The Impact of Motorcycle Positioning on Start-Up Lost Time: The Empirical Case Study of Signalized Intersections in Marrakech using VISSIM

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ABSTRACT

This study explores the influence of a high percentage of motorcycles on the traffic flow and congestion in Marrakech by examining the impact of motorcycle positioning in shaping urban traffic dynamics, in particular, the start-up lost time at signalized intersections. Different motorcycle positioning strategies are analyzed to improve intersection efficiency and safety. A twofold approach was followed to achieve this objective. First, empirical data were collected using computer vision techniques. Second, different strategies were simulated in VISSIM based on the collected data. The approach adopted for data collection was based on mobile phone video recording at a representative signalized intersection in Marrakech, capturing traffic behaviors during four distinct time periods. Then the YOLOv8 algorithm was employed for real-time object detection and analysis, allowing precise monitoring of motorcycle positioning and examining its influence on the start-up lost time. Afterwards, VISSIM simulations were implemented, on the basis of the collected data, to explore various scenarios, such as motorcycles sharing lanes with cars or dedicated motorcycle lanes. The results reveal a compelling correlation between motorcycle proximity to cars and traffic congestion, with closer positioning leading to increased congestion, longer travel times, reduced average vehicle speeds, and extended queue lengths at intersections. On the contrary, scenarios with dedicated motorcycle lanes consistently show reduced congestion and smoother traffic flow.

Keywords-traffic simulation; travel time; start-up lost time; traffic flow analysis; motorcycle position

I. INTRODUCTION

Traffic congestion in urban areas is a growing concern worldwide, with significant impacts on journey time, air quality, and overall urban livability. Marrakech, a prominent city in Morocco, constitutes a unique case in the traffic flow and congestion studies due to its distinct vehicular composition. In particular, the city's traffic comprises around 40% motorcycles and 60% cars [1], a combination of factors that markedly shapes traffic dynamics and congestion patterns, encompassing various elements, such as vehicle volumes, road conditions, and traffic control measures [2]. The predominance of motorcycles in Marrakech's traffic system generates unique challenges with a very serious impact on the city's economy. Motorcycles, with their smaller size and greater maneuverability, interact differently with cars and other means of transportation, affecting the traffic flow and safety. Understanding how these interactions contribute to traffic congestion and travel delays is crucial for effective traffic management and urban planning [3].

This study investigates the impact of this heterogeneous mix of vehicles on the average travel time, with a particular focus on the effects of motorcycles on the urban traffic. The motivation behind this research stems from the need to develop more efficient traffic management strategies to meet the specific characteristics of Marrakech's roads. By analyzing the factors that contribute to congestion and the role of motorcycles within it, this study aims to provide insight into potential improvements in traffic regulation and infrastructure development. This study focuses mainly on a crucial challenge among these urban traffic dynamics, namely the positioning of motorcycles at signalized intersections in Marrakech. The objective is to analyze the time lost when starting the motorcycle, but also to improve the fluidity and safety of traffic at intersections. The lack of empirical data makes the analysis and simulation very difficult. This study used mobile phone video recordings at a representative signalized intersection, which were then processed and analyzed using computer vision techniques. With these data available, different strategies were examined deploying the VISSIM simulation.

To optimize traffic efficiency and improve road safety, this study examines the impact of motorcycle positioning on start-up lost time in Marrakech, having the following concerns:

- Use computer vision techniques, specifically the YOLO-V8 deep neural network, to collect empirical data.
- Analyze the impact of motorcycles on traffic dynamics at signalized intersections using the VISSIM simulator based on the collected empirical dataset.
- Focus on key metrics and indicators, such as travel time, average vehicle speed, stop-and-go events, and queue length, providing valuable insights into the influence of motorcycles on overall traffic flow.

