

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Intelligent Transportation Systems (ITS) have resulted in an increase in the amount of interest in Dynamic Traffic Assignment (DTA) in order to effectively manage the vehicles in real time and to predict the state of the network in the future. One of the main components of Intelligent Transportation Systems is Advanced Traveler Information Systems (ATIS) whose main aim is to provide descriptive or prescriptive information to the users to improve their travel experience. Descriptive information updates the user about the general state of the network or of certain important links in the network. Examples of descriptive information are the travel times on important corridors or the location and severity of incidents in the network. On the other hand, prescriptive information provides specific recommendations to users (e.g. by prescribing the routes to follow) . An example of prescriptive information is the route to be followed from the users' origin to the destination. While providing prescriptive information through route guidance, the strategies used to generate the information provided plays an important role in determining the success of the Advanced Traveler Information System. This chapter provides a review of existing literature on mathematical models and formulations which can be used to generate information strategies for Advanced Traveler Information Systems (ATIS). The literature review first focuses on single user class User Equilibrium (UE) and System Optimal (SO) models. In the single user class models, all the users in the network are assumed to be uniform in terms of information availability, information type supplied and behavioral response to information. Then some of the multiple user class models, where users are classified based on information availability, information supply strategy and behavioral responses are discussed. In the above models, the numbers of users belonging to each user class are assumed to be known beforehand and do not change with time. Some of the limitations of the above model in modeling information strategies for ATIS are discussed.

The next few sections (2.2-2.4) focus on some of the mathematical models, which are commonly used for modeling network information and identifies some of their limitations. Section 2.5 of the literature review focuses on some of the models used in determining

information strategies for Dynamic Message Signs (DMS). The existing information strategies are discussed and some of the limitations of the current models are identified and discussed.

2.2 User Equilibrium Models

According to the definition of user equilibrium condition by Wardrop (1952), no user can improve his experienced travel time by unilaterally switching routes. Therefore, at user equilibrium, the travel time on all routes connecting a given Origin-Destination (O-D) pair is equal and minimal. In other words, the travel time on any unused route will be more than the travel time on a used route. Hence, at user equilibrium, there is no incentive for a user to shift from the current path to any other route. Beckmann et. al. (1956) formulated the static user equilibrium problem with fixed demand as an equivalent optimization problem. A detailed analysis of the static UE problem and its extensions is given by Sheffi (1985). An interesting variant of the static UE problem is the Stochastic User Equilibrium(SUE) problem in which the link travel times and/or user's perception of the travel times are assumed to be random. Sheffi(1985) also gives an extensive review of the concepts involved in Stochastic User Equilibrium. Mahmassani and Chang (1987) proposed a boundedly rational user equilibrium (BRUE) based on Simon's boundedly rational behavioral principle.

Despite its intuitive appeal and valuable insights, several researchers have noted that the assumptions of the static user equilibrium models are severely restrictive in the context of modeling real-time traffic flows. For instance, assumptions such as constant link flows and travel times over the entire peak period may be unrealistic. These models cannot be used to model congestion and user response to real time information (Peeta, 1994). Therefore, to account for time-dependent flows, several quasi-dynamic user equilibrium models have been developed. In a quasi-dynamic user equilibrium model, the planning horizon is broken into smaller intervals and the static user equilibrium problem is solved for each of the intervals. An example of the quasi-dynamic user equilibrium assignment problem can be found in Halati and Boyce (1991). However, one of the disadvantages of the quasi-dynamic approach is that it does not adequately capture the link flow variations in reasonably small intervals of time. Also there is no conservation of flows at boundaries of intervals in which the static user equilibrium problem is solved. The need for modeling congestion and link flow variations in extremely small intervals of time resulted in the development of the time-dependent user equilibrium assignment models.

The early analytical formulations of the time-dependent user equilibrium model were called Dynamic User Equilibrium (DUE) models. These were obtained by extending the Wardrop's condition to departure time choices as well. Under dynamic user equilibrium, all used routes connecting an origin-destination (O-D) pair at a departure time interval have lower travel times than the unused ones for that departure time interval. However, models developed based on the DUE concept were found to have restrictive assumptions like single O-D pair(Ben Akiva et. al.,1986) or found to be analytically intractable(Friesz et. al. ,1993).

