

Predictive Framework for Smart Toll Pricing Using Demand Analytics and Intelligent Transportation Data

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Abstract- Traffic jam has become the order of the day in most urban centres and highways. The classic toll pricing mechanisms have fixed price usually that does not change depending on the traffic situation. Due to this, they can hardly be used in handling congestion during the high traffic hours and end up increasing travel time and limited use of the roads. There are works that have attempted this issue with the help of optimization models and control-based pricing in order to adapt toll prices. Other studies have predicted the level of congestion using machine learning and data of traffic. To a certain extent, these approaches have been improved, although they are largely investigated independently. Real time demand prediction is not regularly used in Toll pricing models whereas prediction models are not applied to make decisions on pricing. There is still a gap. There is no single system that integrates the issue of demand in traffic with real-time dynamic toll pricing. This contributes to the fact that congestion is hard to control in the new transportation systems. This paper suggests a framework that integrates the demand analytics and the dynamic toll pricing. It relies on the traffic information like the number of vehicles, their speed and the number of vehicles on the highway to forecast demand and increase or decrease the price of the tolls. This is possible to improve the traffic flow and minimize congestion. Through this practice, the transportation systems will be able to become more effective and competitive. It can assist road operators as well as the people in charge since it will make traffic control smarter and effective.

Keywords: Smart Toll Pricing, Dynamic Tolling, Demand Analytics,

I. INTRODUCTION

1.1 Background of the Study

Transport system has a major role to play in promoting economic development and urban transportation. Due to the dynamic growth in the traffic of metropolitan regions, the traffic congestion along with highways and urban roads has become a

grave issue. Besides the congestion adds time to traveling, it also causes wastage of fuel, toxication of the environment and economic gains.

One of the mechanisms that are common to control the traffic has been the use of toll roads as a way of generating income on the transportation structures.

But the conventional toll pricing systems are largely fixed, that is, the toll fee is not responsive to the conditions of the traffic.

This is because such pricing strategies are not effective in regulating the congestion during the peak hours.

The new opportunities in Intelligent Transportation Systems (ITS) and data analytics have also emerged and brought fresh possibilities to enhance traffic management.

The provision of traffic sensor data, route search records and other forms of transportation data enable the researcher to understand the traffic demand and come up with more adaptive pricing schemes.

New and improved smart toll pricing systems applying demand analytics and machine learning methods can enhance the traffic distribution and eliminate congestion.

1.2 Problem Statement

Despite the fact that the dynamic toll pricing and congestion pricing models have been considered by a number of researchers, many of the models currently used are based on simplified assumptions as far as the traffic demand and the behavior of drivers are concerned.

Toll pricing models that are based on optimization tend to be based on a fixed or deterministic traffic demand, whereas the reality of traffic variability is not applicable to the real world.

Moreover, other papers concentrate on congestion prediction with the help of machine learning methods and fail to incorporate the resulting predictions into the toll prices.

Consequently, the absence of integration frameworks of predictive demand analytics into real-time toll pricing mechanisms is a phenomenon.

Such a weakness limits the performance of the existing toll pricing schemes in controlling the congestion within intricate urban transport networks.

1.3 Motivation

The growing access to transportation data and the development of data analytics offers an opportunity to come up with a smarter system of traffic management.

Through a combination of the demand prediction methods with the dynamic-toll pricing methods, the systems can be designed to be able to respond to the changing traffic conditions better.

Smart toll pricing may be used to optimize the traffic movement, decrease the traffic congestion, as well as, to increase the efficiency of the transportation processes.

These systems may also facilitate superior decision-making by the transportation authorities since they will give information-based understanding of how people travel and how they act.

As such, developing the demand-based smart toll pricing models has both scholarly and useful arguments.

1.4 Objectives of the Study

Objective 1: To revise the existing solutions concerning dynamic pricing of tolls and intelligent transport systems.

Objective 2: To find out research gaps and limitations in existing toll pricing models. Objective 3: To suggest a demand-based smart toll price model combining predictive analytical with intelligent transportation data.