II. RELATED WORK

Cities with a high percentage of motorcycles face challenges in traffic management, affecting urban dynamics. In Marrakech, mass motorcycle positioning at intersections hampers traffic flow and safety. Factors, such as start-up lost time, affected by driver behavior and intersection design, exacerbate congestion [3]. In [4], a three-parameter Burr model and log-logistic distribution were put into service to examine the start-up time in Guangzhou, China, with implications for optimizing green signal times and improving urban traffic flow. Meanwhile, a parallel investigation in Qatar delved into the driver reaction time, acceleration, and jerk, presenting statistical findings and exploring demographic influences, involving gender, ethnicity, and age. These insights, particularly in reaction times and jerks, offer valuable data for simulation models that assess driver behavior and safety at signalized intersections [5, 6]. Telematics integration improves the start-up behavior, ameliorating the traffic capacity by 20% [7]. In [8], the variability of the start response time was linked to saturation flow rates, crucial for signal performance. In [9, 10] factors affecting the start-up delays, aiding intersection design, and phasing decisions were identified. In [11], a Mullered Model accurately estimated delays, facilitating traffic analysis. In [5], a study on start-up behavior highlighted demographic influences, essential for diverse traffic environments. Despite extensive studies on car behavior, understanding the motorcycle rider behavior at intersections remains lacking. In [7, 12], detailed loss time values were provided, advocating for safer infrastructure. Meanwhile, in Indonesia, where motorcycles constitute a significant portion of the traffic, a study exposed shortcomings in existing traffic models and introduced a novel approach to determine saturation flow based on motorcycle behavior, aiming to improve traffic management at signalized intersections [13]. In [14], factors influencing motorcycle riders' stopping choices at signalized urban intersections were identified utilizing Unmanned Aerial Vehicles (UAVs) to collect data and employing multinomial logistic regression to identify key factors that account for nearly 50% of the variation in motorcycle riders' stopping behavior [15].

The impact of motorcycles' proportion on queue length in a specified region was investigated in [16, 17], but although high motorcycle proportions were observed on all the roads studied, these studies concluded that there was no significant correlation between the proportion of motorcycles and the queue lengths observed in real-world scenarios. However, it is important to note that these studies may have limitations in terms of the data used and the representation of motorcycle behavior. One notable limitation is the absence of real-world data or simulations that accurately capture the nuanced behavior of motorcycle riders. Motorcyclists often exhibit a preference for strategically positioning themselves, typically seeking a position at the front of the queue or maneuvering between cars to navigate traffic efficiently. Failing to incorporate these aspects into studies can limit their practical relevance, as real-world motorcyclist behavior can significantly affect intersection dynamics and safety.

III. METHODOLOGY

This study explores the influence of motorcycle positioning on start-up lost time at signalized intersections in Marrakech. To achieve this goal, a comprehensive methodology was devised to integrate empirical data collection with advanced traffic simulation techniques, specifically employing VISSIM. This method was meticulously crafted not only to navigate the intricacies of urban traffic dynamics, but also to meticulously analyze the impact of various motorcycle positioning strategies on the overall efficiency and safety of the intersections. VISSIM was chosen for the simulations because it provides the necessary parameters, including start-up lost time, queue lengths, stop-and-go events, and travel times, essential for this investigation. Taking advantage of the VISSIM's capabilities, this study aims to unravel the nuanced relationship between motorcycle placement and intersection performance, shedding light on potential strategies to optimize traffic flow and enhance road safety in urban environments like Marrakech.

A. Data Collection

This study developed a focused and innovative approach to collect data on motorcycle positioning and its impact on start-up lost time at signalized intersections in Marrakech. This method used mobile phones for video recording, providing an accessible yet effective means of capturing real-time traffic flow. This approach allows for a detailed and authentic representation of the traffic dynamics at the chosen intersection. To ensure a robust and representative dataset, data collection was carried out during four critical periods, each chosen to reflect different traffic conditions that are typically observed throughout the day. These periods included the morning rush hour from 10:00 AM to 10:30 AM, a midday slot from 12:00 PM to 12:30 PM, an early afternoon interval from 3:00 PM to 3:30 PM, and finally, the evening rush hour from 6:30 PM to 7:00 PM. Each recording session lasted 30 minutes, providing a substantial amount of data to analyze the various traffic scenarios. Figure 1 outlines the intersection layout and identifies two key data collection points, labeled A and B. Point A is strategically placed to observe the motorcycle behavior when leading the queue at red lights, focusing on their maneuvers and interactions with cars. Meanwhile, point B provides a broader view of the intersection, facilitating accurate vehicle counting and classification. This dual-camera setup ensures comprehensive data collection, capturing detailed motorcycle behaviors in both leading positions and within the traffic flow.