Another class of UE formulations arose which assumed the knowledge of time-dependent O-D desires a priori. This removed the departure time choice from the trip maker's choice set. The objective of these models was to equilibrate flows on instantaneous or experienced trip times for every assignment interval in the planning horizon. Many of the time-dependent UE formulations based on control theory equilibrate the instantaneous travel times. However, when equilibrium is based on instantaneous travel times, the actual travel times experienced by the user can be significantly different from the current travel times. Users can switch routes and move to a path with lesser travel times. Some of the earliest models along this line of enquiry, Boyce et. al. (1991), Ran (1993) are applicable for smaller sized networks only and are unrealistic in modeling congestion as they use static link performance functions. Smith (1991) and Janson(1991) modeled the time-dependent user equilibrium using mathematical programming techniques. However, the solution for the above model may lead to unrealistic travel behavior in some cases due to the reliance on static link performance functions, and the properties of the procedure are not sufficiently well established.

Peeta and Mahmassani (1995) obtain the UE conditions for the time-dependent case by generalizing the Wardrop's UE condition. According to this extension, for each O-D pair (i,j), and every departure interval τ , the travel times on all used paths are equal and minimal and the travel times on all unused paths are greater than the travel times on the used paths. These conditions can be succinctly represented by the following equations:

$$r_{ijk}^{\tau} (T_{ijk}^{\tau} - \theta_{ij}^{\tau}) = 0 \quad \forall i, j, k, \tau \quad (2.1a)$$

$$(T_{ijk}^{\tau} - \theta_{ij}^{\tau}) \geq 0 \quad \forall i, j, k, \tau \quad (2.1b)$$

where r_{ijk}^{τ} refers to the number of vehicles traveling on the kth path between origin i and destination j departing at time τ , T_{ijk}^{τ} refers to the travel time experienced by these vehicles and

θ_{ij}^τ refers to the minimum path travel times from origin i to destination j for the departure interval τ . Hence if $r_{ijk}^\tau > 0$ then $T_{ijk}^\tau = \theta_{ij}^\tau$ and if $r_{ijk}^\tau = 0$ then $T_{ijk}^\tau > \theta_{ij}^\tau$.

This section described models and formulations where each user tried to minimize his experienced or instantaneous travel time. However this strategy may not optimal from a system point of view. When every user tries to minimize his individual travel time, the system travel time may become worse. The next section provides an overview of models in which the total system travel time is minimized.

2.3 System Optimal Models

In a System Optimal (SO) model, vehicles are assigned to paths such that the total system travel cost (travel time) is minimized. In the SO assignment, since drivers can reduce their individual travel time by shifting to alternate routes, the system optimal flows generally do not represent equilibrium conditions. Peeta(1994) has classified the studies dealing with system optimal time-varying patterns into 5 classes. The first class of problems involves optimizing the departure time of vehicles along a corridor with a single origin-destination pair (Henderson, 1981). The second class of problems aims to minimize the total system cost in a network with multiple origin and single destination with known time-dependent origin destination desires. Merchant and Nemhauser (1978a, 1978b) formulated the above problem as a discrete-time, non-linear, non-convex mathematical program. Ho (1980) proved the existence of a global optimum by solving a sequence of at most $N+1$ linear programs for N periods. Carey (1987) formulated the above program as a well-behaved convex non-linear program using link exit functions. The above problem is also formulated as a continuous time optimal control formulation where O-D trip rates are assumed to be known continuous functions of time (Friesz et. al., 1989). However the above methodologies are not applicable for multiple destination networks as the First-in First-Out (FIFO) constraint will have to be explicitly specified resulting in a non-convex constraint set.

