life system, or a part thereof, using mathematical models and algorithms, [1]. It can be used to generate numeric data [2] and graphic representations (videos, pictures, and maps) [3], but its primary advantage is the acquisition of data related to a real-world problem in a manner that efficiently uses time and resources. Simulation also enables researchers to test alternative scenarios, of events that may not currently exist, by changing system parameters, [4]. Because of these advantages, coupled with the rapid and vast development of computational technology, simulation methods, and techniques have gained popularity in all fields of research and academic studies, [5], [6].

The same holds true for the traffic context, wherein travel patterns and vehicle trajectories are simulated using models developed on the basis of the observed behaviors of travelers including drivers, passengers, pedestrians, and bicyclists, [7]. Traffic simulation can be classified on the grounds of scale and scope into macroscopic and microscopic simulations. Macroscopic simulation deals with the travel patterns associated with an entire region, which is divided into smaller zones to estimate trip generation and its associated characteristics, [8]. Microscopic simulation focuses on the behavior of drivers and vehicles on the road, including their movement patterns and interactions with each other, [9].

Over the years, randomness, driver behaviors, and the impact of such behaviors on vehicle interactions, especially driver-related conflicts that could lead to crashes, have become issues of prime importance for researchers and students of traffic engineering, [10]. The current research is a step forward in this direction, with its proposal of an object-based approach for developing a traffic simulation program that incorporates the variation in driver behavior and an automated conflict monitoring tool that can help the authorities evaluate the safety implications of different design solutions. The inclusion of driver behavior can enable the planners and designers to impact of changes in infrastructure on the driver behavior and in their interaction with each other, which has been done through the use of driving simulators or observational studies with test subjects, [11]. The proposed approach was used to carry out a microscopic simulation of traffic movement on a four-legged intersection. The novelty of this study lies in the methodology used for the aforementioned incorporation, and it is expected to provide accurate results on other segments of a highway system.

2 Literature Review

Traffic microsimulation works on the basis of several sub-models that are used to accurately predict and implement the choices of individual drivers with regard to lane change and car-following behaviours, [12]. The development of simulation software involves the following steps: defining the scope of work, collecting data, developing a base model, checking errors, developing a working model, calibrating the model using field data, and forecasting and analysis of traffic flow, [13]. Some of the practical constraints to the development of microsimulation software are those associated with budgets, the availability of appropriate tools, the accuracy of data, and the engagement of stakeholders, [14]. Some well-known simulation programs are VISSIM, AIMSUN, TransModeler [15], and PARAMICS [16].

The main parameters for the development and calibration of traffic microsimulation software include vehicular flow, vehicular speed, vehicular acceleration, headway, and spacing between vehicles. These parameters are subject to change depending on road conditions and the indigenous behavior of drivers, [17]. Simulation software enables the effective analysis of the effects of traffic management strategies and devices on traffic flow and capacity, [18]. It can be used to assess the outcomes of strategies for mitigating traffic congestion in specific zones or corridors, [15]. Such software can also be employed to optimize plans and strategies for emergency or evacuation management, which is a critical yet scarcely implemented initiative, [19]. An important aspect in relation to the above-mentioned parameters is to determine the underlying distributions that can best correspond to actual driver behaviors, [20].

There have been attempts to integrate simulation software with other models to incorporate and analyze other parameters that affect or are affected by traffic flow, such as network protocols [21] parking choice [22], and emissions. Given the multidimensional results derived from the simulation programs, they have been used as sources of valuable inputs for multicriteria decision-making related to transport planning, [23].

The initial focus of simulation software has been on car movement, for which mixed traffic conditions are considered to ascertain the effects of public transport, freight movement, or other road users on traffic flow parameters, including volume, speed, density, and travel time, [24]. Early models treat other road users as simulation units that are similar to vehicles but have different characteristics. However, this approach has changed because of the development of different sub-models that revolve around individual road users or modes of transport and are used in tandem with traffic simulation programs, [25]. Other areas of concentration of simulation software are intersections, specifically with regard to conflict resolution and right of way. This concentration is prompted by the significant impact of these intersections on safety and congestion, [26].

