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Impact of Construction Work Zone on Urban Traffic Environment

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Abstract

Objectives: Traffic management is challenging during construction because of the effects of traffic congestion, travel time, delay, and queue length. Long-term work zones on urban roads lead to many problems such as speed, inconvenience, and economic losses to drivers, which are focused on in previous studies.
Methods: Moreover, due to the construction work zone (CWZ), the impact on environmental factors such as air quality and noise levels was not focused on. Because of the building work zones, this research focused on comprehending how traffic congestion measurements and environmental factors affect urban traffic management.
Findings: The present research uses TransCAD to estimate air pollution due to increased traffic in the urban areas. Furthermore, three nonlinear AI-based models (ANFIS, FFNN, and SVR) and one linear black box model were developed to predict the noise level in the city, in which each contained the total traffic and speed as well as the ratio of heavy vehicles in the traffic.
Novelty: For traffic control, a variety of techniques are available, including video data analysis, infrared sensors, inductive loop detection, wireless sensor networks, etc. These are all practical techniques for efficient traffic management. It is necessary to conduct studies on the amount of traffic, the topography, accidents, time delays, and the level of safety offered in the work area. Construction operations are facilitated by the implementation of traffic flow, and during this process, long-term CWZs are inevitable. Therefore, the proposed model accomplishes the goal, namely that only analytical research and a few traffic diverter signs point drivers to alternate routes to their destinations.

Keywords
construction work zone, delay, noise and air quality levels, queue length, traffic congestion, traffic management

I. Introduction

Due to the rapid growth of urban population and increasing vehicle count supplemented by increased use of private vehicles, congestion on urban roads has increased tremendously. In a developing country like India, augmentation of road infrastructure is projected as the solution to address this problem. Implementation of these projects paves way to the construction activities, and in this process long-term construction work zones (CWZ) in urban areas are inevitable. Though these projects are aimed at decongesting the roads, a lack of proper planning and implementation norms for these long-term

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urban work zones leads to many problems such as reduction in capacity, increase in the travel time delays, queue length, a number of forced merges, and roadway accidents; these effects, in turn, have their major manifestation in traffic congestion, which leads to unaccounted economic losses. So, as a first step, it becomes necessary to study and quantify the impact of mass rapid transit system CWZs on their traffic environment. Transportation, especially road transportation, is essential in fostering financial evolution and prosperity across the country [1]. The number of vehicles will increase as cities grow and people move from rural to urban regions, leading to severe traffic congestion if the issue is not properly managed. There are several socio-economic and physical effects such as increased fuel consumption, air pollution such as CO2 and greenhouse gas (GHG) emissions, and lost productivity. Traffic congestion is a problem that is getting worse in urban areas and has negative consequences on the economy, ecology, and health [2]. Activities in work zones are crucial for preserving excellent roads, fostering economic growth and competitiveness, and enhancing safety. Despite their being transitory activities, road repair can have long-lasting effects on drivers due to their carelessness and blunders [3].

CWZs are one of the main factors contributing to traffic congestion and the delays experienced by road users. According to current data from the Federal Highway Administration (FHWA), highway construction zones cause 10% of total traffic congestion and 24% of non-recurring delays for motorists [4]. For a long time, researchers have studied and put into use work-zone safety mitigation approaches. Vehicle speeds can be controlled and balanced with the use of speed monitoring displays and signs with changeable messages. There may be a reduction in work-zone fatalities due to flaggers, flashers, and pavement center/edge lines [5]. Due to the emergence of infrastructure activities, construction bustles along road sections are frequent engagements; nevertheless, these bustles also serve as sensitive zones for traffic movement across the road network. The consequences of these construction operations on the traffic stream may change the traffic flow features on the road sections that must be managed with adequate planning [6]. Figure 1 depicts the CWZ's layout.

Road-traffic noise (TN) is acknowledged as a severe problem that has an impact on metropolitan areas. Transportation in metropolitan regions has grown because of urbanization and industrialization. Due to their complex environments, cities in developing countries like India have far more diverse TN characteristics than those in industrialized countries. TN pollution has increased as a result of the variety of vehicles on urban roads, including heavy trucks, four-wheelers, three-wheelers, and two-wheelers, as well as slow-moving vehicles like

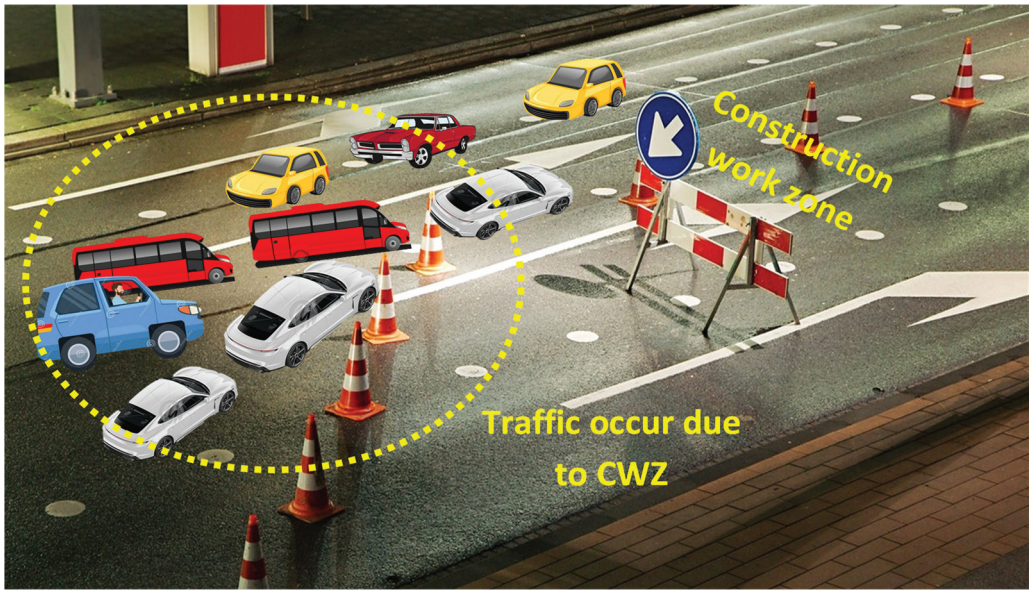


Figure 1: Layout of CWZ. CWZ, construction work zone.

bicycles [7–8]. Traffic congestion is a major issue on a global scale because of a number of causes, such as high population density, the growth of motor cars, related infrastructure, and the development of ridesharing and delivery services. Congestion is a noticeable phenomenon in most metropolitan locations, and is attributable to several reasons. Traffic congestion is divided into recurrent and non-recurring congestion based on several factors. Regular congestion occurs mostly because of the overabundance of traffic at peak hours. On the other hand, irregular occurrences like bad weather, construction zones, accidents, and special events constitute the causative factors responsible for constant congestion [9]. Increasing productivity and its related economic benefits while decreasing delays, pollution, and stress are all advantages of reducing congestion [10]. The consequences of travel times, queue length, overall delay, noise and air quality levels, and traffic congestion related to the CWZ must therefore be considered in order to minimize effects. The following major contributions to this study are listed:

TransCAD, a transportation planning tool, is used to estimate air pollution due to increased traffic during and after the construction of the A-25 expansion project in order to offer cleaner air in urban traffic environments where CWZs are present.

