Present and Future Perspective on Optimization of Road Network Management

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***Abstract*— The road network is salvation for economy of any region and social welfare. In observation of dynamicity on road networks and the sharp increase of traffic congestion, accidents, states, the road traffic management becomes more challenging research area. It is need to develop efficient and optimized road network management to prevent the traffic congestion and accidents in the present development. The aim of this paper is to provide a short and snappy review of available various optimization techniques for road network management. Also, open issues on road network optimization is discussed.**

***Keywords*— Road Network Management, Traffic Congestion, Optimization, Fuzzy Logic, Genetic Algorithm, Swarm Intelligence.**

I. INTRODUCTION

Road network is a vital infrastructure for economic growth and development of a country. India is one of the largest road networks of over 64, 99, 000 km [1]. Government of India has launched a motivated 100 smart cities programme and it is expected to expansion of Indian Road Network. Efficient road network enable a better mobility for people and goods as well as better connection between regions. A region cannot be competitive without an efficient road network and it stimulus both economic growth and social harmony.

The expansion of road network is an important for the economic growth and in the same time road safety is also an important issue of national concern, considering its magnitude and gravity. The consequent of it negative impacts on the economy, public health and the general welfare of the people. Today, road traffic injuries are one of the leading causes of deaths, disabilities and hospitalizations, with severe socioeconomic costs, across the world. 4, 86, 476 road accidents were reported in India during year 2013 and 1, 37, 572 persons were killed and 4, 94, 893 persons were injured during this accidents [2]. Another, economic problem arises in the road network is traffic congestion. As per the joint study of Transport Corporation of India and Indian Institute of Management Calcutta estimated the India loses nearly 600 billion of Indian Rupees a year due to traffic congestion, slow speed of freight vehicles and waiting time at toll plazas and checking points etc.[3].

In view of the increase of vehicle number, accidents and traffic congestion situations in all road networks have become wide spread all over the world. An accurate road network management will allow more efficient vehicle routing over time and space, in order to improve traffic efficiency, etc. Dynamic involvements means the need of an auto detection of road congestion situations or incidents, so vehicles will be adapted according to the new road network situation.

Since the traffic management requires clear understanding of the flows, especially congestion cases, researchers are encouraged to have recourse to traffic simulations. The traffic simulation is the best achievable option to make predictions in a scientifically proven way. It may be very expensive to carry out the real plan. Simulation results allow researchers and manufactures to make better decisions, understand and optimize the performance or reliability of complex systems. The applications are designed to inform drivers about the traffic situation and give recommendations, regulate the traffic with signals and messages, and so on. In fact, since some years, various successful experiments notified the advantages of combining transportation field with artificial intelligence and soft computing [4].

The above scenario highlights the need for efficient road network management research and the many researchers have contributed in this field. The current trend of research work in road network management is to investigate in intelligent approaches integrating soft computing techniques, distributed and collaborative intelligence, bio-inspired intelligence, hybrid approaches, and others. The challenge is to take advantage of each research trend and provide an innovative road network management [5]. These methods can be roughly classified as Graph Theory based road traffic management, Genetic algorithm based road traffic management, fuzzy logic based road traffic management, and swarm intelligence based road traffic management.

This paper presents a concise detailed survey of road network optimization methods and explores the future scope of research in this field. The next section literature review on optimization technique of road traffic management will be provided. Section 3 will provide a

list of available freeware and commercial simulator which used for the road network management. Section 4 shows the future research perspective on this field. Finally, the study will be concluded on section 5.

II. Literature Review of Road Traffic Management

The optimization techniques for the road network management were proposed by researchers. In this section, optimization techniques were grouped as per the utilized approach and a brief review is provided incorporating with the strength and limitation of those algorithms.

