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Article

Modelling of Applying Road Pricing at Airport Highway Using VISUM Software in Jordan

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Abstract: Road congestion in Amman city increased yearly, due to the increase in private car ownership and traffic volumes. This study aims to (a) evaluate the toll road's effects on society andthe economy in Amman, Jordan through a survey questionnaire using statistical software (SPSS), (b) identify the optimal price at selected road using micro-simulation (VISUM). Traffic, geometric and cost data of toll technique of two sections on the Airport Highway (From Ministry of Foreign Affairs to Madaba Interchange.; and From Madaba Interchange to Queen Alia International Airport (QAIA) interchange) were used for simulation purpose. The toll road (across 7 different scenarios at different price) were evaluated for an optimal revenue. The survey questionnaire was made based on all scenarios including AM peak hour. The operation cost for toll road was determined based on greater Amman Municipality (GAM). The best scenario was determined based on the value of revenue (JD), and type of payment. The results indicate that users found the most charging method to be based on traveled distance (54.02%) and the optimal value of the toll to be equal 0.25 JD (34.08%). In Addition, the total cost of Manual Toll Collection method (MTC) in 2025 is 126,935JD and the revenue is 1122.6 JD so this indicates to positive result. Eventually, the result of applying road pricing on the airport road in 2025 indicate to be effective and economically feasible only by using Manual Method.

Keywords: Road Pricing scheme; toll road; VISUM; traffic Congestion; SPSS; Fuel Consumption; Sustainable Transportation

1. Introduction

Traffic congestion is a pervasive issue in urban areas worldwide, leading to substantial economic, environmental, and social costs. In Amman, Jordan, this problem is particularly acute along the Airport Highway, a critical artery connecting Queen Alia International Airport to the city and serving as a vital link to the southern regions of the country, including major tourist destinations like Petra and Aqaba, as well as the kingdom's sole container port. The rising traffic volumes on this highway, driven by both local and international travel, highlight the urgent need for effective congestion management strategies.

The significance of this research lies in its potential to address the multifaceted impacts of traffic congestion in Amman. Economically, congestion leads to wasted fuel, increased travel time, and decreased productivity, imposing substantial costs on individuals and businesses. Environmentally, the idling vehicles contribute to higher emissions and noise pollution, adversely affecting air quality and public health. Socially, prolonged travel times reduce the quality of life and increase stress for commuters[1–8].

Given the existing and planned developments along the Airport Highway, traffic is expected to intensify in the future, exacerbating these issues. Therefore, it is imperative to explore viable solutions to mitigate congestion and enhance the overall efficiency of the transportation network.

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This paper proposes road pricing as a potential solution to Amman's traffic congestion problem. Road pricing has been successfully implemented in various cities around the world, demonstrating its effectiveness in reducing traffic volumes, improving travel times, and generating revenue for infrastructure improvements.

This study focuses on analyzing the economic impact of traffic congestion by calculating costs for the old years and current year, and identifying trends in the growing economic burden. It also aims to assess public acceptance of road pricing through a questionnaire to gauge support and concerns among various demographic groups. Additionally, the study evaluates the economic feasibility of implementing road pricing by using traffic models (VISUM) for 2012 and 2025, considering both manual and automatic toll collection methods. Finally, it proposes practical recommendations for expanding toll roads to other congested routes in Amman and exploring the potential for road pricing on major highways across Jordan.

2. Literature Review

Many studies discussed various effects of road pricing systems, including traffic, environmental, distributive, and social impacts. In terms of traffic effects, road pricing schemes have shown promising results in reducing congestion and altering travel behavior (Table 1). Examples from Singapore[12,13], London[14,15], and Norway[16] demonstrate significant reductions in traffic volume during peak hours, leading to improved traffic flow and modal shifts towards public transit. Studies like those by Xie and Olsozewski (2011) in Singapore further highlight the positive correlation between road pricing and enhanced accessibility to public transit, emphasizing the potential for traffic management and mode shift strategies[17].

Table 1. Literatures on road pricing from international countries, and Jordan compared to current study.

	Country (Ref.)	Outcomes Measure	Interventions	Traffic Simulation Software	Statistical Software	The type of payment	Payment Method	Findings
1.	Flanders, Belgium (2011)[36]	impact of road pricing on people's inclination to adjust their current travel behavior	the implementation of a variable road pricing system, with charges of 7 eurocents on roads at un-congested periods and 27 eurocents at congested periods, for each kilometer traveled by car.	N/A	AMOS 4.0	Based distance	N/A	-Charges must surpass a minimum threshold and benefits should be clearly communicated for behavior change
2.	Seattle (2012)	reduced travel time, increased travel reliability, reduced emissions, and reduced traffic accidents	Implementation of cordon-based road pricing and toll collection	N/A	N/A	N/A	Different scenarios	-road pricing in downtown Seattle is projected to have positive impacts on the city and region.
3.	Jordan (2013) [26]	To investigate the travel behavioral responses of affected road users to road pricing in Amma	A pilot Survey questionnaire	N/A	SPSS	N/A	N/A	-half of the respondents reporting that they would use -the public transport system and car pooling

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								instead of using -their vehicles while firms will increase the price of their goods
4.	Denmark (2014)	To investigate the effect of price and travel mode fairness and spatial equity in transit provision	a web-based questionnaire for revealed preferences data collection	structural equation modeling (SEM)	SPSS	N/A	N/A	-Higher perceived service quality is associated with greater perceived ease of payment, leading to increased frequency of transit use.
5.	Philippines (2016) [37]	To reduce traffic congestion and fuel consumption	Manual Toll collection system, Electronic Toll Collection system	N/A	N/A	Based time	Different scenarios	-The optimal collection method is the Electronic Toll Collection (ETC)
6.	Spain (2017) [25]	Delay	participants received were information about and questions regarding three different road-pricing schemes: a surcharge to avoid congestion at any time (express toll lanes), a time-based pricing scheme (peak versus off-peak), and a flat fee-charging system (vignette).	N/A	Binary choice Models	Based time	Different scenarios	-Support for pricing options is not linked to income, with attitudinal factors playing a more significant role in acceptability. Users' perceptions vary significantly depending on the type of charging scheme proposed.
7.	Malaysia (2019)[34]	Delay Queue length	Real data from the position to evaluate the traffic congestion	VISSIM	N/A	Based distance	Different scenarios	The collection toll method is the mains case of congestion, queue and delay especially for heavy vehicles.
8.	India (2021)[35]	to reduce peak hour travel, traffic congestion and	Revealed preference data is derived from real-life situations and is based on users' perceptions.	N/A	Multinomial Logit Model.	Based distance	Different scenarios	The optimal collection method is the Electronic

		environmental impacts.						Toll Collection (ETC) and Open Road Tolling
9.	Jordan **(Current Study)**	-reduce traffic congestion assess the social and economic impacts	Revealed preference data is obtained from actual situations and is grounded in users' perceptions	VISUM	SPSS	Based distance	Different scenarios	-The users found the most charging method to be based on traveled distance (54.02%) -the value of the toll to be equal 0.25 JD (34.08%). -The effective method is the Manual Toll Collection (MTC) in 2025 (cost : 126,935JD and the revenue : 1122.6 JD)

(N.A : Not Available).

Regarding environmental effects, road pricing aims to mitigate emissions and noise pollution associated with transport activities. Studies, such as Johansson's analysis in Sweden[18], underscore the need for road users to internalize the environmental costs of their trips. By reducing travel time and vehicle kilometers, road pricing systems contribute to lower emissions levels, with variations in charges reflecting different vehicle types and environmental considerations. The design of road pricing charges, exemplified in Singapore's approach to electric and hybrid vehicles, influences their environmental effectiveness, underscoring the importance of tailored strategies to address specific environmental concerns[19].

Distributive effects of road pricing systems are contingent upon charge design and revenue allocation. Revenues collected from road pricing schemes can benefit public transit users and infrastructure improvements, as seen in Oslo's case[20]. However, disparities in income levels among road users may lead to inequities, with higher-income groups more likely to afford the charges compared to lower-income individuals. The division of road users into different types based on their response to charges highlights the complex socio-economic dynamics at play, underscoring the need for equitable and inclusive policy considerations[21].

Morever, social benefits of road pricing systems encompass improvements in travel time, accident reduction, reliability, and emissions. Studies by Parry and Bento (1999) advocate for the recycling of collected revenues to enhance public transit services, emphasizing the importance of reinvestment for broader social welfare gains[22]. Danna et al. (2012) further quantify the social benefits of road pricing, considering factors such as toll collection costs, transit subsidies, and overall societal welfare impacts. Their findings suggest that while toll revenues may represent cash transfers, effective road pricing policies can yield net social benefits over the long term, highlighting the potential for sustainable transportation planning and investment strategies[23].

The evolution of road pricing acceptance can be traced through various studies conducted globally. Initially met with resistance due to perceived higher costs, road pricing gradually gained traction as studies highlighted its benefits. For examplem, In Gothenburg[21] in 2002 indicated minimal public agreement with the fairness of road pricing, but by 2000, support increased to 38% when presented as a solution to reduce queues[21] Similarly, opposition in Oslo[15,24] , spain[25] and Jordan[26] , in

Oslo decreased from 70% to 54% after charges were implemented, demonstrating increased support post-implementation and in spain, the research investigated the impact of different factors on the support for these pricing options. Interestingly, the study found that attitudes towards road pricing, rather than income levels, played a significant role in influencing support for the proposed schemes. In Jordan, a study by Jdaan explored how road pricing in Amman affected travel behavior, using a pilot survey questionnaire. The findings revealed a notable shift in respondents' preferences towards utilizing public transport and carpooling as alternatives to using their vehicles. Studies in other cities like Singapore and Trondheim also showed growing acceptance over time[15,24]

Further research, such as the study by Ubbels and Verhoef in 2004, underscored the importance of adequate technical and administrative groundwork for road pricing acceptance[23]. Studies like those by S.jaensirisak et al. and Ubbels and Verhoef in 2005 and 2006, respectively, revealed that acceptance varied based on factors such as personal characteristics and perceived revenue use[23,27]. Melhorado et al. in 2010 emphasized the need for policymakers to understand the purpose of road pricing for its effective implementation and economic development[28].

Cools et al.'s 2011 study explored the link between driver behavior and road pricing acceptability, highlighting the importance of socio-cognitive factors[29]. Meanwhile, local research by Jadaan et al. in 2013 in Jordan revealed potential shifts towards carpooling and public transportation due to road pricing, impacting both individual behavior and business practices[26].

In 2014, Kaplan et al. delved into the impact of fairness and spatial equity on transit perceptions and usage, showcasing the intricate relationship between perceived service quality, ease of payment, and frequency of transit use. Together, these studies provide insights into the evolving acceptance and understanding of road pricing worldwide, emphasizing its multifaceted implications on transportation behavior and societal dynamics[30].

Several studies have created various models to examine how individuals' attitudes, behaviors, and characteristics influence the acceptability of RP. Simulation modeling offers a comprehensive approach to assess the impact of tolls across various dimensions, including economic, environmental, social, and traffic factors. Komada and Nagatani's (2010) study focused on traffic dynamics on toll highways, revealing how vehicular density and tollgate configurations influence traffic flow and queuing patterns. By deriving fundamental diagrams, they provided insights into traffic behavior under different conditions[31].

Tsekeris and Vos (2010) explored the nexus between public transport and road pricing in Greece, using simulations to demonstrate that well-designed policies could bolster public transport usage without substantially raising road user charges[32].

Chakirov and Erath (2012) delved into the intricate factors shaping road pricing design, employing Multi Agent Transport Simulation (MATvis) to model economic and socio-demographic variables influencing travel demand patterns[33]. Morever, In 2019, Malaysia employed VISSIM to simulate traffic conditions, revealing that toll collection methods have a notable impact on congestion, queues, and delays, particularly affecting heavy vehicles[34].

Road pricing systems employ various payment methods, categorized into three main types: distance-based[34,35], time-based[36,37], and toll station-based[14]. Distance-based payment, utilized in Switzerland, Germany, and Gothenburg, relies on technologies like GPS and GSM to track vehicle movement and calculate charges based on driven distance. In this system, vehicles equipped with GPS transponders communicate with central units via GSM, allowing for automatic payment processing after the vehicle enters the charging zone. This method offers real-time tracking and efficient billing, enhancing user convenience and accuracy[38].

On the other hand, Payment systems based on time, exemplified by London's congestion charging scheme, offer drivers multiple payment options and timeframes for payment. Failure to pay by the designated time incurs fines, encouraging compliance. Despite the flexibility provided to users, time-based systems require strict adherence to payment deadlines, posing challenges for enforcement and revenue collection. Nonetheless, London's scheme generates substantial annual revenues, indicating its effectiveness in managing congestion and generating funds for transportation infrastructure[39].

Toll station-based payment methods, involving munual collection, bank accounts or smart cards, streamline toll collection processes. In malaysia , a study conducted employing VISSIM for traffic simulation, which highlighted the notable influence of toll collection methods on congestion,

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queues, and delays, especially concerning heavy vehicles. However, results of astudy in India found that the optimal collection method is the Electronic Toll Collection (ETC) and open tolling road. Morever, In other studies[37, in other countries like Oslo, Philibeans, singapora and dubai found that the optimal

In Oslo, electronic payment is preferred due to its speed and convenience, with charges deducted directly from registered bank accounts via subscription transponders. Smart card systems, like those in Singapore and Dubai, offer similar benefits but require users to preload funds onto cards for automatic deduction upon passing toll gates. These systems minimize transaction times and enhance user convenience, contributing to efficient toll collection and revenue generation[15,24,37].

Therefore, the novelty of this research has been investigated the efficacy of toll road deployment, specifically in evaluating the most suitable method for toll collection booths and their impact on traffic flow and congestion. Through the application of sophisticated simulation modeling methods, valuable insights are provided into the effectiveness of toll road strategies. These insights can assist transportation planners and policymakers, not only in Jordan but also in other areas facing comparable transportation issues. As a result, policymakers can utilize these findings to develop informed toll road deployment strategies aimed at enhancing traffic flow, alleviating congestion, and improving road safety and mobility.

The toll road on Airport Road in Amman, analyzed through VISUM, offers significant contributions to the transportation landscape. Utilizing advanced simulation techniques, VISUM allows for a comprehensive understanding of the toll road's impact on traffic flow, congestion levels, and overall efficiency. Moreover, by designing and administering a questionnaire regarding the application of road pricing, valuable insights are gained into public perception, acceptance, and potential behavioral responses to toll implementation. Following the collection and analysis of questionnaire data, the operational costs associated with the toll road, including toll collection infrastructure, maintenance, and administration, are carefully calculated. By juxtaposing these costs with revenue projections derived from VISUM simulations, a thorough assessment of the toll road's financial viability and sustainability can be achieved.

Toll road in Amman contributes to environmental sustainability by reducing fuel consumption and vehicle emissions. By optimizing traffic flow and reducing congestion, toll roads minimize idling time and stop-and-go traffic, which are major contributors to fuel waste and air pollution. Additionally, toll roads' efficient operation helps mitigate greenhouse gas emissions associated with transportation.

3. Methodology

The methodology used in this study follows a structured scientific approach to analyze various characteristics and data related to the Queen Alia International Airport Road. Firstly, geometric data detailing the design of the highway, such as the number of lanes, lane widths, and locations of interchanges, was collected from reputable sources including the Greater Amman Municipality, the Ministry of Public Works and Housing in Jordan. This data provides a comprehensive understanding of the physical layout of the road.

