CHAPTER-1: INTRODUCTION

1.1 : INTRODUCTION TO TRAFFIC MANAGEMENT SYSTEM

(**Source**: Urban Traffic Flow Prediction: A Review https://www.sciencedirect.com/science/article/pii/S235214651830283X](https://www.sciencedirect.com/science/article/pii/S235214651830283X)

Smart cities is a label that is associated with a significant paradigm shift of interest towards proposing and using various innovative technologies to make cities ”smarter” in order to improve the people’s quality of life. As a very important and highly visible initiative, the European Commission has launched the European Initiative on Smart Cities in 2010 [1] that addresses four dimensions of the city: buildings, heating and cooling systems, electricity and transport. Strictly related to transportation, the goal is to identify and support sustainable forms of transportation, to build intelligent public transportation systems based on real-time information, Traffic Management Systems (TMS) for congestion avoidance, safety and green applications (e.g. to reduce fuel consumption, gas emissions or energy consumption).

One major consequence of this increase is related to management problems that range from traffic congestion control to driving safety and environmental impact. Over recent years, researchers from both industry and academia were focusing their efforts on leveraging the advances in wireless sensing equipment and communication technologies, along with simulation and modeling tools to make the existing road TMS more efficient, enabling them to cope with the above issues in future smart cities. One of the most critical consequences of traffic congestion is the delay of emergency services, such as police, fire and rescue operations, medical services, etc. Indeed, very often individual human lives, general population safety and institutional economic or financial situation in case of incidents, robberies or criminal attacks highly depend on the efficiency and timely response of emergency vehicle services. Additionally, recent road traffic statistics reveal another extremely serious concern which is the increasing number of vehicle crashes.

These crashes usually happen in the areas around congested roads as the drivers tend to drive faster, before or after encountering congestions, to compensate for the experienced delay. The negative consequences of these accidents are many, at personal, group and societal levels, and could be exacerbated if emergency vehicles are involved in a crash. However, most large cities in the world are still suffering from traffic congestion, despite employing different solutions to reduce it, including using TMSs deploying advanced congestion control mechanisms. To best contribute to the ongoing efforts to solve the traffic congestion problem or at least reduce its impact, there is a need to understand the different types of congestion and their impact. Two major types of congestion can be distinguished: recurrent and nonrecurrent. Recurrent congestion usually occurs when many vehicles use the limited space of the road network simultaneously (e.g. weekday morning and afternoon peak hours). Non-recurrent congestion mainly results from random events such as traffic incidents (e.g. car crash or a stalled vehicle), work zones, bad weather conditions and some special events like sport events, Christmas, etc. According to recent statistics (http://www.transport2012.org), road traffic congestion costs billions to the world economy. For instance, losses have reached:

- 200e billions in Europe (2% of GDP)
- $101 billion in USA

Source: Deep Multi-View Spatial-Temporal Network for Traffic Prediction (https://arxiv.org/abs/1803.08902)

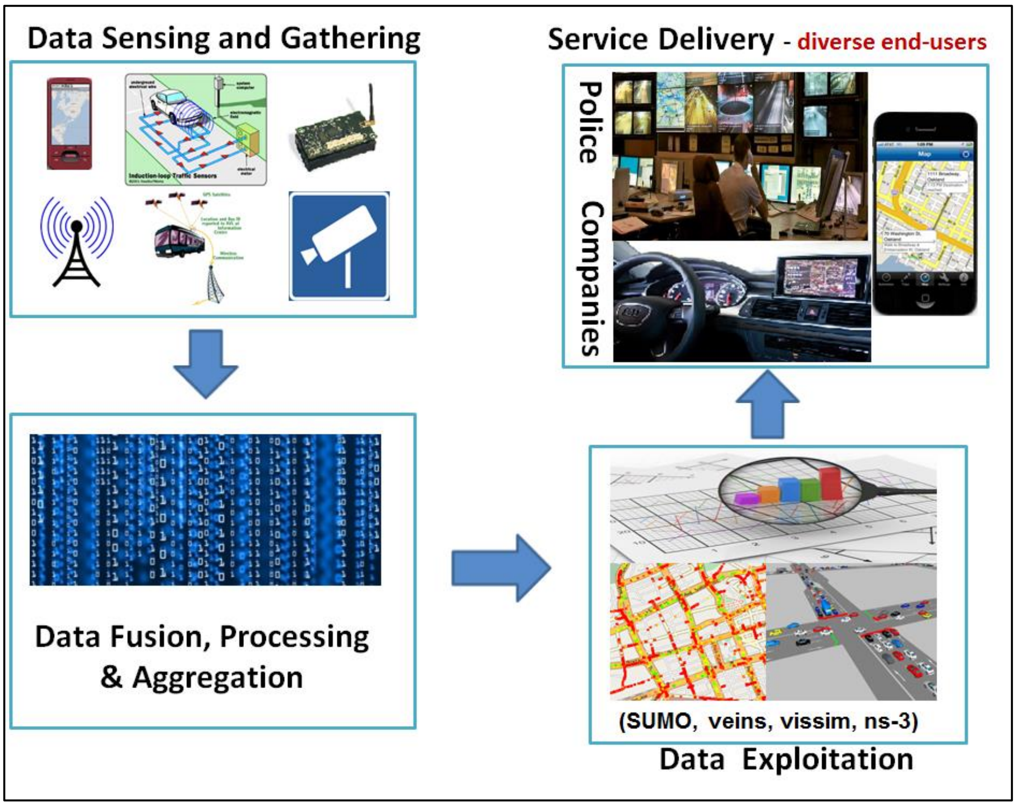


Figure 1: Data life cycle in smart transportation
(**Source**: Communications-oriented Perspective on Traffic Management Systems for Smart Cities)
https://ieeexplore.ieee.org/document/6857980

1.2: OVERVIEW TO TRAFFIC MANAGEMENT SYSTEM

(**Source**: Short-Term Traffic Flow Prediction Based on Patio-Temporal Correlation in Vehicular Ad Hoc Networks
https://ieeexplore.ieee.org/document/6681758)

A Traffic Management System (TMS) offers capabilities that can potentially be used to reduce road traffic congestion, improve response time to incidents, and ensure a better travel experience for commuters. A typical TMS consists of a set of complementary phases, as shown in Figure 1, each of which plays a specific role in ensuring efficient monitoring and control of the traffic flow in the city. The cornerstone phase of a TMS is Data Sensing and Gathering (DSG) in which heterogeneous road monitoring equipment measure traffic parameters (such as traffic volumes, speed, and road segments occupancy, etc.), and periodically report these readings to a central entity. For example, these monitoring tools can detect random incidents and immediately report them through wireless networks, cellular networks, or mobile sensing applications.

