Implementation of Dynamic Traffic Routing for Traffic Congestion: A Review

Norulhidayah Isa[1], Azlinah Mohamed[1], and Marina Yusoff[1,2]

[1] Faculty of Computer and Mathematical Sciences,
[2] Institute of Infrastructure Engineering and Sustainaibility Management,
University Technologi MARA
40450 Shah Alam, Selangor, Malaysia
norul955@tganu.uitm.edu.my, {azlinah,marinay}@tmsk.uitm.edu.my

Abstract. Traffic congestion is a condition where traffic demands exceed traffic capacity. It is a global problem in transportation that occurs around the world especially in metropolitan city. Dynamic traffic routing has been recognized as one of the methods that is capable of dispersing traffic congestions efficiently. This paper reviews the recent implementations of dynamic traffic routing in traffic congestion problems. Study on how the dynamic or online concept has been implemented in traffic routing focusing on definition of dynamic routing, traffic routing environment, traffic routing policy and routing strategy is reviewed in this paper. Some issues such as proactive routing and handling non-recurrent congestion are properly expounded while highlighting some limitations as well as suggestions for future research. As a conclusion, dynamic traffic routing is shown to be an important method in optimizing traffic congestion release. More studies need to be conducted in search of better solution.

Keywords: Traffic routing, Dynamic traffic routing, Online routing, Traffic Congestion.

1 Introduction

Traffic Congestion occurs in various network domains such as, airline travel-planning, video streams in computer networks and transportation network systems [33]. The problem happens when demand is higher than network capacity which leads to the disruption in traffic flow of the network. Traffic congestion in transportation domain has been recognized as a global issue especially in urban areas. One contributing factor to traffic congestion is the increase in human population. Traffic congestion is not only troublesome to drivers, but also lead to increase in air pollution [27] as well as higher probability of accidents [22],[26].

Traffic congestion can be divided into two categories namely recurrent and non-recurrent. Recurrent congestion is a cyclical basis or regular type of congestion due to imbalanced traffic flow during peak hours [16], complex network design structure and planning [47], and frequent ramp on and ramp off [36]. Non-recurrent congestion is an irregular network disruption caused by unplanned incidents and natural disasters

M.W. Berry et al. (Eds.): SCDS 2015, CCIS 545, pp. 174–186, 2015.
DOI: 10.1007/978-981-287-936-3_17

[30], road constructions and work zones[41],[43], and specially planned events such as football tournaments [23].

Various solutions have been developed and implemented in solving traffic congestions especially for congestions in urban areas. Chen et *al.*[4] categorized the solutions into two strategies; hard and soft . Hard strategy involves changes in network topology structure while soft strategy focuses on managing the traffic based on current structure. Hard strategy will incur extra cost and manpower compared to soft strategy. In addition, Liang and Wakahara[24] categorized the solutions into three levels; solution that focuses on reducing traffic demands for example congestion pricing [13], shifting road traffic to other travel modes for example ride and share [1], and dispersing the traffic to maximize the usage of traffic network capacity such as Route Guidance System (RGS) [7],[20].The last solution is the most significant solution. This is due to the ability of reducing the demand especially during peak hours. This is because the first solution will not lessen non-recurrent congestion [15] and for the second solution, it is impossible to control people's mode of transportation.

Traffic routing is known for its capability to normalize the traffic flow by distributing the traffic demands efficiently throughout the network. There are two steps in traffic routing which are traffic route pre-planning and traffic re-routing. In route pre-planning, the idea is to provide route suggestions to the drivers before they left to the destination. Drivers are expected to follow the suggested routes throughout their journey. While in traffic re-routing, the suggested routes will be altered considering several factors, such as real time congestion information and possibilities of congestion. Thus, the vehicle will be re-routed to the least congested route.

This paper reviews the implementation of traffic routing especially dynamic traffic routing in dispersing the traffic in both recurrent and non-recurrent types of congestions. It will discuss how dynamic traffic routing has been implemented in current researches and their limitations.