A. Graph Theory based Road Traffic Management

The classical minimum shortest route algorithm such as Dijkstra algorithm, Priority queues, bidirectional search etc. are used by many research for road traffic management [6]. Appert et al. [7] utilized graph theory for the measuring urban road network vulnerability. Baruah and Baruah [8] proposed cut-set of graph for the traffic control problem. As the complexity of traffic control on network expansions it becomes more complicated to coordinate the actions of the large number of heterogeneous traffic management instruments that are available in the network. One way of handling this complexity is to divide the coordination problem into smaller coherent sub-problems that can be solved with a minimum of interaction. Multiagent systems can aid in the distribution of the problem (over the various agents that comprise the multiagent system) and facilitate the coordination of the activities of these agents when required. In the literature no consensus exists about the best configuration of the traffic managing multiagent system and how the activities of the agents that comprise the multiagent system should be coordinated [9]. Katwijk et al. [9] reported a test bed for multiagent control systems in road traffic management that can deals the traffic managing multiagent system can be configured, evaluated in a realistic simulated traffic environment, easily transferred to a real world application. Raza and Rao [23] proposed agent based urban traffic and transportation control. This paper gives a theoretical foundation of an intelligent traffic clouds.

B. Genetic Algorithm based Road Traffic Management

Genetic Algorithms (GAs) have been demonstrated to be a promising search and optimization technique. It has been successfully applied to system identification and a wide range of applications including filter design, scheduling, routing, control, and others. For applying GAs to complex problems has been the high computational cost due to their slow convergence rate is one of the main obstacles. Han and Tabata [10] combined a genetic algorithm and controlling lethal gene for solving of the vehicle routine problem but the performance for the practical example was not investigated. Meshkat and Vrancken [11] used multi-objective technique for the road network partitioning. This study fast and elitist Non-dominated Sorting Genetic Algorithm (NSGA-II) and Pareto Archived Evolution Strategy (PAES) were implemented. Jiang et al. [12] proposed an agent model with adaptive weight-based multi-objective algorithm to manage road-network congestion problem. The aim of this study was to construct a quantitative index series to describe the road-network congestion distribution, and use such indexes as weights in the multi-objective algorithm to shunt vehicles on those congested links. In the first phase, a multi-agent system was built, where each agent stands for a vehicle that adapts its route to real-time road-network congestion status by a two-objective optimization process: the shortest path and the minimal congested degree of the target link. The agent-based approach captures the nonlinear feedback between vehicle routing behaviors and road-network congestion states. Next, a series of quantitative indexes was constructed to describe the congested degree of nodes, and such indexes were used as weights in the two-objective functions which were employed by the agents for routing decisions and congestion avoidance.

C. Fuzzy Logic based Road Traffic Management

The fuzzy logic appeared in 1965 by Zadeh introducing the concept of fuzzy sets. It was shown as a very capable mathematical approach for dealing with subjectivity, ambiguity, uncertainty, and imprecision [5]. Fuzzy logic was used as a framework to solve transportation problems such as traffic assignment problem, accident analysis and prevention, traffic control at roads intersection, and traffic light control.

During the last decade, some developments in information acquisition technologies through advanced traveller information systems have been done. However, many contextual factors (such as departure time, travel distance, usual driving speed of the driver, weather information, personal preferences, roadwork information, and other information which could be available to the guidance systems in real-time) increase the uncertainty of the itinerary choice.

Ridwan [13] used choice function based fuzzy preferences relations and considered the spatial knowledge of individual drivers. This method strengthened the travel decision by fuzzy preference relations but it utilized small number of influence factors and in real scenario there are multiple influence factors. Hawas [14] estimated the route utility by using neuro-fuzzy data training with a hidden neuron in each fuzzy process. This method used adaptive to the variation of perceptions from drivers but there is no fuzzification

training not exist. Arslan and Khisty [15] developed route choice model. They utilized hybrid model based on fuzzy logic and analytical hierarchy process. The preference was extracted from driver's psychology.

Ghatee and Hashemi [16] proposed quasi logist formula based algorithm for traffic assignment. It maximizes the level of certainty and minimizes the perceived travel delays. The limitation of this study is no results for real networks. Balaji and Srinivasan [17] proposed multi agent system based on type-2 fuzzy decision module for urban traffic management. This method reduces the total delay of vehicles and it was simulated on real traffic of Singapore. The limitation of this method is unavailability of vehicle route guidance. Kammoun et al. [4] [5] proposed an adaptive multiagent system based on the ant colony behaviour and the hierarchical fuzzy model. This system allows adjusting efficiently the road traffic according to the real time changes in road networks by the integration of adaptive vehicle route guidance system. This system was implemented and simulated under a multiagent platform in order to discuss the improvement of the global road traffic quality in terms of time, fluidity and adaptivity.