The third class of problems involves the joint assignment of users to departure times and routes (Chang et. al., 1988). However, the empirical formulation that was proposed dealt with a scenario in an urban corridor with only a single destination. The fourth class of problems involves assignment of random time-dependent O-D desires in a network with multiple origins but a single destination with the objective of minimizing the total system cost. Birge and Ho

(1993) formulated the above problem as non-linear and non-convex multi stage stochastic mathematical programming formulation. In this problem the current assignment decisions are assumed to be independent of future O-D desires.

The fifth class of problems involves assigning known time-dependent origin destination desires between multiple origins and multiple destinations so as to minimize the total system travel time. An optimal control based approach was developed by Ran and Shimazaki(1989). However, this model was illustrated using a small network and does not adequately consider the First-in-First-Out (FIFO) issue. Ghali and Smith(1992a) propose a formulation where vehicles are routed using time dependent marginal travel times . A simulation based procedure is developed which assumes that congestion only develops at pre-specified bottleneck locations. The method for calculating marginal link travel times by Ghali and Smith (1992c) may not be efficient in large-scale networks as their approach is based on brute-force enumeration of of alternative scenarios.

Peeta and Mahmassani(1995) formulate the time dependent System Optimal assignment problem as a non linear mixed integer problem whose objective function is to minimize the experienced travel time of all the vehicles in the network. A computationally more tractable method for estimating the time-dependent marginal travel times was developed to handle larger networks. The time-dependent least cost path algorithm proposed by Ziliaskopoulos and Mahmassani(1993) is used to compute the time dependent least marginal travel time paths and vehicles are assigned to these paths. DYNASMART – a dynamic traffic assignment tool developed at the University of Texas- Austin is used to simulate the traffic. The use of a traffic simulator obviates the necessity of a link performance and exit functions. The use of simulation can also ensure the FIFO condition and capture the complex dynamic interaction between vehicles at a richer level of resolution than analytical models.

The previous sections assume that all the users in the network are homogenous in terms of behavioral response and access to information. However, this assumption is unlikely to hold in many real-world network contexts, where some users may have access to pre-trip information, and others may be able to access en-route information through DMS. Besides, the objective of different users may vary depending on his aspirations, trip purpose, time-of-day etc. Therefore, in order to capture the heterogeneity across drivers, multiple user class models have been developed, which are reviewed in the next section.

2.4 Multiple User Class Models

In the multiple user class models, users are classified into various classes based on access to information, the information supply strategy and the behavioral response of the users to the information supplied. Van Vuren and Watling(1991) describe a multiple user class static assignment problem with three user classes. The travelers are classified into equipped and unequipped class. The equipped travelers are further sub-divided into those who follow paths which minimize their individual travel time – UE class and those who follow paths which attempt to minimize the total marginal travel time for their O-D pair – SO class. The unequipped travelers follow paths which minimize their perceived travel time - SUE class. Hicks et. al. (1992) formulated a multi user class static network assignment model for three user classes as a variational inequality. Unequipped vehicles are routed along SUE paths whereas equipped vehicles are routed along paths corresponding to SO and UE classes described previously. Note that the path of the UE (SO) class paths can differ from the UE (SO) paths discussed in Section 2.2 (2.3), because of the dynamics induced by the presence of multiple user classes. Dafermos (1982) formulates the general multi-modal network equilibrium model where the demands are elastic. In the above formulation, the cost of using a mode on a link is assumed to be dependent on the flows of different modes on all network links.

Nagurney(2000) formulates a multiclass, multicriteria traffic network equilibrium model as a variational inequality in which each class of traveler perceives the travel disutility associated with a link is determined by applying class-specific weights to two criteria : travel time and travel cost. The existence of an equilibrium flow is proved for continuous travel disutility functions, and the uniqueness of the link flows is also established for strictly monotonic travel time functions. The travel time function is dependent on the link volumes (composed of flows from all user classes). Nagurney (2002) extended the above model to deal with elastic demands also. The above models have been illustrated empirically by the authors only for the static (departure-time independent) loading case.