2 Traffic Routing

Traffic routing is the process of improving traffic flow by redirecting and re-routing the vehicles in the traffic network according to changes in traffic conditions. The main purpose of traffic routing is to homogenize and improve traffic flow in network structure. It is a different problem compared with Vehicle Routing Problem (VRP). In VRP, the algorithm tends to find the shortest path for vehicles to visit all nodes at a time. While in routing process, the objective is to find the best route for vehicles from its origin to the destination.

The routing process is performed with several objectives. In earlier years of routing development, most of the researchers focused on finding the shortest travelling distance. However, with the development of traffic network and the increase in traffic routing process, it is acceptable to sacrifice distance over the time as long as it would prevent traffic breakdown in the network [40]. Regardless of time and distance consideration, the most important objective in solving congestion problems is to normalize the traffic flow. Traffic flow is defined as the number of vehicles passing a given location per time unit [40]. To disperse the traffic flow efficiently, traffic capacity must be fully utilized. Traffic capacity in transportation engineering is defined as the maximum hourly rate vehicles could travel from one point to another in a given time period [37]. That means traffic capacity can be represented by the number of vehicles per hour on a certain lane. To utilize the traffic capacity, traffic assignment must be manipulated where vehicles will be assigned to route depending on traffic state and time. This can be calculated through traffic density. Traffic density is expressed as the number of vehicles on a road segment at a given time [40]. It represents traffic flow over vehicle speed. Traffic flow is number of vehicles passing the specific point in a time interval. Thus, traffic density can be expressed as shown in equation 1.

$$\text{Traffic density} = {}^{Q}\!/_{V} \quad (1)$$

Where: $Q = \frac{\Delta N}{\Delta T}$ (N: number of vehicle, T: time interval), V = Vehicle speed

According to Wardrop principle, improving traffic flow can be done according to two principles which are System Optimal (SO) and User Equilibrium (UE) [37]. SO principle will find the best possible network performance route. It will improve total travel time for whole network and sacrifice individual performance. While UE principle attempts to improve individual performance disregarding the total network performance.

3 Dynamic Traffic Routing

Traffic congestion is a dynamic problem where the traffic environments change continuously over time. Traffic congestion recovery, especially for non-recurrent congestion, can be done by detouring the traffic towards less congested area. In recent years, solutions like Advanced Traveler Information System (ATIS) and Intelligent Transportation System (ITS) have been widely used. The main component in both systems is Dynamic Route Guidance (DRG) which reallocates a new route in order to disperse users from congested lane towards less congested area. The core role of DRG is dynamic traffic routing process where the system must be able to capture real time information and compute the optimal path within acceptable computational time [20].

Dynamic routing falls under dynamic optimization problem where input elements of the problem are changing over time. The objective function for dynamic optimization problem can be deterministic at a given time; however it can be changed throughout optimization process [38]. Russel and Norvig[33] stressed that dynamic algorithm must process the input data as they are received rather than waiting for the input data set become available. In defining dynamic routing Treiber et al. [40] suggested that the routing process must consider the changes in traffic demand and network infrastructure. While Sever et al.[34] stressed that dynamic routing must update the route upon realization of disruption while travelling through the network. Thus, it can be concluded that there are two processes in dynamic routing. First is capturing the changes in the network environment which includes cost and constraints. Second is the process of updating the route or the algorithm responses towards the internal changes and feedbacks along the routing processes. These will be further discussed in Section 3.1 and 3.2.

3.1 Deterministic and Stochastic Environment

According to literature review, traffic routing was developed in two types of environments; deterministic and stochastic. Russel and Norvig [33] highlighted that the specification of these environments is crucial in designing the algorithm. In deterministic environment, current state will determine the next state of environment and action executed by algorithm [33]. The environment is fully observable where it uses static representation of network structure; variables and cost of the surface are predetermined and constant[10],[35]. However, most of the recent DRGs have been implemented in stochastic environments where travelling cost and changes in traffic environments are treated according to the dynamic nature of the problem. In stochastic environment, the next state is partially observable and non-deterministic. The changes will be captured and stored for routing purposes. Stochastic variables are varied from fluctuating cost between two nodes and the changes in the network topology. Most of the researcher considered the road cost as stochastic variables. However, only selected variables will be treated as stochastic.