1.5 Contributions of the Paper

The following are the contributions of this paper: Conducts an in-depth discussion of the recent such research concerning the concept of dynamic toll pricing and congestion management. Establishes the important research gaps in the current toll pricing model especially the demand prediction and real-time flexibility.

Introduces a conceptual model of smart toll prices, which is based on the idea of demand analysis and data on intelligent transportation as the means to enhance traffic control.

II. LITERATURE REVIEW

There has been an escalation of traffic congestion in most cities and highways. It has presented difficulties to the road users as well as road authorities.

The prices in traditional toll systems are generally fixed and they do not vary with the traffic conditions. This is the reason why they are not that effective in the control of congestion.

Researchers have proposed various solutions to the solution of such problems based on optimization models, machine learning, and intelligent transportation systems.

Certain researchers have concentrated on the dynamic toll pricing in which the toll prices are adjusted according to the nature of the traffic.

Other researches have paid attention to forecasting traffic congestion with machine learning and

traffic statistics including the number of vehicles and time taken during the traffic.

Nevertheless, the majority of these researches consider these issues individually.

There are hardly any works that correlate demand prediction and toll pricing.

This puts a gap in the existing research. The literature sources that have been chosen in this research paper are comprised of various solutions including control-based models, optimization techniques, machine learning techniques, deep learning models, and IoT-based traffic systems.

I. Phan et al. (2016) – Model-Based Dynamic Toll Pricing Strategy

Early research on the pricing of tolls was largely based on mathematical models and the traffic flow theory.

Through these methods, they employed optimization to find the prices of toll that would be able to control the demand of the traffic and minimal congestion.

As an illustration, the bilevel optimization models and user equilibrium models have been applied to establish optimal toll prices that reduce the overall travel time in transportation systems.

Some of the researches came up with control based pricing where the toll fees were revised depending on the density of the traffic or the level of congestion.

These measures will keep the traffic movement to an optimal level.

In spite of good theoretical underpinning in the traditional models, most of them use deterministic traffic demand and simplified network conditions, which are not necessarily in line with the actual traffic system in the real world.

ii. Hassan et al. (2025) – Bilevel Optimization for Toll Pricing

On the rise of transportation data, machine learning has been involved in traffic analysis and prediction of

congestion. Regression models, gradient boosting algorithms, and reinforcement learning have been employed to cope with traffic demand analysis, followed by optimizing the strategies of setting toll prices.

Certain researches employ the reinforcement learning to automatically control the prices of the tolls based on the situation in the traffic.

These models enable the system to acquire the best strategies of pricing by interaction with the traffic environment.

In other works, there are investigations aimed at the forecast of the level of congestion through applying machine learning algorithms to the input of historical traffic and route search logs.

Though these methods enhance the accuracy of the prediction, a large number of them are not involved in the real-time toll pricing decisions including the demand prediction.

iii. Zhang et al. (2023) – Reinforcement Learning for Dynamic Tolling

In recent studies, the concept of deep learning models in predicting traffic and smart transport system has been discussed.

Long Short term memory (LSTM) networks and convolutional neural network (CNN) neural network structures are the neural network architectures that have been utilized to study the trends in traffic with time as well as forecast the situation involving congestion.

Deep learning models can also determine complexities in big traffic data such that it is applicable in demand forecasting.

Other researches have suggested the deep learning-based frameworks of adaptive toll pricing reacting to forecasted traffic demand.

Nonetheless, these models are usually very demanding in terms of large datasets and high computing resources that could be not as scalable to real-time application.

iv. He et al. (2024) – MPC-Based Congestion Pricing

Recent works have suggested hybrid schemes, which implement combinations of optimization methods and machine learning models.

These strategies are trying to implement demand forecasting algorithms along with the dynamic toll charges strategies.

Moreover, in other studies, Intelligent Transportation System (ITS) information, including traffic sensors, GPS information, and route search records are included in the decision-making of pricing.

The idea behind hybrid models is to achieve a superior congestion control compared to using predictive analytics and adaptive toll pricing mechanisms.

Nevertheless, various challenges that are associated with several current frameworks include decreasing the scale, availability of data, and the merging of multiple sources of data.

v. Shukla et al. (2020) – Deep Learning-Based Toll Pricing

This paper was aimed at applying deep learning models (LSTM) in order to predict traffic demand and change the price of tolls.