Microsimulation has been recognized as a method that effectively caters to the sample size and data availability issues pertaining to crash data collection. This is especially true when analyzing mitigation measures that require a before-and-after analysis, which could take months before any reasonable assessment can be made of the effectiveness of improvements. Thus far, Time-To-Collison (TTC) within microsimulation has been readily used by researchers to generate data related to conflicts, [27]. The primary data for such conflict analysis is the vehicle trajectory data obtained from observation of real-time traffic. Other important safety parameters include Post Encroachment Time [10], Deceleration Rate to Avoid Crashes, and the Proportion of Stopping Distance, [28]. The primary challenge in the use of microsimulation software for safety analysis is its employability in online-based heterogeneous traffic conditions, [10].

The advent of vehicle technology has come to a point where connected and automated vehicles are foreseen to be responsible for a significant share of traffic in the near future. Considering this development, the future of microsimulation seems to be directed toward modeling the effects of these vehicles on traffic flow, and efforts have already been taken in this regard, [29]. Some of studies have been devoted to the planning aspect of automated vehicle sharing. Despite the fact that the aforementioned issues are examined under the macrosimulation approach, the impact of the dynamic assignment of automated vehicles can be explored using a microsimulation methodology, [30].

The problem is that considerable time will pass before these automated vehicles completely capture traffic flows as it depends upon market conditions and the acceptance of road users. Until that moment and beyond, researchers cannot neglect the impact of human intervention, whether in endeavors involving traditional vehicles alongside automated vehicles or those dedicated solely to the latter. This requirement justifies the call for the continuous development of simulation programs that can accurately model the effects of variations in driver/human behaviors on traffic flow and, more so, on the safety of road users.

3 Simulation Strategy

To achieve the aim of this research, and facilitate future improvements and fine-tuning, a multi-object traffic model is developed to simulate the behavior of traffic and predict the performance of traffic intersections under given parameters.

Since the "behavior" of each "component" of a traffic simulation needs to be detailed and specified in a simulation, the object-oriented philosophy was implemented when defining the interaction logic of each of those components. The object-oriented programming approach allows easy manipulation of these components and the construction of complex components with multiple interaction layers out of simple building blocks, which follows a "divide and conquer" strategy.

A graphical summary of the main simulation components is provided in Figure 1.

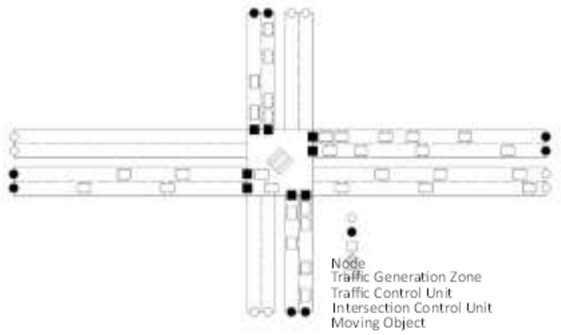

Fig. 1: Main simulation components

As previously mentioned, multiple objects are used in the simulation of traffic behavior. The various objects that are part of this simulation are described in the following sections along with their parameters and their abilities.

3.1 Node

The node is a point in two-dimensional space that defines the start and end of a path segment. A node can be further specialized in various subtypes such as Traffic Generation Zones (T) and Traffic Control Units (TCUs). Two parameters are required to define a node, namely it's x coordinate and y coordinate. Furthermore, it has a traffic status S_T. This status for nodes is always an "unconditional pass". A node has no methods. A class view of the "node" object is further shown in Table 1.

Table 1. Node object outline

Node (N) Inherits from: N/A	
Fields	x y S_T: • Unconditional pass • Pass if unable to stop • Stop

3.2 Traffic Generation Zone (TGZ)

Based on nodes, TGZs are special types that are responsible for generating the traffic during the simulation. The traffic generation occurs at random normally distributed time intervals.