AI models like ANFIS, FFNN, and SVR are used to estimate the noise level in an urban traffic environment caused by CWZs. By using the outputs of the single models as the input variables for the ensemble procedures, Inmode3l took advantage of the advantages of each individual model and improved the performance of the single models.

To forecast the noise level, a statistical method known as multilinear regression (MLR) is used, which employs a number of explanatory factors.

The structure of the study is as follows: Section 2 provides a review of the literature on various strategies for enhancing traffic management elements; in Section 3, the methodologies are summarized; in Section 4, the article is concluded; and in Section 5, the future scope is reviewed.

II. Literature Survey

Various investigations into traffic impacts due to CWZs are reviewed in the forthcoming sub-sections.

Figure 2 shows that the guideline has been formulated in five distinctive directions related to impacts in traffic environment. Also, the significance and limitations of these techniques are described in the following sub-sections.

a. Impact of travel time in traffic environment due to CWZ

In a two-lane highway construction zone scenario, Abdulsattar et al. [11] developed an agent-based modeling framework to evaluate the impact of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technologies on mobility performance. An ABMS framework was created to evaluate the impact of changing MP and traffic flow rates on mobility benefits in the context of a two-lane highway work zone (HWZ). Travel time and its dependability, average speed, and the vehicle throughput to capacity ratio in the work zone were used to gauge the impact of V2V and V2I communication deployment in

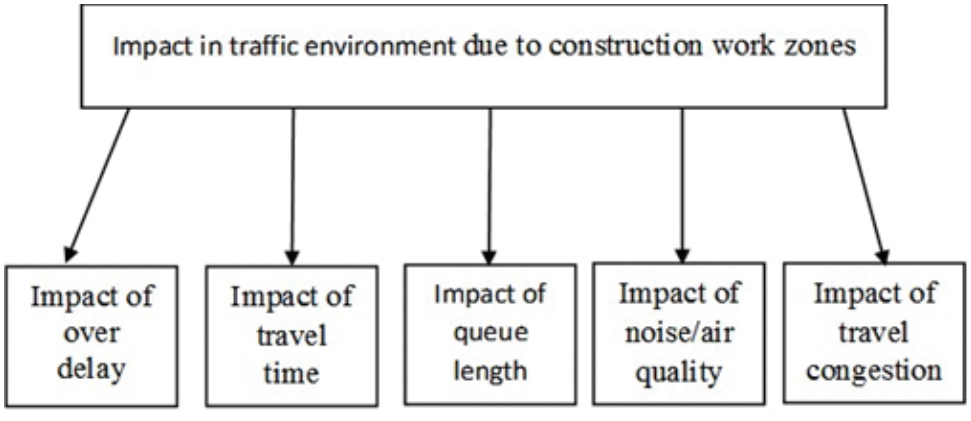


Figure 2: Guidelines for examining different impacts in the traffic environment.

the specified work-zone scenarios. Additionally, this research found that, in mixed traffic conditions, a higher MP level is required to give mobility benefits the higher the traffic flow rate. However, this method needs high computational power to apply for higher traffic volume.

The effects of a road building project on freeway and arterial street link-level travel times were modeled by Kukkapalli et al. [12]. Information about a 6-month resurfacing project was compiled using data from traffic incident management systems (TIMS). Travel time data were acquired and processed for the 6 months prior to the start of the resurfacing construction project and the 6 months throughout the resurfacing project for each chosen freeway and its accompanying arterial street connection. The upstream and downstream links on a number of lanes serve as the foundation for the validation of the trip time. This model predicts a bigger influence of travel time for upstream and a smaller effect for downstream, and it appropriately calculates the travel time throughout the construction project on the connecting arterial street linkages. However, there was no information on the amount of construction activity or the times when it really occurred.

Cao et al. [13] proposed a cooperative traffic control technique that makes full use of the spatial resources upstream of work zones to boost the capacity of non-recurring bottlenecks like work zones. There are two zones in the upstream area: regulatory and merging zones. The mean travel time (MTT) is used as a metric for efficiency, and it is measured from 1720 m upstream of the work zone. The sorting algorithm is utilized in the merging area to create lane-changing (LC) trajectories based on the controlled platoons. This research is conducted at non-recurrent bottlenecks such as construction zones or crash sites. However, this method ignored the attendant safety issues, such as the safety of the workforce in a work zone.

In addition to examining the effects of four varying levels of police presence on work-zone safety, Ravani et al. [14] studied the extent of the speeding issue in highway construction zones. Data collected in six different work-zone locations in northern and southern California were used to establish the scope and makeup of the speeding issue in highway construction zones. Additionally, information was gathered over the course of 11 test days in four work zones with four different levels of police presence: radar speed displays with police decal and lighting, passive use of a police vehicle with radar speed display, passive use of a police vehicle without radar speed display, and active police speed enforcement close to work zones. After studying the four corresponding measures of effectiveness, it could be ascertained that appreciable safety gains were obtained resultant to their deployment, and that these improved incrementally in tandem as the level of police presence underwent enhancement. However, the results were not statistically significant.

Wen et al. [15] concentrated on predicting journey times in connected vehicle (CV) environments in highway construction zones. In a V2I context, the simulation model interfaced with linked cars using portable RSUs to collect traffic data. When compared to loop detectors, portable RSUs are less expensive to install and maintain, and their number and placement are modified. Sixteen traffic parameters were gathered from the V2I data and twelve RSUs were installed along the work-zone area of the simulation model to determine potential RSU locations. Four distinct modeling techniques were studied for travel time prediction and variable selection, including linear regression, MARS, stepwise, and elastic net. However, this study did not explore the vehicle penetration rates and work-zone types.

By characterizing the city's various routes in terms of vehicle load vs. trip time during rush hour traffic conditions, Zambrano-Martinez et al. [16] conducted an experimental analysis of traffic distribution in Valencia, Spain. According to experimental results based on actual vehicular traffic traces from the city of Valencia, only a small number of street segments fit within the general theory of vehicular flow, providing a good match using quadratic regression, while a large number of street segments fall into other categories. In addition, we provide an equation to describe travel times along a section of the sigmoid family. Specifically, we employ logistic regression to improve curve-fitting outcomes for the majority of the street segments under consideration. This technique illustrates a predictable traffic pattern that is optimized for driverless vehicles using logistic regression during peak city hours. However, the traffic control system must be improved before using this technique could become fully feasible and effective.

Tufuor et al. [17] extended the research by using a larger testbed. It pinpoints the origins and magnitudes of travel time variability that influence the HCM6 inaccuracy. The first step in refining the HCM6 model is to better represent actual situations to understand potential sources of inaccuracy and their quantitative

values. The testbed was modeled using the HCM6 approach, and the estimated TTD by source of trip time variability was statistically compared to the corresponding empirical TTD. On the longer testbed, the HCM6 was found to be 67% off in terms of TTD variability. The major cause of inaccuracy in the HCM6 TTD was determined to be the demand component, missing variable(s), or both, which were not explicitly included in the HCM6.