Secondly, traffic data was collected to understand the volume and flow characteristics of traffic on the Airport Road. This information was sourced from the Central Traffic Department, providing insights into traffic patterns, congestion levels, and peak traffic hours. Additionally, data on fuel prices and vehicle counts were obtained from the Al-Manaseer Oil & Gas Group and the Department of Statistics in Jordan, respectively.

Furthermore, toll infrastructure cost data and survey questionnaires were utilized to assess driver attitudes and preferences towards road pricing schemes. The cost data, obtained from relevant authorities, includes expenses associated with monitoring and violation cameras, booths, signage, and toll machines. Survey questionnaires were distributed to gather feedback from drivers regarding their acceptance of toll-based pricing schemes, helping to gauge public opinion and willingness to pay

Moreover, the operational costs of toll road methods were evaluated to identify the most economical approach. By comparing the costs associated with manual toll collection versus automatic toll machines, the study aimed to determine the most cost-effective method for toll collection.

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Finally, the transportation planning software VISUM was employed for traffic flow modeling. This software considers various factors such as traffic demand, network structure, and route choice behavior to simulate the impact of proposed interventions on urban transport dynamics. Different scenarios based on toll prices were evaluated using VISUM, and the level of service based on highway capacity was assessed manually, allowing for a comprehensive analysis of potential interventions and their implications for traffic management and infrastructure planning. Figure 1 provides a concise overview of the methodology used in this study.

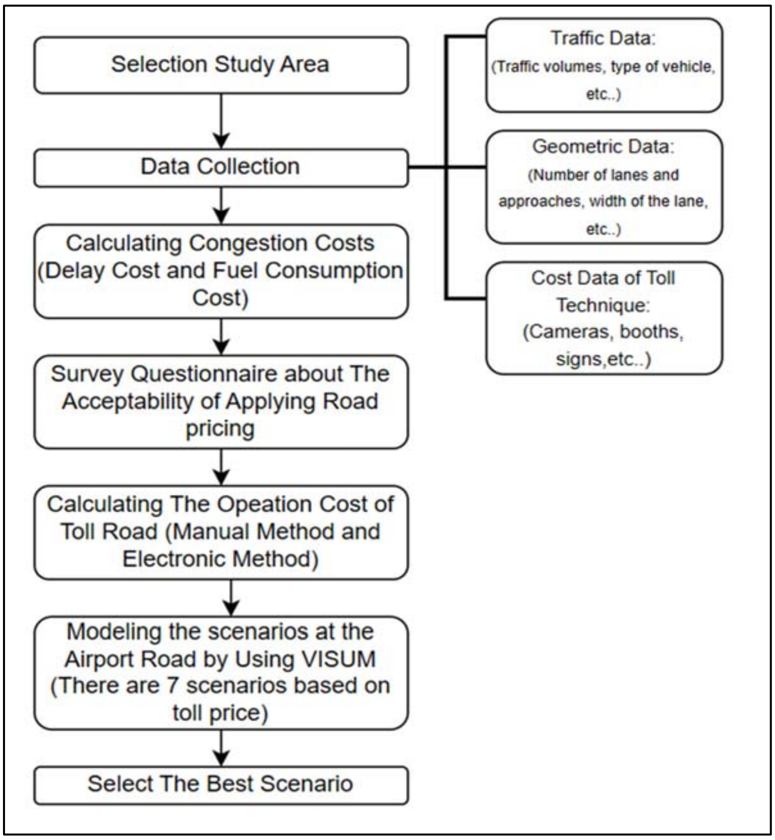

Figure 1. Research methodology at Airport Road.

3.1. Research Location

Amman, a prominent urban center in Jordan, is home to approximately 4.642 million people as of 2021, making up about 42% of the country's total population. The city's dense urban environment has led to a significant increase in vehicular traffic, contributing to congestion challenges on its road network. This study focuses specifically on analyzing two sections of the Airport Highway (From Ministry of Foreign Affairs to Madaba Interchange and From Madaba Interchange to QAIA interchange) , a vital transportation artery in Jordan. The Airport Highway experiences consistently growing traffic volumes, primarily because it serves as a crucial link between Queen Alia International Airport and the southern regions of Jordan. Moreover, the southern region, home to popular tourist destinations like Petra and Aqaba, also serves as a major freight hub due to its sole container port in the kingdoma as shown in Figure 2. With numerous ongoing and planned developments along the Airport Highway, traffic is anticipated to continue expanding, underscoring the importance of studying this area for effective traffic management strategies.

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Figure 2. An aerial photography for Amman city with the two sections from foreign ministry through Madaba bridge to Queen Alia Airport along Airport Highway (Greater Amman Municipality).

3.2. Geometric Data

As stated by the Greater Amman Municipality (GAM), geometric data comprises crucial information regarding the design of highways, encompassing essential details about highway design such as the number of approaches, lanes, lane widths, length of studied sections, and locations of interchanges. This data provides a basic understanding of the layout and structure of the road.

3.3. Traffic Data Collection

Traffic data collection involves gathering detailed information about the flow of traffic, particularly focusing on the volume of traffic passing through specific points over time. This includes determining the type and number of vehicles crossing selected sections. The data gathered includes information on traffic volume, free flow speed, and congested speed during morning AM peak hour along the study area. These valuable metrics are sourced from the Greater Amman Municipality (GAM) and Ministry of Public Works and Housing (MPWH), specifically collected during morning rush hours as detailed in Appendix A

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Free-flow travel speed: This represents the speed at which vehicles can travel under uncongested conditions, providing a baseline for comparison, and Congested speed: This indicates the reduced speed experienced during periods of traffic congestion, highlighting the impact of traffic volume on travel times and efficiency as shown in Appendix A.

3.4. Cost Data of Toll Technique

The cost data associated with toll techniques involves assessing various economic factors related to transportation infrastructure and operations. This includes evaluating the average cost of time attributed to working hours, representing the monetary value associated with time spent due to work commitments. Additionally, the cost of fuel per gallon is examined to understand the financial implications of fuel consumption in transportation activities.

Key variables collected for analyzing the cost of toll techniques include:

- Average yearly income (JD): This provides insights into the financial capacity of individuals in the region and their ability to afford transportation-related expenses.
- Working days and working hours: These parameters help determine the average time spent on work-related activities, influencing travel patterns and demand for transportation services.
- Cost of time: Calculated by dividing the average yearly income by the working hours, this metric signifies the value of time spent on work commitments.
- Average cost of fuel and diesel (per liter): These values reflect the cost of fuel consumption, essential for understanding the economic implications of transportation activities.a number of variables were collected from different sources as summarized in Table 2.

Table 2. The Required Variables to Calculate Congestion Cost for 2011,2012, 2013 and 2024)**.**

Constant	Value (2011)	Value (2012)	Value (2013)	Current value(2024)
Avg. yearly income (JD)[1]	3276.80	3438.6	3662.83	425.07
Working days[2]	255	255	255	255
Working hours[3]	2040	2040	2040	2040
Cost of Time[4]	1.21	1.27	1.36	1.66
Avg. Cost of Fuel (L)[5]	0.620 JD/L	0.723 JD/L	0.800 JD/L	0.925JD/L
Avg. Cost of Diesel (L)[5]	0.515 JD/L	0.568 JD/L	0.648 JD/L	0.72 JD/L

[1] From the Regression Model in Appendix B [2] Source: Department of Statistics, Jordan (Annual Yearbook of Statistics 2011, 2012, 2013, 2024). [3] By subtracting all Fridays and official holidays in 2011, 2012 and 2013= (365-96-14); and based on job law section 56 in Jordan, the daily working hours =8hr, so working hour per year = 255*8 = 2040 hr. [4] By dividing the avg. yearly income by the working hours in 2011,2012 and 2013 = (1.21,1.27, 1.36 and 1.66) JD. [5] Source: Al-Manaseer Oil & Gas Group.

In Addition, Toll techniques includes various components and equipment necessary for the operation of toll booths or collection points as shown in Figure 3. The Table 3 provides a summary of the costs associated with different toll collection devices including cameras, booths, signs, pavement markings, and automated toll machines.

3.5. Congestion Cost

The cost of congestion encompasses two primary components: delay and fuel consumption. Delay refers to the additional time spent by motorists due to congestion, resulting in lateness for work or other commitments. Fuel consumption increases during congestion due to prolonged engine usage, leading to higher costs and increased emissions, contributing to environmental issues like global warming.

Data collection involved studying traffic volumes and speeds during peak hours along the Airport Highway sections. The delay cost was calculated by determining the difference in travel time between congested and uncongested periods, based on the value of a working hour in Jordan.

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Additionally, fuel-wasted costs were estimated by comparing fuel consumption rates at congested and uncongested speeds. These costs were then added to obtain the total congestion cost for each roadway section.

The following general steps are used to calculate the congestion cost in this study for each urban roadway section:

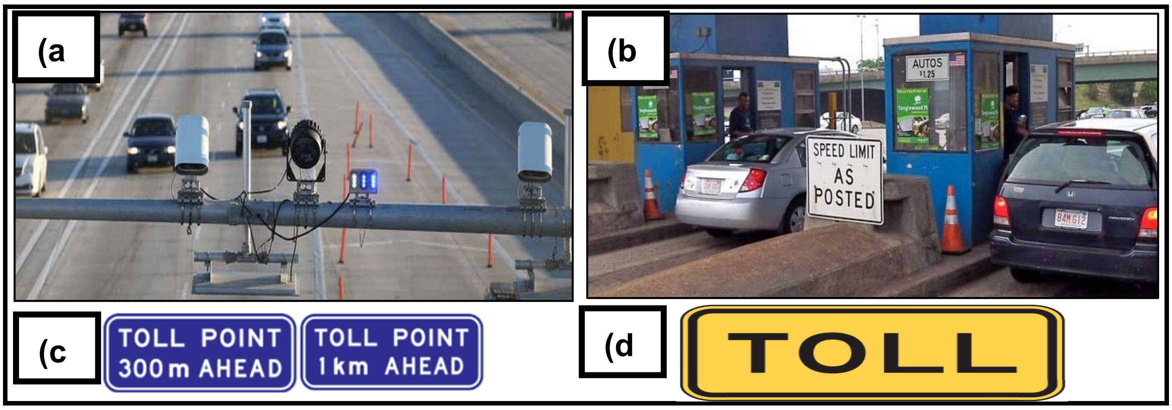
1. Obtain traffic volume data by road section.
2. Determine AM peak hour and PM peak hour for years 2011,2012 , 2013 and 2024.
3. Obtain congested & uncongested speed for each section.
4. Calculate vehicle delay by measuring the sectional time lost between congested and uncongested conditions.
5. Determine wasted fuel for each section as the difference between fuels consumed on congested and uncongested speed.

Determine the total congestion cost.

Table 3. Details of Charging Method Costs.

Techniques	The cost of one (JD)*
Monitoring Cameras	4,000
Violation Cameras	40,000
Booths	9,000
Signs in Advance of a Toll Point	443.75
Signs at a toll Point	303.75
Pavement marking at toll points	150
Direction Signs	443.75
poly venile chloride cone	14
Employer	300
Toll Machine	56,000

(*) 1 JD = 0,72 US.



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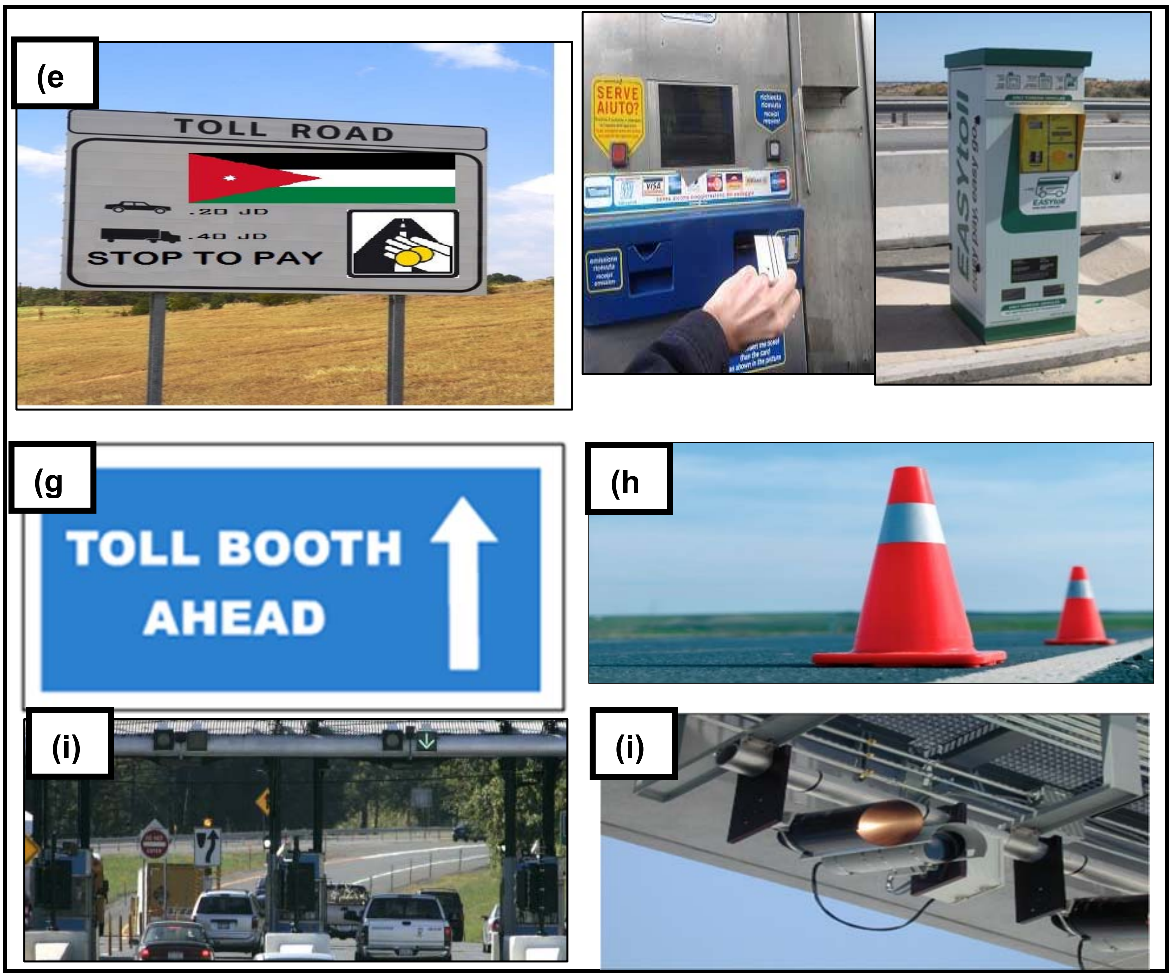

Figure 3. Toll Techniques at Airport Road: (a): Monitoring cameras., (b): Toll booths, (c) Advanced Sign of Toll Station, (d): Pavement markings at the Toll Point, (e): Sign at Toll Point, (f): Automatic Toll Machine, (g): Directional Sign, (h): Polyvinyl Chloride cone, and (i): Violation Cameras.

3.6. Survey Questionnaire

In this study, a road pricing scheme was designed for the Airport Highway to examine drivers' attitudes towards such schemes. A survey questionnaire was conducted with travelers at various locations along the airport road (Madaba, Marj Al-Hamam, and the South of Jordan). Participants were asked several questions to determine their preferences regarding road pricing, their acceptance, and their willingness to pay for the implementation of such a scheme.