Thus, a TGZ requires the average μ_t and standard deviation σ_t of the generation time. They also keep track of the last time a moving object was generated t_{lg}, to calculate whether a new object is to be generated. Furthermore, TGZs store all possible routes along with their probabilities. Finally, a traffic generation status S_{TG} is stored to denote whether a moving object is to be generated in the next time step. TGZs inherit the fields of nodes. It also has a status update method that consists of calculating a random time interval of generation based on the normal distribution provided. If the time interval is larger than the time of the last object generation, its status is set to "Generate". The class outline is shown in Table 2.

Table 2. TGZ outline

Traffic Generation Zone (TGZ) Inherits from: (N)	
Inherited	x y S_T
Fields	μ_t σ_t t_{lg} S_{TG}: Generate Idle
Methods	UpdateStatus

3.3 Traffic Control Unit (TCU)

TCUs are an extremely important part of the simulation based on nodes. TCUs can be standalone or controlled in groups by an Intersection Control Unit (ICU). TCUs control the traffic flow by allowing or denying the passage of moving objects through them.

A standalone TCU is one that does not need an ICU as it is not connected to other TCUs. An example would be a timed pedestrian traffic light. Other TCUs such as an intersection traffic light system or an intersection yield sign would need an ICU to relay information and allow or disallow the passage of traffic.

3.4 Traffic Lights` (TL)

A traffic light is one of the TCUs based on nodes. It also incorporates a moving object counter that counts the number of vehicles passing through N_{MO}. Those are further categorized into timed traffic lights and controlled traffic lights. The object is further outlined in Table 3.

Table 3. TL outline

Traffic Light (TL) Inherits from: (N)	
Inherited	x y S_T
Fields	N_{MO}

3.5 Timed Traffic Lights (TTL)

A timed traffic light is one of the TCUs that does not need an ICU to control its traffic status S_T, but relies on its own timer to switch between its different phases. To facilitate this, TTLs store their red phase duration $\boldsymbol{t_r}$, amber phase duration $\boldsymbol{t_a}$, green phase duration $\boldsymbol{t_g}$. Furthermore, it stores the time when the phase last change t_{lc} to determine if a phase change is needed. TTLs also have the status update method, that checks whether enough time has passed to switch from one phase to the next. The object is further outlined in Table 4.

Table 4. TTL outline

Timed Traffic Light (TTL) Inherits from: (TL)	
Inherited	x y S_T N_{MO}
Fields	$\boldsymbol{t_r}$ $\boldsymbol{t_a}$ $\boldsymbol{t_g}$ $\boldsymbol{t_{lc}}$
Methods	UpdateStatus

3.6 Controlled Traffic Lights (CTL)

Controlled CTL is a controlled TCU. Those organize more complicated traffic situations at intersections. The CTL is based on the TL and does not add anything to the basic TL with exception to be compatible with a Control Unit (CU), which controls the S_T of CTLs. CUs will be explained later.

3.7 Traffic Signs (TS)

TSs control the flow of traffic at simple intersections with lower traffic volume. Currently, only two traffic signs are implemented in the simulation: Yield All and Priority All. A curved priority or stop signs are not yet implemented and would be the subject of future work. A traffic sign stores one field, namely the traffic sign type T_{ST}. The outline of TSs is shown in Table 5.

Table 5. TS outline

Traffic Sign (TS) Inherits from: (N)	
Inherited	x y S_T
Fields	T_{ST}

3.8 Control Unit (CU)

CUs control and coordinate the status of TCUs to allow for more complicated traffic scenarios such as traffic light control of intersections. CUs come in various forms such as timed CUs, sensor-actuated CUs, traffic-aware CUs or a combination of the aforementioned. Two ICUs are implemented in this simulation, namely a Traffic Light Control Unit (TLCU) and a Traffic Sign Control Unit (TSCU).