To illustrate the implementation of stochastic environment, columns three and four in Table 2 depicts several stochastic variables and variables' update strategy in routing process. First, it shows that the most common stochastic variables that had been employed is route density [6],[7], [9],[19],[22],[44]. Route density represents the relation between traffic demand and route capacity. Second is traffic demand or amount [8],[24],[31] where number of vehicles on the road in a time is counted and updated. Other variables that have been employed are vehicle speed, and traffic flow. Traffic flow represents number of vehicle passing certain point on network in a time interval (usually in one hour [24]). Conventionally, route density captures the most researchers' attention in traffic condition representation, however there is an argument saying that traffic amount is better than route density since it was calculated based on data captured in a time interval, which not presenting the current information even it was updated in discrete time[24].

There are two common methods to update the stochastic variables. First is time based update method which can be divided into two fold; discrete time and interval time. In discrete time, the update time is specific. For example if the time t=5 seconds, the variable will be updated for every five seconds. Meanwhile, for interval time, data is updated according to time range for example time t is between 5 to 10, so any change in variable value will be captured and updated within that time. Second method is node or intersection based. The update process happens whenever vehicles arrive at new node or intersection. It will be based on vehicles' positions.

3.2 Online and Offline Routing Policy

Referring to the dynamic routing definition defined in previous section, routing algorithm should be able to react according to the internal changes and feedbacks along the routing processes. It means that even when the vehicles have begun to traverse the route, the algorithm must consider re-routing the path if there are changes in traffic cost. In implementing traffic routing, there are two types of routing policy which are online and offline routing [34] and some of the researchers use terms such as static and dynamic routing [37].

In offline policy, the route is pre-planned before vehicles begin travelling according to specified origin and destination. The routing process stops when the vehicles leave the destination. Offline policy can be implemented in stochastic environment where variables or traffic cost is updated before the route is generated. Another category of offline policy is known as robust strategy that manipulates predicted data in routing process. The route is generated with the guideline of predicted data on the assumption that the projected data is 100% correct.

For Online routing policy, the algorithm tries its best to respond towards the changes and feed back in real time manner even when the vehicles have started traversing the route. To implement this, the route is preplanned beforehand; when the vehicles started to traverse the route, the algorithm will monitor the changes of the variables and will check for the need to re-route. Therefore, online routing must be executed in stochastic environment.

Table 1 demonstrates twelve publications from 2012 to 2014 that used dynamic or real time in the tittle. It shows that even though it uses dynamic or real time in the title, the routing policy used is not necessarily dynamic or online. The word dynamic in the tittle is referring to the stochastic environment used in the routing process. Going through the twelve publications, it can be construed that the implementation of dynamic or real time can be divided into two, dynamic in both environment and algorithm policy and dynamic in terms of environment only. Even with the usage of stochastic variables, the second type of implementation will lead to oscillation of traffic congestion at certain path because it disregards the dynamic state of traffic congestion. Even if it uses robust policy where the congestion is predicted, cost will increase because the projected data are only assumed 100% correct [37].

To give a clear view on how dynamic traffic routing have been implemented, columns five to seven in Table 2 presents a review on Routing Policy, Optimization Method, and Online Policy Implementation in recent traffic routing implementations. According to the literatures, the implementation of Online routing policy was done in two fold; re-route in a time interval and re-route at a node or intersection. For time interval implementation, routing algorithm will re-calculate the remaining route in specific time frame. If there is a better route, the vehicles will be re-routed. If not vehicles will follow the pre-calculated route. Second method is re-calculating the best route at each node or intersection. When the vehicles arrived at an intersection, algorithm will calculate the next movement for the vehicles. If there is a better route compared to pre-calculated route, the vehicles will be suggested to follow the new route.

Re-routing process happens in several conditions, (1)when routing algorithm predicts there would be a congestion for the next traversal lane [24], (2)based on level of congestion impact towards current route [32], (3)when there is delay in travel time [5] , and (4) when the density of the route exceeds route capacity. The re-routing process was done by focusing on the origin of journey and destinations of each vehicle that is; routes were calculated for single vehicles according to their specified destinations. Then during the process, rerouting will be implemented either for all vehicles or just focusing on selected vehicles only. The selection of the vehicle process will be based on the urgency which will be measured according to the impact of congestion or disruption towards the vehicles.