The primary tool of this study was a stated preference questionnaire, organized into four sections, as detailed in Appendix C.

Section 1: This section includes questions about the demographic and socioeconomic characteristics of the drivers, such as gender, age, household income, and education level.

Section 2: The objective of this section was to inform and raise awareness about road pricing schemes, focusing on their potential positive and negative impacts. It contained questions about the advantages and disadvantages of a congestion pricing scheme, which was especially relevant for users with little experience with road pricing.

Section 3: This section gathered information related to respondents' travel behavior, specifically the number of trips and the purpose of these trips. The assumption is that travelers' acceptance and willingness to pay for a congestion charging scheme depend on their trip characteristics.

Section 4: This section included questions about the preferred payment method and acceptable pricing. The objective was to identify the most suitable payment method and an acceptable fee or price.

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3.7. Evaluation the Operation Cost of Toll Road

The operation cost includes the costing of two toll road methods: the manual method and the automatic toll machine method for the service road along main road. Specifically applied to the service road alongside the main thoroughfare of the airport road, this assessment underscores the importance of exploring various charging mechanisms to determine the most cost-effective approach that optimizes revenue generation. The manual method entails a detailed estimation of expenses, encompassing the deployment of monitoring cameras, booths, pavement markings, signage, and employee salaries during peak operational hours. Considering the airport road's three lanes, each section requires three booths, as illustrated in Figure 4. Thus, three monitoring cameras are installed in each section's three lanes to ensure efficient monitoring. Booths play a vital role in facilitating the payment process, occupying an area of approximately (3.10m × 3.66m). Detailed specifications of the booths are provided in Appendix D.

Figure 4. The positions of Toll Booth at Airport Road with Red Circles.

Different types of Toll Road Signs play pivotal roles in guiding drivers and providing essential information before they enter toll roads. These include Signs in Advance of the Toll Point, Signs at the Toll Point, Pavement Markings at the Toll Point, and Direction Signs. Signs in Advance of the Toll Point serve to inform drivers about approaching toll points, ensuring they are aware of upcoming toll booths. These signs are crucial in preparing drivers for toll payment and navigating through the toll road. They typically measure (2.5m×1.25m), with a sign column height of 4.5m. Signs at the Toll Point Positioned at toll points, these signs detail payment information and vehicle charges. With dimensions of (1.5m × 0.75m) and a sign column height of 4m. Signs at the Toll Point Positioned at toll points, these signs detail payment information and vehicle charges. With dimensions of (1.5m × 0.75m) and a sign column height of 4m. Signs at the Toll Point Positioned at toll points, these signs detail payment information and vehicle charges. With dimensions of (1.5m × 0.75m) and a sign column height of 4m. Pavement Markings at the Toll Point play a crucial role in guiding drivers within toll areas. These markings, characterized by a black legend on a yellow background, establish a visual connection with the TOLL patch on direction signs. They cover an area of (2m × 2.5m) and are instrumental in ensuring smooth traffic flow within toll plazas.

In addition, the poly vines cones are used to divide the lanes when the toll points are being installed. They are placed about 100 m before toll points. A cone is placed every 3m so the total cones required for the three lanes are 30. Three employees are required for the three lanes.

Conversely, the automatic toll machine system involves calculating the costs associated with toll machines, surveillance cameras, signage, and pavement markings. A camera is important in toll road operations to show more details of payment and to save a fine when vehicles not paying the charge. three cameras in three lanes in each section

3.8. Model Development

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Utilizing the transportation planning software VISUM, an intervention with the urban transport network was modeled. PTV Group developed and maintains VISUM, a tactical modeling package for representing traffic flows in networks. Origin-destination matrices for various user classes to characterize the traffic demand and a geographically precise supply model that specifies a particular road network are the fundamental parts and inputs of the traffic planning software. Additional fundamental components of VISUM include distinct assignment protocols, which are necessary to connect supply-side and demand-side traffic. Estimated flows for each vehicle category on each network link are the outcome of the assignment procedure. While VISUM can also manage public transportation, this functionality was not included in these simulations because the demand for both public and private transportation is not very interdependent. Furthermore, compared to individual motorized traffic, calculation durations and data needs for public transport assignments are significantly higher. Owing to the strong supply-side interdependencies between passenger cars and freight traffic, both demand groups were included in our simulations. The underlying ideas of transport assignment models such as VISUM are illustrated in Figure 5.

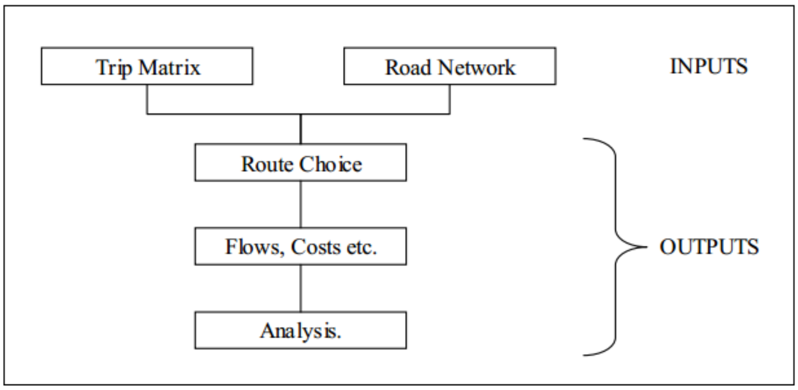

Figure 5. Basic Structure of the Transport Model.

To model the toll road, we created the required road along the route of Airport Road with link type 13 (Freeway speed 110 km/hr, 3 lanes) and edited the link to add the chosen toll charge for each vehicle type. For the service road, we adjusted the link type for the current Airport Road to provide a lower Level of Service (LOS), selecting road type 32 (Suburban dual 2, medium intersected). To incorporate the toll charge into the impedance calculation, we accessed the calculation procedures, opened the functions tab, and selected PrT, then Impedance. For each formula, we used Create and added 1*Toll PrTsys, adjusting the coefficient for Toll PrTsys to, e.g., 2 or 4, to set different tolls for goods vehicles. The toll was input in fils, and the impedance calculation was based on the value of time.

The toll charge must be added for each link, making it challenging to allow users to access different sections and all pay a fixed cost. To address this, we considered the following options:

Option 1: The toll road extends from the Foreign Ministry to the Airport with no intermediate entry points. This would result in lower traffic flow since the toll road would no longer serve South Amman.

Option 2: Three separate toll roads are created for each of the three entry/exit points for journeys to the airport (Foreign Ministry, Marj al Hamam Bridge, and Madaba Bridge). Congestion and speeds would need to be checked manually.

Option 3: Different tolls are applied to each section, so only vehicles traveling from the Foreign Ministry to the airport pay the full amount. Vehicles are charged for all the sections they use, requiring the definition of three link types.

Option 4: The toll is applied only to vehicles using the section from Madaba Bridge to the airport, restricting access to the toll road for those not using this section.

After testing all options, we found that due to the low levels of vehicles assigned to the toll road in 2012 and 2025, Option 1 was the most suitable. Subsequently, we tested Option 4 using two sections

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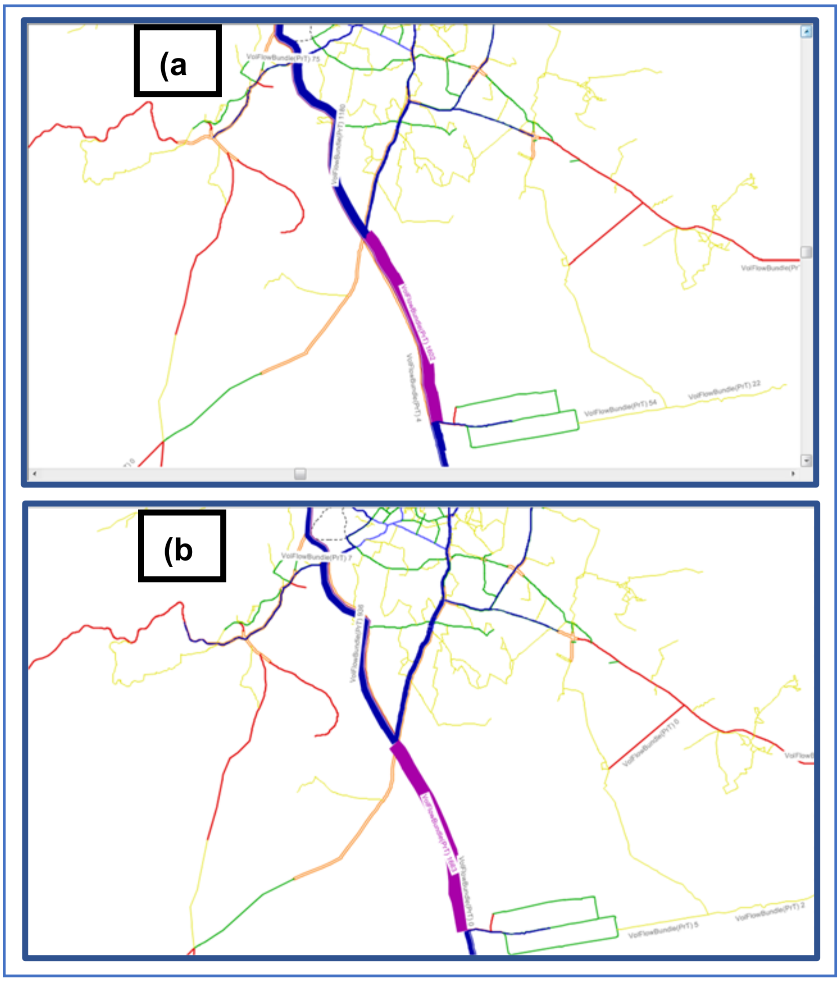
of the toll road. The toll was charged on the first section (from the Foreign Ministry to Madaba Bridge), and only vehicles using this section were allowed to use the second section (from Madaba Bridge to the airport). This configuration allowed the toll road to be accessed from Madaba Bridge for trips to or from Amman only.

The traffic infrastructure that is currently in place is represented in a simplified manner by the network model. It is made up of nodes with links between them. The regional location and connections of the nodes and links in the network model are first determined by the network structure that has to be mapped as detailed in Figure 6a and 6b. Furthermore, in VISUM, every network element can be given a set of unique properties.

Equation 1 calculates the length of the stretch, the speed at which a vehicle may travel freely, the maximum capacity, and the proportion of the road that is congested for linkages. Figure 6c displays an example of a VISUM network.

$$\%\ Traffic\ Congestion = \ Volume/(Capacity\ ) \times 100\ \% \qquad (1)$$



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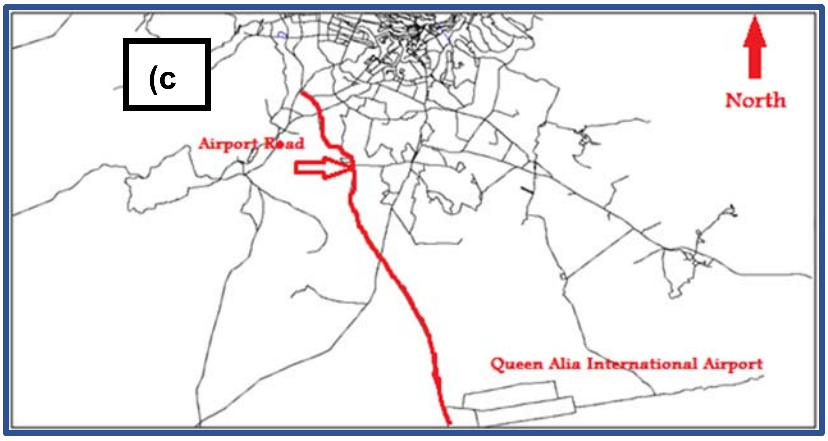

Figure 6. (a):Southbound Traffic Flow Bundles and (b):Northbound Traffic Flow Bundle. (c): VISUM Network Model for Amman.

The number of trips (from / to traffic zone) for each origin-destination (O-D) pair is represented by fixed, typically symmetric matrices in VISUM, which is used to analyze travel demand. As a result, distinct transport demand segments (such as those for cars and trucks) can be distinguished. The alternate routes for the travel demand of an origin-destination pair are determined by the network's structure as well as the physical attributes of each individual route section. Usually, when modeling the simultaneous route choice of all road users, a mono-criteria method is used. This indicates that the various factors considered while selecting a route—such as travel durations, tolls, and trip times—are combined into a single value known as "generalized costs."

For every demand segment, average values of time and distance (VoT, VoD) must be stated in addition to link-specific conditions like a toll. This makes it possible to see a road user's route selection as a unique cost minimization issue. When using the same links to make trips for distinct O-D relations, the route chosen is reliant on each other. As a result, capacity-limited assignment techniques typically operate iteratively, beginning with an initial demand allocation on possible network paths that is frequently arbitrary. But in VISUM, a change in the overall costs—for example, because of a toll or newly constructed road—only affects route choice behavior and has no effect on demand levels. We exogenously modeled these effects on demand levels since the premise of a stable demand is impractical for greater changes in generalized costs.

4. Results and Discussions

4.1. Congestion Cost

The traffic volume data provided by the Ministry of Public Works and Housing (MPWH) allowed for the identification of morning (AM) peak period: 8:00 to 9:00. Engineering drawings from MPWH provided the estimated lengths of sections, and speed data (congested and uncongested) were also obtained from MPWH designs. Delays were calculated for each section by measuring the time difference between congestion and uncongested conditions. This information was then used to calculate the congestion cost caused by delays. The results are detailed in Table 4.

Table 4. (a) Delay Time on the Airport Highway during AM Peak Hour for 2011 and (b): Delay cost, Fuel Consumption cost and congestion cost during AM Peak Hours.

(a) **HCM Control delay for vehicles (seconds)**	**LOS**	**General Description**
0-10	A	Unrestricted Flow
>10-15	B	Consistent Flow (minor delays)
>15- 25	C	Consistent Flow (Tolerable delays)
>25-35	D	Approaching Unsteady Flow

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>35-50	E	Unsteady Flow
>50	F	Forced Flow

(b) Delay Time on the Airport Highway during AM Peak Hour for 2011

Section	Length of the section (Km)	Travel time based on congestion speed (min)	Travel time based on uncongested speed (min)	Delay per vehicle (min)	LOS
Sec # 1	16	12	9.6	2.4	F
Sec # 2	11	8.25	6.6	1.65	F

(c)Delay cost, Fuel Consumption cost and congestion cost during AM Peak Hours

Year	Delay cost (JD)	Fuel consumption cost(JD))	Congestion cost(JD)
2011	73,853	4,129,501.5	4,203,354.5
2012	107,141.5	6,300,127.5	6,407,269
2013	91,549	5,624,965.6	5,716,514.6
2024	1,182,960	5,911,486.6	7,094,446.6

Based on MPWH data:
Average Traffic volume = 1392 + 2330 + 2153 + 1216 = 3,546 vehicles/hour
Total delay in 2011 = 2.4 + 1.65 = 4.05 min/vehicle
*Yearly delay per vehicle = 255 * 4.05 = 17.21 hours*
*Total yearly delay for AM peak volume = 17.21 * 3,546 = 61,035.5 h-veh*
Total cost = total delay × cost of time (hours)
*Total cost = 61,035.5 * 1.21 (JD)*
Total congestion cost due to delay time for 2011 = 73,853 JD

Similar calculations were conducted for 2012 ,2013 and 2024 for AM peak hours resulting in congestion costs of 107,141.5 JD ,91,459 JD and 7,094,446.6 respectively

Air resistance is a major component that affects fuel usage. A car's energy expenditure to overcome air resistance might reach 40%. Since air resistance increases exponentially with speed, the increase in air resistance during a 65 mph to 70 mph acceleration is greater than the increase during a 55 mph to 60 mph acceleration. More energy is needed to overcome greater air resistance, which increases fuel consumption.. For instance, accelerating from 65 mph to 70 mph requires significantly more energy than accelerating from 55 mph to 60 mph because air resistance rises exponentially with speed.