3.9 Traffic Light Control Unit (TLCU)

TLCUs control the phases of groups of traffic lights at an intersection. Thus, a significant parameter for all TLCUs is the CTL groups and sorting. This is a sorted list of groups of CTLs $\boldsymbol{G_{CTL}}$ that are to be controlled together. The TLCU implemented in this simulation is a timed TLCU. Thus, the TLCU cycles through the sorted list to allow traffic for each group while blocking traffic for all other groups. Some interesting traffic scenarios can be realized by carefully designing the TLCU groups. Another parameter in a timed TLCU is the red phase duration $\boldsymbol{t_r}$, amber phase duration $\boldsymbol{t_a}$, green phase duration $\boldsymbol{t_g}$ for each $\boldsymbol{G_{CTL}}$ and intersection clearance times $\boldsymbol{t_{cl}}$.

Regarding the methods of TLCUs, it has a status update method that checks if any $\boldsymbol{G_{CTL}}$ needs to change its phase similarly to what a TTL does, with the difference being that a full group of CTLs is controlled in a similar way as explained a TTL. The class outline of TLCU is shown in Table 6.

Table 6. TLCU class outline

Traffic Light Control Unit (TLCU) Inherits from: (CU)	
Fields	$G_{CTL} = [G_{CTL1}, G_{CTL2}, \dots, G_{CTLn}]$ $\boldsymbol{t_r} = [t_{r1}, t_{r2}, \dots, t_{r3}]$ $\boldsymbol{t_a} = [t_{a1}, t_{a2}, \dots, t_{a3}]$ $\boldsymbol{t_g} = [t_{g1}, t_{g2}, \dots, t_{g3}]$
Methods	UpdateStatus

3.10 Traffic Sign Control Unit (TSCU)

TSCUs provide the current status of an intersection that is controlled by TSs. In the current simulation, an intersection can have a maximum of 4 road branches, 2 priority and 2 yield co-linear branches. The priority logic used in this simulation is as follows:

- Level 1 Priority: Moving objects on a priority branch moving straight or right.
- Level 2 Priority: Moving objects on a priority branch moving left.
- Level 3 Priority: Moving objects on a yield branch moving straight or right.
- Level 4 Priority: Moving objects on a yield branch moving left.

Thus, the TSCU stores the traffic sign on each of the branches as fields. Furthermore, it stores all moving objects approaching the intersection as subscribers S_{MO}, along with their expected arrival times t_{aMO}, clearing times t_{clMO} and intended direction of travel d_{MO}. Regarding the methods of TSCU, it has a status update method that updates the S_T of each traffic sign based on the current conditions of the intersection. An outline of a TSCU is shown in Table 7.

Table 7. TSCU outline

Traffic Light Control Unit (TSCU) Inherits from: (CU)	
Fields	TS_{p1} TS_{p2} TS_{y1} TS_{y2} $d_{MO} = [S_{MO1}, S_{MO2}, \dots, S_{MOn}]$ $t_{aMO} = [S_{MO1}, S_{MO2}, \dots, S_{MOn}]$ $t_{clMO} = [S_{MO1}, S_{MO2}, \dots, S_{MOn}]$
Methods	UpdateStatus

3.11 Path Segment (PS)

Path segments are used by moving objects to navigate from their starting point to their end point. Those segments can also be used to approximate curved roads by means of discretization. PSs store the top speed of the segment v_{max}, the start node N_1, the end node N_2 and the road condition S_R as fields. The road conditions are used later to calculate acceleration modifiers. An outline of TLCU is shown in Table 8.

Table 8. TLCU outline

Traffic Light Control Unit (TLCU) Inherits from: (CU)	
Fields	v_{max} N_1 N_2 S_R: • Normal • Wet • Icy

3.12 Moving Object (MO)

To be able to simulate traffic, moving objects are defined. Those are complex objects that are comprised of a vehicle and a driver. It also takes into consideration other factors that control how a moving object behaves. Moving objects can also be used to model pedestrians, but this has not yet been implemented in this simulation.