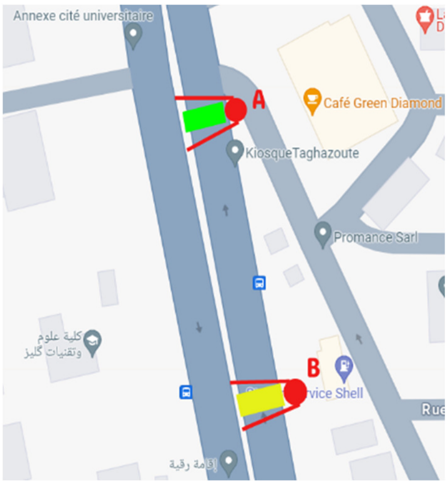

Fig. 1. Visual representation of study location and camera positions.

B. Data Analysis

In the data analysis phase, the YOLO v8 (You Only Look Once) algorithm was chosen, which is renowned for its excellence in real-time object detection, to analyze the complex traffic dynamics at a signalized intersection in Marrakech. This decision is crucial, given the ability of YOLO v8 to process extensive video footage efficiently and accurately, a significant factor considering the volume and nature of the data [18]. The YOLO v8 methodology of dividing the image into a grid, where each segment concurrently predicts bounding boxes and class probabilities, is particularly suited to the needs of this study. It allows for the rapid and precise detection of various objects - motorcycles, cars, and pedestrians - within the dynamic traffic environment of the intersection. This feature is essential for analyzing the intricate behaviors of motorcycles, especially their positioning in relation to cars, and how this impacts the start-up lost time at the intersection. This study showcases the utilization of the YOLO v8 algorithm for a detailed analysis of traffic flow dynamics and the measurement of the start-up lost time at a signalized intersection, as depicted in Figure 2 [19]. The process unfolds as follows:

- Initial Video Input: The process starts with the acquisition of raw video footage from intersection cameras, capturing real-time vehicle movements in varying traffic scenarios.
- Processing with YOLO v8 DNN Model: Raw video data is analyzed through the YOLO v8 Deep Neural Network (DNN) model. This step is crucial as YOLO v8 excels in swiftly processing and interpreting video data, making it ideal for real-time traffic analysis. The model meticulously scans each frame of the video, efficiently detecting and identifying objects present within the scene.

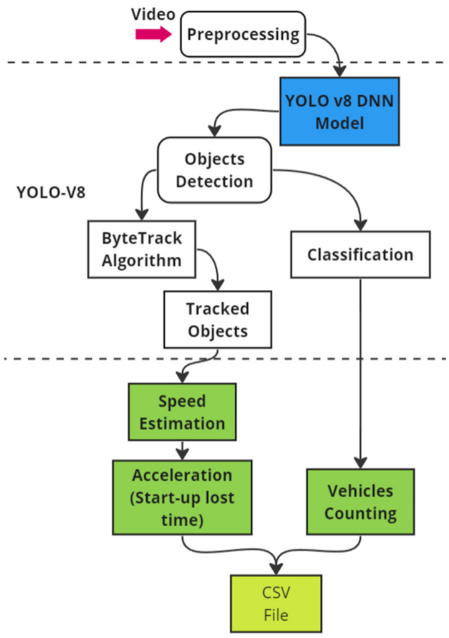

Fig. 2. Counting system based on deep learning and YOLOv8.

- Object Detection: YOLO v8 accurately discerns various objects within the video frames, including different types of vehicles, such as motorcycles, cars, and trucks, as well as pedestrians and traffic signals. Its proficiency lies in its ability to swiftly process multiple objects within a single frame.
- Classification and ByteTrack Algorithm Application: Following object detection, the process diverges into two distinct streams:
  - Classification Stream: Detected objects are classified and assigned a 'class id' based on their type, such as motorcycle or car. This classification is vital for precise vehicle counting and understanding the distribution of different vehicle types at the intersection.
  - ByteTrack Algorithm Stream: Simultaneously, the ByteTrack algorithm is deployed to track the

movement of the detected objects across consecutive frames. This advanced tracking algorithm is instrumental in comprehending the behavior patterns and movement trajectories of objects over time.