Work-zone advisory systems' effects on worker safety were investigated by Mao et al. [18]. The traditional system in a CV environment consists of a dynamic message sign (DMS), whereas the advanced system has an in-car work-zone warning application. The two data collection locations were placed 500 m upstream and downstream of the work zone, respectively. It is important to note that the length of the data collection segment varies based on the study objectives under various conditions. While the safety evaluation indicator was the number of time to collision (TTC) values less than 1.5 s, the assessment efficiency indicators were the average travel time, average speed, average queue time, and average delay time of all vehicles. This approach increases the overall traffic system's safety level while not compromising the system's effectiveness. The responses of actual drivers to DMS and CV warning messages are not captured by this system, though. Researchers have come up with various innovative methods, such as HCM6 TTD and statistical methods, to improve the travel time within or in the proximity of a CWZ; these are reviewed, together with their advantages and disadvantages, in Table 1.

Additionally, the HCM6 TTD algorithm predicts the distribution of average travel times on urban streets, and statistical methods determine the severity of the speeding issue in work zones on highways. However, these methods suffer from inaccuracy when it comes to prediction of the distribution of travel times and

Table 1. Impact on travel time in traffic environment due to CWZ

Reference No.	Method/Tool	Significance	Limitations
[11]	Agent-based modeling framework	Determines the impact of changing MP and traffic flow rates on the advantages of mobility	Needs high computational power to apply higher traffic volume
[12]	TIMS	Determines how a road construction project will affect the highway and any connecting arterial streets' link-level traffic times	No information on the amount of construction activity or the times when it really occurred
[13]	Cooperative traffic control technique	Makes merging control easier when vehicles are coming up in the obstructed lane	Ignores the safety issues such as the safety of the workforce in a work zone
[14]	Statistical methods	Determines the severity of the speeding issue in HWZs	Not consistently statistically significant
[15]	PARAMICS	Predicts the trip time through a work zone to assist users in choosing more efficient routes	Does not explore the vehicle penetration rates and work-zone types
[16]	SUMO, DFROUTER	Outlines the street segments in Valencia in terms of trip times under various levels of traffic congestion	The traffic management system must be improved.
[17]	HCM6 TTD	Predicts the distribution of average travel time in the urban streets	Inaccuracy in analyzing the traffic parameters
[18]	VISSIM	Examines how work-zone advisory systems affect safety	Does not accurately portray how drivers will respond to DMS and CV warning signs in the real world

CV, connected vehicle; CWZ, construction work zone; DMS, dynamic message sign; HWZ, highway work zone; TIMS, traffic incident management systems.

are not consistently significant. Therefore, additional study should be conducted to reduce travel time caused by the CWZ.

b. Impact of overall delay in traffic environment due to CWZ

Shahin et al. [19] proposed a HWZ optimization model that calculates the influence of HWZs on worker safety, mobility, and costs. The two goals are as follows: measuring the effects of HWZs on worker safety, mobility, and costs; and second, by regulating site layout, temporary traffic control (TTC), and work management, developing an optimization model to reduce the overall expenses. Within the cost evaluation, this approach uses a location-based timetable. To find a set of optimal scheduling and decision factors, a genetic algorithm is applied. The overall traffic delay in terms of vehicle-hours and variations in traffic speeds produced by HWZs quantify the influence on mobility. However, this method did not consider the effects on traffic flow.

In a hypothetical work zone along I-65 in Birmingham, Alabama, Saha et al. [20] studied the operational effects of two temporary traffic control systems: static late and early merge control and 3-to-1 lane-drop arrangements. The experimental design examined two TTC approaches for both long- and short-term lane closures in a 3-to-1 lane-drop configuration with a workspace length of 500 feet. To reduce delays in the work zone under the 3-to-1 lane-closure scenario, this analysis was done utilizing the VISSIM simulation platform. The late merge method slightly outperforms the early merge strategy when short-term work zones are considered during the morning peak, particularly when the volume-to-capacity ratio is still below 1. However, this approach did not consider traffic diversion during the 3-to-1 lane closures at the jobsite.

Osman et al. [21] investigated the variables that affect how serious injuries are in passenger-car accidents. To consider the discrete ordinal nature of injury severity categories, a Mixed Generalized Ordered Response Probit (MGORP) modeling framework was developed. The effects of the following variables were found to vary significantly between the various work-zone configurations: access-control, number of lanes, roadway functional class, condition of the surface, speed limit, component area of the work zone, presence of workers, time of day, number of involved vehicles, and truck involvement. However, the duration of the work zone and the specific speed limit were not considered by this strategy.

Weng et al. [22] created a time-varying mixed logit model for vehicle-merging behavior in work-zone merging zones during the merging implementation phase. From a safety perspective, factors influencing vehicle-merging decisions include the likelihood and severity of vehicle accidents involving the merging vehicle and its surrounding cars. The model's findings show that compared to past models that relied on vehicle speeds and gap widths, incorporating the likelihood and severity of vehicle accidents may improve forecast accuracy. A number of factors were shown to have time-varying effects on merging behavior, including lead vehicle type, through lead vehicle type, through lag vehicle type, merging vehicle accident likelihood vs. through lag vehicle, and merging vehicle collision severity vs. through lead and lag vehicles. However, this strategy did not account for how drivers' merging behavior in work-zone merging zones was affected by elements linked to work-zone configuration, such as the number of restricted lanes, the severity of the work, and the speed restriction.

Zijin et al. [23] used field data from Florida to develop a micro simulation network of highway work-zone intervals. The simulation model is used to investigate the safety impact of work-zone truck egress speed, and the results demonstrate the significance of giving trucks an adequate acceleration space when exiting. After that, the truck egress system (TES) is created, which aims to give trucks enough room to merge into as they leave the work zone. Then, using different TES parameter values and traffic volumes, the truck egress procedure is simulated. The results show that the TES is characterized by improved safety, and the ideal settings are then suggested for various traffic volume scenarios while taking both efficiency and safety into consideration. Efficiency was considered in this investigation as well, and the results of the delay time showed that the TES performed admirably in this area. However, this approach needs to improve the safety of vehicle egress from the work zone.

Steinbakk et al. [24] investigated the impact of apparent roadwork activities on work-zone speed preferences using a video-based experimental approach. Four videos were utilized, all of which were taken from genuine work zones in Norway. With and without obvious roadwork activity, two roadwork zones were filmed at two different times. A total of 815 drivers viewed two movies and completed an online survey. Participants selected their preferred pace for both films before assessing the impact of 17 common

work-zone characteristics on their speed choice. The videos with evident roadwork activities had lower desired speeds, according to the data. Drivers considered speed regulation, transient motives, flow pressure, and situational factors when determining their speed. These findings support the hypothesis that visible roadwork activity is a significant influence in lower work-zone speed preferences. However, this finding-method only uses two work zones to predict the roadwork activity.

In a complex traffic flow expressway work zone, Wu et al. [25] simulated and evaluated CAV-based speed and LC control approaches. The model predictive control-based multi-layer control structure optimizes the control strategies used by CAV. Cellular automata are used in this expected distance-based symmetric two-lane cellular automated (ED-STCA) LC model and CAV car-following model to produce a heterogeneous traffic flow comprised of CAVs and human-driven cars. The six control strategies include testing LC, variable speed limits (VSL), and their coordinated control methods. Under the six control strategies, the impacts of vehicle arrival rate and CAV mixed ratio on traffic performance are examined using flow, density, and speed diagrams. Each combination of vehicle arrival rates and CAV mixed ratios is investigated, and the advantages and disadvantages of various solutions are compared. However, this method requires more computation time.