Moving objects keep track of multiple parameters that affect their behavior under traffic conditions. It's always aware of its own status S_{MO}, which could be accelerate, decelerate, decelerate to match target speed, static. The acceleration and deceleration are calculated based on the vehicle and driver performance. Also, it is aware of its intended travel direction: straight, turning left, turning right. This intended travel direction dir_i simulates the usage of travel direction indicators and is of paramount importance for TSCUs to determine its priority settings. Furthermore, the time of last status update t_l is kept, to simulate reaction times when the status is to be changed. Other "situational awareness" parameters relative to other CUs are included, such as: distance to next CU d_{CU}, time to next CU t_{CU}, minimum clearance from CUs $d_{min,CU}$. Furthermore, parameters relative to other moving objects for "collision detection and avoidance" are stored, such as: distance to nearest MO d_M, time to nearest MO t_M, minimum distance from MO $d_{min,M}$. Other kinematics parameters such as current position (x, y), speed v_t, acceleration a_t and heading θ are also stored. Finally, the trip information of the moving object, which is a list of path segments to follow, is stored.

Moving objects have sophisticated behavior that is part of their abilities. Those abilities are mentioned here and expanded upon later. These include, but are not limited to, planning courses, studying its current position, making decisions and calculating acceleration and kinematics. Those calculations and decisions are further influenced by the driver and vehicle that are part of the moving object. MOs simulate deep decision-making abilities, that are best described in a flow chart later.

3.13 Vehicle (V)
The mechanical part of a moving object, vehicles, are described by parameters that define their accelerating and decelerating abilities as well as their top speed.

An acceleration ratio ρ_a vs. speed ratio ρ_v profile is defined, along with the vehicle's top acceleration a_m and top deceleration a_d. There is no deceleration profile, and it is assumed that the car is always able to provide the maximum deceleration at any given time regardless of the vehicle's current speed.

The vehicle itself has no abilities or behavior, but is controlled by the moving object, which couples the driver and the vehicle to produce complex responses to a variety of traffic conditions.

3.14 Driver
The human factor in a moving object. It is key to providing an accurate representation of the traffic simulation. Various parameters are taken as normally distributed random variables and are sampled when the driver is initialized along with the initialization process of the moving object.

A variety of driver types exist, namely: distracted, normal and aggressive drivers, each with his own set of statistical variables to be used in the generation of his own behavior. Among others, the following statistical variables are considered: the average reaction time μ_{rt}, the standard deviation of the reaction time σ_{rt}, the average performance ratio $\mu_{\rho a}$, the standard deviation of the performance ratio $\sigma_{\rho a}$, average passing tolerance ratio $\mu_{\rho t_c}$ and standard deviation of the passing tolerance ratio $\sigma_{\rho t_c}$

It is worth mentioning that the performance ratio represents how hard the driver hits the acceleration pedal, whereas the passing tolerance ratio is the time the driver considers it to be "acceptable" to pass an amber traffic light, which is also referred to as dilemma zone.

4 Description of the Simulation
The simulation follows an incremental calculation, where the global simulation parameters are defined, such as the total simulation time t_{total}, time increment d_t and maximum number of moving objects n_{MO}.

The flowchart of the simulation, shown in Figure 2, consists of an initialization phase, followed by a time step iterator that continues running until the simulation time is reached. During each step of the time iterator, the simulation cycles first through all traffic generation zones, generating moving objects. This is followed by looping all ICUs and standalone TCUs, updating their status based on their own models. Finally, all MOs are updated.