Subsequently, these data feeds are fused and aggregated during the Data Fusion, Processing and Aggregation (DFPA) phase to extract useful traffic information. The next phase, Data Exploitation (DE), uses this acquired knowledge from the processed data to compute: optimal routes for the vehicles, short term traffic forecasts, and various other road traffic statistics. Finally in the Service Delivery (SD) phase, the TMS delivers this knowledge to the end users (such as drivers, authorities, private companies, etc.) using a variety of devices such as smart phones, vehicles' on-board units, etc. The capabilities offered by a TMS are not confined to serve drivers and road authorities only, but can also contribute significantly to the economic growth of a country, to the preservation of citizens' safety and to the support of national security. The currently deployed technologies for road traffic surveillance still suffer from a lack of traffic parameters measurement

Moreover, the gathered traffic data usually needs to undergo a filtering process to improve its quality and eliminate the noise. Deploying highly sophisticated equipment to ensure accurate estimation of traffic flows and timely detection of emergency events may not be the ideal solution, due to the limitation in financial resources to support dense deployment and the maintenance of such equipment, in addition to their lack of flexibility. Therefore, alternative cost-effective and flexible solutions are needed to guarantee better management of road traffic in both developed and developing countries.

A modern TMS aims to overcome some of the above limitations by designing innovative approaches able to exploit advanced technologies to efficiently monitor the evolving critical road infrastructure. These approaches should be scalable enough to enable better control of the traffic flow and enhanced management of large cities' road networks. This will certainly improve the accuracy of the acquired real-time traffic information and the short-term traffic prediction. This will enable making and using short-term predictions based on current traffic volumes to identify bottlenecks and make more informed decisions about how to best reroute traffic, change lane priorities, modify traffic light sequences, etc.

A modern TMS should also provide a visual tool that can display in real-time traffic information related to location of bottlenecks, incidents, and congestion level in each road segment, as well as estimated travel time from one location to another in the road network. In this way, the transport authorities will have an overall view of the road network in real-time, and will enable the best support for improvements in the traffic flow management and more efficient reactions to emergency incidents on the roads.

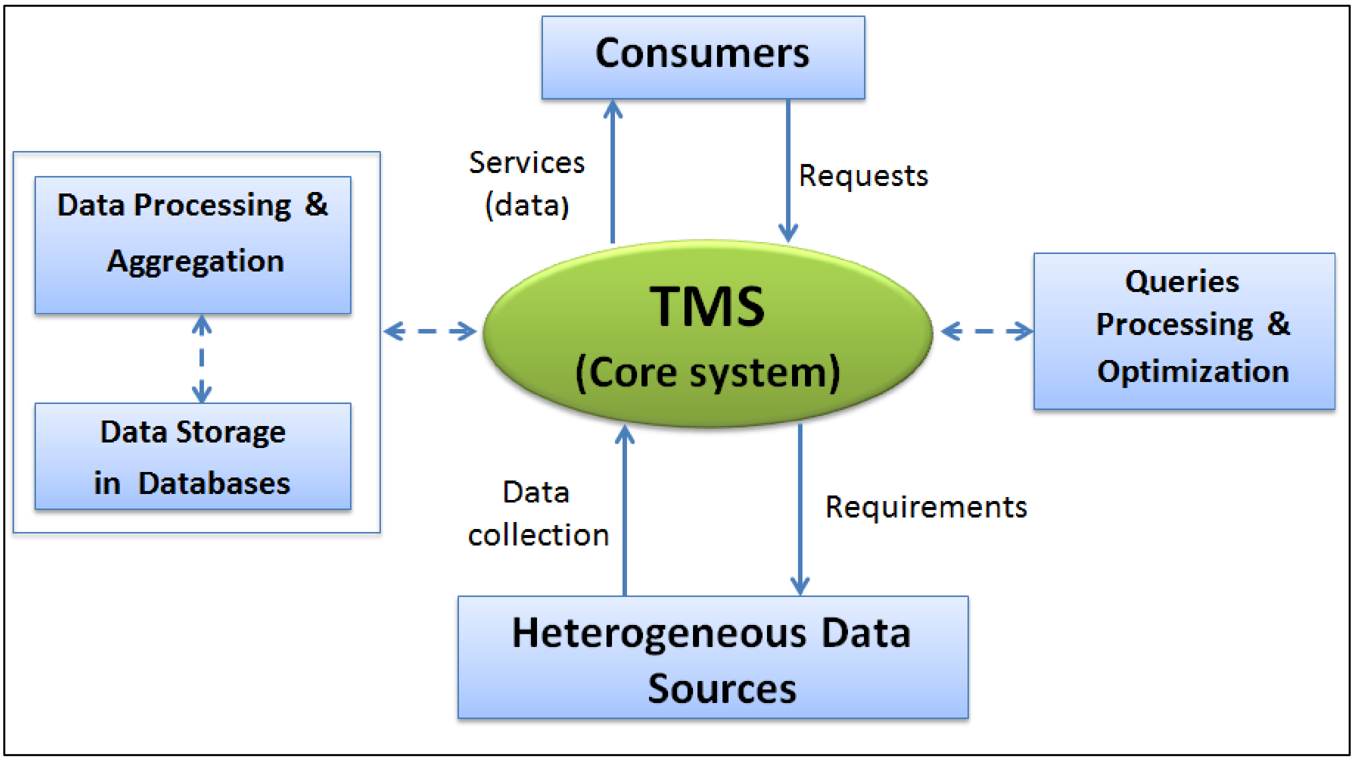


Figure 2: A simple architecture of a modern TMS
(Communications-oriented Perspective on Traffic Management Systems for Smart Cities)
https://ieeexplore.ieee.org/document/6857980

An adequate TMS for future smart cities should fulfill the following requirements: Ensure higher accuracy in estimating traffic conditions and better efficiency in dealing with emergency situations on the roads, compared to the existing TMSs. Be able to efficiently manage the traffic in road networks of varying size and characteristics. Provide real-time road traffic simulation and visualization to help authorities more efficiently manage the road infrastructure and improve route planning for commuters. Ensure simplified and smooth integration of existing systems and new technologies, and manage the evolution of these systems.

