This chapter discusses the study and analysis conducted during this research on various conditions of traffic density estimation. A close glance on different methodologies, algorithms, techniques and their limitations are presented in this chapter. This process would enable the researchers to understand the research contributions in the area of traffic density estimation.

Due to the limitations of the previous research the comprehensive introduction of all related methods is not possible, therefore only those of greater importance shall be discussed to give the reader an overview on the currently applied procedures.
3.1 Vehicle Detection and Counting

Automatic detecting and counting vehicles in unsupervised video on highways is a very challenging problem in computer vision with important practical applications such as to monitor activities at traffic intersections for detecting congestions, and then predict the traffic of which assists in regulating traffic. Manually reviewing the large amount of data they generate is often impractical [44].

H.S. Mohana [45-47] et.al., developed a new approach in detecting and counting vehicles in day environment by using real time traffic flux through differential techniques. Counting object pixel and background pixel in a frame leads to the traffic flux estimation. The basic idea used is variation in the traffic flux density due to presence of vehicle in the scene. In this paper a simple differential algorithm is designed and tested with vehicle detection and counting application. Traffic flux estimation will play vital role in implementing vehicle detection and counting scheme. Real time dynamic scene analysis has become very important aspect as the increase in video analysis. The technique developed is having simple statistical background. Dynamic selection of images from the sequence is implemented successfully in order to reduce the computation time. The designed technique are evaluated such a 20 different video sequences and weighed thoroughly with simple confidence measures. To make the design illumination invariant, a section of the background is taken as reference, which will not be affected by the traffic flow. Threshold is fixed and used to discriminate the low, medium and high traffic flux. There is a plot for traffic flux density; it’s basically 1% flux density versus number of frames. Basically vehicle detection is carried out by using this plot. Suppose if there is vehicle in the scene, then there is a flux change according to vehicle size. Obviously if there is big vehicle (or object), there is maximum or if there is small vehicle (or object), there is minimum amount of flux (white pixels).
For online learning, incremental algorithm of the SVM was previously proposed in [48], and the approach was adapted to other variants of kernel machines [49]. When a single data point is added and/or removed, these algorithms can efficiently update the trained model without re-training it from scratch. Although these algorithms were developed in different context, they can be considered as instances of parametric programming or path-following [18].

Laura Munoz et.al., [50] proposed a system to estimate traffic density with the cell transmission model. This uses cell densities as state variables instead of cell occupancies, and also accepts non uniform cell lengths, and allows congested condition to be maintained at the downstream boundary of a modeled freeway section. Using cell densities instead of cell occupancies permits to include uneven cell lengths, which leads to greater flexibility in partitioning the highway.

Tomas Rodriguez et.al., [51] proposed a system on real-time traffic monitoring; the system is self-adaptive and is able to operate autonomously for long periods of time, i.e. no hidden parameters to be adjusted. It performs in all weather condition and automatically selects the appropriate algorithm for day, night and transition periods. The system is robust against fast and slow illumination changes and is able to cope with long broken shadows, and shadows from parallel roadways. Ordinary camera movements (i.e. wind vibrations) hardly affect its performance because the system is tolerant against temporal tracking errors and strict constraints are used to identify the vehicles. They also provide an adequate treatment of occlusions and heavy vehicles, and obtained reasonable results in dense traffic. An exhaustive analysis of the operational environment; an effective calibration and image rectification method; an original segmentation approach, complemented with an innovative method for the automatic selection of the segmentation parameters; a detection and tracking approach specially designed for traffic environments;
a robust shadow removal method; specific provisions for heavy vehicle detection and the treatment of occlusions; and finally, semantic testing and benchmarking methodology. Here the system segments the video by extracting the moving objects of the scene and performing a preliminary classification (i.e. it will not attempt to identify shadows). Once the work image has been created the image is segmented by extracting the moving objects using an adaption of well-known back-ground suppression techniques. The system uses detection and tracing steps to make an abstraction of physical objects implicit in the segmentation mask for every incoming image and then track those objects in the sequence until all vehicles and shadows present in the scene is identified.

P.F Alcantarilla et.al., [52] proposed a automatic road traffic control and monitoring system for day time sequence using a black and white camera. Important road traffic information such as mean speed, dimension and vehicles counting are obtained using computer vision methods. Firstly, moving objects are extracted from the scene by means of a frame-differencing algorithm and texture information based on grey scale intensity. However, shadows of moving objects belong also to the foreground. Shadows are removed from the foreground objects using top hat transformations and morphological operators. Finally, objects are tracked in a Kalman filtering process, and parameters such as position, dimensions, distance and speed of moving objects are measured. Then, according to these parameters moving objects are classified as vehicles (trucks or cars) or nuisance artifacts. For counting vehicles, moving objects must be extracted from images.

Frank Y. Shih et.al., [53] proposed a system for automatic seeded region growing algorithm for color image segmentation. First, the input RGB color image is transformed into YCbCr color space. Second, the initial seeds are automatically selected. Third, the color image is segmented into regions where each region corresponds to a seed. Finally, region-merging is used to merge similar or small regions.
M. Vargas et al., [54] proposed a system for video based traffic density estimation. Successful video-based systems for urban traffic monitoring must be adaptive to different conditions. They should include algorithms for detection of moving vehicles and short-term stood-still vehicles (especially important in urban environments). Therefore, foreground/background discrimination or feature tracking. An adaptation of sigma-delta background subtraction algorithm has been presented. This adaptation tries to keep the simplicity and computational efficiency of the original method, while providing more robustness to the achieved background model in typical urban traffic scenes. Starting from the basic sigma-delta algorithm, a confidence measurement has been included, taking into account not only the intensity variance on each pixel but also the estimation of the traffic flow over that pixel.

Some heuristics have been established for updating the confidence of each pixel and for making a decision about the convenience of updating the background model value at that pixel. Some experimental tests have been done on a typical urban traffic scene, where this algorithm is compared with the basic sigma-delta method and more elaborate existing versions. These tests demonstrate that a more stable background model is obtained without being polluted with slow moving vehicles of vehicles which are stopped for a time gap. Besides, the proposed algorithm avoids the complex spatiotemporal processing or the combinations of multiple frequency background models used in the previous advanced versions of the sigma-delta algorithm. This background-model estimation algorithm has been successfully implemented on an ARM-based embedded multimedia processor.