- Extraction of Analysis Outputs: The final stage involves extracting and interpreting data from both streams:
  - Vehicle Counting (from Classification Stream): This output provides a quantitative analysis of traffic, detailing the number and types of vehicles traversing the intersection. It plays a crucial role in evaluating traffic composition and volume.
  - Speed Estimation and Acceleration Analysis: By continuously tracking objects over time, the algorithm computes their speed and acceleration. These data are indispensable for assessing start-up lost time for each vehicle type, particularly motorcycles, providing insights into how different vehicle positioning affects intersection efficiency.

By meticulously following these steps, the YOLO v8 algorithm facilitates a comprehensive and nuanced analysis of the traffic patterns at the intersection. This methodological approach not only ensures accurate vehicle counting, as shown in Table I, but also deepens the understanding of vehicle behavior, mainly focusing on start-up dynamics and lost time, which are essential to optimize the traffic flow and improve road safety.

TABLE I. RESULTS OF VEHICLE COUNTING

Time		Cars	Motorcycles
10:00 - 10:30	10:10	93	62
	10:20	84	56
	10:30	107	71
12:00 - 12:30	12:10	139	92
	12:20	134	89
	12:30	154	102
15:00 - 15:30	15:10	81	54
	15:20	74	49
	15:30	103	68
18:30 - 19:00	18:40	167	111
	18:50	149	99
	19:00	172	114

During each interval, data were meticulously recorded in 10-minute increments, noting the number of cars and motorcycles present. A critical observation was the difference in the start-up lost time, based on the position of motorcycles - whether they were in front of cars or interspersed between them. For motorcycles at the front of the queue, the start-up lost time was consistently measured at 1 second across all time slots. However, when motorcycles were positioned between cars, this time increased to 2 seconds, suggesting that their ability to maneuver and accelerate was fairly hindered by the surrounding vehicles. In contrast, cars exhibited a uniform start-up lost time of 4 seconds across all time intervals and positions. This longer duration compared to motorcycles can be attributed to their heavier build and comparatively slower acceleration.

IV. VISSIM SIMULATION

The data collected from the signalized intersection in Marrakech, including vehicle counts, types, positioning patterns, and signal timings, were meticulously integrated into the VISSIM model. This integration involved configuring the simulation environment to reflect the real-world traffic conditions observed at the intersection. The model was calibrated using the collected data, ensuring that the simulated traffic behaviors closely resemble those recorded in the field. This calibration is critical to achieving reliable and valid simulation results, enabling the evaluation of various motorcycle positioning scenarios and their impact on the start-up lost time and intersection efficiency.

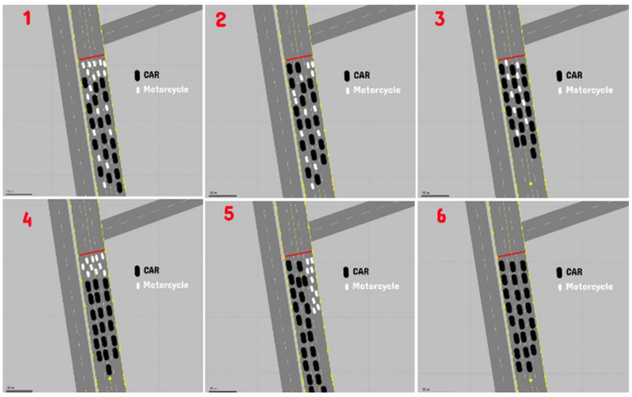

Fig. 3. Traffic flow scenarios with varied motorcycle positions.

