Article

A Study on Application of Stochastic Queuing Models for Control of Congestion and Crowding

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Abstract:

Traffic congestion is a common day-to-day trouble in many countries, especially large cities. Gradually, even medium-sized and small towns are experiencing such problems and suffering from their negative effects. Importantly, traffic and crowd congestion largely spoils a region's economic and social status. For commuters, traffic congestion gives rise to excess travel costs, duration, and travel discomfort. From a traffic management perspective, traffic congestion leads to more expenses in the traffic system for handling inconvenient road networks. At the social level, traffic congestion causes road accidents, environmental damages and pollution. This article provides an overview of current time's traffic and crowd management system through a review of literature on stochastic queuing models for congestion and congestion control. In particular, we will focus on issues related to tackling the practical need and available features, and alleviation of daily traffic blockages. Dealing in terms of the concepts taken from Operation Research, the most important techniques are analytical queuing model application, stochastic optimality, and robust effective optimal solutions to common road congestion problems.

Keywords:

Stochastic Queuing Models, Congestion and Crowding, Traffic Management, Stochastic Optimization, Robust Decision-Making

1. Introduction:

In recent years, operation research (OR) methodologies for modelling and improving the potentiality of road traffic handling system have reached to upgraded level. Indeed, the management and optimization of traffic and crowd

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management performance necessitate analysis of a wide variety of strategic, situational, and operational challenges, which can vary depending on regional and administrative situations.

Furthermore, issues such as safety management, uneven traffic distribution, weather conditions, and so on mean that examining the operations of a single area- based traffic management may only provide limited knowledge. Although few scholarly researchers have approached to include the whole gamut of factors that may encourage sound decision in reality. In addition, operation research methods' capacity to evaluate results and propose improvement measures have been demonstrated on a regularly basis.

The purpose of this work is to give a literature survey in order to show how important stochastic modelling approaches have become in modern traffic and crowd management research. The paper also looks at the way the methods can be used to solve heavy-sized, dynamic, non-stationary optimization problems with trends that aren't always straightforward to identify or describe.

Many of the immediate challenges in transit planning have to reach critical limit values, targets, and finalization part, and the addition of uncertainty to such problems adds an extra complexity pressure to the problem in getting the right procedure and modelling stochastic impacts in an appropriate way. Being well equipped to give robust decision-making support for traffic and crowd management, on the other hand, are far too great to be overlooked, and the amount and variety of "big data" are giving scholars in this subject new opportunity to build really well versions of transport systems.

This review of traffic management based on stochastic queuing examines research studies attempts to overcome the ambiguity to difficulties of previous basic/manual traffic handling processes, and tends to suggest an additional scope for stochastic modelling to enhance the standard of outcome or usability checks in comparable conditions, to highlight the extra value that stochastic modelling solutions can promise.

2. Objective:

The review article on stochastic queuing model for control of congestion and crowding is an approach where it is attempted to locate the avenues where different models of the said technique can be ideally applied as well as can be used for predictive traffic handling computations giving optimal result.

3. Methodology:

The present review article on traffic management based on stochastic queuing-based model is entirely composed based on the existing authentic management and industrial governance updates and articles that are published in acknowledged online portals/publications. Genuine facts and information's are gathered from trusted web libraries, and Institute portals are thoroughly studied, sorted and selected based on their relevance.

4. Literature Review:

Using principles of the stochastic process-based queuing theory and an initial value problem framework, Jojo Desmond Lartey (2014) [1] contributed to the modelling and subsequent prediction of road congestion on a Ghanaian metropolitan road. The proposed queuing based traffic estimation scheme was used to define usability measure criteria, allowing for the estimation of the level of a queue formed at a signalized junction as an insight into vehicular gridlock in road transport system and solutions to reduce such problems.