Peeta and Mahmassani (1995) solve the Multiple User Class time-dependent assignment problem for a network with multiple origins and destination in quasi real time. Four user classes are assumed to exist: equipped drivers who follow paths as per the system optimal rule, equipped drivers who follow paths as per the user equilibrium behavioral rule noted at the beginning of this section, equipped drivers who follow a boundedly rational switching rule on prevailing

information and non-equipped drivers who follow externally specified paths. The equilibrium flows are solved using the rolling horizon procedure. In the multiple user class at equilibrium, unequipped drivers can change their routes in response to path changes by equipped drivers.

In the above multiple user class problems, users are assumed to belong to and follow the information or behavior specific to a given user class, with no opportunity to change the class in response to information and/or experience. A user who belongs to the UE class does not receive or have the opportunity to receive other types of information. Hence the number of users belonging to each class is fixed. These formulations do not serve to model certain situations where there are number of information sources each having different network scope or reach. The above assumption of pre-specified classes may be too restrictive while modeling the effect of ATIS. For instance, the fixed multiple user class model precludes modeling traffic when the type of information that is provided to users may change dynamically in response to network conditions (the DMS may switch from providing UE route guidance to SO route guidance if an incident is detected). This class of MUC models are therefore referred to as fixed/static MUC models hereafter. An example of such a situation would be when the controller decides to shift from UE route guidance to SO route guidance depending on the evolving network dynamics. Hence, there is a need to develop multi user class based models where the classes are not pre-specified and are dependent on the dynamics. The models which relax the assumptions regarding the pre-specification of user classes are referred to as Dynamic Multiple User Class Models (DUC) in this study. One instance of application of Dynamic Multiple User Classes is in the context of real-time information through dynamic message signs, where the information/guidance may be varied dynamically in response to network conditions. In this context, the following section reviews pertinent literature on information strategies for DMS.

2.5 Dynamic Message Signs

Dynamic Message Signs (DMS) have been used to display information which can be classified into three main types: advisory, mandatory or requirements and warnings or prescriptive. The various types of information provided by Dynamic Message Sign include recurrent and non recurrent congestion, inclement weather conditions, congestion induced due to special events like football matches, alternate routes, speed restrictions and other special conditions which a user normally does not expect. The main factors affecting the effectiveness of

Dynamic Message Signs are credibility, control logic, message, format, location and spacing of Dynamic Message Signs (Wei, 1992). The main focus of this section is to review existing literature on DMS control strategies or information strategies and the factors affecting their effectiveness. Some of the limitations of the existing strategies are also discussed in this section.

Tsavachidis (2000), conducted a driver response analysis using aggregated data for a DMS based re-routing system in the Greater Munich area. The results of his study indicate that if the alternative route provided is a feasible option to several users, the DMS is more likely to be effective. The study shows that re-routing using DMS can have a significant impact on the routes chosen by travelers and can thus aid in reducing congestion in urban areas. Hounsel et. al. (1998), also recommend increased usage of DMS in providing current information about incidents. When the proportion of users diverting due to DMS increased to 50 %, the journey time increase due to incident was found to be 10 % compared to 22 % under low/no diversion. Up to 40 % of the users found the message on the DMS to be very useful. Chatterjee et. al. (2000), claim that immediate warning messages about unexpected incidents have the potential to significantly benefit the drivers for whom the information is relevant. However the overall benefit was found to be limited and traffic flow data analysis claimed that the number of DMS induced diversions were small. This was attributed to the low proportion of people accessing the DMS from among those passing through the DMS corridor. Up to 4 % reduction in network travel time was observed under such conditions. The study proposes that the impact of DMS can be increased with more accurate, timely and reliable information. The information strategy used is identified as an important factor in enhancing the effectiveness of DMS. Thakuriah et. al. (1996), remarked based on their study, that ATIS systems have tremendous potential for travel time savings (up to 33 %) under carefully constructed route guidance strategies.