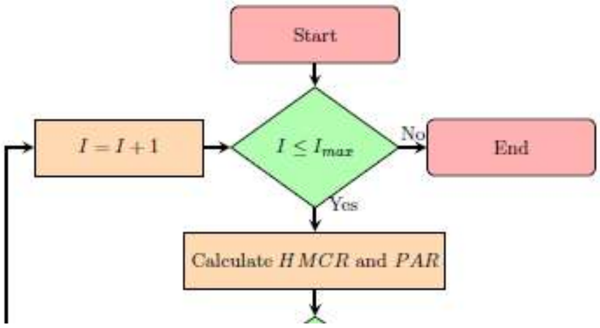

Fig. 2: Simulation process flowchart

As an example, the update process of a timed standalone TCU and a time ICU are shown in Figure 3 and Figure 4, respectively.

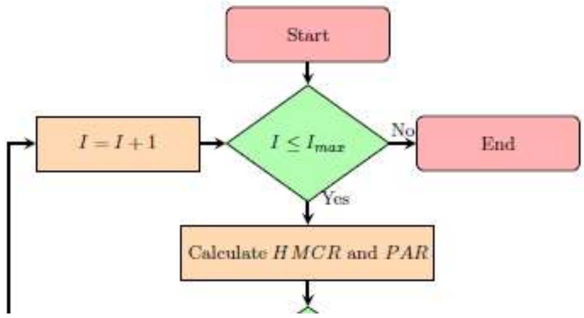

Fig. 3: Timed ICU Updating Flowchart

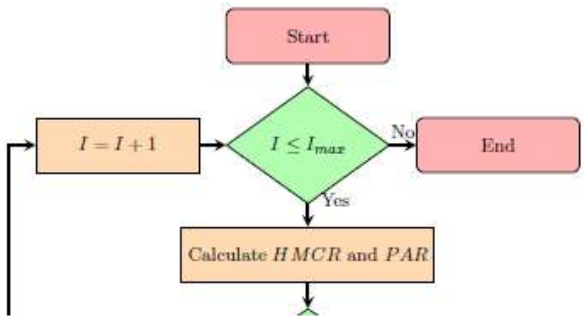

Fig. 4: Timed standalone TCU updating flowchart

The updating of each MO is a more sophisticated three-step process, namely: Position Analysis, Decision Making, Decision Implementation, and Movement. A flowchart of this process is shown in Figure 5.

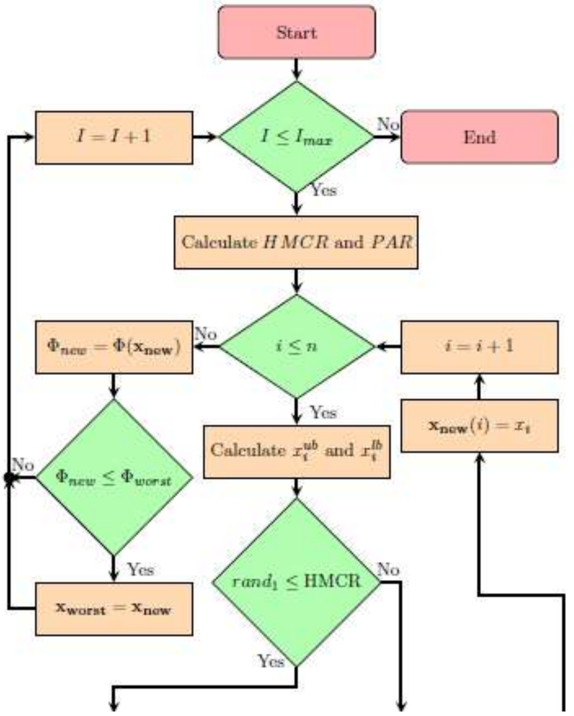

Fig. 5: Moving object updating flowchart

5 Study Area

This research is based in Bahrain wherein the prototype of the simulation approach is applied. Bahrain, an island country situated in the Arabian Gulf, is renowned for its strategic location, historical significance, and vibrant culture. Geographically, it is positioned east of Saudi Arabia and west of the Qatar peninsula. Despite its small size, Bahrain boasts a bustling economy driven by industries such as finance, tourism, and petroleum processing, [31]. The traffic patterns in Bahrain reflect its dynamic urban landscape, characterized by a mix of modern highways and traditional alleyways. The road network is well-developed, with major thoroughfares connecting key cities and landmarks, [32]. However, traffic congestion can be a challenge during peak hours, particularly in urban centers like Manama, the capital, [33].