Table 1. Recent publication on Dynamic Routing.

Ref.	Publication Tittle	Routing Policy
[5]	Research on Dynamic Route Guidance for An Emergency Vehicle Considering the Intersection Delay	Online
[8]	Multiple Constrained Dynamic Path Optimization based on Improved Ant Colony Algorithm	Online
[24]	Real Time Urban Traffic Amount Prediction for Dynamic Route Guidance Systems	Online
[25]	Dynamic Route Guidance Algorithm Based on Improved Hopfield Neural Network and Genetic Algorithm	Offline
[22]	Dynamic Travel Path Optimization System Using Ant Colony Optimization	Online
[29]	Distributed Regret Matching Algorithm for a Dynamic Route Guidance	Online
[46]	Dynamic Route Choice Based on Prospect Theory & Online	Online
[2]	Dynamic Route Choice Based on Prospect Theory	Offline
	Real Time Vehicle Routes Optimization by Cloud Computing in The Principle of TCP/IP	
[34]	Dynamic Shortest Path Problems: Hybrid Routing Policies Considering Network Disruptions	Online
[39]	Real-time Vehicle Route Guidance Based on Connected Vehicles	Offline
[45]	Dynamic Route Guidance Using Improved Genetic Algorithms	Offline
[11]	Dynamic Routing Under Recurrent and Non-recurrent Congestion Using Real-Time ITS Information	Online

3.3 Reactive versus Proactive

Another aspect that has been discussed in dynamic routing is type of data. In traffic routing, there are three categories of data commonly used. First category is historical data. Second category is data collected in real time representing current conditions of traffic environment and third category is predicted data, calculated based on current and historical data. Routing process that employs current data, or current data together with historical data is known as reactive routing. While routing process that include predictive data is known as predictive or proactive routing.

Reactive routing uses the snapshot of current traffic information to develop the route while proactive or also known as predicted routing strategy utilizes predicted traffic information to predict the future traffic condition. The implementation of the route planning in reactive strategy is faster [18], nevertheless it will lead to oscillation congestion problem since the future condition of the traffic is not considered [44].

In proactive routing, the routing is calculated considering future conditions. Different proactive variables have been used for example route density, time arrival probability, and route disruption possibility. The proactive data is used especially in avoiding congestion. References [6], [9], [44] consider route density of the routes based on on-going plan route in routing the vehicles. The constructed route will avoid the routes that have higher predicted route density. While Chen et *al.* [3] estimated probability of arriving at the destination based on expected travel time.

Table 2. Recent Traffic Routing Implementation

Ref.	Stochastic Variables	Update Strategy	Routing Policy	Optimization Method	Online Policy Implementation
[5]	Vehicle Speed	Intersection	Online	Dijkstra Algorithm	Time Interval
[7]	Route Density	Discrete Time	Offline	Inverse Ant Based System	NA
[8]	Traffic Amount	Discrete Time	Online	Genetic Algorithm	Intersection
[9]	Route Density	New Demand	Offline	Genetic Algorithm	NA
[14]	Traffic flow	Discrete Time	Online	Mathematical Programming	Intersection
[17]	Travel speed	Intersection	Online	Ant Colony Optimization	Time Interval
[22]	Route density	Intersection	Online	Ant Colony Optimization Algorithm	Intersection
[24]	Traffic Amount	Interval Time	Online	Dijkstra Algorithm	Travel Delay Exist or predicted
[29]	Traffic flow	Interval Time	Online	Regret Matching Algorithm	Intersection
[31]	Traffic Demand	Interval_Time	Online	Ant Colony Optimization & Dijkstra Algorithm	Time Interval
[42]	Route Density	Discrete Time	Offline	Ant Colony Optimization	NA
[21]	Route Density	Intersection	Online	Brownian Agent	Intersection
[32]	Vehicle speed	Interval Time	Online	Dijkstra & A* Algorithm	Time Interval
[34]	Disrupted Lane	Discrete Time	Online	Backward Recursive Algorithm	Intersection
[39]	Vehicle Speed	Segmentation	Offline	Dijkstra Algorithm	NA
[44]	Route Density	New Available data	Offline	A* Algorithm	NA
[11]	Vehicle velocity, incidents & delays	Discrete Time	Online	Markov Decision Process	NA