The model utilised traffic and weather information.

Consequently, it depicted well the predictability.

The study ends towards the end by concluding that the deep learning enhances prediction yet it consumes high computing algorithms.

vi. Kosugi et al. (2022) – Traffic Congestion Prediction

The primary aim of this research was the prediction of congestion with the help of route search logs and machine learning.

Real-life traffic statistics were employed in the model.

Consequently, it enhanced accuracy of prediction.

In the concluding part, the study gives a conclusion that prediction is helpful but it is not merged with the decisions concerning the cost of the tolls.

vii. Pelchor -Espinosa et al. (2025) – IoT-Based Dynamic Tolling

The primary goal of the research was to provide a simulation of the active toll apparatus based on the IoT information and traffic density.

SUMO simulation has been taken in the model.

Due to this, it enhanced traffic congestion.

The study concludes in the later part that the IoT-based systems have their way but they are not predictive.

viii. Liu et al. (2024) – Tri-Level Toll Optimization

The primary goal of this research was the design of toll charges with the help of a tri-level optimization model that takes into account the power and transport systems.

The given model proved to be efficient and easy in calculation.

At the end, this study comes to the conclusion that the approach is high powered but difficult to calculate.

ix. Duncan et al. (2026) – Multi-Region Toll Optimization

The study had its main aim which was to optimize the toll prices in large networks with the help of MFD models.

The study concluded that these large scale models are useful but not applicable in real time systems.

x. Li et al. (2024) – EV Charging and Toll Pricing

The key perspective of the research was the synthesis of EV charging demand and toll price.

The system balanced the traffic and power demand.

In the latter part, the research ends with a finding that, the synthesis is helpful but needs the right data with high calculations.

2.2 Comparative Analysis of Existing Methods

There are numerous attempts as people have made to solve the issue of traffic jams and enhance the system of toll prices.

There are studies which aim at adjusting the prices of tolls based on mathematical models whereas some studies apply machine learning and traffic information to comprehend the traffic patterns.

Such approaches vary in the way they operate, the form of data they are fed on, and the efficiency of such approaches in the real-life scenarios.

Other methods involve optimization media which is used to determine the price of the tolls depending on the amount of traffic and user conduct.

The benefits of these methods are that they give unambiguous mathematical answers though they usually assume that the traffic demand is fixed.

Other methods apply machine learning to estimate traffic congestion based on such data as the number of cars, their velocity, and time.

These are more flexible methods, but rely quite on the quality of data.

Time series prediction of traffic has also been done using deep learning models like LSTM.

These models are able to model the complex relationships in traffic data yet they demand huge datasets and huge computational power.

Besides that, other research has employed IoT system and simulations to track traffic and assign price to tolls dynamically.

The comparison of the chosen studies is presented below, referring to the approaches used, data, performance, and limitations.

Author	Year	Method	Dataset	Performance	Limitations
Pan et al.	2016	Control-based dynamic toll pricing	Multi-class traffic data	Improved congestion control	Limited to specific highway
Zhang et al.	2021	Reinforcement learning	Real-world roadway data	Improved revenue and traffic flow	Low simulation data
Hassan et al.	2021	Bilevel optimization	Synthetic traffic data	Reduced travel time	Static demand assumption
He et al.	2024	MPC based pricing	Multi-region network data	Better congestion control	High computational cost
Balakrishna et al.	2020	Deep learning (LSTM)	Traffic + weather data	Accurate prediction	Requires large dataset
Kung'u et al.	2022	ML-based optimization	Local road traffic	High prediction accuracy	Not linked to pricing
Potharaju et al.	2021	IoT-based detection	RTMP dataset	Improved traffic flow	Simulation-based model
Liu et al.	2020	Two-level optimization	Four transport network	Reduced cost and congestion	Complex model

2.3 Critical Review

As much as most of the current research offers meaningful input to the human study of intelligent transportation system, there are still a number of challenges.

A positive attribute of the existing strategies is that optimization models offer good theoretical frameworks of toll pricing strategies.

These models are able to determine the most appropriate toll that would reduce time of travel or equilibrium of the traffic demand.