In our study, we analyzed fuel consumption across different speeds to illustrate this relationship. As shown in Figures 7 and 8, we found that vehicles consume more fuel at both low and high speeds compared to an optimal speed. Specifically, at lower, congested speeds, vehicles are often forced to operate inefficiently due to frequent stops and slow-moving traffic, leading to higher fuel consumption. For example, vehicles traveling at an optimal speed of around 55 kph (kilometers per hour) tend to have better fuel efficiency because this speed strikes a balance between minimizing air resistance and maintaining steady, smooth driving conditions.

Conversely, when vehicles travel at lower speeds, such as those seen in congested traffic, they consume more fuel per kilometer. This is because constant acceleration and deceleration, idling, and lower engine efficiency contribute to higher fuel use. Our figures illustrate that vehicles traveling at congested speeds (such as 90 km/h in our study) have higher fuel consumption rates than those traveling at an optimal, steady speed of 55 kph. In our studied street the values of congested and uncongested speeds are 90 and 100 km/h, respectively, then Similar calculations were conducted for 2012, 2013 and 2024. resulting in fuel consumption costs, respectively, then total congestion cost as shown in Table 4 for AM peak hours.

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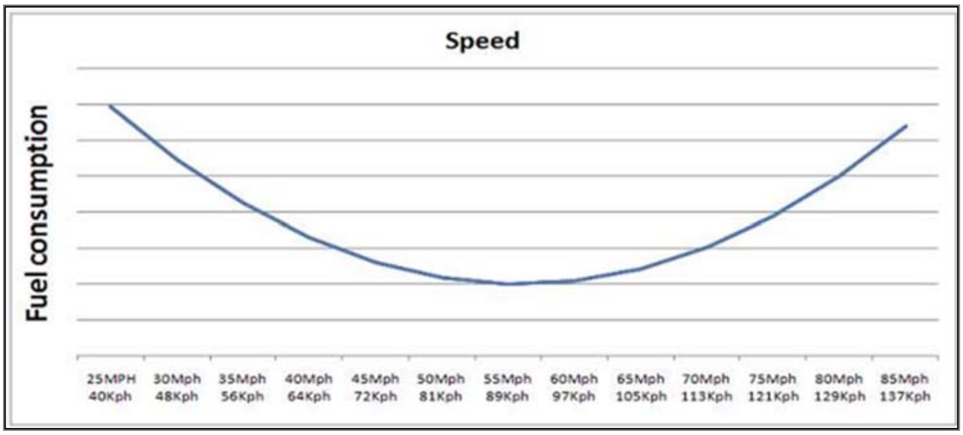

Figure 7. Relationship between Speed & Fuel Consumption[40].

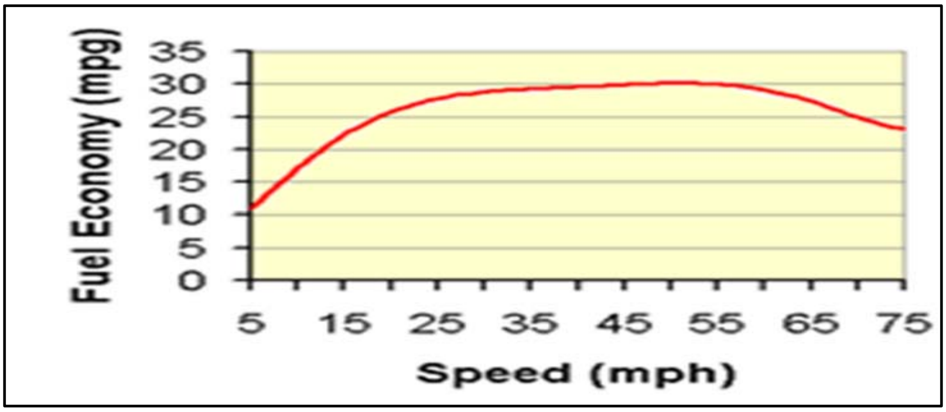

Figure 8. Standard curve between Speed and Fuel Economy[41].

At 90 km/hr (congested speed), fuel economy = 30 mpg (mile/gallon).
At 100 km/hr (uncongested speed), fuel economy =28 mpg(mile/gallon).
Fuel wasted/ vehicle /km = 30- 28= 2 mile/gallon = .28 L/km.
*Annual Fuel wasted cost by PC = .28 * 27 * 2,278 * 0.62 * 255= 2,722,747.6 JD*
*Annual Fuel wasted cost by HV = .28 * 27 *1,227 * 0.515 * 255= 1,218,186.5 JD.*

4.2. Survey Questionnaire

The questionnaire was filled out through in-person, direct interviews. Decision-makers and other road users, including drivers, passengers, students, etc., participated in the sample.The goal of the field study was to gather various drivers and trip characteristics, hence it was carried out on weekdays (working days) during various working hours. In order to give the respondents all the time they needed to answer the questions, the majority of the interviews were conducted in offices of the Greater Amman Municipality, the Ministry of Works and Housing, the Land Transport Regulatory Commission, universities like Al-Isra'a, MEU, Petra, and Zaytouna, and roadside gas stations. To ensure that participants understood every aspect of congestion pricing, thorough explanations were given both during the interview and when completing the questionnaire. In order to avoid any doubt about the responses given, the interviewers thoroughly explained each question to the respondents.

After 650 questionnaires were completed, the responses were carefully examined, and 26 of the completed surveys were excluded from the analysis because they contained errors or inconsistent information. As a result, 624 questionnaires made up the final sample.

4.2.1. The Demographic and Socioeconomic Characteristics

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This section includes questions related to the demographic and socioeconomic characteristics of the drivers; including: gender, age, household income and level of education obtained as shown in Table 5.

Table 5. Summary of Socioeconomic and Demographic Characteristics**.**

Gender		Age		Employment		Education		Monthly Household Income	
Male	335	18-24	213	Employed	195	Un-educated	11	<250	61
		25-34	232			School	52	250-500	183
		35-44	97	Self-Employed	156	Diploma	66	500-750	177
Female	289	45-54	44	Unemployed	37	Bachelor	360	750-1000	116
		55-64	19	Retired	28	Master	98	1000-1500	49
		>65	19	Student	208	PhD	37	>1500	38

Table 5 shows that 53.7% of the sample were males while, 46.3% were female. The highest percentage of age groups was (37.2%) for the (25–34-year-old, and the lowest percentage was for group between 45-64 years & more than 65 years with about 19.0%.

Table 5 reveals that the category with highest percentage within the sample was students with (33.3%), and the percentage for employee reached (31.3%), while the lowest percentage was for the retired (4.5%). The highest percentages for education 57.7% of the sample were bachelor degrees, while the lowest percentage for uneducated with only.(%1.8)

Table 5 also shows that the highest percentages of interviewees came from households of low-income brackets (250-500) with 29.3%, and for (500-750) reached 28.4%. The lowest percentage of respondents came from the highest income category; earning more than 1500JD was a mere 6.1%.

4.2.2. Trip Characteristics

This section involved information related to elements of respondents travel behavior with respect to their trip characteristics. In particular, the number of travel trips and the purpose of their trip. The necessity of obtaining such information is based on the assumption that traveler acceptability and willingness-to-pay for a congestion charging scheme is dependent on trip characteristics.

Driver trip characteristics were also analyzed and the results are presented in Table 6. The majority of drivers driving on Airport Road make work related trips (38.5%) and (35.4%) were on studying trips to the many universities on airport road, either in Amman or in the South of Jordan. The majority of trips were frequent trips, 2-4 times in a week (39.9%), because most workers and students come from the south to work in Amman or come from Amman to work in southern destinations like Aqaba.

Table 6. Trip Characteristics.

Number of trips/week		Trip Purpose	
Never	6.80%	Work	38.50%
<2	19.80%	Travel	24.20%
2-4	39.90%	Studying	35.40%
>4	16.50%	Social relations	1.9%
Every day	16.90%		

Table 7 shows that the answer to the occurrence of congestion with the highest percentage of responses was “sometimes” which reached 59.9% (N=374) while the response “rarely” reached (32.2%); while the lowest percentage was for “always” (7.9%). The last questions related to the road pricing charging method. About 54% of respondents chose the “Travelled Distance”. The most agreed upon response on the suitable value of toll was (0.25JD), with a percentage 34.8% as explained in Table 13.

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Table 7. Responses to Occurrence of Traffic Congestion.

Congestion Occurrence	Frequency	Percentage
Rarely	201	32.20%
Sometimes	374	59.90%
Always	49	7.90%
Total	624	100

4.2.3. The Advantages and Disadvantages of a Congestion Pricing Scheme

Statistical analysis by SPSS of the data extracted from the second section of the questionnaire elicited driver preferences in relation to the measure of road pricing. What needs to be considered together with the identified trends is that the survey participants have not experienced the implementation and effects of such a measure. Increased travel time was considered to be the most important effect of traffic congestion by the participants being followed by environmental pollution and deterioration of psychological calm.

The advantages and disadvantages of a congestion scheme as perceived by the road users provide an indication of user acceptability factors.

Tables 8 and 9 illustrate drivers perceptions on the advantages and disadvantages of a congestion pricing scheme.

Table 8. Advantages of Road Pricing.

Advantage	Low Effect	Moderate Effect	High Effect
Improve highway quality	18.30%	48.40%	33.30%
Reducing Environmental pollution	18.40%	40.40%	41.20%
Increase in the use of transit	18.10%	43.90%	38%
Reduction in congestion	15.70%	49.40%	34.90%

Table 9. Means and Standard Deviations of Responses.

	Statement	Mean	Standard deviation
1	Applying road pricing improves highway quality	2.15	.703
2	Applying road pricing reduces environmental pollution	2.23	.738
3	Applying road pricing increases the use of transit	2.20	.723
4	Applying road pricing reduces traffic congestion	2.19	.686

Table 8, users perceived improvement in environmental conditions as the most important advantage of a road pricing scheme (41.2% chose it as an important advantage) while the increase in use of transit came second with 38% selecting it as an important advantage.

The overall means and standard deviations of the responses are displayed in Table 9. The results indicate that the mean of Statement 2 (Applying road pricing reduces environmental pollution) was the highest (2.23), with the standard deviation =0.738; followed by the overall mean of Statement 3 (Applying road pricing increase the use of transit) which was (2.20), with a standard deviation =0.723, while Statement 1 (Applying road pricing improves highway quality) had the lowest impact with a mean =2.15 and (0.703) standard deviation.

A one sample t-test was conducted to evaluate whether their mean was significant. The results are in Table 10. The sample mean (2.19) was significantly t (623)=10.390.

Table 10. One way t-test of Advantages.

Mean	Standard deviation	T	df	Sig
2.19	0.462	10.390	623	000

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Most respondents (37%) explained that road pricing was not fair because people with low income are not able to afford to pay for every trip ; this makes sense wince most monthly household incomes of respondents were between (250-500 JD). Another disadvantage highlighted was loss of privacy with a percentage of (30.1%)as shown in Table 11.

Table 11. Disadvantages of road pricing.

Disadvantage	Low Effect	Moderate Effect	High Effect
Not Fair	22.30%	40.70%	37%
Loss of privacy	23.70%	46.20%	30.10%

A one sample t test was conducted of respondent sample about disadvantages of a congestion pricing to evaluate whether their mean was significant. The results are in Table 12. The sample mean (2.10) standard devation (0.593) was significant as t(623) =4.451.

Table 12. One way t-test of Disadvantages.

Mean	Standard deviation	T	df	Sig
2.105	0.593	4.451	623	000

4.2.4. The Details of Payment

This section included two questions about the best method to pay and the value of price. The objective of this section is to find the most suitable payment method and an acceptable fee or priceas shown in Table 13.

Table 13. Road Pricing Characteristics.

Value of Toll (JD)		Road Pricing Method	
0.25	34.80%	Travelled distance	54.20%
0.5	25.50%		
0.75	7.70%	Travel time	28.70%
1	20.80%		
1.25	7.10%	Type of vehicle	17.10%
1.5	4.10%		

4.3. Costs of Road Pricing Scheme

The road pricing scheme encompasses two methods: the manual method and the automatic toll machine method, each requiring thorough cost estimation for comparison. In the manual method, costs include 12,000 JD per section for cameras, 27,000 JD for booths, and variable costs for signs and pavement markings. The signs at the toll point, for instance, amount to 303.75 JD each, while pavement markings cost 150 JD per lane. Direction signs are priced at 443.75 JD each, and PVC cones total 420 JD. Additionally, the monthly salary for three employees per section is 900 JD.

In contrast, the automatic toll machine method involves significant equipment costs. Each toll machine costs approximately 56,000 JD per section, with a total of three machines required. Cameras for this method amount to 12,000 JD per section. Similar to the manual method, signs and pavement markings incur costs, with advance signs estimated at 443.75 JD each and signs at the toll point at 303.75 JD each. Pavement markings cost 150 JD per lane, direction signs 443.75 JD each, and PVC cones 420 JD in total.

Two charging methods are explained. The costs of both methods are summarized in Table 14.

Table 14. Details of Charging Method Costs.

Techniques	The cost of one (JD)	Total Number	Total Cost	Total Cost (Automatic

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			(Manual Method)	Toll Method)
Monitoring Cameras	4,000	9	36,000JD	-
Violation Cameras	40,000	9	-	360,000JD
Booths	9,000	9	81,000JD	-
Signs in Advance of a Toll Point	443.75	6	2,662.5JD	2,662.5JD
Signs at a toll Point	303.75	3	911.25JD	911.25JD
Pavement marking at toll points	150	9	1,350JD	1,350JD
Direction Signs	443.75	3	1,331.25JD	1,331.25JD
poly venile chloride cone	14	70	980JD	980JD
Employer	300	9	2,700JD	2,700JD
Toll Machine	56,000	_____	_______	504,000 JD
Total Cost			126,935JD	873,935JD

*(Note: excluding the maintenance costs and cycle life).

4.4. Outputs of Model Development

4.4.1. Modelling the Toll Road (2012)

In the AM peak hour model for 2012, the following outputs and results were obtained:

Travel Time Analysis: Table 15 summarizes the travel time between the Foreign Ministry and QAIA during the AM peak hour on both the main road and service road, in both directions. Notably, southbound travelers on the main road spend 16.76 minutes, while it takes 24.06 minutes on the service road in congested conditions. The difference in travel time between the two roads is 7.30 minutes. Similarly, in the northbound direction, the difference between the two roads is 4.88 minutes as detailed in Appendix E. Additionally, Figure 9 illustrates the difference between free-flow time and the current service time of the toll road.

Table 15. The (a): Travel Time in AM peak hour on both roads in 2012(without pricing) and (b): Travel time on the main road and toll road in AM peak hour (2012).