Renata et al. [26] explored if work zones are a form of environment that might cause the development of particular personality characteristics, resulting in considerable disparities in speed preferences across individuals. Another goal was to see if the predicted association between personality qualities and work-zone speed was influenced by the presence of visible roadwork. The UPPS impulsivity scale was extended to include subscales measuring perseverance, premeditation, negative urgency, and sensation seeking, as well as normlessness and altruism. The findings also show the impact of contextual influences in speed choices. It was also found to interact with different personality traits to have varying effects on preferred speeds. It was found to play a larger role than other factors in predicting lower speed preferences in work zones. The results of this methodology, however, suggest that additional research is required to scrutinize other factors that may explain the variation in speeds as well as practical ways to lower this variation in work zones for various types of drivers. Various methods providing better delay reduction of the traffic environment, such as the MGORP and VISSIM tools, have been developed by researchers; these are reviewed, together with a discussion of their advantages and disadvantages, in Table 2.

As seen in Table 2, the VISSIM model reduces delays in the work zone under the 3-to-1 lane-closure scenario, while MGORP observes the effects of factors like speed limit, and number of lanes across the different work-zone configurations. However, these methods do not consider traffic diversion during the 3-to-1 lane closures at the worksite, as well as do not account for work-zone duration and specific work-zone speed limit. Therefore, more research should be conducted to enhance the system's speed reduction.

c. Impact on queue length in traffic environment due to CWZ

Using a full range of performance variables, Edara et al. [27] examined the effectiveness of the variable advisory speed limit (VASL) method. Four congested work zones with lane reductions from four to three on Interstate 270 in St. Louis were selected for empirical and simulation examination. This improved VASL algorithm significantly reduced queue length, enhancing compliance with overall safety regulations in congested areas. A VASL system can therefore be created to improve traffic and safety in busy work zones. However, this approach did not analyze how reduced speed limits and shorter lines would affect travel times.

In New Jersey, Du et al. [28] built a hybrid machine-learning model using data from the work zone, the road geometry, the volume of traffic, and probing car data to anticipate users' delays on highway segments upstream of a work zone. The developed ANN model was used as an input to forecast spatiotemporal speeds in work zones. SVM was used to assess the reduced capacity caused by lane closure. The research also found that the residual backlog must wait longer to be cleared when the 5-h work zone ends close to or during peak hours, adding to the delay and cost. Nevertheless, the work zones were not concentrated using this strategy on arterials with signalized intersections.

Abdelmohsen et al. [29] presented the creation of a novel multi-objective optimization model for discovering and identifying a set of Pareto-optimal work-zone layouts that provide a wide range of optimal trade-offs between minimizing traffic delays and lowering the probability of crashes. The model is broken down into four stages: identify all pertinent decision variables for work-zone layout; formulate the

Table 2. Impact on overall delay in traffic environment due to CWZ

Reference No.	Method/Tool	Significance	Limitations
[19]	HWZ optimization model	Measures the effects of HWZs on worker safety, mobility, and costs	Does not consider the effects on traffic flow
[20]	VISSIM	Minimizes traffic delays in the construction zone in the case of a 3-to-1 lane closure	During the 3-to-1 lane restrictions at the project, traffic diversion are not considered
[21]	MGORP	Serves as a tool using which to observe the impact of variables like the speed limit and the number of lanes in various work-zone designs	Does not consider the work-zone duration and specific work-zone speed limit
[22]	Time-varying mixed logit model	Determines how a vehicle is behaving when entering a work zone	Does not account for the impact of work-zone configuration
[23]	TES	Ascertains the safety-enhanced method for various traffic volume scenarios	Needs to enhance the work-zone truck egress safety
[24]	Video-based experimental design	Investigates the impact of apparent roadwork activities on work-zone speed	Uses only two work zones to predict the roadwork activity
[25]	ED-STCA LC model	Estimates the traffic performance of the work zone	Requires more computation time
[26]	Online video-based experiment	Investigates if the presence of obvious roadwork activity affected the predicted link between personality characteristics and speed in work zones	More research is needed to investigate other variables

CWZ, construction work zone; ED-STCA, expected distance-based symmetric two-lane cellular automated; HWZ, highway work zone; LC, lane-changing; MGORP, Mixed Generalized Ordered Response Probit; TES, truck egress system.

optimization objective functions in the model; define all pertinent and practical constraints that affect the optimization problem; and compute model optimization using multi-objective genetic algorithms. However, this approach did not consider how the cost of the work zone would be affected by this optimization challenge.

The best average halted time, queue length, and vehicle throughput were achieved by Hua et al. [30].'s enhanced control systems for two-lane highway lane-closure construction zones. The flagger control, pre-timed control, actuated control, and pre-timed control were the four control systems that were employed. As important methods, a simulation model validated with field data and a mathematical delay model based on signalized junctions were proposed. The research results showed that two-lane construction zones on highways also utilized junction control techniques. In lane-closure work zones on two-lane highways, this research aims to increase operational effectiveness and work-zone control strategy. But for the flagger control scheme, this solution requires a more accurate mathematical delay model.

Algomaiah et al. [31] examined two late merging methods for work zones with and without allowing CV technology. The late merging without CV enabled is the first tactic. The second tactic uses a CV-enabled cooperative merging to improve work-zone efficiency by allowing open and closed lane vehicles to communicate with one another. A rule-based decentralized control algorithm is used by the CV-enabled method. Both late merging procedures were applied in micro simulation and the operational results were analyzed in this study. Throughput, latency, and queue length are the three main performance indicators utilized in

Table 3. Impact on queue length in traffic environment due to CWZ

Reference No.	Method/Tool	Significance	Limitations
[27]	VASL	Significantly reduces queue length, enhancing compliance with overall safety regulations in congested areas	The effects of lowered speed limits and shorter lines on travel time are not studied.
[28]	Hybrid machine-learning model	Has been used to anticipate traffic delays on certain highway portions upstream of a work zone in New Jersey	The work zones are not concentrated on arterials with signalized junctions.
[29]	Multi-objective optimization model	Finds and recognizes a collection of Pareto-optimal work-zone designs that offer a variety of optimal trade-offs between reducing traffic delays and the risk of accidents	Does not consider how this optimization would affect the cost of the work zone
[30]	VISSIM	Enhances the control systems for two-lane highway lane-closure work zones	The flagger control approach requires an improved mathematical delay model.
[31]	VISSIM	Serves as a tool using which to find a late merge system with and without CVs	Does not focus on the safety aspect of cooperative merging in work zones
[32]	LiDAR	Serves as a tool using which to identify problems encountered in queue length detection, as well as carry out improvement of detection accuracy	Needs to improve detection accuracy by reducing the number of assumptions
[33]	IM approach	Demonstrates excellent stability in response to parameter changes	Heavy vehicle percentage affects the performance of the IM

CV, connected vehicle; CWZ, construction work zone; VASL, variable advisory speed limit.

the evaluation. However, this method did not focus on the safety aspect of cooperative merging in work zones.