3.4 Non-recurrent Congestion

Non-recurrent Congestion (NRC) is a traffic congestion due to unusual event and other factors that change the normal traffic condition. It will cause greater congestion compared to daily problem. A change of 5% in daily condition can be classified as

NRC [28], [12]. The changes are obtained from percentage lane occupancy, traffic volume and vehicle speed [12]. Non-recurrent congestion contributed up to 60% delay in United State [28] and caused 50% of traffic delay [11] in transportation domain. However, this problem attracts less attention compared to recurrent congestion due its infrequent occurrence [12].

Table 3 below depicts several literatures that consider non-recurrent congestion in their routing process. Literatures except for reference [28] re-route vehicles with the objective of avoiding the affected place. The solutions are focusing on routing the vehicles with the objective to avoid the congestion area. The congestion will be predicted according to delay. Even those researchers consider non-recurrent congestion in rerouting process, most of them provide planning to avoid the congestion but not consider vehicles that already trapped in the traffic. In addition, route availability is neglected. Route availability is one of the most important in re-routing process [4] especially when it involved total route closure.

Table 3. Non-recurrent Congestion(NRC) in Dynamic Routing

Author	Variables to Consider	NRC	NRC Handling Methods
[17]	Travel delay	Difference between current & regular delay	Re-route each vehicles(avoid low speed route).
[28]	Flow rate, incident duration & blocked lane info.	5% changes from normal condition	Provide detour plan for traffic control management
[8]	Route Vulnerability.	Predicted based on current and historical data	Vulnerable lane will be avoided for each vehicle
[11]	Incident delay	Incident delay is predicted using Markov Chain Model	The vehicles will be re-routed based on new travel time

4 Findings and Discussions

In summary, there are three main components in traffic routing implementation; i) routing environment, ii) routing policy, and iii) update strategy for environment and routing policy. Dynamic traffic routing falls under online routing policy and must be implemented in stochastic routing environment. To adapt with the changes, the variables and routes must be updated frequently. Update strategy will specify the method uses in updating routes and variables. These finding is shown in Figure 1 above. In real implementation, the route will be updated in specified time; however the implementation of new route will be employed at the next intersections or nodes due to nature of network structure.

In developing dynamic traffic routing, stochastic environment is used to interpret the real environment situation into computer readable. Basic representation for city network structure can be represented using Graph set where $G(A, N)$ where N is a set of nodes and A is a set of links. Then traffic data must be incorporated with the city network structure. Both can be done through several method such as 3D simulation software for example StarLogo Software [5], Traffic Model Simulation software MAINS2IM (Multi- modAl INnercity SIMulation) [7] and others. Simulated data [5]

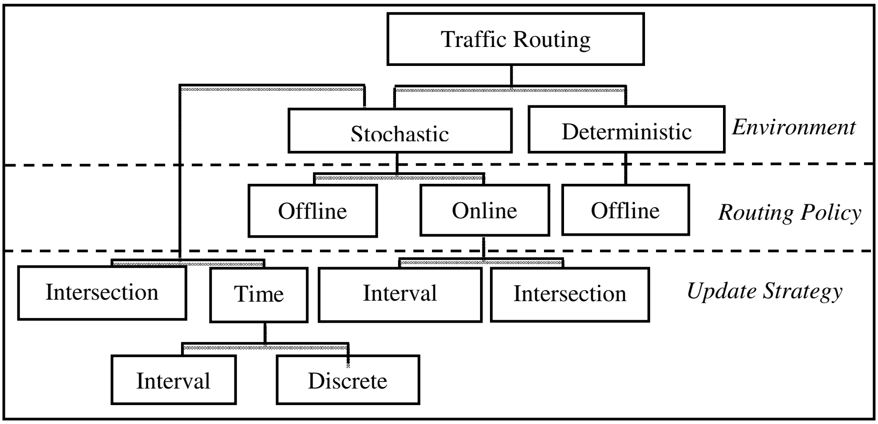

Fig. 1. Traffic Routing Conceptual Framework

or real scenario will be integrated into the simulation software to represent real network structure. The real data were collected uses several methods such as through Vehicle Adhoc Network, Geographical Information System, and loop detector. The data is collected and must be updated to the simulation environment. The update strategy for the data consists of two types. First, the data is updated every time vehicles arrived at the intersection. Vehicles acted as an agent to collect data such as vehicle's location and travel time along. Every time vehicles arrived at the intersection, collected data will be updated. Second strategy is time based strategy. It can be divided into two which are discrete and interval time strategy.