D. Swarm Intelligence based Road Traffic Management

The swarm intelligence has been used to model complex traffic and transportation processes. In fact, the self-organization of the social insects is based on relatively simple rules of individual insect's behavior. Among the different colony insects, the ant colony succeeds to find food by following the path with highest pheromone quantity deposited by other ants [4]. The pheromone signal represents the communication tool between individual ants. It contributes to the formation of collective intelligence of social ant colonies that can be considered as multi-agent systems.

Bertelle et al. [18] proposed road traffic management by using ant system for shortest path in weighted dynamic graph. This method utilized neural networks for traffic flow regulation and it simulated using multiagent platform. Yang et al. [19] proposed optimization model based on coarse-grain parallel ant colony algorithm for the bus network optimization. It was demonstrated on data of Dalian city, China but it did not consider the real time traffic management. Deng et al. [20] proposed hybrid particle swarm optimization algorithm by combining fluid neural network. This method is influenced by search best path in stochastic traffic networks and this method was simulated with only 20 nodes road network. D'Acierno et al. [21] proposed swarm intelligence algorithm to optimize the signal setting of each intersection for the asymmetric traffic assignment and it lacks on real time management. Garcia-Nietoa et al. [22] used particle swarm intelligence to find cycle programs of traffic lights and implemented for 2 cities in Spain.

Mostly, Ant Colony Optimization was used to solve transportation problems such as Travelling Salesman Problem (TSP) and Vehicle Routing Problem (VRP), only few works based on swarm intelligence are developed to solve road traffic management problem [5]. In fact, the problem cannot be solved using the classic versions: artificial ants are able only to generate successively shorter feasible tours by using information accumulated in the form of a pheromone trail deposited on the graph edges.

III. Road Traffic Simulators

There are a number of basic traffic simulators available which have been created to demonstrate many different ideas or phenomena. These simulators can be used in the research on optimization of road network problem. In this section, some popular traffic simulators used by other researchers are listed on the Table I along with the source URL. The details features of these simulators are available on the respective URL; therefore, the features of these simulators are not discussed here.

TABLE I
List of various simulators and its URL

Sl.	**Name**	**URL (Last Access on 13/04/2015)**	**Availability**
1.	Micro simulation of Road Traffic	www.traffic-simulation.de	Freeware
2.	Simulation of Urban Mobility	www.dlr.de/ts/en/desktopdefault.aspx	Freeware
3.	MATSim	www.matsim.org/	Freeware
4.	Mexxo	www.ctr.kth.se/mezzo.php	Freeware
5.	Quadstone Paramics Modeller	www.paramics-online.com/	Commercial
6.	Aimsun	www.aimsun.com	Commercial
7.	Trafficware SimTraffic	www.trafficware.com	Commercial
8.	TransModeler	http://www.caliper.com/transmodeler/	Commercial

IV. FUTURE PERSPECTIVE ON ROAD NETWORK MANAGEMENT

Although, several attempts were made for the optimization of road network by several researchers and still there are several challenges on this field. One challenge is to deal with a massive amount of updates to cost function. Another challenge is to incorporate predictions for upcoming traffic conditions. A third challenge is to allow more flexible cost models, dealing with individual compromises between various objective functions like time, financial costs, convenience, environmental pollution, and perhaps scenic value. The more accurate and efficient traffic optimization and predication technique is required to prevent the accident and traffic congestion. Also, it will help to analyze and optimize the traffic flow on the road network of a city.

V. CONCLUSIONS

The road network management study is an important research area for the economic growth and public health. This paper presented a brief detailed survey of graph, genetic algorithm, fuzzy Logic, swarm intelligence based Road Network Optimization techniques. In this paper, we tried to highlight the strength and limitation of existing methods. In this second phase of this paper, we have identified some open issues and future challenges in the further implementation of the road network management. It will help the new researchers to aware about various available methodologies in field of road network management.

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