Duan et al. [33] proposed a signal-based merging technique to minimize traffic conflicts and boost throughput at bottlenecks. Traffic signals have been shown to significantly improve traffic in work-zone regions, although the current approach still has flaws that call for additional development. The efficiency of the IM approach was confirmed using a comparative examination of the existing merging algorithms and parameter sensitivity analysis based on the cellular automata simulation. The outcomes demonstrated that the IM technique could result in higher throughputs, less aggressive merging, shorter queues, and reduced traffic delays. Further lane-closure combinations should be extended for examination in future work, as this technique has only considered a 2-to-1 lane-closure configuration. Various methods, such as LiDAR model and the VASL algorithm, as well as VISSIM tools, have been developed by researchers for use in identification of the queue length, and these are reviewed in Table 3, together with a discussion of their advantages and disadvantages.

Table 3 shows that VASL algorithm significantly decreased queue length, improving compliance with overall safety regulations in congested areas, and VISSIM improved control systems for two-lane highway lane-closure work zones; additionally, LiDAR identified the problems in queue length detection and improved the detection accuracy. However, these methods did not focus on the effects of lowered speed limits and queue reduction on travel time; thus, these methods need to be improved. To improve the system's effectiveness, further research is needed.

d. Impact of noise/air quality levels in traffic environment due to CWZ

Han et al. [34] studied how urban morphology impacts environmental noise, such as regional environmental noise (RN) and TN. Both socio-economic and topographical landscape variables were considered while evaluating urban morphology features. The results of this study demonstrate strong relationships between urban morphology and RN/TN. In this work, landscape metrics were utilized to quantify the landscape at both the class and landscape levels. These metrics were obtained from high-resolution land-cover data, which included buildings, vegetation, and roads. Building configuration and composition have a big effect on RN. Buildings' irregular shapes and distributed distribution help to attenuate RN. This study's findings have the potential to be used in the reduction of urban environmental noise (UEN). However, this method did not investigate the time delay, queen length, and capacity of the traffic environment.

A noise reduction strategy was formulated by Lee et al. [35] and was based on the Panyu District of Guangzhou City's TN map, which considered both road and railroad-TN. Commercial software was utilized to create the noise maps with and without noise barriers based on the field traffic flow data. Noise compliance maps were made to assess the effects of noise barriers on the required level of the sound environment. Using noise barriers, the variation in populations exposed to unhealthful road noise was estimated. The population exposed to damaging TN significantly decreased as a result of the discovery that noise barriers dramatically improved the acoustic environment in residential areas. However, this method needs improvement to enable the estimation of new types of noises.

In Gwangju Metropolitan City, Republic of Korea, Park et al. [36] proposed a method for determining the noise levels caused by traffic during both day and night, as well as an assessment of the detrimental effects on people's health. To ascertain the geographic distribution of noise levels around the city and the noise level at the façade of a building floor, respectively, road-TN maps in 2D and 3D were created. Major roadways were found to have very high noise levels with little fluctuation during the day and at night. As a result, it was predicted that high levels of irritation and disturbed sleep affected 10% and 5% of the general population, respectively. However, this finding-method needs to improve the prediction of noise levels.

Giunta et al. [37] determined that the development and maintenance of a highway may affect air quality. The major goal is a thorough assessment of the influence on air quality during the two key stages of a road's life cycle. CO, NOx, and PM10 are the key pollutants whose intensities or volumes of emission are used to evaluate the effect on air quality. The results of this study can help stakeholders, road agencies, designers, controllers, and businesses create control strategies and mitigation measures that are site- and activity-specific during construction and operation in order to reduce emissions and improve road construction and operation from an environmental and social standpoint. However, this finding-method is related only to the motorway.

Ogren et al. [38] studied how various noise reduction methods might affect the noise exposure on a citywide basis. Using the standardized Nordic noise prediction approach, traffic flow data, and demographic figures, noise exposure was projected for the period between 2015 and 2035 under a number of alternative scenarios. The scenarios were based on lowering speed limits, congesting traffic, introducing more vehicles with electric motors, and installing low-noise pavements and tires. The most successful interventions were installing low-noise pavements or tires, which, when compared to business as usual, resulted in a 13%–29% decrease in the population exposed to levels over 55 dB equivalent. However, this finding-method did not estimate the noise level.

Amin et al. [39] discovered two results through geographical analyses of NO_2 levels and traffic density for four scenarios. First, the NO_2 levels in the immediate vicinity increased after construction of the A-25 expansion. The volume of traffic increased, which raised NO_2 levels. Second, the simulated traffic density for four scenarios shows that traffic density on surrounding arterials and access roads significantly increased both during and after construction of the A-25 extension project. These results substantiate environmentalists' worries about potential air pollution brought on by the increased traffic from the A-25 expansion project. However, more precise data are needed for this analysis to fully grasp how increased traffic may affect air quality.

Using three AI-based models (ANFIS, FFNN, and SVR) as well as the conventional MLR technique, Nourani et al. [40] investigated and estimated the TN level in Nicosia City. The research region's average TN level is 69.7 dBA, which is greater than the 65 dBA safe level. The health risks associated with TN can be reduced by using the proper pavement

texture while construction, which could be a more cost-effective approach. Four ensemble approaches were developed after the single black box models were developed. These approaches used the advantages of each individual model's strengths by using the single models' outputs as the input variables for the ensemble procedures, which helped the single models perform better. However, this method needs to improve the prediction accuracy of TN.

The fuel consumption and GHG emissions from on-road vehicles were evaluated by Kim et al. [41] under several CWZ scenarios for highway maintenance and repair. While developing the scenario factorials, factors such as traffic volumes, vehicle types, drive cycles, highway classes, and work-zone traffic operation techniques were considered. The fuel consumption and GHG emissions environmental impact indicators were evaluated using the Motor Vehicle Emission Simulator (MOVES). Under the freeway scenarios, compared to the free flow situation without a CWZ, fuel consumption and GHG emissions rose by 85% and 86%, respectively, in the very congested CWZ condition. However, this method needs to reduce the simulation cost. Various methods, such as standardized Nordic noise prediction approach, ANFIS, FFNN, SVR, and MLR, as well as different tools such as TransCAD, have been developed by researchers to ensure the availability of better air pollution attenuation and noise reduction mechanisms for deployment in the traffic environment; these various methods are reviewed in Table 4, together with a discussion of their advantages and disadvantages.