A high-level architectural overview of a modern TMS is depicted in Figure 2. This figure shows the main components of the TMS needed to deliver the collected road traffic information to the intended end consumers (e.g. road authorities, Police, drivers etc.). As we can see from this figure, the core system of the TMS collects road traffic information from heterogeneous data sources according to the consumer needs and specific requests. These data feeds are then aggregated and stored in a unified format in one or multiple databases. Later, upon reception of a consumer request, the core system processes the request and extracts the pertinent data from the appropriate database. Then the requested information is sent back to the intended consumer, tailored for their specific purposes: e.g. analysis and statistics, decision-making, etc.

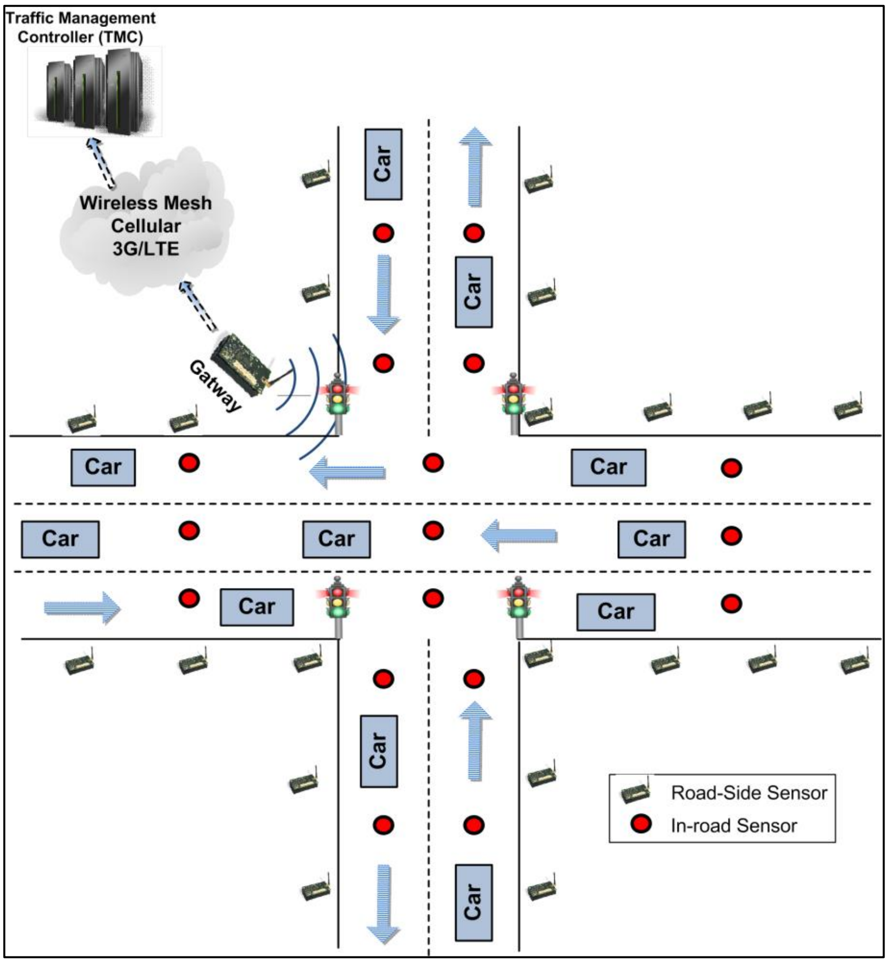


Figure 3: Scenario illustrating wireless technology deployment in road environment for data sensing and gathering (Communications-oriented Perspective on Traffic Management Systems for Smart Cities) https://ieeexplore.ieee.org/document/6857980

1.3: TRAFFIC DATA SENSING AND GATHERING

A. Wireless Sensor Networks (WSNs)

(**Source**: Traffic Flow Prediction with Big Data
https://ieeexplore.ieee.org/document/7797402](https://ieeexplore.ieee.org/document/7797402)

Due to their high efficiency and accuracy in sensing the different events, wireless sensors have been widely deployed in various environments for data collection and monitoring purposes. Indeed, it is foreseen that WSNs can enable several applications that may significantly improve the control of road traffic flow and ease its management, examples of these applications are the real-time control of traffic lights and their adaptation according to the congestion level , as well as parking spaces management. However, the deployment of wireless sensors in the road environment to realize these applications face several challenges, in addition to the well-known issues in WSNs, that require careful consideration and design of appropriate protocols. Among these challenges, we highlight the need of a fast and reliable MAC access protocol and data forwarding mechanisms to guarantee timely transmission of critical messages carrying information about the occurred emergency events on the road. An example of WSNs deployment for road traffic monitoring is shown in Figure 3.

It is also worth mentioning that the expected wide and dense deployment of wireless sensors on the roads necessitates the design of robust data aggregation techniques to deal with the high redundancy and correlation of the transmitted information, especially from neighboring sensors, as the redundant transmission of this information may lead to quick depletion of sensors battery, increase the delay of emergency messages, as well as the collision rate. To reduce traffic data redundancy, the optimal placement of wireless sensors on road networks should be investigated and a trade-off solution between the number of sensors deployed in a specific area, and road events detection and accuracy should be designed. The spatial and temporal correlation of traffic data are intrinsic characteristics of road networks, which can be leveraged to solve both sensor data aggregation and optimal sensors placement problems in future smart cities.