What sets Bahrain apart is its rich cultural heritage, exemplified by ancient archaeological sites like the Bahrain Fort and the Barbar Temple. Additionally, Bahrain's thriving art scene, encompassing traditional crafts and contemporary works, adds a unique dimension to its cultural landscape [34]. In conclusion, Bahrain's strategic location, coupled with its vibrant culture and innovative approach to traffic management, makes it a compelling subject for further study and exploration.

6 Results and Discussion

The above-mentioned simulation methodology was applied to simulate traffic on a four-leg intersection in Bahrain. The selected intersection is located on Shaikh Salman Highway at its intersection with Salmabad city. As shown in Figure 6, this highway is a key route in Bahrain and serves as a vital link connecting various parts of the country. Stretching from the capital city of Manama to the southern regions, this highway plays a crucial role in facilitating transportation and commerce. One of the notable intersections along this highway is located at Salmabad, an industrial area known for its bustling commercial activities. The intersection at Salmabad is a busy juncture, serving as a gateway to numerous industrial facilities and commercial establishments. Despite the heavy traffic volume, efforts have been made to ensure smooth traffic flow with modern traffic management systems and infrastructure upgrades. Despite these efforts, the intersection at Salmabad still incurs delays and traffic jams on a daily basis.

Figure 7 shows the said intersection with the details of the available traffic data. It is evident that the highest volumes of traffic are for through movement at the intersection of Shaikh Salman highway, for reasons already mentioned above. Secondly, the flow towards Salmabad is already higher than on the other side due to the industries which are there. The evening peak hours have the highest total entering volume, although different sides may have their respective high volume in other hours.

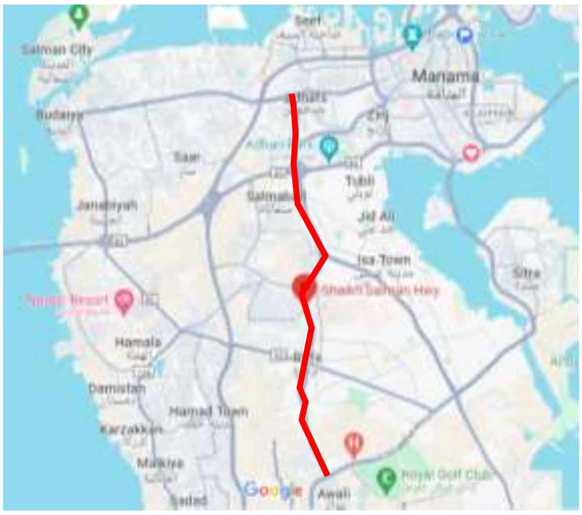

Fig. 6: Shaikh Salman highway

The intersection shown in Figure 7 was drawn in the simulation platform. Then the simulation approach, as described above, was applied to have flow for each movement (mentioned in Figure 7) in each lane. The movements having multiple lanes were divided with a share in each lane. This was done due to the absence of lane-wise distribution of flow, in which case, any other assumption would have under and over-estimated the results for different lanes. The assumption of equal distribution is expected to be a balanced approach. The error for each lane was calculated as the absolute % difference between the simulated and observed values. Table 9 shows the average % error and its standard deviation for each peak hour for each direction.