As stated in Table 4, the population exposed to noise levels over 55 dB equivalent has decreased by 13%–29%. ANFIS, FFNN, SVR, and MLR estimate the TN level using three AI-based models, and

Table 4. Effects of noise and air quality on the traffic environment in a work zone

Reference No.	Method/Tool	Significance	Limitations
[34]	Investigation of the urban morphology features	Ascertains how urban morphology affects the environmental noise such as TN	Does not investigate the time delay, queen length, and capacity of the traffic environment
[35]	FRAGSTATS	Investigates the influences of UEN in the Shenzhen Metropolitan Region of China	Needs improvement to estimate new types of noises
[36]	Highly annoyed (%HA) and highly sleep disturbed (%HSD)	Calculates the noise levels brought on by traffic during both day and night, as well as evaluates the negative effects on people's health	Needs to improve the prediction of noise levels
[37]	CALMET	Evaluates the air impact in highways	Pertains only to motorways
[38]	Standardized Nordic noise prediction approach	Discovers a 13%–29% decrease in the population exposed to levels over 55 dB equivalent	Does not estimate the noise level
[39]	TransCAD	Estimates air pollution due to increased traffic during and after the construction of the A-25 expansion project	More information is needed to fully understand how increased traffic may affect air quality
[40]	ANFIS, FFNN, SVR, and MLR	Estimates TN level in Nicosia City using three AI-based models	Needs to improve the prediction accuracy of TN
[41]	MOVES	Evaluates the fuel use and GHG emissions produced by on-road vehicles under various CWZ conditions	Needs to reduce the simulation cost

CWZ, construction work zone; GHG, greenhouse gas; MLR, multilinear regression; TN, traffic noise; UEN, urban environmental noise.

TransCAD estimates air pollution from the additional traffic during and after the construction of the A-25 extension project. However, these finding-methods need to improve the prediction accuracy of TN, and TransCAD needs more detailed data. Hence, further research needs to be undertaken to ascertain the optimal means that can be used for improvement of the air and noise quality.

e. Impact of traffic congestion in traffic environment due to CWZ

An analytical model was developed by Du et al. [42] to determine the ideal length of a work zone on a multi-lane highway while accounting for time-varying traffic volume and road capacity impacted by light condition, heavy vehicle percentage, and lane width. This finding can be used to assess the effects of work zones such as delays and costs and help engineers and planners create a highway maintenance strategy that is both efficient and affordable. A case study for a HWZ in New Jersey was conducted to determine one such optimum strategy for highway maintenance. A set of guidelines for using the road shoulder is devised. However, this method needs to consider the maintenance cost.

Shuming et al. [43] developed a fault-tolerant VSL control system for freeway work zones using the likelihood estimation approach. For the VSL controller operating in health mode, the Kalman filter utilizing augmented traffic states may offer precise estimation of the traffic density and ramp flow. Meanwhile, the observers can create analytical redundancy for traffic status estimation close to a work zone. The likelihood estimate based technique successfully detects and diagnoses the stationary sensor failures online, utilizing real-time traffic data without the need for past traffic datasets by making use of the analytical redundancy. The fault diagnosis can modify the VSL controller to maintain system performance using the sensor fault detection and identification. However, this method only considers the stationary sensor faults and ignores the concurrent faults and probe sensor faults.

Song et al. [44] analyzed spatiotemporal patterns of traffic congestion using data from several sources to determine the most important causes. For intraregional and interregional routes on weekdays, this data identified six groups, including the busiest times: the morning and evening peaks. The most crucial indication during the morning peak on both intraregional and interregional roadways was building height, which indicates a significant concentration of jobs. During the late-afternoon peak, the links between the commercial district, the work district, and the water body area on intraregional routes significantly increased their impact on traffic congestion, and this method can be utilized to locate traffic congestion hotspots. However, this method needs a combined strategy to reduce the traffic congestion.

Afrin et al. [45] described and contrasted presently accessible congestion and pollution trends vis-à-vis those available from a daily and weekly traffic historical dataset. The findings revealed that although reflecting a similar trend in congestion, each indicator revealed significant variations in congestion levels. A conclusion drawn from the data analysis is the benefits and drawbacks of each measure. There are also seven other categories into which the currently available traffic congestion metrics are divided: speed, travel time, delay, level of services (LoS), congestion indices, federal approaches, and a brief description of the strategies employed in various nations. The present road-traffic congestion measures offer a helpful insight into the means to create a traffic management system that is robust and sustainable. However, this method needs more depth analysis concerning congestion prediction.

A priority-based timetable in work zones was provided during the planning phase by Zhang et al. [46] using a mathematical decision model and a solution method. This model was created to estimate how network interruptions brought on by construction zones will affect and delay traffic in a mutually exclusive way. One of the construction strategies that interests stakeholders is the discussion of day and night building modes, sequencing precedence, and the seasonal changeable influence of demand. By monitoring network-wide traffic delay using a κ-shortest path algorithm, the method analyses drivers' behavior in terms of alternative route selection. However, this method did not investigate the working complexity.

Rista et al. [47] analyzed the effects of several temporary traffic management techniques such as lane closures, shoulder closures, and lane changes on highways' safety. Data were gathered for the times during which these treatments were in use as well as for comparable non-construction times from the previous year. Estimating safety performance functions included consideration of segment length, duration, traffic volume, and closure type. Random parameter count data models were estimated to ensure that unobserved variability and segment-specific temporal

Table 5. Impact on traffic congestion in traffic environment due to CWZ

Reference No.	Method/Tool	Significance	Limitations
[42]	Analytical model	Optimizes the work zone to increase the road capacity	Needs to consider the maintenance cost
[43]	Fault-tolerant VSL control system	Detects and diagnoses the stationary sensor failures online utilizing real-time traffic data	Only considers the stationary sensor faults and ignores the concurrent faults and probe sensor faults
[44]	Multi-source data fusion and data analytical tool	Ascertains the factors having a maximum impact in terms of influencing traffic congestion	Needs a combined strategy for reducing the traffic congestion
[45]	Investigation of the significant variations in congestion levels	Offers helpful insights into the means of creating a traffic management system	Needs more depth analysis for congestion prediction
[46]	Mathematical decision model	Measures the network's work-zone disturbances' mutually interacting impact on traffic and delay	Does not investigate the working complexity
[47]	Investigation of the effects of several temporary traffic management techniques	Estimates the impacts of changes in traffic volumes, work-zone length, and construction period duration	Needs additional research for arriving at a better understanding concerning the specific factors applying to work-zone safety

CWZ, construction work zone; VSL, variable speed limits.

correlation were considered. The number of collisions was discovered to vary almost directly with traffic volumes. The results indicate that crash rates rise more quickly in work zones with shorter lengths or durations because segment length and project duration, in contrast, showed inelastic effects. However, this method needs additional research to arrive at a better understanding of the specific factors underlying the enhancement of work-zone safety. Various methods, such as multi-source data fusion and data analytical tool, have been developed by researchers to ensure an enhanced efficiency with regard to the task of detection and identification of traffic congestion; various such methods are reviewed in Table 5, together with a discussion concerning their advantages and disadvantages.

Table 5 shows that, although the most significant elements influencing traffic congestion were identified using multi-source data fusion and data analytical tools, this method requires a joint approach to alleviate traffic congestion. Moreover, the significant variations in congestion levels offer a helpful insight into the means of creating a traffic management system, but this method needs more depth analysis for congestion prediction. Therefore, further research should be done to lessen the system's traffic congestion.

III. Comparison of Various Impacts in Traffic Environment Due to the CWZ

This section compares the various impacts in traffic environment due to the CWZ with machine-learning techniques with regards to a better air quality, noise prediction, travel time, and delay.