B. Machine to Machine (M2M) communication

A key technology that is a promising solution for reliable and fast traffic data monitoring and collection is Machine to Machine (M2M) communication. The M2M technology has recently attracted increasing attention from both academic and industrial researchers aiming to foster its application for data collection in various environments. Recent forecasts, indicate an outstanding market growth over the next few years for M2M devices usage and connectivity. According to these forecasts, billions of devices will be potentially able to benefit from the M2M technology. The report published by the Organization for Economic Co-operation and Development (OECD) in reveals that around 5 billion mobile wireless devices are currently connected to mobile wireless sensor networks, and foresees that this number will grow to reach 50 billion connected devices by the end of the decade. In M2M communication, a sensor gathers traffic data and sends it via wireless communication/cellular/3G/LTE networks towards one or multiple central servers for processing purposes. The ability of M2M devices to avoid the multi-hop transmission, as opposed to WSNs, makes the data transmission faster and more reliable, which represents a significant benefit for the sensors reporting delay critical events. Moreover, it is foreseeable that this technology will significantly enhance the accuracy of data collection and lead to more flexible deployment of sensors on the roads. M2M over LTE networks is expected to be a key aspect of future TMS. These M2M devices are equipped with access technology capable of communicating in a reliable, fast, and extremely efficient way with the central entity that processes and aggregates the collected data. Moreover, M2M solutions support different classes of QoS, thus they can efficiently collect prioritized data from multiple sources and ensure that appropriate QoS is applied to each stream. The M2M technology provides an extremely attractive solution for data collection in urban areas due to its management benefits in terms of reduced data reporting delay, high efficiency, and low complexity. However, deploying M2M devices as an alternative of WSNs technology will incur an additional cost related to the use of cellular/3G/LTE networks. Therefore, this may hinder the wide deployment of M2M technology by city traffic managers, especially for cities with limited financial resources, which is the case of the majority of cities in developing countries.

(**Source**: Traffic Flow Prediction With Big Data
https://ieeexplore.ieee.org/document/7797402](https://ieeexplore.ieee.org/document/7797402)

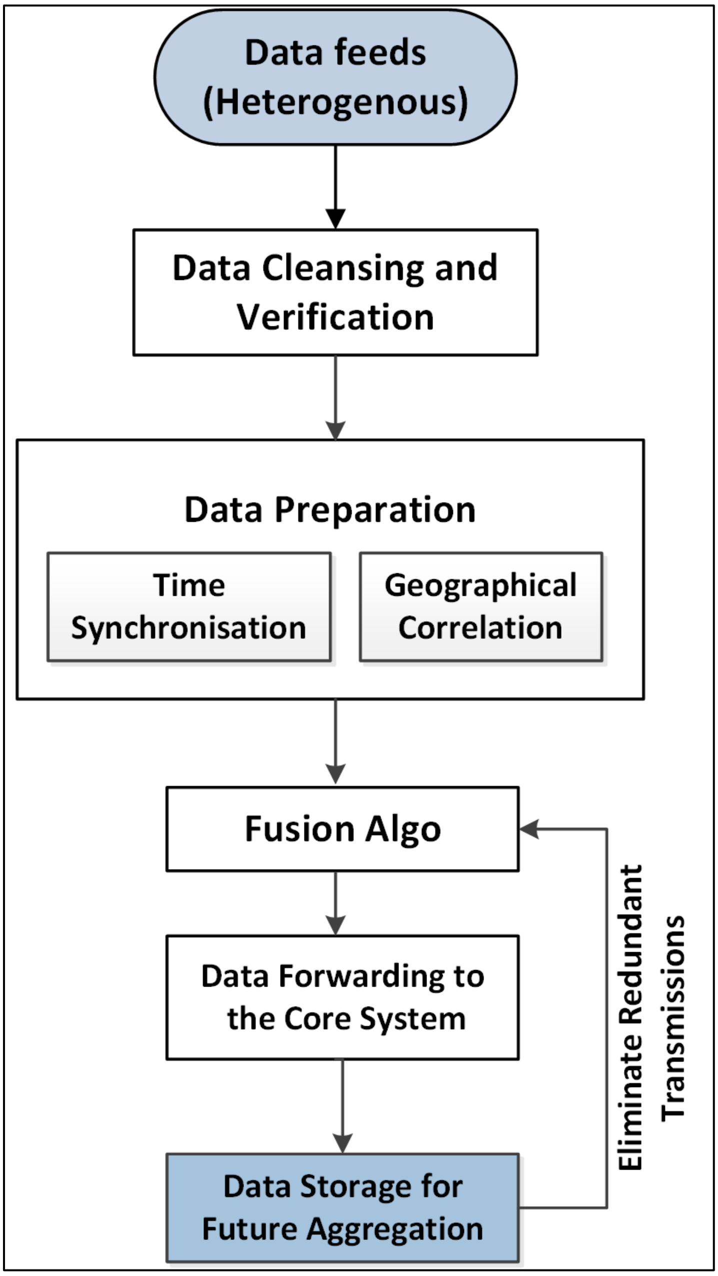


Figure 4: The different steps in DFPA phase

(**Source**: Communications-oriented Perspective on Traffic Management Systems for Smart Cities)
https://ieeexplore.ieee.org/document/6857980

C. Mobile sensing

(**Source**: Traffic Flow Prediction with Big Data

https://ieeexplore.ieee.org/document/7797402](https://ieeexplore.ieee.org/document/7797402)

In addition to the above data sources, mobile sensing using mobile devices is expected to enable fast detection of events on the roads and enhance the accuracy of traffic conditions monitoring. According to recent studies in and, mobile crowd-sensing systems have been recently used to provide more accurate real-time traffic information on large scale, using smart phones that enable services such as, accurate localization of vehicles, faster and more precise reporting of incidents and accurate travel time estimation for improving commuters travel experience. The key enabler of the widespread of mobile sensing applications, mainly for traffic monitoring purposes, is the voluntary participation of the users. These users demand high level of privacy, anonymity and security guarantees to participate to such a system. Indeed, these requirements constitute major concerns that need to be carefully addressed to instigate larger participation of mobile devices users to mobile sensing applications. These issues can be dealt with as discussed in the following to mitigate their impact on the TMS efficiency and accuracy of its decisions. Trust management of mobile sensing data sources: how to build a trust relationship with the mobile sensing data source? In this case, reputation systems, such as, need to be used to continually assess the level of trustworthiness of each mobile sensing data source. A mobile data source is deemed trustworthy if the information it has reported has been validated by either other mobile sources or a trusted data source such as road-side sensors, induction loops or CCTV cameras. Privacy preservation of mobile devices users: several levels of privacy could be defined in the context of smart cities, and users can adjust the setting of their devices to increase/decrease the privacy level according, for example, to traffic conditions (e.g. normal driving conditions, traffic jam, incident) and the service they need to request from the TMS (e.g. optimal/fastest route to their destination). Therefore, adaptive privacy protection techniques that manage the user's privacy preferences and adapt the privacy level to the contextual factors in smart cities are required. Design robust authentication techniques to prevent any misuse of the system such as identity spoofing and fake alerts, etc.