Yi-Hsien Chiang et al., [55] proposed a system which devises a freeway controller that is capable of stabilizing traffic flow when the traffic system is in the unstable (congested) phase, in which a shock wave is likely to occur in the presence of any in
homogeneity and where the system is on the verge of a jam condition. Two types of traffic controllers are developed through the use of either a speed command approach that can be implemented in an intelligent transportation system (ITS) or ramp metering that is a typical way of preventing a freeway from overloading. By means of the feedback linearization technique, the discretized macroscopic traffic flow model is reformulated, in which the desired change of volume in each section is treated as a virtual input. By exploring the casual relations among density, speed, and flow change, the corresponding speed commands can be determined. The traffic flow control problem is formulated as an $H_\infty$ control design problem so that uncertainties that are associated with the macroscopic model can be taken into account. Simulations show that the devised controller can effectively stabilize the traffic flow in the unstable phase. The traffic state is in the unstable phase when the traffic density exceeds a critical threshold value. In this phase, any inhomogeneity is likely to result in a buildup of a shock wave that propagates upstream and may lead the system to a congestion condition. One method to keep traffic from reaching the unstable condition is to balance traffic demand and supply. Alternatively, the phenomena can be avoided by properly coordinating all vehicles speed and distance headway. The latter serves to attenuate unexpected shock wave propagation and to regulate the state to the desired equilibrium condition according to the upstream and downstream situations. By the shock wave theory, the traffic response is affected by the downstream condition, as well as the upstream condition. In this paper, they focus on the design of the traffic flow control system described by a macroscopic discrete-time model.

Long Chen, C. L. et al., [56], proposed a system for image segmentation using fuzzy c-means algorithm. Image segmentation is a central task in many research fields including computer vision and intelligent image and video analysis. Its essential goal is to
split the pixels of an image into a set of regions such that the pixels in the same region are homogeneous according to some properties and the pixels in different regions are not similar. Clustering, particularly fuzzy C-means (FCM)-based clustering and its variants, have been widely used in the task of image segmentation due to their simplicity and fast convergence. By carefully selecting input features such as pixel color, intensity, texture, or a weighted combination of these data, the FCM algorithm can segment images to several regions in accordance with resulting clusters. Recently, the FCM and other clustering-based image-segmentation approaches are improved by including the local spatial information of pixels in classical clustering procedures. For example, an additional term about the difference between the local spatial information and the cluster centers is attached to the traditional objective functions of FCM algorithms. Because of the embedded local spatial information, the new FCM has demonstrated robustness over noises in images.

In addition to the incorporation of local spatial information, the kernelization of FCM has made an important performance improvement. The kernel FCM (KFCM) algorithm is an extension of FCM, which maps the original inputs into a much higher dimensional Hilbert space by some transform function. After this reproduction in the kernel Hilbert space, the data are more easily to be separated or clustered. Previous research on transformation to the kernel space has already been studied.

Recently, developments on kernel methods and their applications have emphasized the need to consider multiple kernels or composite kernels instead of a single fixed kernel. With multiple kernels, the kernel methods gain more flexibility on kernel selections and also reflect the fact that practical learning problems often involve data from multiple heterogeneous or homogeneous sources. Specifically, in image-segmentation problems, the inputs are the properties of image pixels, and they could be
derived from different sources. For example, the intensity of a pixel is directly obtained from the image itself, but some complicated texture information is perhaps gained from some wavelet filtering of the image. Multiple-kernel methods provide us a great tool to fuse information from different sources. It is necessary to clarify that, in this paper, the author have used the term “multiple kernel” in a wider sense than the one used in machine learning community. In the machine learning community, “multiple-kernel learning” refers to the learning.

Mohamed Ben Salah et.al., [57] proposed system for Multiregional Image Segmentation by Parametric Kernel Graph Cuts. Many studies have focused on variation formulations because they result in the most effective algorithms. Variation formulation seeks an image partition which minimizes an objective functional containing terms that embed descriptions of its regions and their boundaries. The literature abounds of both continuous and discrete formulations. Continuous formulations view images as continuous functions over a continuous domain. The most effective minimizes active curve functional via level sets. The minimization relies on gradient descent. As a result, the algorithms converge to a local minimum, can be affected by the initialization and are notoriously slow in spite of the various computational artifacts which can speed their execution. The long time of execution is the major impediment in many applications, particularly those which deal with large images and segmentations into a large number of regions. Discrete formulations view images as discrete functions over a positional array. Combinatorial optimization methods which use graph cut algorithms have been the most efficient. They have been of intense interest recently as several studies have demonstrated that graph cut optimization can be useful in image analysis. Very fast methods have been implemented for image segmentation motion and stereo segmentation tracking and restoration.
Thanes Wassantachat et al., [58] proposed a system to find the traffic density Estimation with On-line SVM Classifier according to the system. Traffic congestion has significant impacts on both the economy and environment. Reducing traffic congestion can improve traffic flow, reduce travel times and the environmental impact. Automatic determination of traffic congestion status is thus introduced to reduce the cost of human resource and the traffic congestion delay. This automatic determination can also establish an effective traffic solution to the traffic light controllers.

In recent research, the Hidden Markov model was used in classifying the traffic congestion state automatically. Even though the performance was considerably good, some restrictions still remain. One key issue was that the HMM approach required segmented video shots as inputs to both its training and testing processes, with frames in each segmented shot representing an identical traffic density state. This possibly makes it difficult to perform an accurate and practical shot segmentation in a video sequence. Furthermore, this introduced a certain delay to the real-time process, making a HMM approach impractical for a real-time implementation.

Another approach is using a static Support Vector Machine (SVM) approach to model the traffic flow in real-time. Compared with the HMM approach, the SVM approach simplifies both training and testing processes and offers a strict real-time process. Unfortunately, similar with a HMM approach, the static SVM could not work correctly on a video sequence with anomalies in its background such as a static shadow. Additionally, the whole process required certain huge number of training samples to achieve good performance. On the other hand, a background modeling approach has been widely used in shadow detection and is able to complement a traffic density estimation process. However, it is problematic under different weather conditions, rapid changing illumination and traffic congestion.
Guohui Zhang et al., [59] proposed a Video-based Vehicle Detection and Classification (VVDC) system for collecting vehicle count and classification data. The proposed approach can detect and classify vehicles using uncalibrated video images. The ability to use uncalibrated surveillance cameras for real-time traffic data collection enhances the usefulness of this prototype VVDC system.