Deep learning and machine learning techniques also demonstrate good results in the prediction of congestion and traffic demand analysis.

Nevertheless, there are also some weaknesses which can be noted.

Most models based on optimization have simplified assumptions of traffic and constant demand behaviour. Such assumptions are not defined to reflect the characteristics of traffic behavior.

Moreover, machine learning models can also be demanding in terms of their size and the resources needed to compute (i.e., the need to have a lot of data and computing is often energy-intensive).

Another issue is the problem of scalability. There are certain models that work effectively in small simulated conditions but they may encounter challenges when applied to large transportation

networks of a city.

Moreover, the datasets applied in a few studies are not very big or are gathered in a particular area, and it can have an impact on the generalizability of findings.

The advanced optimization models are also concerned with the computational cost as those models utilize the multi-level or the complex algorithms.

These models can be time-consuming to process and thus it is difficult to implement them in a real-time.

2.4 Identified Research Gaps

Scholars have put much effort to enhance traffic management by deploying dynamic toll price and machine learning methods.

Numerous analyses have demonstrated that dynamic toll pricing can be used to alleviate the traffic congestion through the adjustment of the toll prices in accordance with the traffic conditions.

Simultaneously, machine learning has been applied to forecast the existing traffic trends based on the data of the number of vehicles in the traffic, their speed, and time. Nevertheless, in the vast majority of cases, these two issues are researched individually.

There are those systems that emphasize predictive traffic congestion based on machine learning models and those that emphasize the optimization of the toll prices based on mathematical means or control approaches.

Few researches have incorporated both the demand prediction and toll pricing in a system. Due to this fact, the solutions that are currently present cannot handle traffic

under real world conditions to manage it completely.

The other issue is that most of the models have simplified or fixed traffic demand models. On the real life, traffic varies at any given time, weather, and road conditions as well as human actions.

These differences cannot be addressed adequately by most existing models and this diminishes their effectiveness. In addition, it has been observed that a lot of systems are built on simulated data or small datasets.

Although simulation is a good method of testing, it cannot always reflect the actual situation of traffic. The real-time and multi-source data like traffic sensors, GPS data, toll records, route search logs are not significantly used altogether with one system.

The other significant constraint is that most of the models utilize single types of data. To illustrate, there are those models that consider traffic flow data only and also those that consider historical only.

Nonetheless, traffic character is determined by the multiplicity of factors and various types of data might fail to produce precise outcomes. It is necessary to provide more than one piece of data because people make changes to their travel behavior depending on numerous factors.

It is necessary to find a solution to these issues so that a system to include both traffic demand prediction and dynamic toll pricing can be implemented within one framework.

Such system must be using real-time data, must be able to address various traffic situations and must be able to function effectively within a huge transport system.

This paper seeks to come up with a mechanism that combines machine learning-based demand prediction with the dynamic South Park.

A combination of both strategies can result in the suggested system which will be more effective in terms of controlling traffic and sustaining the congestion and the overall efficiency of traffic.

It is also able to assist transportation authorities in making more decisions and forming smarter and reliable road systems.

III. METHODOLOGY

this section discusses the way to enhance toll pricing systems with the help of traffic data and demand.

It is aimed at facilitating the movement of traffic and decreasing the amount of traffic congestion in the streets, balancing the price of the tolls according to the current situation.

In order to accomplish this, the proposed system relies on traffic metrics, machine learning algorithms, and dynamic pricing algorithms.

Data is gathered by the system of intelligent transportation systems that include sensor on the road, toll booth and the roads with GPS system-based traffic system.

It then processes this data to know the trends in the traffic and forecast congestion. According to this forecast, the prices of the tolls are altered in an attempt to regulate traffic.

The system assists in making better decisions by the transportation authorities and also enables efficiency in the use of the roads.

3.1 System Overview

The proposed system is modeled in the form of a data-based platform which gathers data on the traffic in the form of smart transportation system (ITS) as well as process these data to determine the level of traffic demand and congestion.

The system modulates the toll prices according to the predicted demand in the traffic and thus it manages to control the traffic flow effectively.