(a)Travel Time in AM peak hour on both roads in 2012(without pricing)				
Travel Time	**Main Road**		**Service Road**	
	Southbound	**Northbound**	**Southbound**	**Northbound**
Free flow time (min)	15.33	15.33	22.20	22.20
Current time (min)	16.76	30.80	24.06	35.68
(b)Travel time on the main road and toll road in AM peak hour (2012)				
Travel Time	**Main Road**		**Toll Road**	
	Southbound	**Northbound**	**Southbound**	**Northbound**
Free flow time (min)	15.33	15.33	14.26	14.26
Current time (min)	16.76	30.80	14.26	14.53

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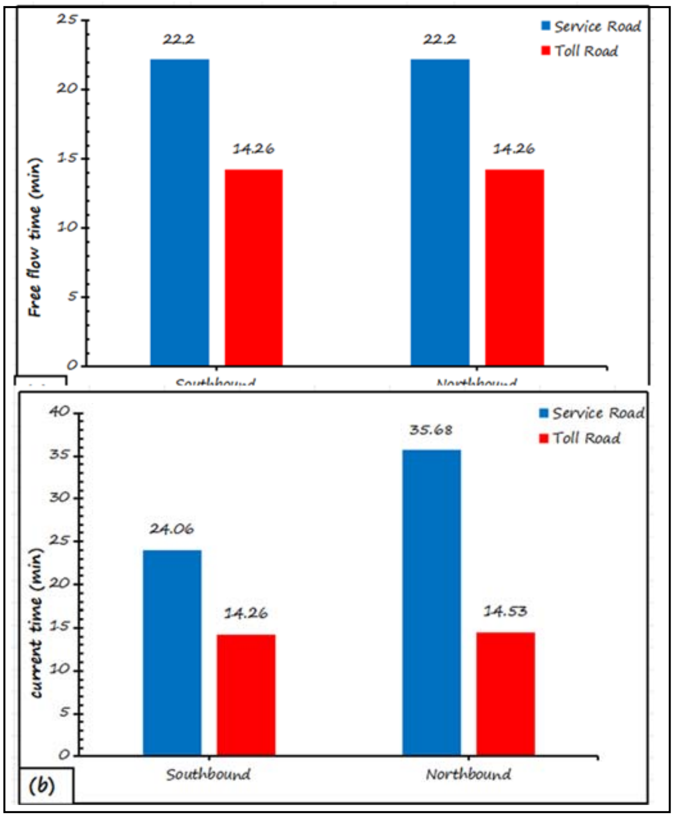

Figure 9. (a)Free flow time in both direction in Service and Toll Road in the AM peak hour (2012), (b): Current time in both direction in Service and Toll Road in the AM peak hour (2012).

– Speed Analysis: Figure 10 depict the speed variations on the main road and the service road, respectively, during the AM peak hour. Speeds reach up to 107 km/h on the main road and 70 km/h on the service road.

– Traffic Congestion Percentage: Figures 10 illustrate the percentage of traffic congestion during the AM peak hour on both the main road and the service road for 2012. Congestion levels are depicted as 179% in the northbound direction and 75% in the southbound direction on the main road. The service road experiences congestion starting at 153% and 70%, respectively, gradually decreasing along the distance.

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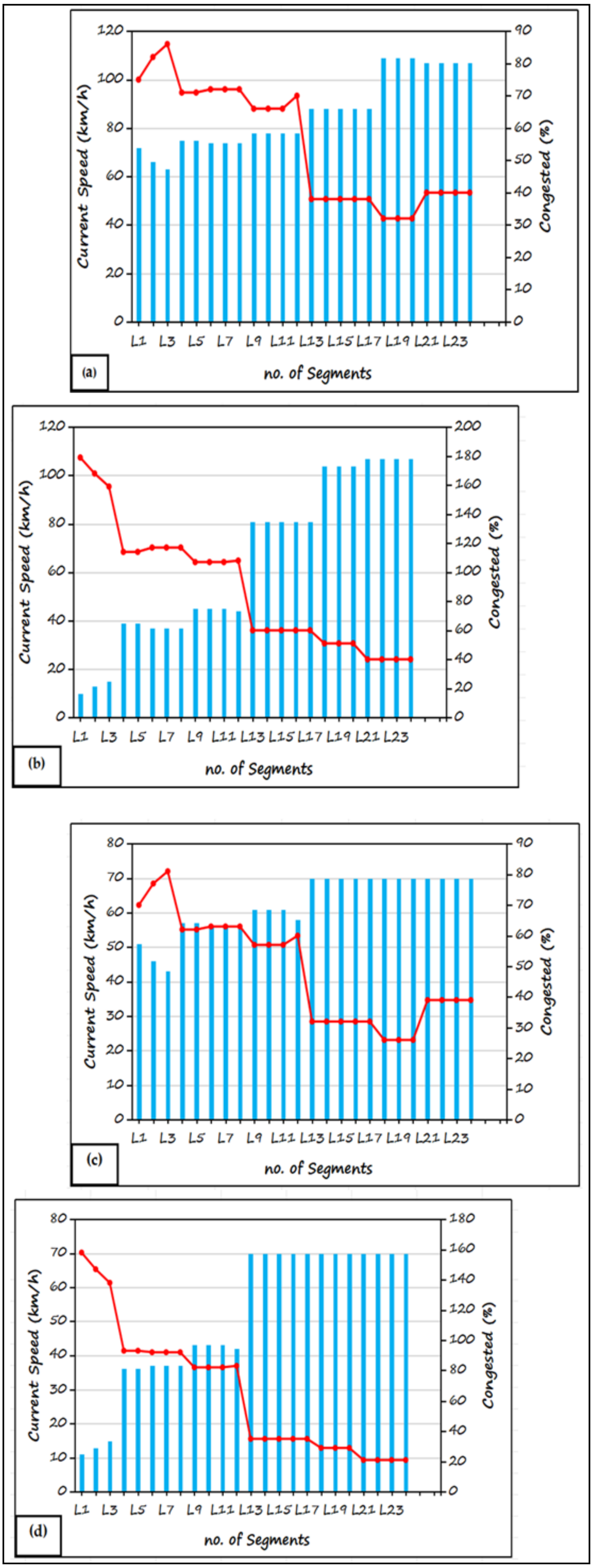

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Figure 10. (a)Details of speed and congested on the Southbound of main Road in the AM peak hour (2012), (b): Details of speed and congested on the Northbound of main Road in the AM peak hour (2012), (c): Details of speed and congested on the Southbound of Service Road (Toll) in the AM peak hour (2012) and (d):Details of speed and congested on the Northbound of Service Road (Toll) in the AM peak hour (2012).

4.4.2. Modelling the Toll Road (2025)

In the AM peak hour model for 2025, the following outputs and results were obtained. Detailed information can be found in Appendix E.

- Travel Time Analysis: Table 16 summarizes the travel time between the Foreign Ministry and QAIA during the AM peak hour on both the main road and service road, in both directions. Notably, southbound travelers on the main road spend 33.83 minutes, while it takes 35.81 minutes on the service road in congested conditions. The difference in travel time between the two roads is 1.98 minutes. As for the northbound direction, the difference between the two roads is 10.13 minutes. Additionally, Figure 11 illustrates the difference between free-flow time and the current service time of the toll road.
- Speed Analysis: Figure 12 depict the speed variations on the main road and the service road, respectively, during the AM peak hour. Speeds reach up to 70 km/h in the southbound direction and 60 km/h in the northbound direction on both roads. Furthermore, various model runs were conducted to maximize revenue. The toll price was set at 0.25 JD, resulting in reduced travel time to half its value in the northbound direction. Table 16 presents the travel time values with and without the imposed toll.

Users only pay tolls in the northbound direction, where travel time was reduced from 30.8 minutes to 14.53 minutes. As a result, 684 cars and 21 taxis utilized the toll road, generating revenue of 141 JD.

Table 16. (a)Travel Time in the AM peak hour on both roads, (b): The scenarios of different value of price with different values of revenue in AM peak hour, and (c): Travel Time in the AM peak hour on both roads in 2025.

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(a)Travel Time in the PM peak hour on both roads in 2025 (without pricing)				
Travel Time	Main Road		Service Road	
	Southbound	Northbound	Southbound	Northbound
Free flow time (min)	15.38	15.38	22.08	22.08
Current time (min)	33.83	53.43	35.81	43.30

(b): The scenarios of different value of price with different values of revenue in AM peak hour (2025)								
Revenue (JD)	Number of taxis in North	Number of taxis in South	Number of cars -in North	Number of cars in South	Number of goods vehicle	Toll for goods vehicle	Toll for car	Number of scenarios
970.6	131	30	3659	1033	0	0.4	0.2	1
1122.6	173	30	4380	1030	0	0.4	0.2	2*
971.4	131	30	3664	1032	0	0.8	0.2	3
977.5	115	19	3150	626	0	0.5	0.25	4
843.6	94	4	2608	106	0	0.6	0.3	5
660	56	0	1594	0	0	1.60	0.4	6
0	0	0	0	0	0	2.00	0.5	7

(c):Travel Time in the PM peak hour on both roads in 2025 with pricing				
Travel Time	Main Road		Toll Road	
	Southbound	Northbound	Southbound	Northbound
Free flow time (min)	15.38	15.38	14.20	14.20
Current time (min)	33.83	53.43	14.20	15.51

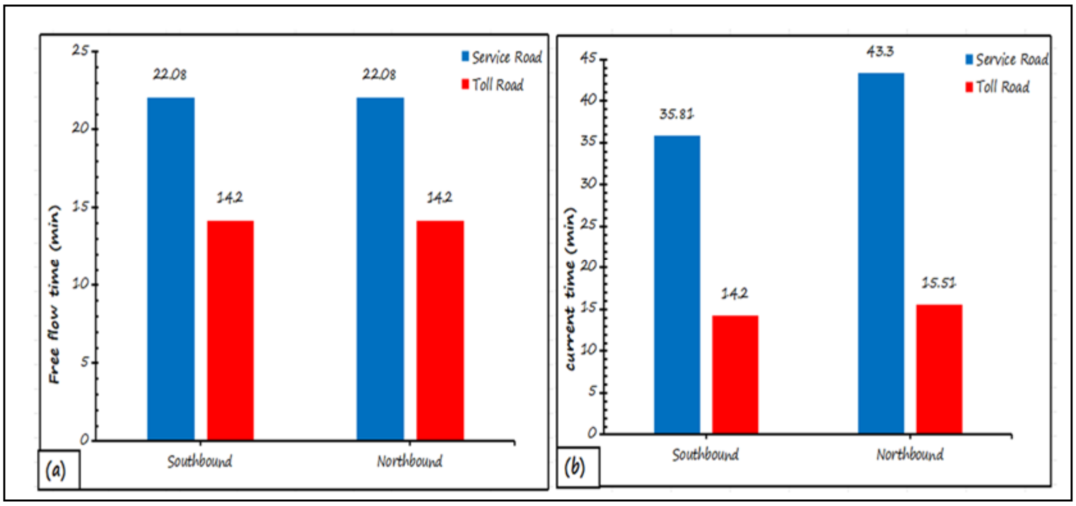

Figure 11. (a)Free flow time in both direction in Service and Toll Road in the AM peak hour (2025), (b): Current time in both direction in Service and Toll Road in the AM peak hour (2025).

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Figure 12. (a)Details of speed and congested on the Southbound of main Road in the AM peak hour (2025), (b): Details of speed and congested on the Northbound of main Road in the AM peak hour (2025), (c): Details of speed and congested on the Southbound of Service Road (Toll) in the AM peak hour (2025) and (d):Details of speed and congested on the Northbound of Service Road (Toll) in the AM peak hour (2025).

– Traffic Congestion Percentage: Figures 12 illustrate the percentage of traffic congestion during the AM peak hour on both the main road and the service road for 2025. Congestion levels are depicted as 155% in the northbound direction and 155% in the southbound direction on the main road. The service road experiences congestion starting at 125% and 115%, respectively, gradually decreasing along the distance. Furthermore, multiple model runs were conducted to maximize revenue. The toll price was set at 0.2 JD. Table 16 presents the scenarios with different toll prices and their corresponding revenue. Additionally, Figure 13 shows the revenue values obtained from the different simulated models. seven scenarios were investigated to achieve the maximum revenue, which was about 1122.6 JD when the toll was set at 0.20 JD for cars and 0.40 JD for goods vehicles. Finally, Table 16 presents the difference in travel time with or without the toll. Travel time changed from 33.83 minutes to 14.20 minutes in the southbound direction and from 53.43 minutes to 15.51 minutes in the northbound direction.

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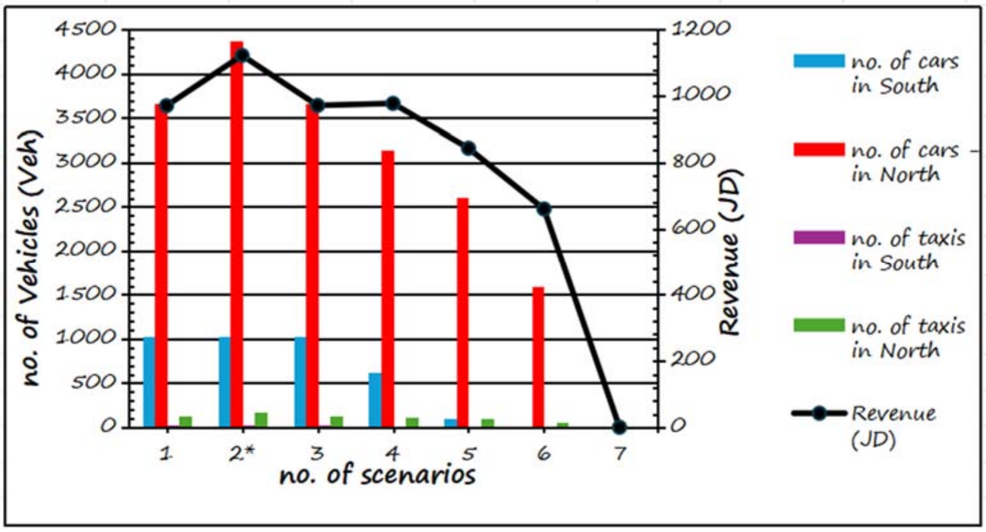

* (No goods vehicles are using the toll road in either direction)

Figure 13. The number and type of vehicles and the value revenue in AM peak hour for all scenarios (2025).

5. Significance of the Study

The significance of toll roads in Jordan, particularly as outlined in this study, is primarily focused on addressing the significant congestion costs on Airport Road. This road has become a major traffic problem due to the increasing volume of vehicles and inadequate infrastructure. The study highlights the significant challenge of traffic congestion in Amman, especially along the Airport Highway, a crucial route in Jordan. This congestion is intensified by increasing traffic volumes due to Queen Alia International Airport, which serves as a main connection to southern Jordan, including major tourist sites like Petra and Aqaba, and the kingdom's only container port. With current and planned developments along this highway, traffic is expected to worsen.

While the Savonius wind turbine (SWT) study, which explored wind turbines along Queen Alia Airport Road, offers a valuable approach to renewable energy, its impact on directly alleviating traffic congestion is less immediate [42]. On the other hand, toll roads provide a more direct and immediate solution to addressing traffic congestion. This study stands out in its approach by focusing on practical solutions to traffic congestion, such as road pricing, and evaluating their feasibility through survey questionnaires and simulation tools like VISUM , whereas other approaches, like the cellular automata model study, delve into advanced simulation technology and its effects on traffic flow[43].

In contrast to other research that examines toll road strategies from profit-maximizing perspectives [44], local and federal government conflicts over non-price measures [45], and theoretical toll allocation methods [46], this study provides a real-world context and immediate solutions to congestion through toll implementation. Moreover, while other studies introduce innovative concepts like mobility consumption theory [47] and models for social welfare maximization in urban planning [48], the current study emphasizes the specific challenges of Jordan's Airport Road, supported by comprehensive data analysis and public feedback.