### 3.2 Background Subtraction

A video-based Intelligence Traffic System (ITS) must be capable of continuous operation under various road conditions. Moreover, background subtraction is a very important part of ITS applications for successful segmentation of objects from video sequences. Accuracy and computational time of the initial background extraction are crucial in any background subtraction method. Successful subtraction of foreground objects from a complex background scene is an important initial step in intelligent traffic systems applications. However, in real-world situations, there exist several kinds of environment variations that will make the background extraction and foreground segmentation more difficult. There are several studies in the literature about automatic vehicle detection and tracking. These kinds of systems must work under variable lighting and weather conditions, and also during day and night time.

Chung-Cheng Chiu et al., [32] proposed the probability-based background extraction algorithm to segment objects from surveillance videos. With the proposed algorithm, the initial background can be extracted accurately and quickly by calculating the color probabilities of each pixel to decide the background pixel color. After the initial background extraction, the intrusive objects can be segmented correctly and immediately. Meanwhile, the color background images can be updated in real time to overcome any variation in illumination conditions.
Ren *et al.*, [60] proposed a background extraction method that involved calculating the mean of the background Gaussian distribution in the background map. Thongkamwitoon *et al.* [61] proposed statistical background subtraction methods that made the background extraction more robust to non-stationary backgrounds, illumination changes, and other artifacts, while Li *et al.*, [62] proposed a Bayesian framework that incorporated spectral, spatial, and temporal features to characterize the background appearance. These methods adapt to both gradual and sudden background changes, but the long computation time, the sensitivity to the environment, and inefficient background updating are still issues that must be resolved.

Moving object detection in image sequences is fundamental in application areas such as automated visual surveillance, human-computer interaction, content-based video compression, and automatic traffic monitoring. Especially, vehicle detection with stationary camera is an important problem in traffic management, which is essential for the measurement of traffic parameters such as vehicle count, speed, and flow. In recent years, background modeling is a commonly used technique to identify moving objects with fixed camera. However, accurate detection could be difficult due to the potential variability such as shadows cast by moving objects, non-stationary background processes (e.g. illumination variations), and camouflage (i.e. similarity between appearances of moving objects and the background).

Yang Wang *et al.*, [63] presented an approach of moving vehicle detection and cast shadow removal for video based traffic monitoring. Based on conditional random field, spatial and temporal dependencies in traffic scenes are formulated under a probabilistic discriminative framework, where contextual constraints during the detection process can be adaptively adjusted in terms of data-dependent neighborhood interaction. Computationally efficient algorithm has been developed to discriminate moving cast
shadows and handle non stationary background processes for real-time vehicle detection in video streams. Experimental results show that the proposed approach effectively fuses contextual dependencies and robustly detects moving vehicles under heavy shadows even in grayscale video.

Cucchiara et al. [64] proposed to extract moving vehicles during daytime by means of motion extraction using frame-differencing algorithms and morphological operators, while at night time vehicles are identified by their headlights. For counting vehicles, moving objects must be extracted from images. The most common method is known as background subtraction, which is normally a computationally efficient algorithm. Background must be updated in a dynamic way since background in road traffic images is variable. Subtracting this background image from the original image, moving objects can be extracted. However, this method generates erroneous ghosts during the background evolution period, which affects clustering and tracking processes [65]. Optical flow algorithms can be used too, but the computational burden is sometimes overwhelming for real time applications. One challenging problem in these applications is shadows detection, since shadows move along with the moving objects in the image. Shadows are detected as foreground pixels, since the difference with background is significantly. Shadows can cause object merging and object losses which imply that shadows identification plays a key role in road traffic applications.

Prati et al., [66] studied different algorithms for shadows detection. Normally shadows detection algorithms use colour information or some probabilistic shadows model. After moving objects segmentation and shadows removal, vehicles are tracked using a Kalman filter in a tracking process [67][3].

Daniel et al., [68] presented the background subtraction and modeling technique that estimates the traffic speed using a sequence of images from an uncalibrated camera.
The combination of moving cameras and lack of calibration makes the concept of speed estimation a challenging job. Cheng et al., [69] compare the performance of a large set of different background models on urban traffic video. They experimented with sequences filmed in weather conditions such as snow and fog, for which a robust background model is required.

### 3.3 Traffic incident detection

Detection of incidents, congestions and other traffic operational problems is very important action for operation of the traffic system. Intelligent classification methods can offer efficient ways to classify the state of the transport system.

Yeh et al., [70] have applied fuzzy multi-criteria analysis to performance evaluation for urban public transport system. The fuzzy multi-criteria analysis provides crisp ranking outcomes for the evaluation problem. An empirical study of 10 bus companies in Taipei’s public transport system has been carried out to exemplify the approach.

Wen et al., [71] have developed probabilistic neural network to solve incident detection problem. Efficient incident management is an important issue in freeway traffic management system. A wide range of incidents that include different patterns under a variety of flow conditions and traffic periods were generated to train and evaluate the performance and the transferability of the proposed probabilistic neural network-based algorithm. Test results with simulation data showed that the probabilistic neural network has the potential to achieve good incident detection performance.

For real time traffic incident detection, Xu et al., [72] have developed a real time on-line adaptive algorithm. The developed method consists of two stages. First a real time adaptive on-line procedure is used to extract the significant components of traffic states,
namely, average velocity and density of moving vehicles. Second, a neural network called fuzzy CMAC (Cerebellar Arithmetic Computer) has been applied to identify traffic incidents. CMAC consists of both fuzzy logic unit and neural network unit. The system will help drivers to select an optimum route, it will be able to provide information for efficient dispatching of emergency services and moreover, it will provide accurate knowledge of existing traffic conditions.