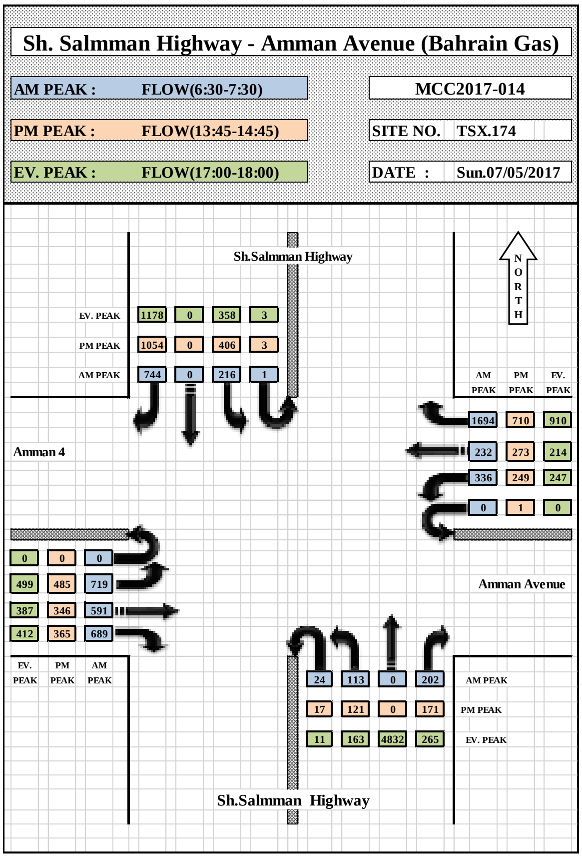

Fig. 7: Intersection orientation and data

Table 9 shows that the errors are generally under 10% while the standard deviation is less than the average error which means the coefficient of variation is less than 1. These indicators point to the satisfactory performance of the simulation approach according to the acceptable values from previous studies [35], [36]. The highest error and standard deviation were found to be for the AM peak hour in the North to South direction. Looking at the volumes (Figure 7) it does not seem to be due to any specific trend in terms of flow as the volume in this hour for this direction is not particularly high or low. Moreover, the same direction has a much lower error and standard deviation in different hours. Most importantly, the simulation strategy gives very good results for the highest and lowest cases of volumes which are more critical. It was also observed that some of the errors were positive, and others were negative. These trends provide evidence of the validity of the approach and encourage its use for other cases and safety evaluation.

Table 9. Error values for the simulation

Movement	AM Peak		PM Peak		EV. Peak	
	Average % error	Standard deviation of % error	Average % error	Standard deviation of % error	Average % error	Standard deviation of % error
South to North	24.24	19.16	4.46	2.45	3.88	2.48
North to South	6.74	6.19	9.78	5.15	10.31	5.54
West to East	6.65	5.54	9.01	4.98	9.51	5.32
East to West	1.54	0.18	1.48	0.57	0.75	0.55

7 Conclusions and Recommendations

This study aims to develop and implement an object-oriented microsimulation for traffic flow that incorporates the variation in driver behavior. This has been done by considering the deceleration/acceleration and spacing of the drivers. A busy junction in Bahrain was taken as the first case study to determine the applicability of the said approach. A signal light controller was used to simulate the effects of signal timing on the flow. Sensers/counters were placed on each lane (in the simulation) to have lane-wise flows.

The simulated results show proximity to the real flows on almost all approaches for different timings. The accuracy of the simulation model was judged based on % error in simulated and actual values and the standard deviation of the error for each approach. Especially, the errors for the critical cases (highest and lowest values) were especially low and had smaller variations in them. These results are encouraging for further use of the same methodology in the future.

Based on these results, the future avenues of research could include the following. The strategy could be applied to different types of intersections and highway segments. Another aspect of research could be to test and evaluate the effects of different design and mitigation strategies on driver behavior. Surrogate safety measures could be used for this purpose. The researchers aim to incorporate an automated counter for these measures which would make the safety analysis much more efficient and easier than the existing tools.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work the authors used ChatGPT in order to improve the readability and language of your manuscript, especially sections related to the study area. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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- Mahmoud Jahjouh carried out the simulation and the optimization.
- Uneb Gazder was involved in data collection.
- Mahmoud Jahjouh Uneb Gazder and Rashid Abdurahman Ismaeel were involved in writing the initial draft of the paper.

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