Feng et al. (2015) [2] suggested three random early detection (TRED) based on nonlinear RED, a stochastic queuing-based optimal solution tool for minimal RED adjustment, in which the packet dropping likelihood tests was divided into three parts to separate between light, mild, and heavy transport volume in order to attain a good compromise in latency and turnout between minimum and maximum traffic loads. According to the simulation report found from NS2, TRED significantly addressed RED's shortfalls to produce better flow control. Furthermore, because just the packet dropping probability profile was altered, transitioning to TRED stepping up from RED on Internet routers took minimal effort.

Cats et al. (2016) [3] used a dynamic and stochastic transit assignment framework to create a method for assessing the effects of increasing load. They dynamically analyze the rise of traffic network need and on-board crowding that used an agent-dependent general transportation simulation process. The approach was incorporated into a bigger project evaluation framework. According to a case study Stockholm various metro extension routes that substantially replaced an overcrowded bus network, congestion effects may account for a major amount of the estimated gains. According to the researchers, a standard static cost-benefit analysis would miss more than a third of the gains. As a result, failure to account for dynamic congestion implications may result in a considerable underestimating of project benefits, especially if the primary purpose of the project is to enhance capacity rather than reduce travel times.

When congestion alleviation is needed, J. West (2016) [4] suggested traffic control models based on six well-known publications and methodologies for studying traffic and road route projects. They used these tools to look at the congestion charge system in Gothenburg, as well as a new metro line and bus service measures in Stockholm. They employed BusMezzo to measure the condition of congestion and crowding, as well as conduct cost-gain assessments, in their transit case studies. They discovered that congestion and crowding critically impacts of more than a third of the total benefits in a case study that they carried out in Stockholm's metro extension routes, and that a normal static model significantly inflated these effects. They analysed a range of operational steps with BusMezzo and compared the findings to data from another case study. The researchers showed that a hierarchal route choice tool with a continuous report on time distribution provided reasonable predictions of route choice effects for the Gothenburg congestion charge scheme, even if the assignment was static. However, in order to analyze congestion charges in Stockholm, they needed to combine dynamic traffic assignment with the demand model, and they found a model that could do so. However, they concluded that failing to account for dynamic congestion impacts could result in a significant underestimating of the advantages of projects aimed solely at relieving congestion rather than reducing travel times. Their models accurately predicted these impacts, highlighting the very huge travel time reductions that pricing regulations and simple operational adjustments may provide. These solutions were inexpensive when compared to new infrastructure investments, and their implementation might result in significant societal benefits.

S. Agnihotri (2016) [5] wrote a review of queuing theory and its applications. This research looked at the importance of queuing theory in the subject of traffic management for the cities of Bhopal, Indore, and Ujjain in the state of Madhya Pradesh. This study examines a variety of queuing theories that have been reached in the areas of waiting time, utilization analysis, and system design. During the day, the traffic throng follows a predictable pattern, which the appropriate people accept as a daily routine.

J. Zhou et al. (2019) [6] examined traffic congestion in the future Unmanned Aerial Vehicle (UAV) traffic system in bad weather in this investigation. Here, they considered UAV traffic to be fluid queues and offered traffic dynamics models for three major traffic components: single link, tandem link, and merging link. Weather uncertainty was quantified as a change in the fluid queue discharge saturation rate (capacity). The uncertainty was expected to be governed by a continuous-time Markov process. They characterized the UAV traffic condition’s resilience as the traffic queues' long-term stability and the best throughput technique under uncertainty. They came up with the essential and adequate requirements meeting traffic queue handling measures that were stable in the three basic traffic components. Both conditions, the team concluded, could be easily confirmed in practice. The stability conditions could be used to compute the optimal throughput. The study’s findings provided valuable knowledge and a tool for building weather-resistant flows in the UAV traffic system.