In dynamic traffic routing, online routing policy must be implemented. The objective of online routing policy is to adapt with the changes in traffic routing environment. This will involve constructing a new route for vehicles. Researchers used traffic density as an indicator in constructing new route. The process can be done two types of update strategy. First is in time interval and second is when the vehicles arrived at new intersection. Balanced route will be re-evaluated, if high density lane is detected in pre-planned route, the pre-planned route will be re-evaluated. New route will be calculated and cost for both routes (pre-planned and new route) will be compared. If new route has a better travel cost, vehicles will continue their journey with new route, if not it will use the pre-planned route.

Dynamic traffic routing has been extensively study and proven as one of the methods to reduce traffic congestion. Fluctuating cost between nodes in terms of route density and traffic flow have been extensively used in developing the dynamic traffic routing. These variables have been proven able to represent current vehicle movement on specific path and could be used in solving traffic congestion and travel delay. However it is not sufficient in capturing the non-recurrent congestion especially when there involves route closure or route availability. Uncertain event like flash flood or fatal accident will lead to serious congestion and will involve several road closures. This problem requires detail solution in detour the vehicles at the congested area

Among the related issues highlighted by researchers in traffic routing are the algorithm's capability in providing real time guidance and the congestion handling efficiency [32]. Most of the proposed routing algorithm assumed the origin and destination of each vehicle are known beforehand. For a large scale network, it would be computationally expensive to calculate or re-route all the vehicles according to the origin and destination during congestion [32]. Current solutions proposed by researchers are to select certain most affected vehicles to be re-routed[24], [32]. [24] found that vehicles which were not involved in re-routing would benefit more in terms of travelling distance compared to vehicles involved in re-routing. Besides, increase in number of re-routings would increase the computational cost. Research findings also show at least 15 percent of the vehicles involved in re-routing will have longer travelling time compared to vehicles which were not [32].

5 Conclusion

In this paper, recent publications in dynamic traffic routing for traffic congestion were reviewed. This review suggests that in general, Traffic Routing Conceptual Framework can be divided into three levels as shown in Figure 1. This framework constitute to the field of traffic routing where it can be used as a reference for further research.

Although the issue of enhancing network performance using dynamic traffic routing has been extensively study, there are a couple of limitations that need to be looked into. One of them is most of the developed researches were focusing on guiding the specific vehicle or single traveler route guidance based on specific origin and destination. Routes are calculated according to the each vehicle preferences. Even though some of the developed route guidance was based on system optimum traffic assignments they still concentrate on individual vehicles. Each vehicle will be guided towards less congested area according to each vehicle preferences.

In disseminating traffic congestion especially in non-recurrent congestion, the main objective is to reduce the impact of the congestion for the whole network by dispersing the traffics at the affected area and to avoid incoming traffic from flowing to the affected area. The setback is, to apply dynamic route guidance for the whole route will require a lot of computational time especially when it involves various origins and destinations. So the question to be answered is what if instead of focusing on single vehicle the dynamic route guidance focuses on multiple vehicles; the objective is to withdraw vehicles from the congested area. So, instead of re-route the vehicles according to their specific preferences, detour plan should be provided to bring the vehicles to the nearest less congested area. The plan should consider all possible directions nearby in constructing the routes.

In non-recurrent congestion, a pre-planned road closure must be executed due to various reasons for example constructions, Independence Day ceremony and etc. In this situation, route density cannot be used in the routing process. In Kuala Lumpur, Malaysia, current implementation is by informing road users beforehand but with no proper guideline given. This raises another question to be answered, what is the best method to re-route the vehicles in such situation.