Also Lee et.al., [73] have developed the fuzzy-logic-based incident detection algorithm that feeds an incident report (i.e., the time, location and severity of the incident) to the system’s optimization manager, which uses that information to determine the appropriate signal control strategy. The developed algorithm was tested under laboratory setting and its overall performance was encouraging in terms of detection rate, false alarm rate and mean time to detect. Fuzzy logic has been successfully used to detect traffic anomalies.

Weil et.al., [74] have developed a novel time-indexed traffic anomaly detection algorithm. Depending on type of the day and time of the day the fuzzy sets “normal” and “abnormal” are determined for each traffic descriptor by using unsupervised learning algorithm. Fusion of the multiple traffic descriptors, on per lane basis, in order to determine membership “normal” or “abnormal” lane status, is implemented with fuzzy composition techniques. Finally, each lane status is fused to determine an over all road segment status.

Due to the considerable differences in performance, size, and weight between long vehicles (LVs) and short vehicles (SVs), length-based vehicle classification data are of fundamental importance for traffic operation, pavement design, and transportation planning. Highway Capacity Manual [75] requires adjustments to heavy-vehicle volumes in capacity analysis. The geometric design of a roadway, such as horizontal alignment
and curb heights, is affected by the different moving characteristics of LVs due to their heavy weight, inferior braking, and large turning radius. The heavy weight of such vehicles is also important in pavement design and maintenance, as truck volumes influence both the pavement life and design parameters [76]. Safety is also affected by LVs: eight percent of fatal vehicle-to-vehicle crashes involved large trucks, although they only accounted for three percent of all registered vehicles and seven percent of total Vehicle Miles Traveled (VMT) [77]. Recent studies [78, 79] also found that particulate matters (PM) are strongly associated with the onset of myocardial infarction and respiratory symptoms. Heavy duty trucks that use diesel engines are major sources of PM, accounting for 72% of traffic emitted PM [80].

Evan Tan et al., [81] proposed a novel approach of combining an unsupervised clustering scheme called AutoClass with Hidden Markov Models (HMMs) to determine the traffic density state in a Region Of Interest (ROI) of a road in a traffic video. Firstly, low-level features are extracted from the ROI of each frame. Secondly, an unsupervised clustering algorithm called AutoClass is then applied to the low-level features to obtain a set of clusters for each pre-defined traffic density state. Finally, four HMM models are constructed for each traffic state respectively with each cluster corresponding to a state in the HMM and the structure of HMM is determined based on the cluster information. This approach improves over previous approaches that used Gaussian Mixture HMMs (GMHMM) by circumventing the need to make an arbitrary choice on the structure of the HMM as well as determining the number of mixtures used for each density traffic state.

3.4 Traffic control

Traffic control is one of the fast growing areas among the transport management problems. More efficient methods are needed for optimizing the road capacity and the traffic control systems. Traffic control involves different kind of problems for instance
traffic signal and lights control, traffic assignment problems, scheduling and planning problems and so on. Traffic light control systems and intersection management systems seem to be the main issues under this problem area.

Intelligent techniques as a part of decision-making can be very effective. Fay [82] has developed a dispatching support system for use in railway operation control systems. System contains expert knowledge in fuzzy rules of the “IF-THEN” type. Actually system is a fuzzy Petri net notion that combines the graphical power of Petri nets and the capability of fuzzy sets to model rule-based expert knowledge in a decision support system. The proposed assistant system for dispatching support can be integrated into an operating center. Improvements can be seen in traffic performance, reliability and customer satisfaction.

Correspondingly, Hegyi et.al., [83] have presented a fuzzy decision support system (FDSS) for assist the operators of the traffic control system. Fuzzy decision support system is part of a larger traffic support system and it can be used to provide a limited list of appropriate combinations of traffic control measures for a given traffic situation. The main role of the fuzzy decision support system is to suggest whether a particular local traffic controller or control measure should be activated or not. The kernel of the system is a fuzzy case-base that is constructed using simulated scenarios. The FDSS uses a case-base and a fuzzy interpolation to generate a ranked listing of combinations of control measures and their estimated performance. In the future system will be complemented with an adaptive learning feature and with a set of fuzzy rules that incorporate heuristic knowledge of experienced traffic operators.

Aid Decision-making fuzzy system is very useful because a lot of knowledge in the real situation concerning decision-making is uncertain. That was kept in mind when Aziz et.al., [84] developed a new strategy for the aid decision-making based on the fuzzy
inferences in the traffic regulation of an urban bus network. The system helps operators of the urban bus network to solve the problem of connections between buses.

Sadek et al., [85] have examined the potential for using case-based reasoning (CBR), an emerging artificial intelligence paradigm, to overcome this task. In their study a prototype CBR routing system for interstate network in Hampton Roads, Virginia, was developed. Cases for building the system’s case-base was generated using heuristic dynamic traffic assignment (DTA) model designed for region. The results showed that the prototype system is capable of running in real-time, and of producing high quality solutions using case-bases of reasonable size.

Montero et al., [86] have developed a combined methodology for transportation planning assessment. The methodology is a combination of a well-known traffic assignment tool, the EMME/2 model, with a microscopic traffic simulator, Advanced Interactive Microscopic Simulator For Urban and Non-Urban Networks (AIMSUN2) with emphasis on the description of the specific interfaces that make consistent the combination of both tools in Generic Environment for Traffic Analysis and Modeling (GETRAM) environment. GETRAM environment has open and flexible computer architecture suitable for modeling complex transportation systems. Evolutionary algorithms seemed to achieve some success as a planning tool of different kind of networks.

Bielli et al., [87] have developed a GA-based heuristic method for bus network optimization. The different networks of buses create the initial population for genetic operators. The final result after genetic manipulation is set of bus network each equipped with fitness function that describes the performance of that network. This heuristic was implemented for bus network planning in northern Italy, Parma. Results were found promising. Future developments are related the usage of neural networks for fitness function evaluation or usage of n-best solutions container.
Teodorovic et.al., [88] have applied fuzzy logic for dynamic dial-a-ride problem. The problem is to assign every new passenger request to one of the vehicles and to design a new route and schedule for the vehicle chosen to serve the new request. The fuzzy logic was used to develop approximate reasoning algorithms. Fuzzy logic seemed to be natural choice because of the fuzziness of travel time and distance estimations. Fuzzy arithmetic can be exploited to perform calculations related to the vehicle waiting times, passenger waiting times, moments of arrival at some nodes etc. These calculated values represent the input data for developed approximate reasoning algorithms. The achieved results were promising.