The Static Traffic Assignment with Queuing (STAQ) road traffic assignment plan was developed by L. Brederode et al. (2019) [7] for instances where static and dynamic traffic assignment tools both faulted, that is, in strategic usage on heavily congested areas. The research discussed the methods building principles, technique, and response algorithm, as well as model applications valid for theoretically small and real time heavy road traffic conditions, in order to demonstrate how it addressed flaws in STA (static traffic assignment) and DTA (dynamic traffic assignment) processes in their strategic applications. The STAQ model, like DTA models, recorded flow metering and bottleneck spillback effects while having slightly higher input and processing requirements than STA models. Their proposed framework was found to be compatible and generate substantial user equilibria on heavy-congestion networks (relative gap less than 1E-04).

Because of its correctness, stability, and suitability, the STAQ model has been presented as a feasible replacement to STA and DTA modelling approaches.

B. Ravi et al. (2019) [8] established the stochastic technique for multi-hop connectivity by studying vehicle-to-network and vehicle-to-vehicle inter-vehicular message delivery infrastructure to achieve road network efficiency. They assessed the performance analysis of the queuing mechanism in their research by testing the traffic flow of major highway lanes. Every collision involving two vehicles in the VANET system's highway lanes frequently resulted in a traffic jam with considerable congestion. The M/M/1 queuing model was used to evaluate the VANET system's utility, which examined at measures, including thorough latency, waiting period, and vehicular road blockage occurred on express highways during peak hours for multi-hop connectivity.

Tso Huang et al. (2020) [9] proposed a traffic-control model that could be employed for two different modes and included eight formulae to determine the outcomes of the analysis. The three formulas in the first calculating mode were designed to simulate the greatest traffic flow in a real-world setting. The findings were calculated in the second mode using simulation data provided by Monte Carlo simulation. They used simulation data to test their model using the Monte Carlo simulation approach to verify the results. The results of the proposed performance measurement showed that the model outperforms earlier investigations. Furthermore, the study approach was straightforward in order to obtain the desired result, and it was considered that the model followed pseudo-randomly, which matched the existing situation. Furthermore, they expected traffic control data to be collected automatically as a result of the Internet of Things (IOT) movement. According to the findings of the study, their proposed model could be implemented after the data was obtained.

H. Wang et al. (2020) [10] attempted to build a traffic signal optimization model that could operate under stochastic distribution control theory. Their model was developed to achieve a pleasant and fair transport passage across signalized crossings in this work. To depict the interconnection between signalling period and length of waiting traffic, they designed static and linear dynamic stochastic distribution models with relevant probability density functions. To regulate signal timing at intersections, two stochastic distribution management techniques were created such that the probability density function at each point of junction where traffic queue was counted was as short and fast emptying as possible. A data-dependent and dynamic recursive input-output traffic queue estimate model was used to compute live traffic queue too by using traffic light timings and loop-detector records. The control plans were checked using a one-signal route, a two-signal route, and a 2 x 2 channels of signalized junctions. The study gave instances of MATLAB simulation records, as well as a comparison to a commonly used semi-actuated control, to demonstrate the use of the suggested methods. The desired results were obtained through the implemented process.

5. Findings and Conclusions:

From the review of literature as discussed above, it is observed that Stochastic Queuing Model can be used for both traffic control as well as passenger management. Furthermore, the method is finding its scope in predictive approach of traffic management, such as, of volume- based traffic control, weather oriented traffic handling measures, etc. and therefore, could be used to obtain an optimal distribution estimate of traffic. The queuing model with the stochastic approach has been applied in big cities as well as small towns currently. However, the models, particularly, the static stochastic queuing models have limited applications in terms of measuring variable traffic control and dynamic model is under being evolved based on existing traffic control data, where the systems are found to be variable in performance based on authenticity of the data.

6. Recommendations and Suggestions:

The paper as presented here shows a variety of stochastic traffic and crowd control queuing approaches that can be applied for road traffic management. However, the model performance is seen to be varying based on availability of data and infra structural constraints. Therefore, these areas, particularly, organised traffic management data, system awareness and geographic and physical constraints should be thoroughly considered and incorporated in future studies for better results and effectiveness of the stochastic queuing-based model usable for road traffic and crowd management.

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