Figure 3 illustrates the following six simulation scenarios, aimed at understanding the impact of motorcycle positioning and presence on traffic flow:

1. Motorcycles Positioned in Front of Cars and Between Lanes: This scenario involves configuring VISSIM to allow motorcycles to pass through traffic, exploiting the space between lanes. It aims to reduce motorcycle waiting times and potentially improve intersection efficiency, although it requires careful calibration to model riskier maneuvers.
2. Motorcycles Searching for a Place in Front of All Cars: Here, VISSIM prioritizes motorcycles to advance to the front of the queue at traffic stops, mimicking urban motorcycle behavior. Adjustments in desired speeds and lane-changing behavior simulate how motorcyclists minimize waiting times.
3. Motorcycles Positioned Between Cars: This scenario reflects motorcycles mixed within car traffic, simulating less dynamic riding styles. It evaluates the impact on safety and car traffic dynamics during standard traffic flow.
4. Motorcycles in Front of Cars: In this conventional scenario, motorcycles follow the same rules as cars, building a picture of the traffic flow without the existence of any special treatment for motorcycles.

5. Motorcycles in a Dedicated Lane Separate from Cars: VISSIM simulates a dedicated lane for motorcycles, focusing on benefits such as reduced conflicts and improved safety. Challenges include real-world implementation and effects on car lanes.
6. Traffic Without Motorcycles (Only Cars): Serving as a baseline, VISSIM simulates only car traffic, allowing for a comparison of the traffic flow and congestion with and without motorcycles. This scenario highlights the specific impacts of motorcycles on the traffic flow.

To calculate the average travel time from a simulation scenario that depends on the start-up lost time, several factors, including the start-up lost time, the travel time under normal conditions, and any other delays that might occur during the trip, should be incorporated .

$$AvgTT = \frac{\sum(NTTime_i+SLT_i+AD_i)}{N} \quad (1)$$

where Σ represents the sum of all cars, $NTTime_i$ is the normal travel time for the i-th car, SLT_i is the start-up lost time for the i-th car, AD_i includes additional delays experienced by the i-th car, and N is the total number of cars. In a traffic simulation software like VISSIM, "Additional Delays" in the context of the formula would be automatically calculated based on the simulation parameters and traffic conditions. These delays could include factors, such as varying speeds, traffic congestion, interactions with other vehicles, and responses to traffic control measures. VISSIM's sophisticated algorithms take into account a multitude of variables to simulate realistic traffic conditions and provide accurate delay calculations for each vehicle.

V. RESULTS AND DISCUSSION

Table II presents a comparative analysis of traffic patterns across six distinct scenarios, focusing on the interplay between motorcycles and automobiles. The control scenario Traffic Without Motorcycles (Only Cars) displays a baseline of the travel times and vehicle speeds, with increased congestion during the evening rush hour. When motorcycles share lanes with cars or are positioned between cars, there is a discernible rise in travel times and stop-and-go events, suggesting increased congestion. Conversely, motorcycles in a dedicated lane exhibit fewer stop-and-go events and shorter queue lengths, underscoring the efficiency of dedicated lanes. The scenario of motorcycles searching for a place at the front leads to variable travel times and a consistent number of stop-and-go events, indicative of the aggressive riding required. The data collectively imply that while shared lanes increase congestion, dedicated motorcycle lanes could streamline traffic flow and improve overall safety.

Figure 4 offers a condensed but insightful overview of the impact of various motorcycle positioning scenarios on key traffic parameters, including travel time, average vehicle speed, stop-and-go events, and queue length across different time slots. At first, it depicts how the absence of motorcycles results in consistently higher average vehicle speeds, shorter travel times, fewer stop-and-go events, and shorter queues at intersections. This serves as a benchmark for optimal traffic flow. In contrast, scenarios where motorcycles are positioned closer to cars exhibit lower average vehicle speeds, longer travel times, increased stop-and-go events, and longer queues, especially during peak traffic periods like the evening rush hour. This highlights the correlation between motorcycle proximity and traffic congestion, emphasizing the importance of effectively managing their positioning.