Different kinds of traffic signal control methods seemed to be very popular issues under traffic control branch. Trabia et.al., [89] have developed a fuzzy logic-based adaptive traffic signal controller for an isolated four-approach intersection with through and left-turning movements. The fuzzy controller uses vehicle loop detectors, placed upstream of the intersection on each approach, to measure approach flows and estimate queues. Data from these measurements are used to decide, via two-stage fuzzy logic procedure, whether to extend or terminate the current signal phase. The performance of the two-stage fuzzy controller was compared to that of the traffic-actuated controller for different traffic conditions on a simulated four-approach intersection. The two-stage fuzzy logic controller resulted better performance especially under non-recurring traffic conditions. Changing conditions in traffic volume can cause vehicular delay, if the traffic signal controllers are not adjustable, that is, the parameters of the controller remain the same in changing traffic situations.

Bingham [90] has presented reinforcement learning method for neuro-fuzzy traffic signal control. Neural network is used in fine-tuning the membership functions of a fuzzy
traffic controller. The neural learning algorithm used was reinforcement learning, which gives credit for successful control actions and punishes for poor control actions.

Heung et. al., [91] have applied a complex fuzzy logic controller for traffic control at a road junction. In this case too the control system has an ability to adapt itself under various traffic conditions. A GA based offline learning algorithm is employed to generate the fuzzy rules in the situation where the complexity of the controller has increased because the increase in the complexity of junction. This fuzzy logic is also hierarchical approach thus trying to reduce the number of fuzzy rules in the system. Results showed that hierarchical fuzzy logic controller (HFLC) perform better than an ordinary fixed-time traffic controller does under both constant and time varying flow-rates.

The effectiveness of urban traffic control systems greatly depends on its ability to react upon changes in traffic patterns. Roozemond [92] has investigated the applicability of autonomous intelligent agents in Urban Traffic Control (UTC) and especially in real-time urban intersection control. Proposed system can also adapt itself, based upon internal rules and its environment, at changing environments. The UTC model is primarily based on several Intelligent Traffic Signaling Agents (ITSA) and some authority agents. The proposed system seemed to improve the use of the capacity of intersections. Henry et. al., [93] have developed a neuro-fuzzy control method for controlling of traffic lights of an intersection. System showed good results for simple and medium-complexity intersections but poor performance on a complex intersection. The neuro-fuzzy controller was mixed with the optimal control to improve performance. Results with this implication were found good for all the intersections tested.

One of the numerous traffic signal control methods has been presented in a paper of Wei et. al., [94]. Their paper presents a fuzzy logic adaptive traffic signal controller for an isolated four-approach intersection with through and left-turning movements. The controller has the ability to make adjustments to signal timing in response to observed
changes. Also the “urgency degree” term, which can describe the different user’s demands for green time is involved into the fuzzy decision making algorithm. The three level model of fuzzy control can determine whether to extend or terminate the current signal phase and select the sequences of the phases. The fuzzy parameters can be tuned off-line or instead the multi-objective genetic algorithm can be used for the same purpose. Results showed better performance for the fuzzy controller than the traffic-actuated controller.

Correspondingly Lin et.al., [95] have introduced a versatile traffic flow model capable of making optimal traffic predictions. Furthermore this model can be used to evaluate various traffic-light timing plans. It also provides a framework for implementing adaptive traffic signal controllers based on fuzzy logic technology. The paper presented the procedure for the design of an adaptive fuzzy controller.

The study of Niittymäki et.al., [96] discusses the fuzzy traffic signal control in general and presents some results of fuzzy signal control. Traffic signal control is a control problem with number of complex and sometimes conflicting variables and objects. The final hypothesis is that fuzzy signal control can achieve better performance compared to traditional vehicle actuated signal control.

Beauchamp-Baez et.al., [97] have developed a new fuzzy logic approach for traffic control. The developed system is a fuzzy logic based phase sequencer (PS) for signalized intersection control. The phase sequencer operates in conjunction to the fuzzy logic controller for traffic systems (FLC-TS). PS decides when to finish a phase and also determines what should be the next phase based on the traffic demand and the time elapsed since the last time maneuver was attended. Results did not show a significant difference between the FLC-TS and the PS + FLC-TS. The adaptive tuning of the membership functions and rule base of the PS might result better performance. Further
research in this area will be needed. Ramp controlling or ramp metering is a technique to limit the number of vehicles entering a freeway. Usually, the main goal of the ramp metering system is to avoid congestion and reduce vehicle’s total travel time.

Bogenberger et.al., [98] have applied self-adaptive fuzzy logic system for ramp controlling problem. The adaptive fuzzy logic algorithm has been used to determine the traffic responsive metering rate. The fuzzy parameters are periodically adapted by an evolutionary algorithm (GA) every 15 min. This guarantees the quick on-line calibration of the existing parameters in new environment or in changes of the traffic patterns. The developed system was tested with the simulated model of the autobahn. The results of the simulation were very satisfying and a real world implementation of the ramp metering system is planned in the very near future.

Zhang et.al., [99] present another application for ramp control. They have showed that neural networks can be exploited in nonlinear ramp control. This coordinated traffic responsive ramp control strategy based on feedback control and artificial neural network. The nonlinear feedback law is realized by a series of neural network. The traditionally used ramp-metering algorithm based on LQR method has been replaced with this new one. The developed algorithm showed promising results in reducing system travel times by preventing the occurrence of traffic breakdowns.

Krause et.al., [100] have used fuzzy technologies to analyze environmental conditions like road carpet, visual range and weather conditions by local stations and road sensors. These analyses help traffic control system to keep traffic flowing, to slow down traffic at the inflow to congestion and to avoid to hazard due to extraordinary weather conditions such as fog or icy conditions. The uncertain nature of the detection of environmental condition is a basis on the use of fuzzy logic. Fuzzy logic can efficiently cope with the measurement problems of the real world sensors. By using fuzzy logic the
operational problems that occur by the wrong evaluation of the conditional system can be avoided.