The current study analyzes the congestion costs for both historical and current years, revealing the growing expenses related to traffic and emphasizing the urgent need for a solution. It also calculates the initial operational costs of implementing a toll road system, considering the use of an alternative service road for toll pricing, making it a practical and cost-effective approach.

To evaluate the feasibility of toll roads, a comprehensive survey questionnaire was conducted, showing that the public is generally in favor of the idea. The survey data on toll pricing was then inputted into the VISUM software to simulate its impact on traffic flow and vehicle movement. This simulation helped analyze how tolls could change traffic patterns, reduce congestion, and improve overall transportation efficiency. The potential revenue from toll roads was compared with the initial

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costs to determine economic viability, with positive results supporting the implementation of toll roads.

By examining traffic data from past, present, and future years, the study offers a detailed understanding of traffic trends, which is crucial for future transportation planning. The detailed analysis, practical solutions, and favorable public feedback underscore the importance of toll roads as a strategic solution to manage congestion and enhance traffic flow on Jordan's Airport Road. The study highlights that toll roads could be a feasible and beneficial improvement for Jordan's transportation system.

6. Conclusions and Recommendations

The study highlights the significant challenge of traffic congestion in Amman, particularly along the Airport Highway, a vital route in Jordan. To evaluate the feasibility of toll roads as a solution, a comprehensive survey questionnaire was conducted, which revealed broad public support for the concept. Data from the survey on toll pricing were then inputted into VISUM software to simulate the impact on traffic flow and vehicle movement.

This simulation enabled an assessment of how tolls might influence traffic patterns, reduce congestion, and enhance overall transportation efficiency. By comparing the potential revenue from toll roads with the initial implementation costs, the study assessed their economic viability. Therefore, the study concludes the findings in main points presented below:

- The study calculated congestion costs for the years 2011, 2012, 2013, and 2024, revealing a consistent annual increase. The results show that congestion costs have been rising each year. For the current year (2024), congestion costs due to delay time and wasted fuel consumption were estimated at 7,094,446.6 JD during the AM peak hour. To address this issue, the study proposed implementing road pricing as a potential solution.
- To evaluate public acceptance of road pricing, a questionnaire was administered, revealing a higher inclination towards such schemes, particularly during peak hours for commuting or education purposes. Environmental benefits were cited as a primary advantage by 41% of respondents, while about 30% expressed concerns about privacy reduction. The preferred charging method was based on traveled distance, with a suggested toll value of 0.25 JD, perceived as fair, particularly considering its potential impact on low-income groups.
- Two models were utilized in the study for old and future years (2012 AM, 2025 AM). The economic feasibility of implementing road pricing in 2025 was assessed, indicating a total cost of 126,935 JD using the manual method and 873,935 JD using automatic toll machines, with an expected revenue of 269,424 JD. Manual toll collection appeared economically viable. However, in 2012, the system was deemed ineffective due to low revenue (141 JD daily during the AM peak hour), outweighed by the substantial implementation costs.
- The reduction in travel time, from approximately 33.83 min to 14.20 min in the southbound direction and from 53.43 min to 15.51 min in the northbound direction, demonstrates positive economic effects. Moreover, reduced travel time yields environmental benefits, such as decreased emissions and noise pollution.
- Practical recommendations include extending the toll road solution to other congested routes within Amman, such as AlMadina Almonawarah Street and Queen Rania Street. Additionally, implementing toll roads on crucial links like Alordon Street, connecting Amman to northern cities, could alleviate congestion and reduce accidents, enhancing overall traffic flow and safety. Future research could explore the applicability of road pricing solutions to other major highways, like the Desert Highway, to further alleviate congestion and improve transportation efficiency across Jordan.

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Data Availability Statement: Data is contained within the article. The data presented in this study are as shown in the article.

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Conflicts of Interest: The authors declare no conflict of interest.

List of Abbreviations

CTD Central Traffic Department
GAM Greater Amman Municipality
HCM Highway Capacity Manual
LOS Level of Service
QAIA Queen Alia International Airport
MTC Manual Toll Collection
ETC Electronic Toll Collection
MPWH Ministry of Public Works and Housing

Appendix A: Traffic Data Used in This Study

Traffic data used for the year 2025										
From Foreign Ministry to Marj al-Hamam Bridge										
	Travelling South					Travelling North				
Number of segments	% Congested	Current speed (km/h)	Free flow time (S)	Current time (s)	Distance (km)	% Congested	Current speed (km/h)	Free flow time (S)	Current time (s)	Distance (km)
L1	152	20	17	71	0.3944	153	18	17	73	0.3650
L2	121	36	12	28	0.2800	166	15	12	69	0.2875
L3	121	36	44	98	0.9800	166	15	44	236	0.9833
L4	128	31	13	34	0.2927	176	12	13	88	0.2933
L5	128	31	11	28	0.2411	176	12	11	72	0.2400
L6	125	33	20	49	0.4491	156	18	20	92	0.4600
L7	125	33	17	40	0.3666	156	18	17	75	0.3750
L8	103	48	37	62	0.8266	143	23	37	128	0.8177
L9	103	48	16	27	0.3600	143	23	16	57	0.3641
Total			187	437	4.1908			187	890	4.1861
From Marj al-Hamam Bridge to Madaba Bridge										
Travelling South						Travelling North				
L10	153	18	21	109	0.5450	182	10	21	201	0.5583
L11	115	39	11	25	0.27080	133	27	11	37	0.2775
L12	115	39	22	51	0.5525	133	27	22	74	0.5550
L13	115	39	23	55	0.59580	133	27	23	79	0.5925
L14	121	34	13	36	0.3400	133	27	13	45	0.3375
L15	121	34	32	84	0.7933	133	27	32	109	0.8175
L16	122	33	31	85	0.7791	139	23	31	122	0.7794
L17	122	34	18	48	0.4533	155	17	18	96	0.45333

L18	122	34	4	11	0.10389	155	17	4	22	0.1038
L19	103	61	37	68	1.1522	148	25	37	167	1.1597
L20	103	61	18	33	0.5591	148	25	18	81	0.5625
L21	94	71	7	11	0.2169	147	25	7	32	0.2222
L22	94	71	27	42	0.8283	147	25	27	119	0.8263
L23	90	74	24	36	0.7400	115	49	24	56	0.7622
L24	90	74	25	37	0.7605	115	49	25	57	0.7758
L25	114	50	12	28	0.3888	106	58	12	24	0.3866
L26	114	50	10	22	0.3055	106	58	10	19	0.3061
L27	114	50	47	104	1.4444	106	58	47	90	1.4500
Total			382	885	10.8300			382	1430	10.9266
From Madaba bridge to Airport										
	Travelling South					**Travelling North**				
L28	111	53	35	72	1.0600	117	47	35	81	1.0575
L29	111	52	41	88	1.2711	125	40	41	114	1.2666
L30	111	52	82	173	2.4988	125	40	82	226	2.5111
L31	111	52	47	99	1.4300	125	40	47	130	1.4444
L32	111	52	15	32	0.4622	125	40	15	42	0.4666
L33	111	53	66	138	2.0316	118	46	66	157	2.0061
L34	94	70	20	31	0.6027	109	55	20	40	0.6111
L35	94	70	21	33	0.6416	109	55	21	42	0.6416
L36	94	70	27	42	0.8166	109	55	27	54	0.8250
Total			354	708	10.8150			354	886	10.8302

Traffic data used for the year 2012										
From Foreign Ministry to Marj al-Hamam Bridge										
	Travelling South					**Travelling North**				
Number of segments	**% Congested**	**Current speed (km/h)**	**Free flow time (s)**	**Current time (s)**	**Distance (km)**	**% Congested**	**Current speed (km/h)**	**Free flow time (s)**	**Current time (s)**	**Distance (km)**
L1	112	41	55	122	1.3894	163	14	55	356	1.3840
L2	162	15	17	105	0.4375	80	68	17	22	0.41550
L3	155	17	9	53	0.2502	79	69	9	12	0.2300
L4	116	38	43	104	1.0977	59	81	43	48	1.0800
L5	116	38	37	90	0.9500	59	81	37	42	0.9450
Total			161	474	4.1250			161	480	4.0550
From Marj al-Hamam Bridge to Madaba Bridge										
Travelling South						**Travelling North**				
L6	96	54	21	35	0.5250	72	74	21	26	0.5344
L7	96	54	11	18	0.2700	72	74	11	13	0.2672

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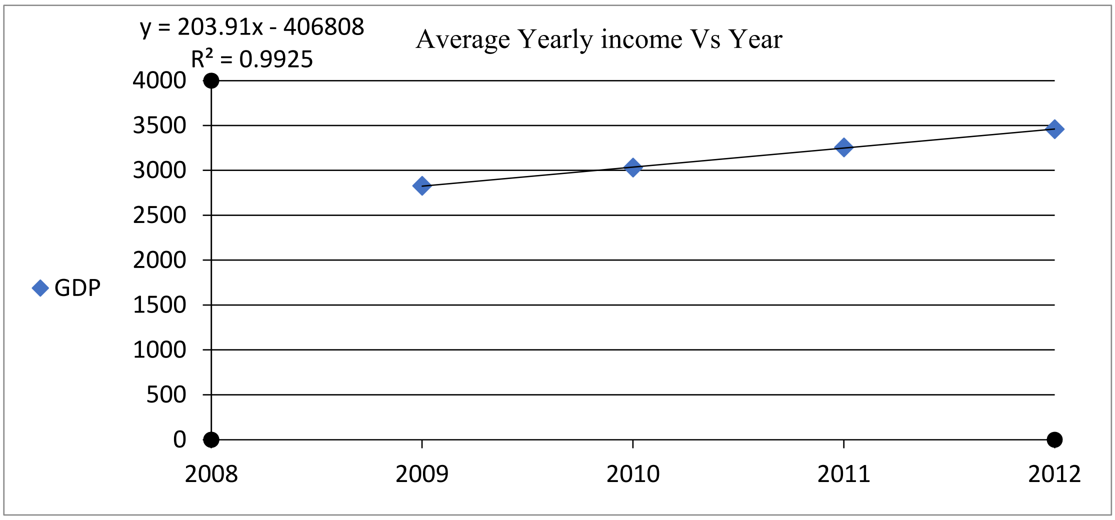
L8	96	54	22	36	0.5400	72	74	22	27	0.5550
L9	89	61	69	102	1.72830	66	78	69	80	1.7333
L10	89	61	31	46	0.7794	66	78	31	36	0.7800
L11	89	61	18	26	0.4405	66	78	18	20	0.4333
L12	88	62	4	6	0.1033	66	77	4	4	0.0855
L13	54	84	13	14	0.3266	37	88	13	13	0.3177
L14	54	84	13	14	0.3266	37	88	13	13	0.3177
L15	54	84	33	35	0.8166	37	88	33	33	0.8066
L16	54	84	38	41	0.9566	37	88	38	39	0.9533
L17	54	84	11	12	0.2800	37	88	11	11	0.2688
L18	46	106	5	5	0.14722	31	109	5	5	0.1513
L19	46	106	69	72	2.1200	31	109	69	70	2.1194
L20	46	106	47	49	1.4427	31	109	47	48	1.4533
Total			405	511	10.8033			405	438	10.7775
From Madaba bridge to Airport										
	Travelling South					**Travelling North**				
L21	36	108	76	78	2.3400	40	107	76	78	2.31830
L22	36	108	41	42	1.2600	40	107	41	42	1.24830
L23	36	108	103	105	3.1500	40	107	103	106	3.15050
L24	36	108	134	137	4.1100	40	107	134	138	4.10160
Total			354	362	10.8600			354	364	10.8188

(Note : % Congested =Volume*100/ Capacity)

Appendix B: Regression Model for Average Annual Income Prediction



Source: Department of Statistics.

Model parameters:

Upper bound (95%)	Lower bound (95%)	Pr > |t|	t	Standard error	Value	Source
-298083.745	-515532.015	0.004	-16.099	25269.094	-406807.880	Intercept

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257.988	149.832	0.004	16.224	12.569	203.910	YEAR

Equation of the model:
GDP = -406807.88+203.91*YEAR
For the year 2013 , and based on the model before GDP = 3662.83 JD

Appendix C:Questionnaire about Feasibility of Applying Road Pricing on Airport Road

.
Gender:

- ☐ Male
- ☐ Femal

Age:

- ☐ 18-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ more than 65

Employment:

- ☐ Employee
- ☐ Self-Employee
- ☐ Un-Employee
- ☐ Retired
- ☐ Student

Education:

- ☐ Unenlightened
- ☐ School
- ☐ Diploma

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- ☐ Master
- ☐ Ph.D.

Household Income:

- ☐ less than 250
- ☐ 250-500
- ☐ 500-750
- ☐ 750-1000
- ☐ 1000-1500
- ☐ more than 1500

The number of trips:

- ☐ Never
- ☐ less than 2 in a week
- ☐ 2-4 in a week
- ☐ more than 4 times in a week
- ☐ Every day

The purpose of using the Airport Road:

- ☐ Employment.
- ☐ Travel
- ☐ Education.
- ☐ Visiting family/Friends.