Mcdonald et. al. (1998), also support the fact that timely and accurate travel information can result in better route choice decisions resulting in reduced travel time. The study claims that substantial economic benefits can be obtained by using DMS strategies which are integrated with the Urban Traffic Control (UTC). The benefit of a DMS was found to depend upon factors like incident severity, location, duration, and the availability of alternate routes. The benefits obtained were found to be maximum when the DMS induced diversion was between 30 to 50 % . Peeta et. al. (2000), in their study found that the message content had an important role to play in affecting the user's willingness to divert and thus in improving the system performance. The willingness

to divert increased with greater information content. Maximum diversion was observed when the message included incident location, alternative route and expected delay. A stated preference survey conducted by the above authors revealed that 53 % of the drivers would divert if the expected delay on the current route was greater than 10 minutes.

The above studies prove that usage of Dynamic Message Signs can have significant benefits in managing congestion, both recurrent and non recurrent. The control or information strategy used is found to play an important role in determining the effectiveness of Dynamic Message Signs. The next section reviews some of the information strategies developed for Dynamic Message Signs.

2.5.1 Information Strategies for Dynamic Message Signs

Most of the information strategies used for Dynamic Message Signs can be classified into prevailing strategy and predicted strategy. Prevailing strategy provides information based on the current state (link travel times) of the network. Strategies based on prevailing information do not account for future state of the network while providing information. On the other hand, predicted strategies account for the future state of the network while providing information. The future link travel times are taken into consideration while providing information to vehicles. This section gives an overview of some of the prevailing strategies and identifies the problems associated with prevailing strategies. Then, some of the predicted strategies which account for future network state proposed in the literature are discussed and their limitations are identified.

One of the most commonly used information strategy involves providing prevailing information to drivers who are accessing the DMS. The prevailing information strategy is based on the instantaneous or current travel time on all downstream links. However, under prevailing information, the impact of information provided is not considered while providing guidance to vehicles. As a result, providing prevailing information can result in congestion being transferred from one route to another due to overreaction, since the ATIS, in this case, does not account for potential user reaction and response to information (Ben-Akiva et al., 1991). Prevailing information also does not account for future time-dependent loading and demand on downstream links while assigning vehicles to paths. Therefore, the travel time experienced by the user may be significantly different from the travel time reported by the ATIS. Hence, the reliability and

accuracy of prevailing information may decrease, which further lowers compliance and reduces information effectiveness.

Kaysi et. al. (2000), used an analytical formulation on a small four link network to confirm that with predictive information (in the context of IVD's), a higher level of guidance validity is achieved as the discrepancy between reported and experienced travel time is reduced. Chen et. al. (1998), conducted simulation based laboratory experiments on a network with three parallel commuting corridors. The results of the experiment reveal that commuters are more likely to comply with prescriptive information than descriptive information. The compliance rates were found to be highly dependent on the quality and reliability of information. Highest level of compliance was observed under reliable predictive information.

Recognizing the effectiveness of predicted information strategies, several studies have been reported where the DMS seeks to provide time-dependent predicted information. Messmer et. al. (1998), presents the design, implementation and evaluation of DMS guidance system in the interurban Scottish highway network. The information strategy developed was based on simple automatic control triggered by real-time traffic data. Two types of information can be provided through DMS in this study: the magnitude of delay, and route guidance information. Route guidance is given only if the delay on the main route is significant. Vehicles are routed on alternate routes only if the alternate routes are faster than the current routes and if there is sufficient residual capacity on the alternate routes. However, the above approach used pre-specified splitting rates associated with each DMS message. Messmer et. al. (1995), formulated the route diversion through Dynamic Message Sign (DMS) as a dynamic, non-linear discrete time optimal control problem. A gradient-based search technique was used to solve the above problem. Other similar studies which use automatic control based technique to generate DMS guidance strategies include Wang et. al. (2003), Manmar et. al. (1996), Diakaki et. al. (1997). All of the above studies were conducted in Europe and involved simulation and partial field evaluation of the proposed strategies. However, the networks under consideration were inter-urban networks with a limited number of origin destination pairs. The number of alternate routes was few (two in most cases) and these were pre-specified. Most of the studies considered information to be provided to only one fixed destination. Also only one source of information was considered to be present en-route. The presence of pre-trip information was not considered in the above studies and hence the interaction between pre-trip and en-route information was not

studied. The above methods may not be effective in intra-urban networks with multiple origin destination pairs and with numerous paths connecting each origin destination pair.