References

1. Agatz, N., et al.: Optimization for dynamic ride-sharing: A review. European Journal of Operational Research 223(2), 295–303 (2012)
2. Cai, M., et al.: Realtime vehicle routes optimization by cloud computing in the principle of TCP/IP. In: 2013 10th International Conference on Service Systems and Service Management (ICSSSM), pp. 113–118 (2013)
3. Chen, B.Y., et al.: Finding reliable shortest paths in road networks under uncertainty. Networks and Spatial Economics 13(2), 123–148 (2013)
4. Chen, S., et al.: Traffic dynamics on complex networks: a survey. Mathematical Problems in Engineering 2012 (2011)
5. Chen, S.S., et al.: Research on Dynamic Route Guidance for an Emergency Vehicle Considering the Intersection Delay. Applied Mechanics and Materials, 848–852 (2014)
6. Cong, Z., et al.: Ant Colony Routing algorithm for freeway networks. Transportation Research Part C: Emerging Technologies 37, 1–19 (2013)
7. Dallmeyer, J., et al.: Don't go with the ant flow: Ant-inspired traffic routing in urban environments. Journal of Intelligent Transportation Systems (2014) (just-accepted)
8. Dewen, S., et al.: Multiple Constrained Dynamic Path Optimization based on Improved Ant Colony Algorithm. International Journal of U- & E-Service, Science & Technology 7(6) (2014)
9. Dezani, H., et al.: Optimizing urban traffic flow using Genetic Algorithm with Petri net analysis as fitness function. Neurocomputing 124, 162–167 (2014)
10. Gubins, S., Verhoef, E.T.: Dynamic bottleneck congestion and residential land use in the monocentric city. Journal of Urban Economics 80, 51–61 (2014)
11. Güner, A.R., et al.: Dynamic routing under recurrent and non-recurrent congestion using real-time ITS information. Computers & Operations Research 39(2), 358–373 (2012)
12. Gurupackiam, S., et al.: A Snapshot of Lane-specific Traffic Operations under Recurrent and Non-recurrent Congestion. International Journal of Traffic and Transportation Engineering 3(4), 199–205 (2014)
13. Hoffman, K., et al.: Congestion pricing applications to manage high temporal demand for public services and their relevance to air space management. Transport Policy 28, 28–41 (2013)
14. Hu, P., Ma, Z.: Travel Efficiency in Urban Traffic Networks Based on Routing Strategies. Journal of Applied Science and Engineering Innovation 1(5) (2014)
15. Isa, N., et al.: A review on Recent Traffic Congestin Relief Approaches. In: 4th International Conference on Artificial Intelligence with Applications in Engineering and Technoology. IEEE (2014)
16. Ishikawa, K., et al.: A decision support model for traffic congestion in protected areas: A case study of Shiretoko National Park. Tourism Management Perspectives 8, 18–27 (2013)
17. Jabbarpour, M.R., et al.: Ant-based vehicle congestion avoidance system using vehicular networks. Engineering Applications of Artificial Intelligence 36, 303–319 (2014)
18. Jahn, O., et al.: System-optimal routing of traffic flows with user constraints in networks with congestion. Operations Research 53(4), 600–616 (2005)
19. Jiang, B., Xu, X., Yang, C., Li, R., Terano, T.: Solving Road-Network Congestion Problems by a Multi-objective Optimization Algorithm with Brownian Agent Model. In: Corchado, J.M., et al. (eds.) PAAMS 2013. CCIS, vol. 365, pp. 36–48. Springer, Heidelberg (2013)