There is congestion on the Airport Road:

- ☐ Rarely
- ☐ sometimes
- ☐ Always

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Applying of road pricing reduce the traffic congestion:

- ☐ in a small effect
- ☐ in a moderate effect
- ☐ in A high effect

Applying of road pricing increase the public transit :

- ☐ in a small effect
- ☐ in a moderate effect
- ☐ in a high effect

Applying of road pricing increase the quality of road:

- ☐ in a small effect
- ☐ in a moderate effect
- ☐ in a high effect

Applying of road pricing reduces the environmental pollution:

- ☐ in a small effect
- ☐ in a moderate effect
- ☐ in a high effect

Applying of road pricing not fair :

- ☐ in a small effect
- ☐ in a moderate effect
- ☐ in a high effect

Applying of road pricing loss of privacy:

- ☐ in a small effect
- ☐ in a moderate effect
- ☐ in a high effect

The factor to determine the price:

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- ☐ travel distance
- ☐ travel time
- ☐ Type of vehicle

The suitable of price on the Airport Road:

- ☐ .25 JD
- ☐ .50 JD
- ☐ .75 JD
- ☐ 1 JD
- ☐ 1.25 JD
- ☐ 1.50 JD

Appendix D: THE Layouts OF Toll Booths

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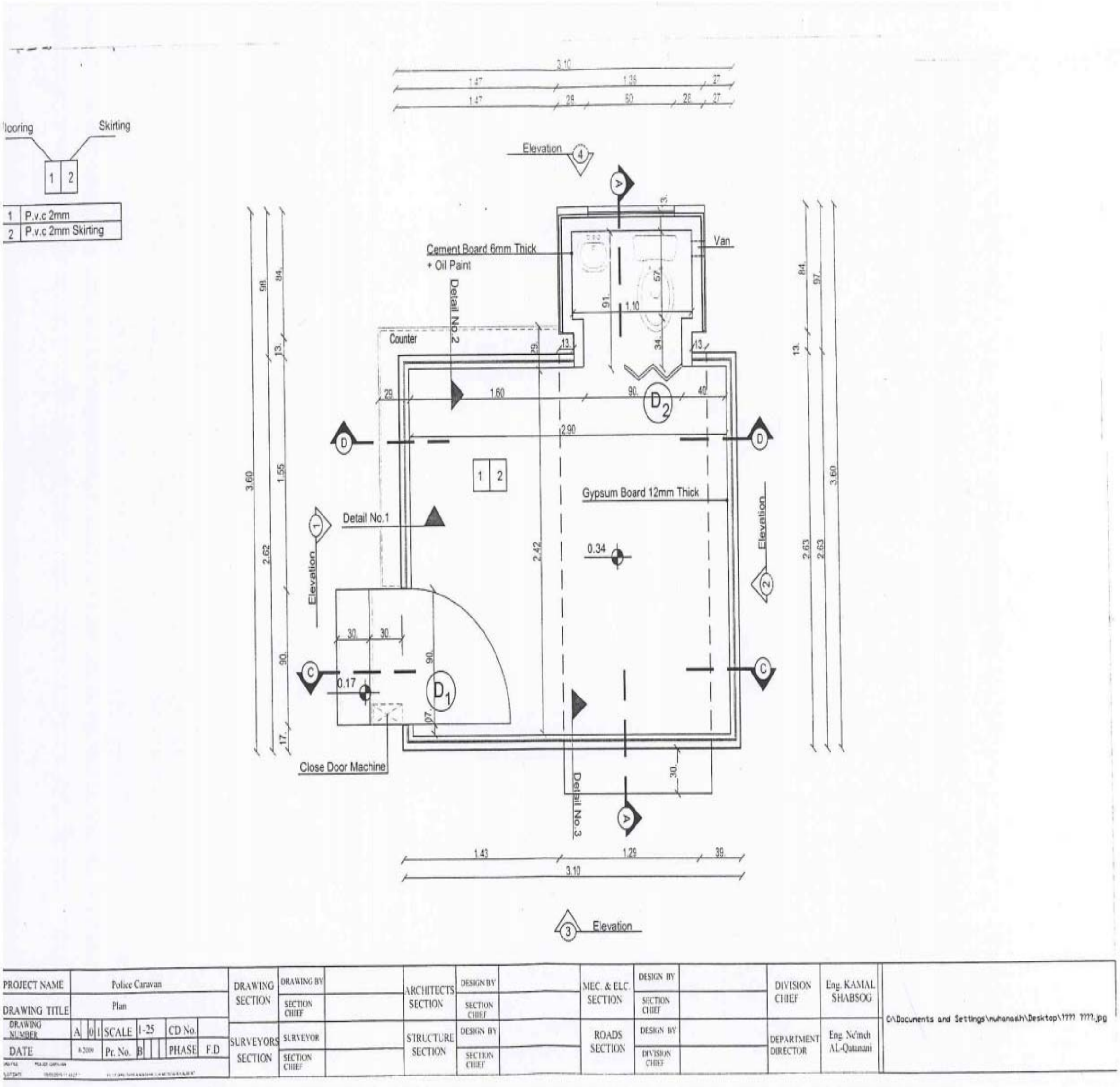

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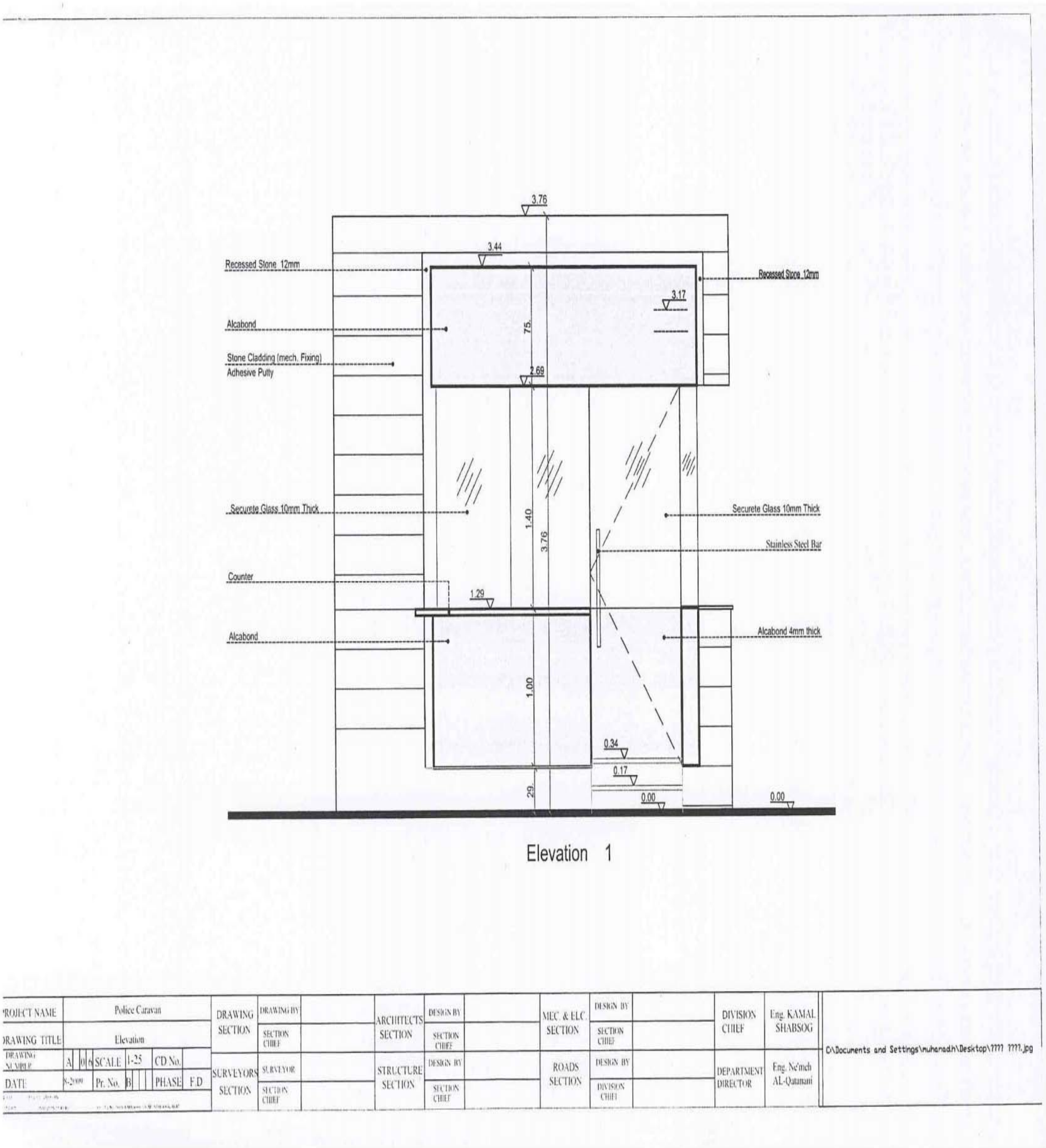

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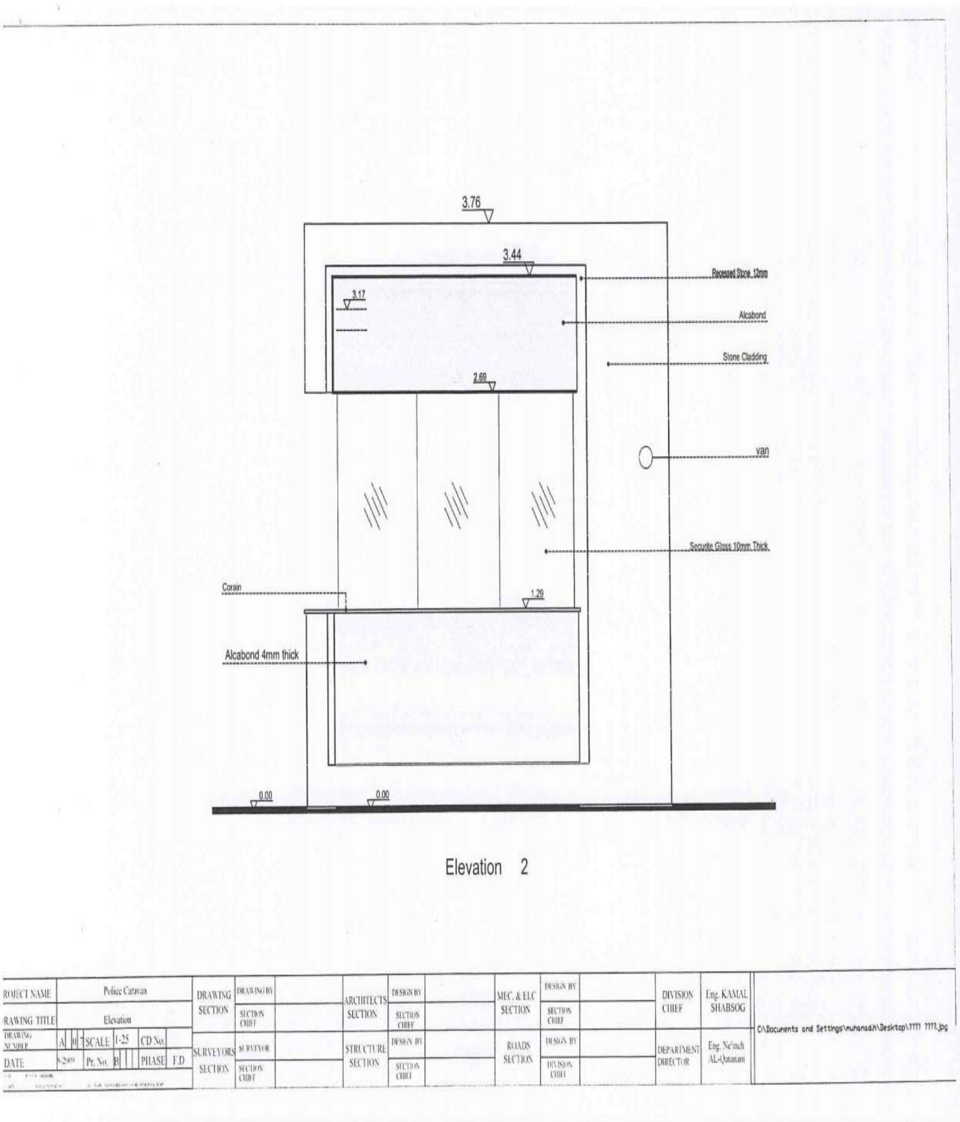

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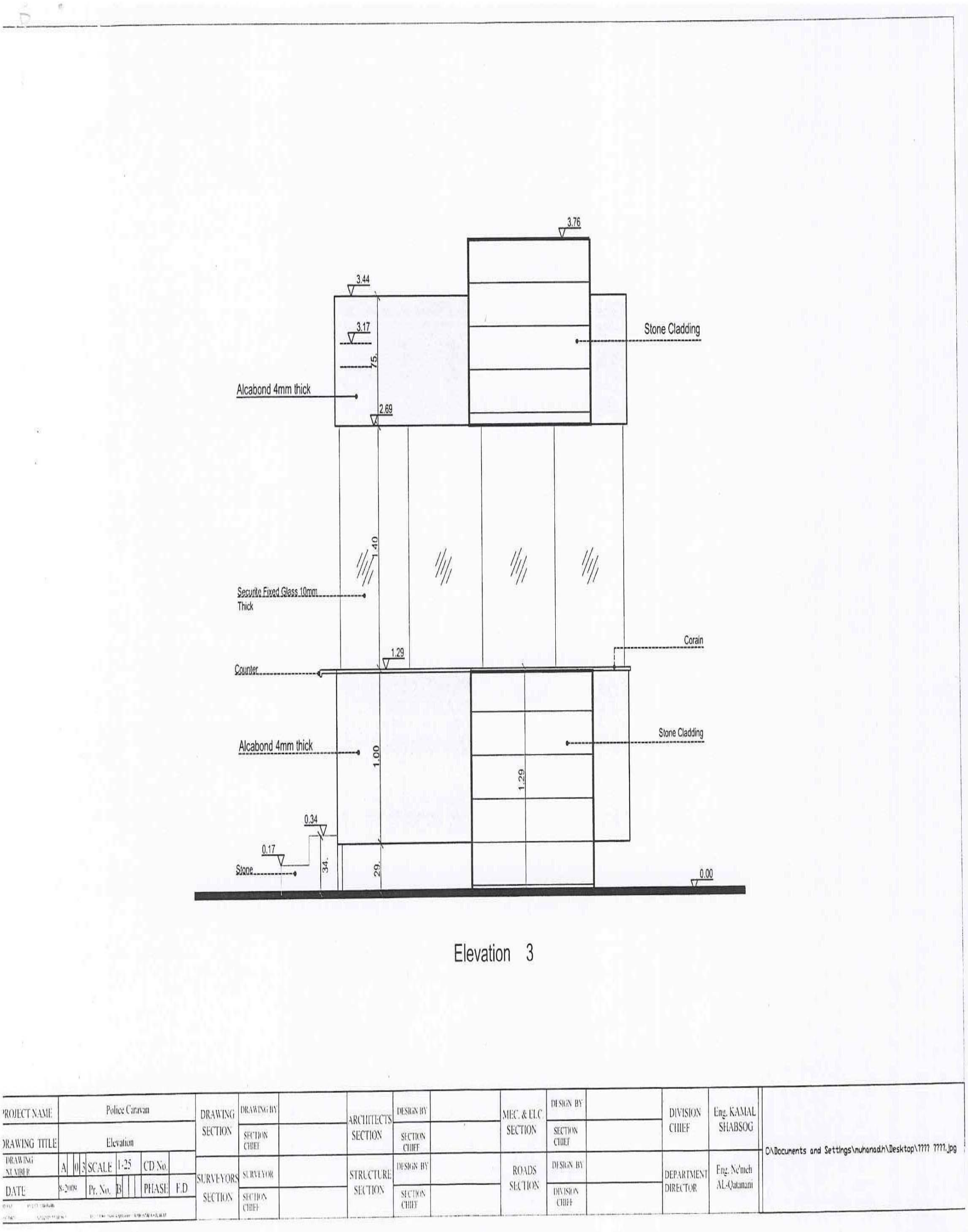