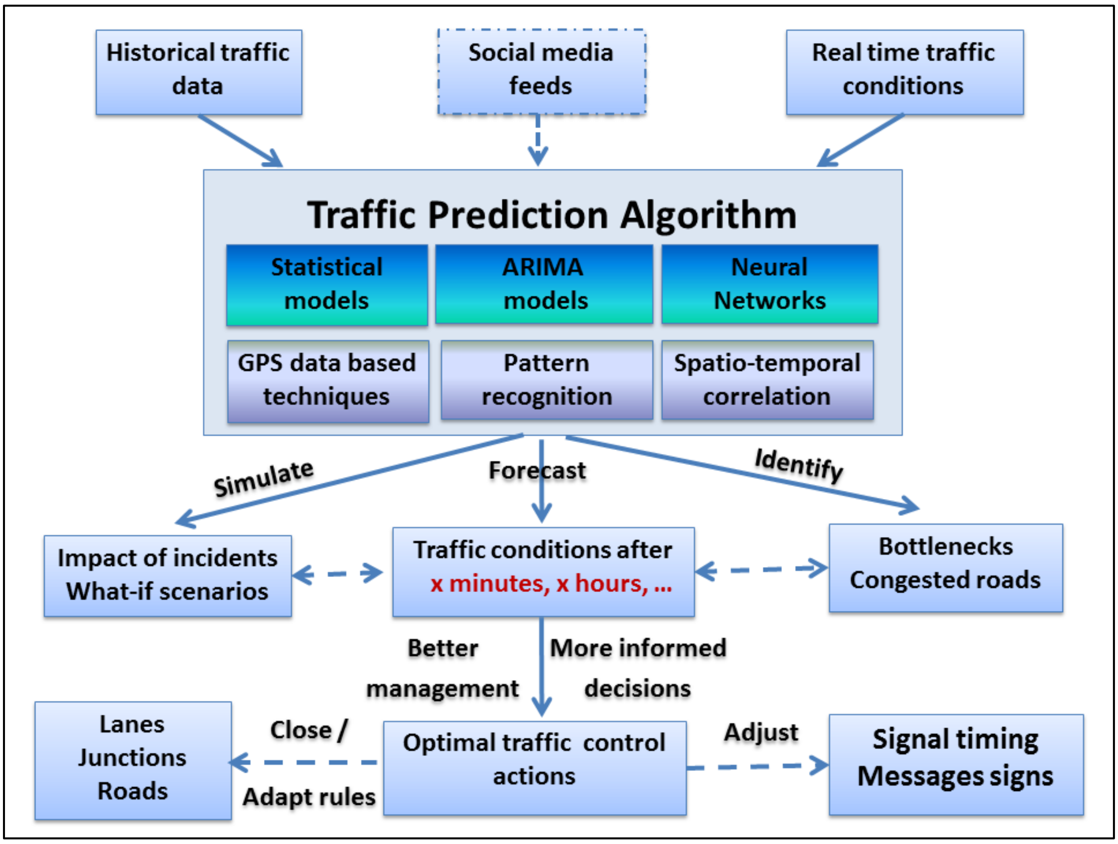


Figure 5: Overview of traffic prediction system and its impact on TMS efficiency
(Communications-oriented Perspective on Traffic Management Systems for Smart Cities)
https://ieeexplore.ieee.org/document/6857980

D. social media

(**Source**: Traffic Flow Prediction with Big Data

https://ieeexplore.ieee.org/document/7797402)

In the context of smart cities, social media feeds, such as Twitter and Facebook for instance, can play an important role in improving the accuracy and richness of the traffic information provided by the traditional monitoring equipment such as road sensors and induction loops. Even though these pieces of equipment can measure the vehicles' speed and road segments' occupancy to enable the estimation of traffic congestion level, they are unable to identify the root event that has led to this situation. has shown that relying on social media feeds, in addition to the traditional data sources, can significantly enrich the real-time perception of traffic conditions in the cities, and help to explain the reasons behind the variation of the congestion level. Indeed, revealing the real causes of the sudden increase of the congestion level (e.g. accident, road works, political or social protest etc.) will enable more appropriate reaction from the road authorities to alleviate the impact of this situation. Therefore, there is a need to deeply investigate this traffic data source to enhance citizens' quality of life and aid the traffic authorities for efficient management of the increasing number of cars.