The following studies also solve for predicted information for DMS, but use time-dependent User Equilibrium (TDUE) or System Optimal (TDSO) routing strategies instead of control heuristics mentioned above. In the Time-Dependent UE (TDUE) strategy, users are assigned to routes that aim to minimize each user's experienced trip time, by applying user equilibrium conditions from the DMS origin to each user's destination. Chiu et. al. (2001) formulated and solved the problem of finding the optimal locations for DMS under stochastic incident scenarios which minimized the sum of each individual's travel time using a bi-level formulation. In this formulation, the upper level problem aimed to determine the optimal location of DMS, given that the information strategy was based on user optimal conditions. The upper level problem was solved using a tabu search methodology. The lower level problem involved determining the optimal information strategy given the optimal locations of the DMS (found by solving the current iteration of the upper level problem). The lower level problem was solved using a simulation-based dynamic network assignment model (DYNASMART). The DMS is assumed to provide route guidance to users along paths to their destinations under a single incident scenario. The travel times on all paths connecting the DMS location to a particular destination are assumed to be equal and minimal.

Valdez-Diaz et. al. (1999) provides a methodology to determine optimal time-dependent percentages of vehicles to be diverted under incident conditions such that the system travel time is reduced. Two classes of users are considered to be present in the system: Class 1 users have no information and class 2 users receive information through Dynamic Message Signs. Class 1 users follow pre-specified paths obtained for a no incident scenario. Class 2 users accessing the DMS follow time dependent System Optimal paths from the DMS location to the various destinations. Optimal time-dependent diversion rates, determined using a MUC model, resulted in a consistently better system performance (up to 15 %) under various incident scenarios.

Oh et. al. (2000) proposed a heuristic to generate dynamic flow splits which were found to be 'close' to a dynamic system optimal solution. The DMS messages are temporally changed to achieve desirable flow splits over time while explicitly incorporating a reasonable driver compliance model. Temporal DMS guidance is found to achieve path flows and network performance comparable to the dynamic system optimum. The performance of the proposed

method was compared with the dynamic user equilibrium strategy. The proposed method was found to perform significantly better than the Dynamic User Equilibrium strategy. However, the improvement in system performance was found to decrease as the DMS update interval increases. When an update interval of 5 minutes was used the Dynamic User Equilibrium strategy was found to perform slightly better than the proposed DMS heuristic.

A common feature of the above studies, which use time-dependent user equilibrium or time-dependent system optimal strategy, is that the network is typically an intra-urban network with multiple origins and multiple destinations. These studies assume that it is possible via a DMS to provide information from the DMS location to each user's destination. This might not be feasible in an intra-urban network with numerous destinations. It is not possible to provide information customized to each user's destination through DMS, due to the cognitive and time constraints associated with information access while traveling at high speeds. Therefore, the DMS can be used to provide information in a region known as the activation zone which normally starts from the DMS location and ends at fixed point located downstream from the DMS location, also referred to as the DMS terminal node hereafter (Wei, 1992). Hence the above studies do not recognize the local scope of the DMS. Furthermore, the studies above do not consider the presence of pre-trip information. As no pre-trip information is provided the interaction between pre-trip and en-route information and its impact on system performance has not received sufficient research attention. In the studies conducted until now, the predicted information provided by the DMS before the incident start time, takes into account the occurrence of the incident. Hence, in these models, the vehicles which start before the occurrence of the incident are also provided with paths that are 'aware' of the incident, even before it occurs. Unfortunately, such a model is unrealistic and over-optimistic, since users that depart prior to the incident start time might still be diverted away from the incident location in response to future occurrence of the incident.

In addition to the UE and SO strategies, other operational and control heuristics have also been proposed for DMS information. Peeta et. al. (2002) have proposed and evaluated a DMS control heuristic framework to find optimal diversion rates under incident situations. The proposed heuristic is found to be consistent with driver response behavior and is responsive to changing traffic conditions. As the messages displayed are consistent with driver behavior, the DMS strategy can be used to generate diversion rates that achieve some system wide objectives.