The scheme is comprised of three primary elements such as data collection, demand prediction and dynamic toll pricing.

During the initial step, the traffic data will be gathered through various sources like road sensors, records of toll transaction and highway search logs. The data is in terms of vehicle numbers, speed of the traffic, time taken, and congestion trends.

The second phase involves the study of historical and real-time traffic information on machine learning models to analyze the demand of traffic and predict congestions [9].

These forecasting assist in determining the high traffic times, and likely congested areas.

On the last step, the dynamic toll pricing module considers solutions to the forecasted demand information to change toll prices.

During the times of high congestion, it is possible to increase the toll prices and control the demand in traffic.

On the other hand, when there is a low flow of traffic, the price of the tolls can be lowered as a way of attracting people to use the road.



Figure 1: System Overview of Smart Toll Pricing Framework

3.2 Framework Architecture

This section contains the major parts required for the suggested framework



3.2.1 Data Collection

This aspect of the system obtains the information by the e-commerce rockets, including: Details about the product

- Customer feedback on those who have purchased the product.
- Who wrote the reviews: Information regarding the authors of the reviews.
- . Information to determine whether the goods are authentic.

The information that the system collects is used to research the product.

3.2.2 Data Preprocessing

Preprocessing step is a step whereby the traffic data collected are prepared to be analyzed. The reason why this step is necessary is that raw traffic data might have missing values or even irregular records.

- Some of the activities that are involved in this phase will be:
- The elimination of unfinished or wrong traffic records.
- Normalizing traffic related factors such as speed and traffic volume.
- Transformation of the data to a common format...

These are measures taken to enhance the quality of the data and make it fit to macho learning models.

3.2.3 Feature Extraction

During this step we examine the traffic statistics which we have gathered, and attempt to extract valuable information relating to them.

This information aids in knowing the behavior of traffic at various roads and specially during various times of year.

The things that we get to learn can be the number of vehicles on the road which is referred to as the volume of traffic.

We also consider the speed of moving vehicles, whereby we obtain the data on the average speed of the traffic.

Travel time is also another crucial consideration that indicates the duration in which vehicles take to relocate to this or that location.

We also check on the levels of congestion which indicate the level of congestion within a road. Patterns of time are also notable including peak hours and non-peak hours since traffic varies with variation of the time of the day.

Besides this we may also consider the external factors such as weather conditions or other special events which can influence the flow of traffic.

All these characteristics such as the volume of traffic, the speed, the travelling time, the

degree of congestion, and time schedule aid us in getting a clearer insight into the state of traffic.

Machine learning models use these features to find patterns and predict demand of the traffic in the future.



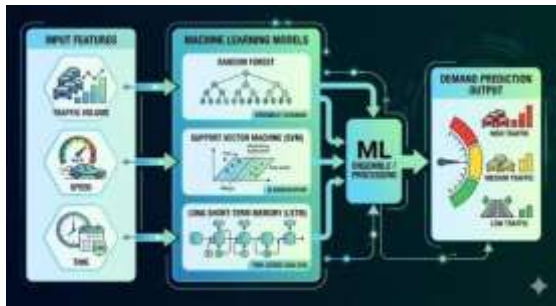
3.2.4 Traffic Demand Prediction

Our models and machine learning are analysed based on the traffic data that we have computed. Those models can help us in understanding such behaviour of traffic and forecasting the future traffic conditions.

These include things like:

- Regression models that can be used to estimate traffic demand.
- Such machine learning algorithms as Random Forest and Support Vector Machine.
- Gradient Boosting or LSTM traffic prediction models are often time-based models.

These models take the characteristics that we have already detected, including traffic volume, speed and travel time to forecast the congestion level.



3.2.5 Dynamic Toll Pricing

In this module, the various means of variation of the toll price according to the condition of the traffic. The primary objective is to manage traffic jams and the traffic conditions in the roads.

Here is how it works:

- It increases and decreases the price of the tolls depending on the demand.
- Toll prices are raised when the number of traffic is high to curb congestion.
- It lowers the prices of tolls when the traffic is inconvenient hence allowing more vehicles to be using the road effectively.
- It makes predetermined decisions on the toll price based on predicted traffic figures of machine learning models.