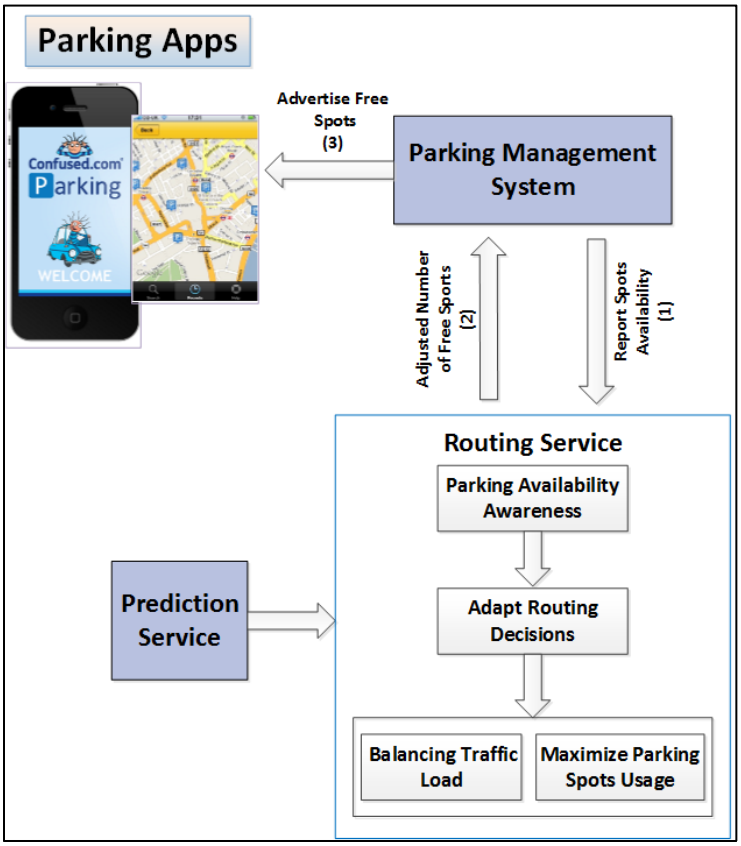


Figure 6: Illustration of Prediction, Routing and Parking services cooperation

(**Source**: Communications-oriented Perspective on Traffic Management Systems for Smart Cities)
https://ieeexplore.ieee.org/document/6857980

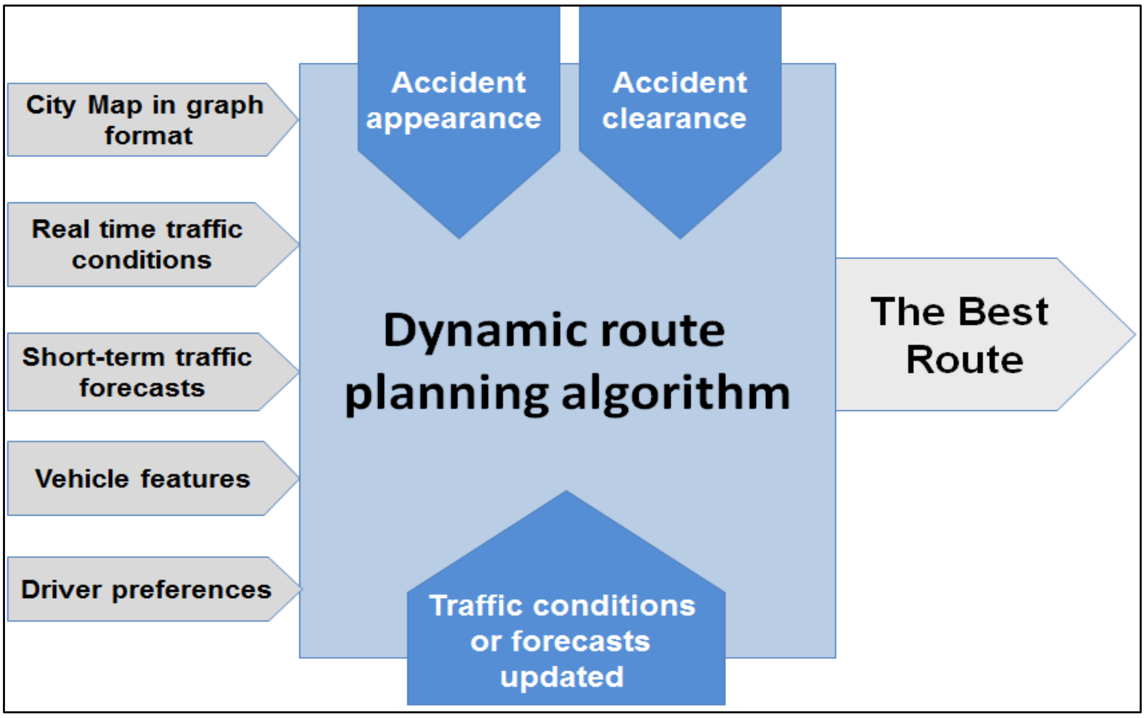
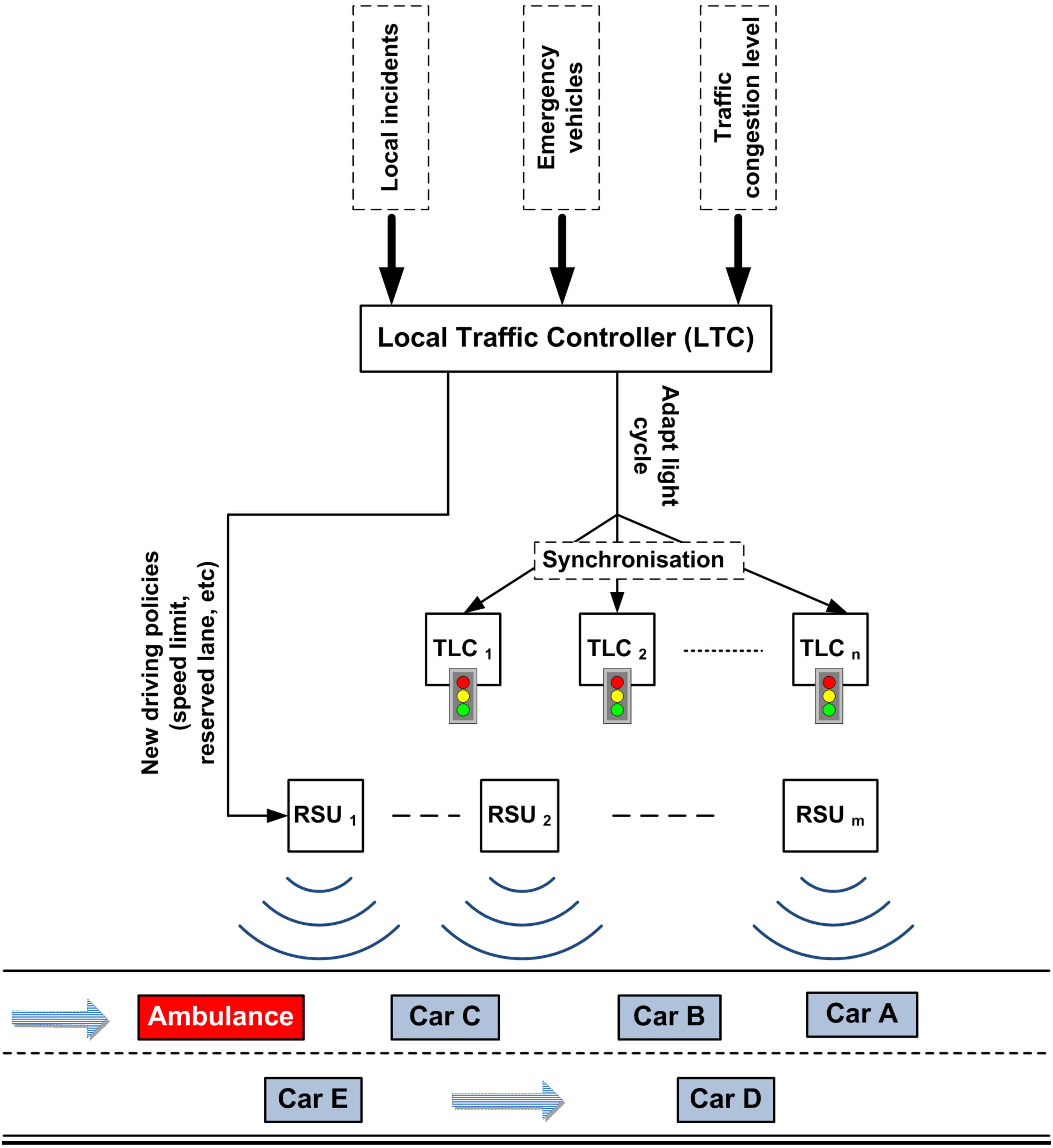