The control heuristic consists of three sub-algorithms whose main aim is to determine which DMS to activate, the message to be displayed on the active DMS and the frequency of updating of messages. The DMS is activated only if an incident occurs or congestion develops in the vicinity of the DMS location.

Sawaya et. al. (1999) have proposed a predictive feedback control approach for managing freeway incidents using DMS information. The feedback strategy provides alternate routes around incidents and equalizes the predictive travel time on alternate routes. The approach is found to be quite robust to system disturbances and uncertainties in demand, compliance rate and incident severity. Sawaya et. al. (2000) applied stochastic programming concepts to develop a multi-stage mathematical model with recourse to develop an information strategy which accounts for demand variation and system uncertainty. The information strategy provided is found to be robust under all test cases and several realizations of demand and incidents. However, the above studies are conducted on relatively small networks (17 nodes, 25 links) with only a single origin destination pair. Also the presence of pre-trip information source is not considered and hence the interaction between pre-trip and en-route information cannot be studied.

Krishnamurthy (2003) has studied the performance of alternate information supply strategies for DMS and In-Vehicle Devices (IVD). The effectiveness of DMS was found to depend upon: information lag, diversion rate (overconcentration) on to the alternative paths, efficiency of reported paths, time-varying interactions between VMS and non-VMS vehicles, residual capacity on alternate paths, compliance rates, and spatial incident characteristics.

Table 2.1: Review of Currently used DMS strategies

Work	Nature of Information	Coordinated	Consistent	Network Size	Other sources	Customized to dest.	Compliance
Messmer et. al. 1998	Automatic control based, prevailing	No	Yes	Small	No	No	Imperfect
Messmer et. al. 1995	Optimal control problem, prevailing	No	Yes	Small	No	No	Imperfect
Manmar et. al. 1996, Diakaki et. al. 1997, Wang et. al. 2003	Automatic control based	No	Yes	Small	No	No	Imperfect
Chiu et. al., 2001	Predicted, user equilibrium based	No	No	Large	No	Yes	Imperfect
Valdez-Diaz et. al., 1999	Predicted, system optimal based	No	No	Large	No	Yes	Perfect
Oh et. al., 2000	Predicted, system optimal based	No	No	Medium	No	Yes	Perfect
Sawaya et. al., 1999	Predictive, feedback control based	No	No	Small	No	No	Imperfect
Sawaya et. al., 2000	Predictive	No	No	Small	No	No	Perfect
Srinivasan et. al., 2003	Prevailing	Yes	Yes	Large	Yes	No	Imperfect
Peeta et. al. 2002	Control based, prevailing	Yes	Yes	Large	No	No	Imperfect

2.6 Summary

The previous section provides a review of relevant literature on information strategies for Dynamic Message Signs (DMS). Most of these studies have been conducted on small networks and their performance on realistic urban networks cannot be determined. Further, many of these studies assume a single origin destination pair which is also not suitable in an urban setting. Although, some studies are conducted on urban networks, these studies typically assume that it is possible for DMS to provide route guidance customized to each user's destination. This may not be feasible in an urban setting with a large number of destinations. In addition, a majority of the studies reviewed do not consider the presence of multiple information sources and their interactions (e.g. pre-trip and en-route information).

Given these gaps in the current literature on DMS, there is a need to develop information strategies for DMS that address these limitations. The DMS information strategy should consider the presence of the pre-trip information strategy while routing vehicles. Similarly the pre-trip assignment strategy should consider the effect of DMS strategy while assigning vehicles to paths. Also the DMS strategy should recognize the local scope of the DMS i.e. the DMS should provide information from a starting node to a node downstream of the DMS location only. The DMS information strategy should recognize the local scope of the DMS device as well as restrict information access to only users passing through the DMS location. Further, when providing predicted information through DMS, care must be exercised to ensure that the prediction mechanism is sufficiently realistic and consistent with real-world networks. In other words, despite the prediction mechanism, it must be ensured that vehicles which reach the DMS before an incident occurs, are not provided information that is 'aware' of the future occurrence of an incident.