Krause et al., [101] have used fuzzy logic for two different kind of traffic management problem. First fuzzy logic is used to take into account the uncertainties of traffic data, and to detect traffic congestion in isolated road sections. Second, a fuzzy model based traffic control approach has been introduced. The approach was also implemented in an existing traffic control system in Germany. The results were compared with the previous approach based on conventional control technology.

Gasser Auda et al., [102] developed a mobile, bus-mounted machine vision system for transit and traffic monitoring in urban corridors, as required by Intelligent Transportation Systems. In contrast to earlier machine vision technologies used for traffic management, which mainly rely on simple algorithms to detect certain traffic characteristics, the new proposed approach makes use of a recent trend in computer vision research; namely the active vision paradigm. Active vision systems have mechanisms that can actively control camera parameters such as orientation, focus, zoom, and vengeance in response to the requirements of the task and external stimuli. Mounting active vision systems on buses will have the advantage of providing real-time feedback of the current traffic conditions while possessing the intelligence and visual skills which allow them to interact with a rapidly changing dynamic environment such as moving traffic.

Shadow detection is critical for robust and reliable vision-based systems for traffic vision analysis. Shadow points are often misclassified as object points causing errors in localization, segmentation, tracking and classification of moving vehicles.

Hong Liu et al., [103] proposed a novel shadow elimination method SEBG for resolving shadow occlusion problems of vehicle analysis. Different from some traditional method which only consider intensity properties, this method introduces gradient feature to eliminate shadows. In this approach, moving foregrounds are first segmented from
background by using a background subtraction technique. For all moving pixels, the approach SEBG using gradient feature to detect shadow pixels is presented in detail. This method is based on the observation that shadow regions present same textural characteristics in each frame of the video as in the corresponding adaptive background model. Gradient feature is robust to illumination changes. The method also needs no predefined parameters, which can well adapt to other video scene. Results validate the algorithm’s good performance on traffic video.

Khalid A. S. Al-Khateeb et.al., [104] have circumvented or avoided the problems that usually arise with systems such as those, which use image processing and beam interruption techniques. RFID technology with appropriate algorithm and data base were applied to a multi vehicle, multi lane and multi road junction area to provide an efficient time management scheme. A dynamic time schedule was worked out for the passage of each column. The simulation has shown that, the dynamic sequence algorithm has the ability to intelligently adjust itself even with the presence of some extreme cases. The real time operation of the system emulated the judgment of a traffic policeman on duty, by considering the number of vehicles in each column and the routing proprieties. RFID together with Internet and GSM technologies are anticipated to create a revolution in traffic management and control systems. The data base contains online statistical information, which can be used by operators and planners to develop better models in the future.

Zs. Lendek et.al., [105] proposed a fuzzy observer for the well-known second-order traffic flow model METANET in order to estimate the non-measured states. To design the observer, first a dynamic Takagi-Sugeno fuzzy model was derived using the sector nonlinearity approach. This fuzzy model is an exact representation of the continuous-time traffic flow model. For the obtained fuzzy model, fuzzy observers were
designed, and also disturbance attenuation has been achieved. In this paper the modeling
and observer design was performed in continuous time.

Neural networks have been widely used in traffic control [106, 107, 108]. In [106],
the traffic incident detection model using neural networks has been developed using
traffic magnetic sensors. Intelligent agent systems have been using in [107] in order to
control the traffic. Hybrid computational intelligent techniques and fuzzy neural networks
have been applied in multi agents in order to control the traffic signals. They have
reduced the average waiting time in the traffic. In [108], traffic flow prediction is
achieved using time delay based neural networks. In this paper, we will use neural
networks for identification of vehicles and traffic density by processing the traffic videos

3.5 Traffic simulation and prediction

The prediction of traffic flows, traffic volumes and travel times is a very important
part of traffic management and information system. The traffic simulation is
correspondingly needed to make these predictions by reliable way. The results of the
traffic condition predictions can be used for different purposes such as to influence travel
behavior, to reduce traffic congestion and generally to improve the performance of traffic
management system.

Saab et.al., [109] have developed a forecasting system for predicting the number
of passengers boarding for the next N scheduled flights on a particular route. The kernel
of the system is Kalman filter. Inputs for the system are the booking levels made for N
departure days ahead of the data date for that flight leg. The strong correlation is assumed
between the numbers of passengers that boarded the plane on that flight and the number
of bookings made for that flight just before departure. The system can be used as decision
support system to find the optimal limits on the number of bookings that may be accepted in a particular fare class on the future flight leg.

Sen et al., [110] have explored the consequences of using link travel time estimates with high variance to compute the minimum travel time route between an origin and destination pair. They have noticed that variances of the travel times remain high even when sample sizes become large. So the increase in sample size of travel times does not guarantee better quality of information given by Intelligent Transportation Systems (ITS). The average route travel times incurred by the guided drivers under numerous ‘guidance strategies’ were tested out. Simulation results showed that static travel time estimates offered better quality of guidance than dynamic travel time estimates. That was, because the variance of dynamic travel time estimates remain high.

The prediction and modeling of traffic flows involves great challenges for sciences. Related to before mentioned problem Wahle et al., [111] have studied the quality of the reproduced traffic states with regard to vehicular densities and link travel times. They have developed a simulation tool for urban traffic, which can also be easily extended to model traffic flow on highways. Both spatial and temporal scales of traffic states can be extrapolate by simulation. The simulation tool can also be used for designing and evaluating dynamic traffic management system taking into account different criteria. Conventional statistical models usually suffer their strict mathematical assumptions when describing complex traffic conditions.

Correspondingly, intelligent adaptive methods are made for describing phenomenon under non-ideal physical environments.

Huisken et al., [112] for their part have compared performances of an ARMA time series analysis method and of a MFL neural network method in congestion prediction. The volume, mean speed, occupancy and standard deviation of speed within
1-minute time bin, which can be regarded as an indicator of the chaos of the traffic, were used as inputs of the model. Results showed better performance for MLF neural network method both the congestion prediction and the processor time efficiency. However, both methods are not so robust in the case of the incident. In the case of the incident the time series analysis method then probably will outperform the neural network method, because its parameters are set on a single point in space. Neural network correspondingly can only recognize events that they have learnt. Previous research efforts have claimed the general superiority of the neural network model in traffic volume forecasting. However, the forecasting power of a single model is limited to the typical cases to which the model fits best.