Figure 7: Route planning algorithms: main inputs and functioning
(**Source**: Communications-oriented Perspective on Traffic Management Systems for Smart Cities)
https://ieeexplore.ieee.org/document/6857980

Although several dynamic routing algorithms have been proposed such as many problems are still unresolved yet. A noteworthy problem in this context is how can we ensure better usage of the road infrastructure while maintaining a reasonable satisfaction of the drivers' preferences? Load balancing mechanisms based on centralized system architecture are more appropriate in this case, but guaranteeing their efficiency is another challenge, especially during the peak hours. We foresee, then, that managing efficiently the growing number of vehicles in smart cities necessitates a mix of centralized and distributed system architectures through leveraging vehicular communication and mobile sensing information during the decision-making process. For example, the vehicle can combine the alternative route received from the system with the acquired information from the vehicles ahead to take more information decision about the alternative route that it will follow. Moreover, the system can adapt the quality of the best route assigned to each vehicle according to the level of participation of the driver to mobile sensing process as well as the level of information disclosure. Consequently, this can help to achieve a balance of the traffic load and maintain adaptive satisfaction of the drivers.

Example of Adaptive TMS



(**Source**: Communications-oriented Perspective on Traffic Management Systems for Smart Cities)
https://ieeexplore.ieee.org/document/6857980

CHAPTER-2: LITERATURE REVIEW

Serial No.	Year	Author	Paper Title	Description
1	2006	Smith, J.	"A Comparative Analysis of Traffic Flow Prediction Models"	Investigates and compares various models used for predicting traffic flow, highlighting their strengths and weaknesses.
2	2013	Patel, A.	"Machine Learning Approaches for Traffic Forecasting"	Explores different machine learning techniques applied to traffic forecasting, emphasizing their practical applications.
3	2009	Wang, Q.	"Real-time Traffic Flow Prediction using Big Data"	Focuses on real-time predictions by leveraging big data analytics to improve the accuracy of traffic flow forecasting.
4	2017	Garcia, M.	"Enhancing Traffic Flow Predictions with IoT Sensors"	Discusses the integration of IoT sensors to enhance the precision of traffic flow predictions, with a focus on practical use.
5	2018	Kim, S.	"Deep Learning for Accurate Traffic Congestion Forecasting"	Explores the application of deep learning techniques for accurate prediction of traffic congestion, considering various factors.
6	2021	Chen, L.	"Data Analytics for Dynamic Traffic Management"	Examines the role of data analytics in dynamic traffic management, proposing strategies to optimize traffic flow in real-time.

CHAPTER-3: CASE STUDY

(Self Written)

Background:

In the bustling metropolis of Smart City, authorities were grappling with increasingly congested roadways, leading to longer commute times, heightened pollution levels, and decreased overall urban mobility. To address these challenges, the city embarked on a journey to implement an intelligent traffic management system using data analytics.

Objective:

The primary goal was to leverage data analytics to forecast traffic flow accurately, enabling the city to implement proactive measures for congestion management, optimize signal timings, and enhance overall transportation efficiency.

Approach:

- Data Collection: Various data sources were integrated, including traffic cameras, GPS devices, and in-car sensors, to collect real-time data on traffic patterns, vehicle speeds, and congestion levels.
- Data Processing and Analysis: Advanced analytics tools were employed to process the vast amount of collected data. Machine learning algorithms were used to identify patterns, correlations, and anomalies in traffic flow.
- Predictive Modeling: Predictive models were developed to forecast traffic conditions for different times of the day, days of the week, and specific events (e.g., concerts, sports games). These models considered historical traffic data, weather conditions, and special events.
- Dynamic Signal Control: The insights derived from the predictive models were used to dynamically adjust traffic signal timings. This proactive approach aimed to alleviate congestion before it reached critical levels.

Results:

- Reduced Congestion: The implementation of the data-driven traffic management system led to a noticeable reduction in traffic congestion during peak hours, improving overall traffic flow.
- Optimized Signal Timings: Dynamic adjustments to signal timings based on real-time predictions allowed for better synchronization and reduced waiting times at intersections.
- Improved Commute Times: Commuters experienced shorter travel times, contributing to increased satisfaction and productivity.
- Environmental Impact: By minimizing congestion and optimizing traffic flow, there was a positive impact on air quality because of reduced vehicle idling times.

Conclusion:

The Smart City traffic management case demonstrates the effectiveness of leveraging data analytics for forecasting traffic flow. The proactive and dynamic approach enabled by predictive modeling and real-time data analysis not only improved traffic conditions but also had positive ripple effects on the environment and overall quality of life for city residents.