This module ensures that one does not charge the same price all the time but varies in response to the current traffic situation. It assists in the balancing of traffic as well as delays on the busy roads.



3.2.6 Decision Integration

The system provides final toll decision following the information that is received in the various parts. The result of the input of traffic prediction and dynamic toll pricing is combined to make this decision.

The system considers a number of things:

It verifies the traffic demand and level of congestion as predicted.

It monitors the situation of traffic on the road. It takes into consideration the proposed toll price of the pricing module.

All this information is used to determine the final toll price by the system. This aids in ensuring that the price administered on the toll is reasonable and can be of use in controlling traffic.

As a combination, the system is able to control the prices of the tolls more effectively.

3.3 Workflow Diagram



IV. EXPECTED RESULTS AND DISCUSSION

The suggested smart toll pricing will be based on superior demand analytics and dynamism in the toll pricing techniques to enhance traffic control.

In this section, the authors provide an explanation of the anticipated results of the proposed system and the assessment of how the efficiency of the approach can be measured compared to the contemporary approaches.

4.1 Expected Outcomes

To integrate the data on the traffic and demand forecasting, a new system must also assist in enhancing the way toll pricing is applied in roads. It may assist in managing the traffic and to improve traffic circulation.

I. Performance Improvements

We believe that the system can enhance the management of traffic using machine learning models in forecasting the demand of the traffic.

These models have the ability to examine the trends such as the number of vehicles, speed, and traveling time in order to get an insight into the conditions of traffic. This is in contrast with the old traditional method of using the tolls which are given fixed prices and which do not oscillate with the traffic. The system will be able to minimize congestion by offering lower prices to different types of tolls depending on their demand at any particular moment to enhance travel time.

II. Robustness

The new system will be able to deal with various forms of traffic situations. It will be able to operate during peak time, normal traffic and even the unexpected traffic conditions.

The system is able to change the prices of the toll in real-time depending on the prediction models as well as the change of the traffic patterns. This generated

the system to be more reliable and effective under real life circumstances.

III. Scalability

We believe that the system would be effective on large transportation systems like highway and smart

cities. It is capable of processing extensive traffic information gathered on sensors, GPS and toll.

This data can be processed by the system and real-time changes will be made to the prices of tolls. This renders it applicable to massive implementation and contributes to the enhancement of the traffic control over many road networks.

4.2 Comparative Evaluation Plan

The system will be compared to the current toll pricing and traffic management techniques in order to determine their performance. We will examine the degree of prediction accuracy of the system and its ability to respond to effective changes of toll prices.

To measure the performance, we will use various measures that are prediction accuracy, error levels as MAE or RMSE and improvement in traffic flow. We are also going to check the extent of the capacity of the system to alleviate congestion and to enhance the travel time.

The system will also be tested with the help of traffic data gathered by such sources as road sensors, GPS systems and toll records. This will aid us to learn the levels of performance of the system in actual real life scenarios.

We will contrast the findings with the traditional methods of toll pricing that involve constant prices with the current models like optimization-based toll pricing model, and machine learning-based traffic prediction model. A dynamic pricing of the toll is also present in the system. We will measure the adaptability of this component in adjusting the prices of the tolls in accordance with the traffic demand. This is a critical section since it has a direct impact on the movement of traffic.

The traffic forecasting as well as the toll prices

sections of the system will undergo collective evaluation. This will be useful in knowing the overall effectiveness of the entire system in dealing with congestion and the efficiency of roads.

4.3 Discussion

The new system is superior to the conventional toll pricing systems. It is described that most of the current approaches involve machine learning in order to predict the traffic or optimization models to determine the toll price. These techniques are in most cases applied independently and cannot entirely resolve the issue of the traffic congestion.

The new approach is more comprehensive as it integrates the demand forecast of the traffic and the dynamic toll pricing. This implies that the system is able not only to interpret the traffic situations but also act on its own, by modifying the prices of the tolls. Due to this fact, the system will be able to control congestion in a better way.

The strategy would make transportation systems more effective. Better utilization of roads can be made and traffic widely spread out. This minimizes wastages in time and enhances travel time of road users. This proves applicable to both the road users and the transport authorities.