Yun et.al., [113] have studied the relationship in forecasting traffic volume between data characteristic and the forecasting accuracy of different neural network models. The three different data sets collected from interstate highways, intercity highways and urban intersections were tested using a back-propagation network model, a FIR model and a time-delayed recurrent model. The used data sets showed very different characteristics in terms of cyclic period, stability, and randomness, as measured and described by the Hurst exponent and the correlation dimension. It was noticed that the FIR and back-propagation model, which have claimed a nonlinear learning mechanics, may not be very good in handling randomly fluctuating events. Instead, the time-delayed recurrent model outperforms other model in forecasting very randomly moving data. The FIR model shows better forecasting accuracy for the relatively regular periodic data. Also different considerations were made when apply these results to transportation. The used data should always be filtered in an appropriate way to guarantee highly accurate forecasting. The effects of unexpected events should also be involved to the system
design. Otherwise the neural network model cannot forecast the effects of these unexpected events.

Most of the traffic control systems rely on historical and current traffic data as a basis for traffic management actions. These systems have no information of future events and therefore their performance is constrained. The potential to alleviate traffic congestion and enhance the performance of the road network can be added by providing predictive information for the traffic control centers.

Dia [114] have developed the object-oriented neural network model for predicting short-term traffic conditions on a section of the Pacific Highway between Brisbane and the Gold coast in Queensland, Australia. The object-oriented neural network was developed to predict speed at a detector station up to 15 minutes at the future and shows how similar models were developed for freeway travel time estimation. The results showed high degree of accuracy (90 – 94 %) when predicting speed data up to 5 minutes into the future. The models developed for travel time estimation were also successful in predicting travel times up to 15 minutes into the future with a similar degree of accuracy (93-95 %). The longer prediction horizon with the same accuracy could be achieved by using additional traffic data inputs (e.g., flow and occupancy) and measurements from previous time intervals.

Chang [115] have studied an approach of combining both advanced neural networks and conventional error correction techniques to improve freeway traffic operational behavior analysis based directly on real world traffic measures. The error correction algorithm as a part of the system can be used to smooth out the errors that may be caused by sharp neural net prediction. The developed system was found to be promising in traffic prediction and proactive control.
Jiang et al., [116] have developed an artificial neural network prediction model based on the relationship of segment traffic volume and average travel time. The model is especially designed for the urban traffic network installed self-adapted traffic control system. The outputs of the neural network were traffic volume and average speed. The average was then used to calculate the average travel time. The approach was tested using the data from an arterial road in Changchun. The method was found to be reliable, fast in computation and economical.

Chen et al., [117] have investigated the potential of dynamic neural network for forecasting motorway traffic in normal and unexpected conditions. Especially, one of the main objectives was to report on the application and performance of an alternative neural computing algorithm, which involves sequential or dynamic learning of the traffic flow process. A Dynamic learning can be considered as a use of ‘piecewise’ models i.e. where different models is selected according to traffic flow conditions. Three different neural networks, the dynamic neural network, Kalman filter neural network and medium-sized neural network, were compared. The simple dynamic neural network model seemed to have the best forecasting performance.

Wei [118] has presented a neural network method for dynamic traffic movement modeling. The developed model is essential part of the freeway ramp metering control. Modeling of freeway traffic flow is a challenging task because traffic along a freeway varies not only with time but also with space. Neural network models are used to simulate typical time series traffic data simply because their learning capability.

These models are expanded to capture the inherent time-space interrelations. Inputs to neural network models are traffic states in each time period on the freeway segments while outputs are the desired metering rate at each entrance ramp. The simulation results indicated good results for neural network model governing the freeway
traffic operations. Genetic algorithms can be a suitable method for different kind of combinatorial optimization problems.

Lee et.al., [119] have developed generic road shape modeling algorithm for simulation of traffic scenes. The algorithm is a part of a bigger autonomous vehicle navigation system, and more accurately it can be used for simulation of geometric road alignment. The main objective of the research was to develop an automated procedure for accurate geometric modeling of road shapes. GA-based algorithm simulates horizontal road alignment, according to the road geometry design standards, in the form of alternating straight section and curve segment arrangement. The input of the system is a set of critical points representing points with extreme road curvature. The output of the system is the two-dimensional coordinates of the road centerline, optimized for driver’s safety and comfort. The achieved results were successful for various road types and shapes, and exhibits good tolerance to noise.

Recently, also fuzzy-neural methods have been applied to prediction of traffic conditions. Yin et.al., [120] have developed a fuzzy-neural model to predict the traffic flows in an urban street network. The system consists of two modules: a gate network (GN) and an expert network (EN). The GN classifies the input data into a number of clusters using fuzzy logic, and the EN is used for specifying the input-output relationship as in conventional neural network approach. The parameters of the model are adaptive adjustable in response to the real-time traffic conditions. The results showed that fuzzy-neuro model (FNM) outperforms the conventional neural network model (NNM). FNM also showed better performance in computing time than NNM. The developed system was tested both with simulation and with real observation data.

Zhencheng Hu et.al., [121] presented a novel solution of vehicle occlusion and 3D measurement for traffic monitoring by data fusion from multiple stationary cameras.
Comparing with single camera based conventional methods in traffic monitoring; our approach fuses video data from different viewpoints into a common probability fusion map (PFM) and extracts targets. The PFM concept is efficient to handle and fuse data in order to estimate the probability of vehicle appearance, which is verified to be more reliable than single camera solution by real outdoor experiments. An AMF based shadowing modeling algorithm is also given in this paper in order to remove shadows on the road area and extract the proper vehicle regions. Non-recursive techniques, such as Frame Differencing (FD), Median Filter (MF), Linear Predictive Filter (LPF), and recursive techniques, such as Approximated Median Filter (AMF), Kalman filter (KF), Mixture of Gaussians (MoG), are evaluated in retrieval measurement (recall and precision), to quantify how well each algorithm matches with the ground truth in different weather conditions.