Figure 3 depicts a comparison of the travel time of the work zone. It shows that, pursuant to the use of V2V and V2I technologies for mobility performance, the estimated capacity travel time increased by 60% in comparison with the traffic volume. During the traffic flow, where the proposed technique to increase the travel time capacity of 90% was employed, a high traffic volume was obtained pursuant to use of the SUMO and DFROUTER techniques. Nevertheless, this method needs to be used to enhance the traffic control system.

Figure 4 shows a comparison between the delays involved under different techniques. The vehicles' delays on the road network, caused by various factors including ongoing road development works, cost in terms of money and time. Where the ED-STCA model to be reduce the cost of the work zone is 23.9% and more the TES method to increase the cost of the

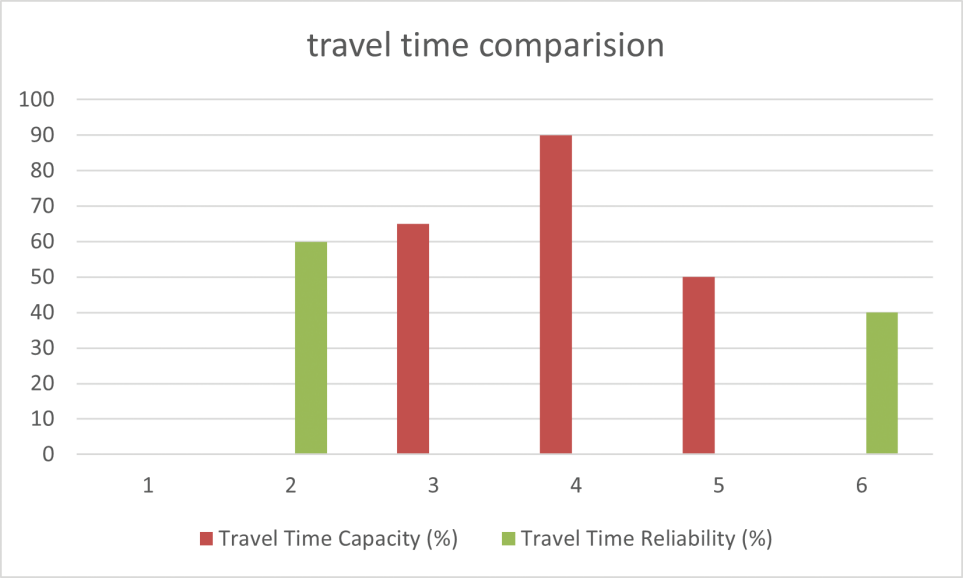


Figure 3. Comparison of travel time.

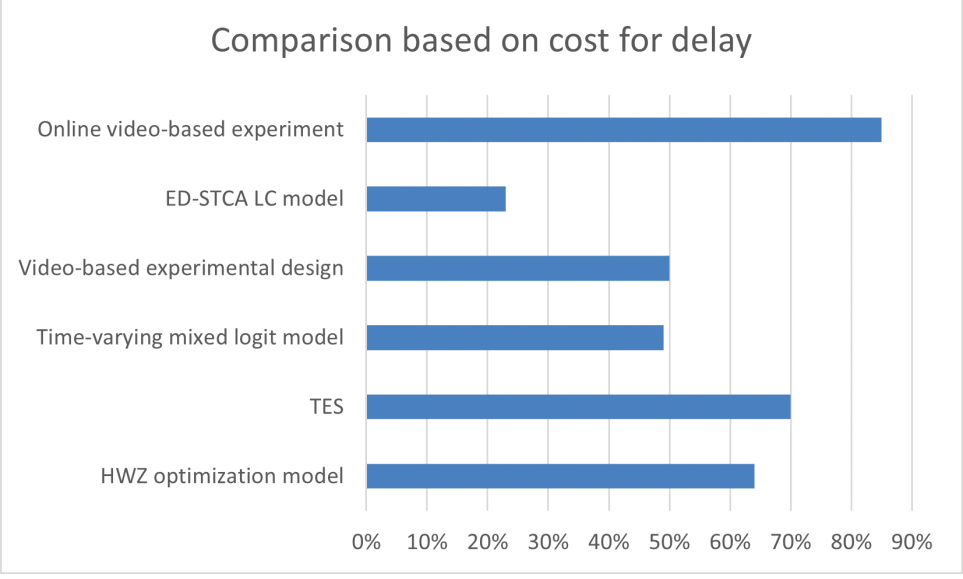


Figure 4. Comparison of delay.

work zone is 70%. So that the proposed model to prevent cost of construction area which to reduce the delay of traffic flow.

Figure 5 shows a comparison of the noise/air quality in the CWZ. The most successful method of reducing adverse noise/air in the construction area is FRAGASTATS. The highly annoyed and highly sleep disturbed, corresponding to noise and air pollution, are 18% and 24%, respectively. For standardized Nordic noise prediction approach, the values of noise and air pollution are 15% and 20%, respectively. Hence the FRAGASTATS is a method to achieve the reduction, which is reduce the noise/air on work zone.

Hence, the report states the different challenges that occur when using the Urban traffic environment on CWZ. The increase in traffic flow makes this task highly challenging.

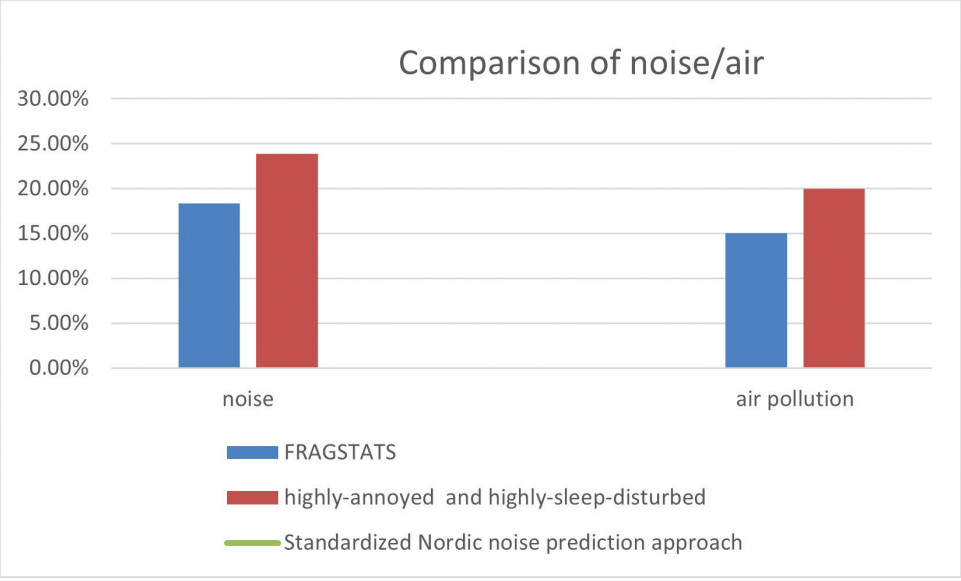


Figure 5. Comparison of air/noise.