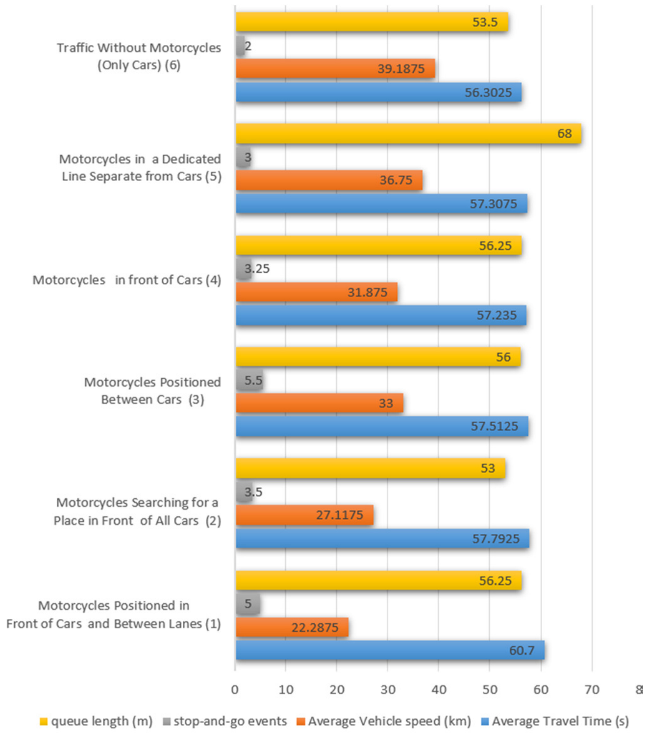

Fig. 4. Comparison of travel time, vehicle speed, stop-and-go events, and queue length across six scenarios.

TABLE II. RESULTS OF THE VISSIM SIMULATION

Scenarios	Average travel time (s)	Average vehicle speed (km)	Stop-and-go events	Queue length (m)
1. Motorcycles in front of cars and between cars	60.7	22.2875	5	56.25
2. Motorcycles in front of all cars	57.7925	27.1175	3.5	53
3. Motorcycles between cars	57.5125	33	5.5	56
4. Motorcycles in front of cars	57.235	31.875	3.25	56.25
5. Motorcycles in a dedicated line separate from cars	57.3075	36.75	3	68
6. Traffic without motorcycles (only cars)	56.3025	39.1875	2	53.5

The scenario with motorcycles segregated in dedicated lanes stands out as it maintains competitive average speeds, shorter travel times, fewer stop-and-go events, and shorter queue lengths across most time slots. This underscores the benefits of separating motorcycles from cars in terms of maintaining smoother traffic flow and higher vehicle speeds. From this comparison, it is evident that the most effective method to minimize the impact of motorcycles on other vehicles is by implementing dedicated lanes for motorcycles. These lanes not only ensure smoother traffic flow and higher average speeds, but also reduce the frequency of stop-and-go events and shorten queue lengths at intersections. By segregating motorcycles from other vehicles, traffic congestion can be minimized, resulting in improved overall traffic efficiency and safety on the roads. Therefore, the creation of separate lines for motorcycles emerges as the optimal solution to alleviate the disruptions caused by their presence in mixed traffic scenarios.

VI. CONCLUSION

This study thoroughly investigated the impact of motorcycle positioning on the start-up lost time at signalized intersections in Marrakech. Through a robust methodology combining real-world data collection and advanced traffic simulation using VISSIM, valuable insights were provided into how different motorcycle positioning strategies affect intersection efficiency and safety. Data collection involved strategically recording traffic dynamics at a representative signalized intersection utilizing mobile phones. Data were collected during four distinct time periods to capture varied traffic conditions throughout the day. To analyze the data gathered, the YOLO v8 algorithm was applied for real-time object detection, allowing precise monitoring of motorcycle positioning and its impact on start-up lost time. This algorithm efficiently handled extensive video footage, ensuring the accuracy of the analysis. Deploying VISSIM simulations based on the collected data, traffic dynamics were evaluated across various scenarios, including motorcycles sharing lanes with cars and dedicated motorcycle lanes. The findings revealed that the proximity of motorcycles to cars significantly influences the traffic flow. Specifically, when motorcycles are positioned close to and between cars, traffic congestion increases, leading to longer travel times, reduced vehicle speeds, more frequent stop-and-go events, and longer queues at intersections.

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