Gazis et.al., [122] discussed a method for estimating the number of vehicles on a section of a freeway from speed and flow measurements at the entrance and exit points of the section. They proposed one real-time method for estimating traffic densities from time series of flow and speed data. The method consists of obtaining a true estimate of vehicle count at regular intervals and then filtering random errors of these estimates by means of a sequential correction scheme. Periodically, an estimation of vehicle travel times is needed from time series speed data, and then a rough estimate of vehicle count is obtained from the inventory of car arrivals at the entrance of the section and the travel times of existing cars.

Lopez-Lopez et.al., [123] provided an alternative approach to estimating SMS and density based on point processing techniques. This approach treated vehicle arrival at a given location as a point or counting Poisson process whose rate is a function of the state of the traffic at every instant of time. The traffic state is modeled as a finite-state Markov
chain. A sequential point process filter, optimum in the mean-squared error sense, was designed to estimate the state from observations of the vehicle arrival-time sequence.

Sheu [124] proposed a stochastic system modeling approach for dynamic prediction of section wide lane traffic characteristics on freeways. This was a recursive estimation algorithm using an extended Kalman filter, truncation and normalization procedures, and a density-updating procedure. This method provided information of inter- and intra-lane traffic variables, though the procedure was very complicated.

Wang et.al., [125] addressed estimation of traffic density and SMS(Space, Mean and Speed) from single-loop data. They found that the assumed uniform vehicle length used to convert occupancy to density is not a constant and varies with the fraction of long vehicles such as trucks in the fleet. They estimated the percentage of long vehicles based on occupancy variance and computed mean vehicle length from a log-linear regression model based only on single-loop outputs. The estimated mean vehicle length could then be used to estimate speed and density.

Angel et.al., [126] applied automated vehicle identification to estimate traffic flow variables including traffic density, but the report did not provide further detail about estimation methodology.

Junghans et.al., [127] used wide area video surveillance for measuring wide area traffic flow parameters such as traffic density. Occlusion robust measurement of traffic density was based on motion measurements and the evaluation of the continuity equation.

Astarita et.al., [128] proposed a method to estimate traffic flow characteristics from a sample of traffic population by using instrumented vehicle counts.

3.6 Vehicle Occlusion Detection

In recent years advanced driver assistance systems (ADAS) have received increasing interest to confront car accidents. In particular, video processing based vehicle
detection methods are emerging as an efficient way to address accident prevention. Many video-based approaches are proposed for vehicle detection, involving sophisticated and costly computer vision techniques. Most of these methods require ad hoc hardware implementations to attain real-time operation and there have been many approaches proposed for tackling related problems in ITS [129-144].

Jun-Wei Hsieh et al., [145] presented an automatic traffic surveillance system to estimate important traffic parameters from video sequences using only one camera. Different from traditional methods which can classify vehicles to only cars and non-cars, this method has a good capability to categorize vehicles into more specific classes by introducing a new “linearity” feature in vehicle representation. In addition, this system can well tackle the problem of vehicle occlusions caused by shadows, which often lead to the failure of further vehicle counting and classification. This problem is solved by taking advantages of a line-based shadow algorithm which uses a set of lines to eliminate all unwanted shadows. The used lines are devised from the information of different lane dividing lines. Therefore, an automatic scheme to detect lane dividing lines is also achieved. The found lane dividing lines also can provide important information for feature normalization, which can make the vehicle size more invariant and thus much enhance the accuracy of vehicle classification. Once all features are extracted, an optimal classifier is then designed to robustly categorize vehicles into different classes. When recognizing a vehicle, the designed classifier can collect different evidences from its trajectories and the database to make the best decision for vehicle classification.

Alternatively, other approaches perform a domain change —via transforms like FFT, inverse perspective mapping (IPM) or Hough transform— that simplifies otherwise complex feature detection. In this work, a cooperative strategy between two domains, the original perspective space and the transformed non-perspective space computed through
IPM, is proposed [146] in order to alleviate the processing load in each domain by maximizing the information exchange between the two domains.

### 3.7 Summary

Although large investments have been made and are continuing to be made in transportation infrastructure, inefficient (and often unscientific) transportation management and traffic control fail to keep pace with increases in population and car use (i.e., increased demand typically measured in Vehicle Miles Traveled). This results in roadway congestion. To minimize the impacts of congestion, it is becoming increasingly important to accurately measure real-time roadway-traffic conditions and manage it. During the past decade, numerous research projects have been carried out in traffic surveillance in terms of measuring traffic performance.

Travel time and travel time reliability are key factors in road management systems, as they are the best indicators of the level of service in a road link, and perhaps the most important parameter for measuring congestion [147]. Travel time estimation is necessary to assess the operational management and planning of a road network. Moreover, travel time information is the best and most appreciated traffic information for road users. The below figure shows the number of papers referred in each area.

![Figure 3.1: Number of Papers Studied in Each Area](image-url)
The strengths and weaknesses of each method discussed in this chapter are shown in tabular format.

Table 3.1: Advantages and Shortcomings of Video Image Processing Methods

<table>
<thead>
<tr>
<th>Methods/Techniques</th>
<th>Advantages (+) and Shortcomings(-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neural Network</td>
<td>+ High Efficiency</td>
</tr>
<tr>
<td></td>
<td>- Vulnerable to Complex Environment and occlusion</td>
</tr>
<tr>
<td>Morphological Operations</td>
<td>+ Good Estimation result</td>
</tr>
<tr>
<td></td>
<td>- Vulnerable to vehicle occlusion</td>
</tr>
<tr>
<td>Markov network &amp; Hidden Markov model</td>
<td>+ Simple</td>
</tr>
<tr>
<td></td>
<td>- Vulnerable to low contrast or poor illumination</td>
</tr>
<tr>
<td>Edge Detection</td>
<td>+ Good Estimation result</td>
</tr>
<tr>
<td></td>
<td>- Vulnerable to Complex Environment and Lighting</td>
</tr>
<tr>
<td>Morphological Operators &amp; Edge Statistical Analysis</td>
<td>+ Good to withstand the variation of the lighting, contrast, rotation</td>
</tr>
<tr>
<td></td>
<td>- High Complexity</td>
</tr>
<tr>
<td>Support Vector Machine</td>
<td>+ Good estimation result</td>
</tr>
<tr>
<td></td>
<td>- Vulnerable to low contrast or poor illumination</td>
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