20. Jiang, B., et al.: Time-dependent pheromones and electric-field model: a new ACO algorithm for dynamic traffic routing. International Journal of Modelling, Identification and Control 12(1), 29–35 (2011)
21. Jiang, Z., Li, S.: Research on Optimized Control Model of Freeway Based on Dynamic Traffic Demand Estimation. Advances in Mechanical Engineering 2014 (2014)
22. Kponyo, J., et al.: Dynamic Travel Path Optimization System Using Ant Colony Optimization. In: Proceedings of the 2014 UKSim-AMSS 16th International Conference on Computer Modelling and Simulation, pp. 142–147 (2014)
23. Kwoczek, S., et al.: Predicting Traffic Congestion in Presence of Planned Special Events (2014)
24. Liang, Z., Wakahara, Y.: Real-time urban traffic amount prediction models for dynamic route guidance systems. EURASIP Journal on Wireless Communications and Networking 2014(1), 1–13 (2014)
25. Lin, N., Liu, H.: Dynamic route guidance algorithm based on improved hopfield neural network and genetic algorithm. Int. J. Innov. Comput., Inf. Control. 10(2), 811–822 (2014)
26. Litman, T.: Factors to Consider When Estimating Congestion Costs and Evaluating Potential Congestion Reduction Strategies (2013)
27. Litman, T.: Smarter Congestion Relief in ASIAN Cities. Transport and Communications Bulletin for Asia and the Pacific 82(1) (2013)
28. Liu, Y., et al.: Decision Model for Justifying the Benefits of Detour Operation under Non-Recurrent Congestion. Journal of Transportation Engineering 139(1), 40–49 (2013)
29. Ma, T.-Y.: Distributed Regret Matching Algorithm for a Dynamic Route Guidance. In: Jezic, G., Kusek, M., Lovrek, I., Howlett, R.J., Jain, L.C. (eds.) Agent and Multi-Agent Systems: Technologies and Applications. AISC, vol. 296, pp. 107–116. Springer, Heidelberg (2014)
30. Mun, L.S.: Blue Ocean Strategy in Traffic Management for Bandaraya Kuala Lumpur (2013)
31. Ochiai, J., Kanoh, H.: Hybrid Ant Colony Optimization for Real-WorldDelivery Problems Based On Real Time and Predicted Traffic in Wide Area ROad Network. Computer Science (2014)
32. Pan, Y., Xu, J.: Traffic network design problem with uncertain demand: A multi-stage bi-level programming approach. World Journal of Modelling and Simulation 9(1), 68–73 (2013)
33. Russell, S., Norvig, P.: Artificial intelligence: A modern approach. Prentice Hall Pa. (2009)
34. Sever, D., et al.: Dynamic shortest path problems: Hybrid routing policies considering network disruptions. Computers & Operations Research 40(12), 2852–2863 (2013)
35. Spears, W.M., Prager, S.D.: Evolutionary search for understanding movement dynamics on mixed networks. GeoInformatica 17(2), 353–385 (2013)
36. Spiliopoulou, A., et al.: Macroscopic traffic flow model validation at congested freeway off-ramp areas. Transportation Research Part C: Emerging Technologies 41, 18–29 (2014)
37. Suson, A.C.: Dynamic routing using ant-based control (2010)
38. Talbi, E.-G.: Metaheuristics: from design to implementation. John Wiley & Sons (2009)
39. Tian, D., et al.: Real-Time Vehicle Route Guidance Based on Connected Vehicles. In: Green Computing and Communications (GreenCom), 2013 IEEE and Internet of Things (iThings/CPSCom), IEEE International Conference on and IEEE Cyber, Physical and Social Computing, pp. 1512–1517 (2013)
40. Treiber, M., Kesting, A.: Traffic Flow Dynamics: Data, Models and Simulation. Springer, Heidelberg (2013) ISBN 978-3-642-32459-8

41. Tympakianaki, A., et al.: Real-time merging traffic control for throughput maximization at motorway work zones. Transportation Research Part C: Emerging Technologies 44, 242–252 (2014)
42. Wei, C., et al.: Formulating the within-day dynamic stochastic traffic assignment problem from a Bayesian perspective. Transportation Research Part B: Methodological 59, 45–57 (2014)
43. Weng, J., Meng, Q.: Estimating capacity and traffic delay in work zones: An overview. Transportation Research Part C: Emerging Technologies 35, 34–45 (2013)
44. Wilkie, D., et al.: Adaptive Route Planning for Metropolitan-Scale Traffic. In: SPARK 2013 (2013)
45. Yu, Z., et al.: Dynamic route guidance using improved genetic algorithms. Mathematical Problems in Engineering 2013 (2013)
46. Zhang, W., He, R.: Dynamic Route Choice Based on Prospect Theory. Procedia-Social and Behavioral Sciences 138, 159–167 (2014)
47. Zhao, D., et al.: Computational intelligence in urban traffic signal control: A survey. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews 42(4), 485–494 (2012)