Data can help authorities to manage traffic in a better way, and make smarter decisions. This is good to the user as they enjoy a smooth flow of traffic and congestion will be reduced.

The ultimate objective of the framework is to streamline the transportation systems in a smarter, efficient and reliable manner. With the help of the data and smart approaches, the system will be able to enhance the overall traffic management and contribute to the creation of smart cities

V. APPLICATIONS AND USE CASES

The suggested smart toll pricing system can find various uses in the current transportation networks. The system will be able to assist in improving the efficiency of the road network and in better traffic management by integrating demand analytics and

smart transportation information. The section holds the discussion about real world applicability of the proposed approach as given in the industry, social, policy and the academic perspective...

5.1 Industry Use

Smart toll pricing systems can be used to make transportation authorities and highway management agencies more effective in traffic congestion management. Conventional forms of tolling make use of predetermined prices that are not adjusted to the demand of the traffic. Conversely, the proposed method enables the price of the tolls to be being dynamic with regard to the actual traffic conditions. These types of systems are able to assist operators in spreading out the traffic across the road networks in a more even manner and also cut down on the congestions during the rush times of the day. Moreover, transportation networks and providers of tolls can employ the demand-based pricing strategy to enhance the operational efficiency and the management of revenues.

5.2 Social Impact

Traffic jams have intensive social impacts such as the increased time of travel, excessive fuel usage and pollution. The proposed system can assist the road users by adding value to their travel experiences by reducing the delays and improving traffic flow by ensuring that dynamic toll pricing is implemented. The intelligent toll price can also prompt drivers to select other traveling times or paths that could result in a more balanced transportation infrastructure utilization. Consequently, this system can help alleviate stress as a

consequence of congestion and enhances urban mobility.

5.3 Policy Relevance

Scientific toll payments schemes can be employed by the governments and transport planners as components of the overall traffic management policies. Transportation planning can rely on evidence-based decision making can be among the supported data-driven toll pricing strategies. Demand analytics (which may be based on insights obtained through the use of data analytics) may be used by policy makers to develop superior congestion management approaches and infrastructure investments. Moreover, the utilization of smart toll pricing systems will be able to assist in the formation of sustainable transportation policies since it will decrease the unneeded road congestion and enhance the caliber of road usage.

5.4 Academic Value

Academically, the proposed framework has added to the studies in intelligent transportation system, data analytics, and dynamic pricing models. It offers a base of the future study covering the issues of incorporating machine learning methods into the transportation management systems. The scholars can move the current theory further by investigating more sophisticated forecasting models, using more with several transportation datasets, or using the framework in other urban transportation settings. Thus, the proposed research is capable of contributing to the current advances in data-based studies on transportation.

CONCLUSION

This paper provided the literature review regarding dynamic toll pricing and traffic demand analysis and intelligent transportation system. It is demonstrated in the literature that various methods, including optimization-based toll pricing models, congestion prediction through

machine learning methods and traffic demand analysis using deep learning, were studied by many researchers. Such researches are helpful in the field of traffic management and congestion control. Nonetheless, the paper also produces some critical limitations of the contemporary studies.

Most of the available models are based on simplified assumptions regarding the demand of the traffic or they use synthetic data that might not capture a complete picture of the actual traffic scenario. Moreover, other papers concentrate on congestion forecasting whereas others concentrate on toll maximization though there are few studies that have adopted both elements in the same framework.

To combat these shortcomings, the proposed paper developed an idea of a conceptual framework of smart toll pricing incorporation of predictive demand analytics coupled with dynamic toll adjustment mechanisms. The suggested study method will integrate smart transportation data with machine learning to assist in making adaptive toll prices.

The primary value of this work is that it uncovers research gaps and indicates that a data-driven methodology can be proposed to enhance the systems on Toll pricing.

This type of systems can help manage congestion, improve the efficiency of traffic flow, and be helpful in more intelligent transportation planning on the contemporary urban background. Altogether, the framework suggested within the framework of this paper reveals that demand analytics should be integrated with intelligent transportation data to create more effective and responsive toll pricing models in the future smart transportation systems.

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