IV. Discussion

Traffic congestion and delays are said to be mostly caused by road construction and the ensuing work zones. A smaller number of traffic lanes, narrower lanes, and work-zone speed limits all impair the capacity of the roadway. Traffic engineers can more accurately estimate the features of the traffic flow by making an accurate projection of the construction work-zone capacity. To this purpose, different approaches have been developed to quantify the impacts of work zones on traffic flow. By developing transportation management plans (TMPs) for road projects and actively monitoring and managing work-zone impacts during the project's execution, work-zone impacts during construction can be better managed. The revised Work Zone Safety and Mobility Regulation (the Rule) incorporates specific provisions that call for TMP creation and implementation as well as the management of work-zone impacts during project implementation in recognition of these factors. This is a quick discussion of these clauses. Video graphic surveys were conducted, and macroscopic characteristics were evaluated for both study sections (with and without CWZ). The results showed that at given flow levels, the stream speeds dropped from 70 kph to 50 kph, followed by a drop in efficiency in terms of per-lane capacity. Traffic moving away from a work zone experiences an average increase in travel time of 78.5%, a decrease in speed of 61.75%, and an increase in traffic concentration of 40%. Traffic moving toward a work zone experiences an average decrease in travel time of 138%, a speed increase of 150%, and a reduction in congestion of 55%.

V. Result and Summary

Various investigations aimed at improving the traffic issues arising due to the CWZ were reviewed, and their results are presented in this section.

To improve the forecasting of the journey time through the construction zone, HCM6 TTD and statistical methods were applied. However, this method suffers from low accuracy in the prediction of the distribution of travel times, and moreover the predicted results are not statistically significant. Additionally, TIMS determines the impact of road construction projects on the freeway and connecting arterial street link-level travel times, but it does not provide information on the volume of construction activity or the actual times when it happened. The upstream and downstream links on a number of lanes serve as the foundation for the validation of the trip time. This model predicts a bigger influence of travel time for upstream and a smaller effect for downstream, and it appropriately calculates the travel time throughout the construction project on the connecting arterial street linkages.

VISSIM tool and LiDAR based methods were used to detect the problems in the queue length and also improve the detection accuracy. However, this method still needs to improve the detection accuracy, and

at the same time, it must reduce the number of assumptions. Additionally, a hybrid machine-learning model predicts users' delays on highway segments upstream of a work zone, although this technique requires a more accurate mathematical delay model for the flagger control mechanism. The results also suggest that the proposed hybrid machine-learning model with SVM outperforms the others for all three real-world study cases with greater prediction accuracy, especially when work zones are placed in daytime, facing high traffic volumes.

ED-STCA LC model estimates the traffic delay performance of the work zone but this method requires more computation time. Moreover, MGORP and VISSIM tool provide better delay reduction of the traffic environment. These solutions, however, did not account for the worksite's 3-to-1 lane closures, the length of the work zone, or the specific work-zone speed limit. The results provide information about the impact of each control strategy on density, speed, travel time, etc. They also help determine what time of day is best for lane closings in order to reduce adverse impacts from capacity reduction.

Standardized Nordic noise prediction approach has discovered a 13%–29% decrease in the population exposed to levels over 55 dB equivalent but this method did not estimate the noise level. ANFIS, FFNN, SVR, and MLR models provide better air pollution attenuation and noise reduction mechanisms with regard to the traffic environment but lack an accurate estimation of the noise level due to the requirement of additional data; further, these methods are characterized by a need to improve the prediction accuracy of TN. The most dominant parameters in order of their importance were determined to be number of cars, number of van/pickups, number of trucks, average speed, and number of buses. Classifying the number of vehicles into five categories before feeding the traffic data into the AI models was observed to improve the performance of the single models by up to 29% in the verification phase. Out of the four ensemble models developed, the nonlinear ANFIS ensemble was found to be the most robust, since, in the verification stage, it has resulted in an improvement of the performances of ANFIS, FFNN, SVR, and MLR models by 11%, 19%, 21%, and 31%, respectively.

Mathematical decision model, fault-tolerant VSL control system, and analytical model provide better efficiency in the detection and identification of the traffic congestion. However, these methods only consider the stationary sensor faults and ignore the concurrent faults and probe sensor faults, implying a low detection accuracy; resultantly, the necessity arises for conducting more in-depth data analyses by considering various locations (or road segments), different traffic conditions, and the complexity of the road structures. Overall, this study determines current challenges in traffic congestion measurement approaches and provides a new insight into various means that can be employed for development of a sustainable and resilient traffic management system in the long run.

VI. Conclusion

A proposed methodology for determining the work-zone capacity, and for estimating the extent to which the location within or in the proximity of a work zone affects the environment in terms of causing noise and air pollution, as well as the implications of these in terms of cost in work zones, is developed, together with an assessment of the impact on air quality within the construction zone. The research reported in this paper attempts to understand the effect that deploying CV technology has on traffic environment in a network with work zones, which involves an analysis of the impacts of travel time, queue length, overall delay, and noise and air quality levels as well as traffic congestion due to CWZs. The impact caused by work zones in terms of noise and air pollution within an urban traffic environment is reviewed using various analytical and machine-learning techniques such as ANFIS, FFNN, SVR, and MLR and different tools such as TransCAD. Then, a stochastic user equilibrium (SUE) model simulates the traffic flow on each road segment of the network with a logit model. The SUE is computed in TransCAD using the method of successive averages (MSA). Corresponding to the use of AE, in the verification stage, the performances of ANFIS, FFNN, SVR, and MLR single models were improved by 11%, 19%, 21%, and 31%, respectively, and accordingly, AE can be opined to be the most robust technique. The efficiency of the linear ensemble techniques outperformed that of the single models except for the ANFIS model, which was the best among the single models since linear average always provides a result lower than that of the maximum value in the set. As seen in this study, the performance of the linear ensembles is less than that of the ANFIS model, which is due to lower performance of the MLR model. In future studies, to ensure the availability of higher efficiency concerning the prediction of TN, only nonlinear ensembles should be used.

VII. Future Perspective

There is always a need to decrease travel time, queue length, noise, air impact, and delay, as well as raise the detection performance of the system, although many different finding-approaches have been utilized to improve the satisfaction of traffic management needs attributable to CWZs. In the future, the following measures can be undertaken:

An efficient statistically significant predictive model must be created by extracting information about the different types of barriers, the precise nature of the work, the posted speed limits, and the lateral distance to the obstacle in the work zone, in order to reduce the impact of travel time and delay on CWZs.

Using static loop detectors at regular frequencies along with upstream of the work zone, to collect traffic data that is provided to an improved DL with an optimization model in order to estimate how far queues propagate and subsequently detect the selection of the appropriate route without delay can solve the problem in the detection and selection of queue length.

The need for detailed historical data to enable an analysis and estimation of the impact in terms of air quality and noise level in the traffic sector due to CWZ can be eliminated by using an intelligent forecasting model with a decision making approach that is adaptable to dynamic atmospheric variables; using the information derived from such a model as an input or aid in the formulation of proper, planned managerial actions, it would be possible to estimate as well as control the impact in terms of air quality and noise level.

Federated learning based control mechanism has to be used in managing the traffic congestion; federated learning eliminates the need for combined strategy and exhaustive analysis of traffic data, and thus reduces computational overhead and time consumption. Also, the control mechanism based on federated learning has to be adaptable with regard to the management of various faults in sensing devices, and thus identify and manage traffic congestion without faults.

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