CHAPTER-4: DISCUSSION

(Self Written)

Vehicular communication can play an essential role in improving the efficiency of both data collection and TMS reaction to some circumstances or emergency events. Smart vehicles are usually equipped with on board sensors that can detect both in-vehicle events as well as the surrounding traffic conditions. These inner events such as sudden deceleration and airbag trip the other hand, the received events from other vehicles or road sensors are processed and reported similarly to the inner ones. The gathered traffic data from smart vehicles are then analyzed and combined with other data feeds to speed up traffic congestion detection and improve the congestion levels evaluation accuracy. In this context, these data need to be quickly disseminated with high transmission reliability, especially if it reports safety critical events.

Thus, appropriate dissemination protocols are required. In what follows, we discuss a set of scenarios in which the interaction between the TMS and smart vehicles will significantly help to reduce traffic congestion and improve roads safety. In the first scenario, we propose to investigate the possibility of affecting/changing the cars behavior (e.g. speed, optimal route etc.) and the driving policies (e.g. maximum speed, minimum speed, reserved lanes etc.) rather than only closing some road segments as proposed in the legacy systems. In this case, the cars need fast and accurate coordination when they change lanes to temporarily use a lane which was reserved for buses or slow cars, to prevent crashes. To this end, a real-time dissemination of lane change notification is a must since lane change in this context may lead to collision if more than one car moves to the same lane simultaneously and without coordination.

Moreover, the road-side infrastructure may also make use of the information exchanged between the vehicles through the transmission of beacon messages. It will then combine the content of these beacons (i.e. vehicle speed, position, heading etc.) with the reported data from the road monitoring equipment, as shown in Figure 1, to speed up the congestion detection and improve its accuracy, and thus the TMSs can take early actions to control the traffic congestion. In the second scenario, we propose that the road-side infrastructure (e.g. traffic light controller at an intersection) communicates the remaining time for the current traffic light cycle (i.e. to switch from green to red and vice versa) to the approaching vehicles, to reduce their waiting time when they reach the intersection. In this case, the vehicles are informed about the optimal speed which allows them to cross the intersection without stopping.

To achieve this goal, the vehicles need to coordinate between each other to adjust their current speed according to the speed advised by the infrastructure. The purpose of the coordination between the vehicles is to avoid collision when they adapt their speed according to the information received from the traffic light controller. One of the most critical consequences of traffic congestion is the delay of emergency services, such as police intervention, fire, and rescue operations as well as medical services. This scenario aims to reduce the latency of emergency services delivery by dynamically adjusting traffic lights, changing related driving policies, recommending behaviour change to drivers, and applying essential security controls [28]. This will create green route for these vehicles and significantly reduce their response time, which may save human lives and reduce the induced damage/loss in case of fire or robbery. The TMS should be also able to control the behaviour of nonemergency vehicles to ensure minimum number (ideally zero) of crashes, minimum disruption to the regular traffic flow, and satisfaction of security requirements to prevent any misuse of the system. To make this scenario viable and valuable in real road environment, some specific actions should be taken by both TMS and smart vehicles in addition to some requirements which should be satisfied, sucking are immediately reported to the neighboring vehicles and the Road-Side Units (RSUs).

CHAPTER-5: CONCLUSION

Improving the efficiency of Traffic Management Systems (TMS) is still an active and challenging research area due to the criticality of transportation infrastructure being monitored by such systems. This survey has provided a comprehensive study of the different phases of a modern TMS, emphasizing the main challenges and shortcomings of the existing systems, and suggesting some directions to make the TMSs more efficient in future smart cities.

First, we have presented the different existing technologies used for traffic data gathering and highlighted the main new technologies that can significantly improve the accuracy of the collected data. We have also surveyed the numerous routing protocols used in VANETs to disseminate the collected data among vehicles and shown their respective advantages and shortcomings. The congestion problem in VANETs as well as the simulation tools are also deeply discussed.

Second, a critical discussion of data fusion and aggregation solutions are provided along with a brief overview on the TMDD standard used by IBM. Third, routes planning and traffic prediction services are investigated with focus on highlighting the limitations of the existing algorithms and suggesting alternative directions for better accuracy and efficiency.

Finally, we presented our vision on improving TMSs efficiency and robustness, which consists in leveraging smart vehicles capabilities and advanced parking systems to achieve the desired level of accuracy and control of the traffic. Moreover, the security threats targeting TMSs, the open challenges need to be addressed as well as the major international research projects dealing with TMS related challenges are presented.

CHAPTER-6: RECOMMENDATION

(Generated through ChatGPT)

1. Smart Traffic Lights: Implementing intelligent traffic lights that use real-time data to adjust signal timings based on traffic flow can help optimize the overall traffic management system.

2. Dynamic Signage: Utilizing electronic message boards to provide real-time information to drivers about traffic conditions, alternative routes, and upcoming events can improve communication and help in diverting traffic.

3. Public Transportation Improvements: Enhancing public transportation options can encourage people to use alternatives to personal vehicles, reducing overall traffic congestion. This could include improving the frequency and efficiency of buses, trains, and other modes of public transit.

4. Variable Speed Limits: Implementing variable speed limits that can be adjusted based on traffic conditions can help maintain a smoother flow of traffic and reduce the likelihood of congestion and accidents.

5. Carpooling and Ridesharing Incentives: Encouraging carpooling and ridesharing through incentives such as dedicated lanes, reduced tolls, or other benefits can help decrease the number of individual vehicles on the road.

6. Traffic Monitoring and Analytics: Implementing advanced traffic monitoring systems that use sensors, cameras, and data analytics can provide real-time insights into traffic patterns. This information can be used to make data-driven decisions for better traffic management.

7. Urban Planning and Design: Incorporating efficient road design and urban planning strategies can contribute to reducing traffic congestion. This may involve creating dedicated lanes for specific types of traffic, improving intersections, and optimizing road layouts.

8. Pedestrian and Cyclist Infrastructure: Investing in pedestrian and cyclist-friendly infrastructure, such as sidewalks, bike lanes, and pedestrian crossings, can encourage alternative modes of transportation and reduce reliance on cars.

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