Elevation 3

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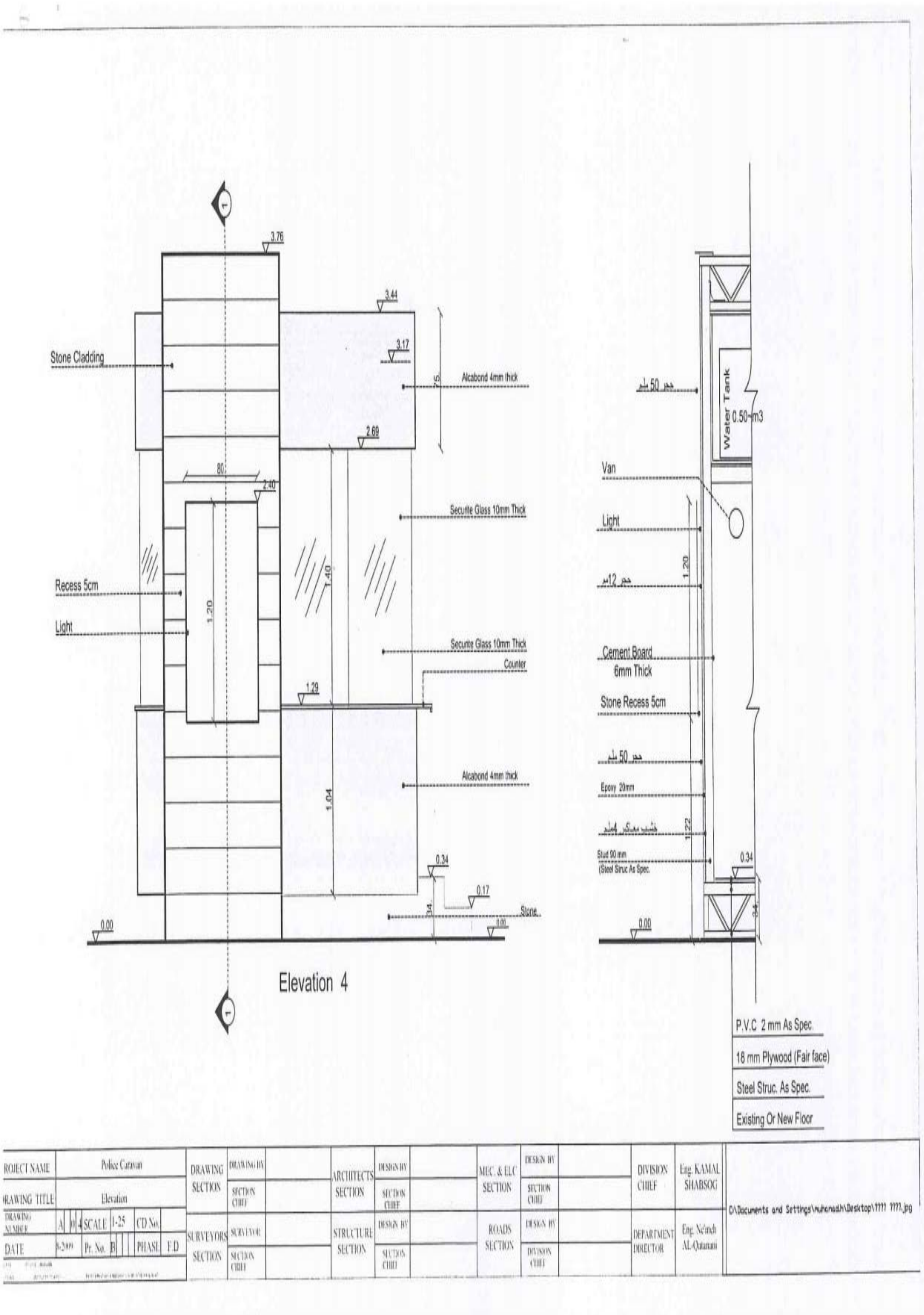

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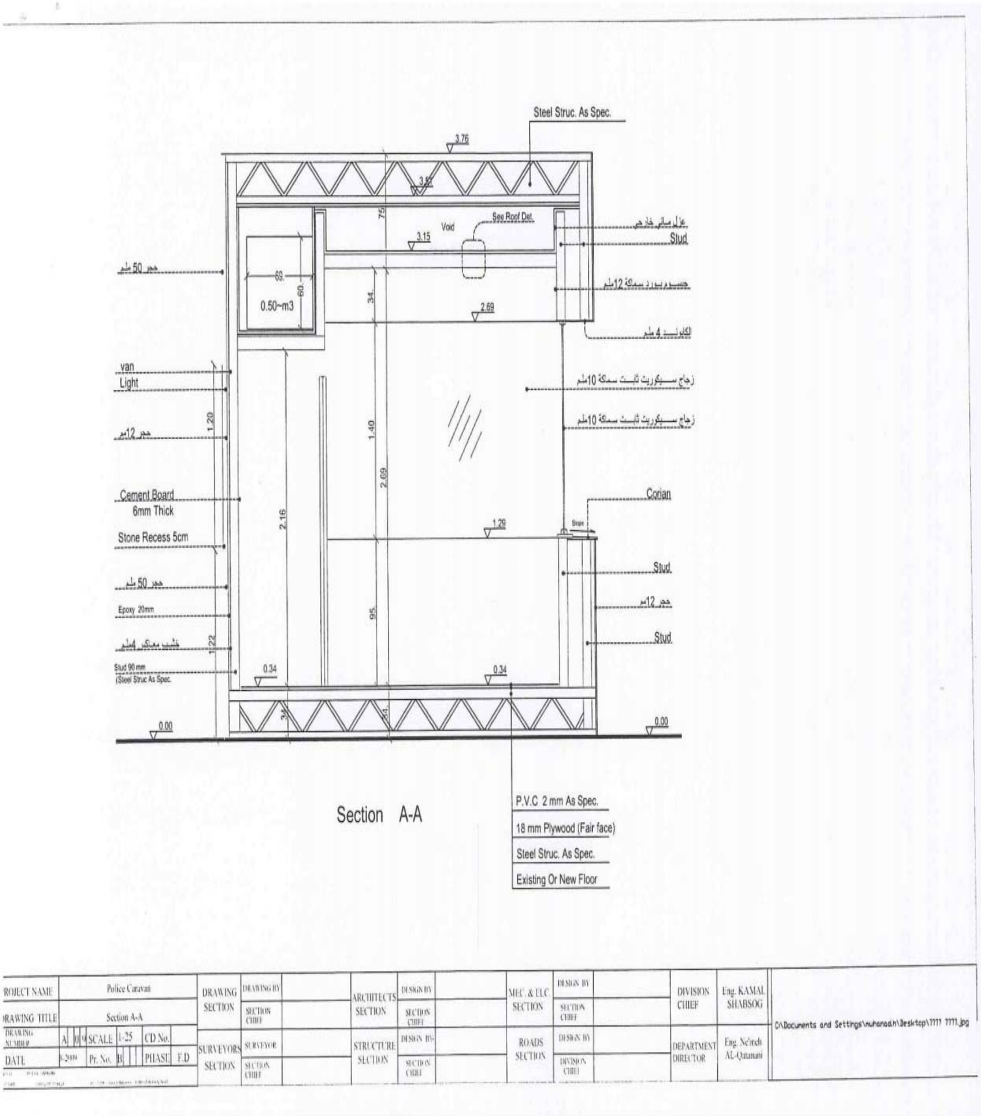

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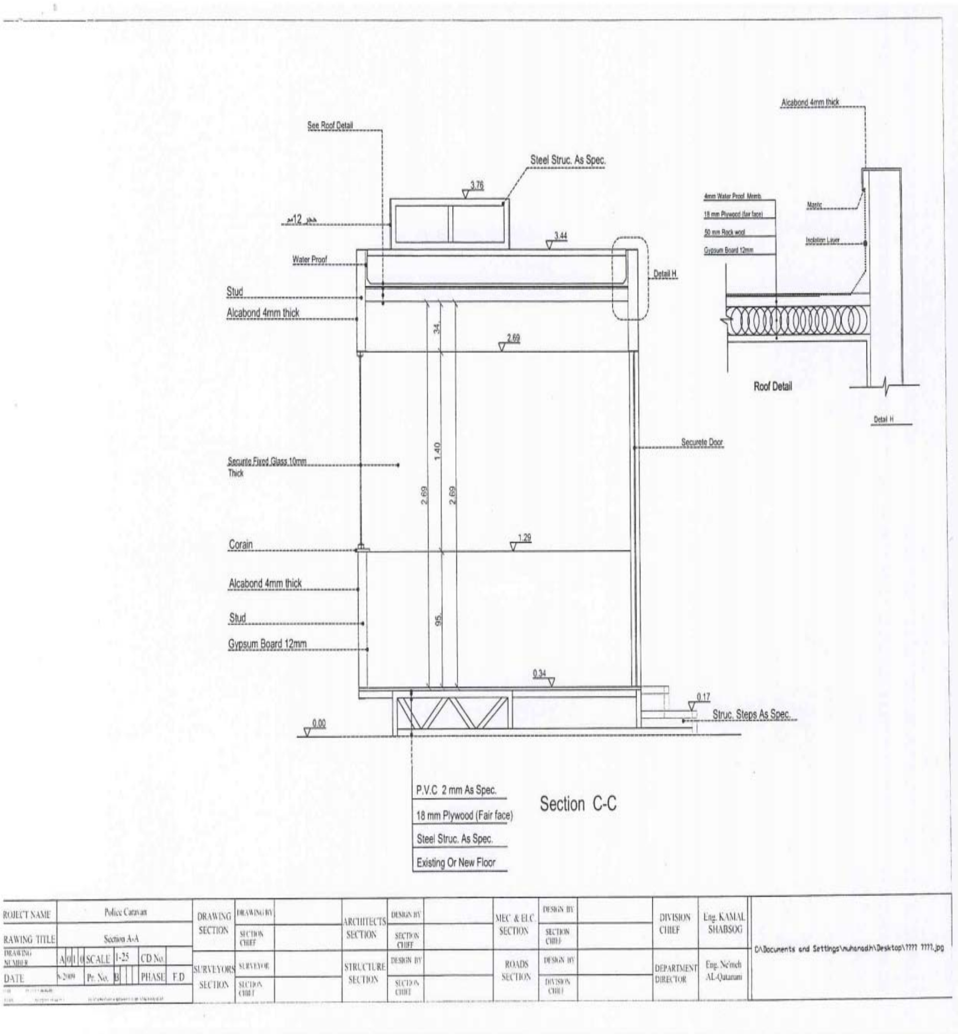

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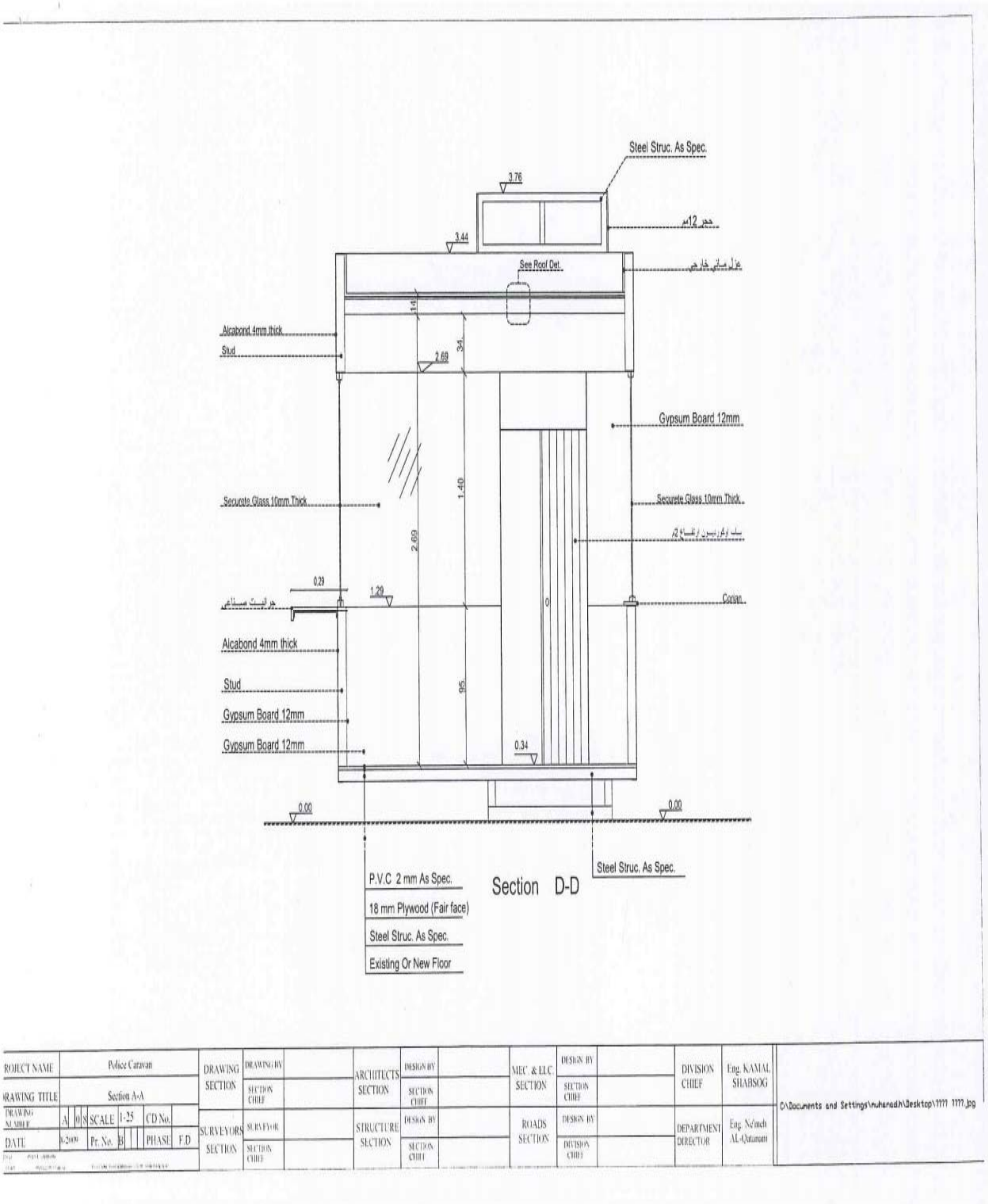

Appendix E : The Outputs of VISUM Model with Toll Road

The outputs of VISUM Model with Toll Road for the year 2025										
From Foreign Ministry to Marj al-Hamam Bridge										
Number of sections	Travelling South					Travelling North				
	% Congested	Current speed (km/h)	Free flow time (S)	Current time (s)	Distance (km)	% Congested	Current speed (km/h)	Free flow time (S)	Current time (s)	Distance (km)
L1	126	17	20	83	0.3919	115	20	20	68	0.3777
L2	93	32	14	32	0.2844	126	17	14	62	0.2927
L3	93	32	50	111	0.9866	127	17	50	212	1.0011

L4	102	27	15	40	0.2925	138	13	15	81	0.3000
L5	102	27	12	33	0.2475	138	13	12	66	0.2475
L6	100	28	23	60	0.4666	119	19	23	87	0.4666
L7	100	28	19	49	0.3811	119	19	19	72	0.3811
L8	79	40	42	75	0.8333	108	24	42	126	0.8333
L9	79	40	19	33	0.3666	108	24	19	56	0.3666
Total			214	516	4.2508			214	830	4.2669
From Marj al-Hamam Bridge to Madaba Bridge										
Travelling South						**Travelling North**				
L10	124	19	27	99	0.5225	144	13	27	142	0.5127
L11	87	40	14	25	0.2777	98	32	14	31	0.2755
L12	87	40	28	50	0.5555	98	32	28	61	0.5422
L13	87	40	30	54	0.6000	98	32	30	66	0.5866
L14	94	35	17	35	0.3402	98	32	17	38	0.3377
L15	94	35	41	82	0.7972	98	32	41	90	0.8000
L16	95	34	40	83	0.7838	104	29	40	99	0.7975
L17	95	34	23	47	0.4438	119	21	23	75	0.4375
L18	95	34	5	11	0.1038	119	21	5	17	0.0991
L19	75	58	59	71	1.1438	109	32	59	128	1.1377
L20	75	58	28	34	0.5477	108	32	28	61	0.5422
L21	67	65	11	12	0.2166	107	33	11	24	0.2200
L22	67	65	43	46	0.8305	107	33	43	91	0.8341
L23	63	68	39	40	0.7555	75	58	39	47	0.7572
L24	63	68	40	41	0.7744	75	58	40	48	0.7733
L25	86	49	20	28	0.3811	59	70	20	20	0.3888
L26	86	49	15	22	0.2994	59	70	15	15	0.2916
L27	86	49	74	106	1.4427	59	70	74	74	1.4388
Total			554	886	10.8172			554	1127	10.7733
From Madaba bridge to Airport										
	Travelling South					**Travelling North**				
L28	79	54	55	70	1.05	72	61	55	63	1.0675
L29	85	50	65	92	1.2777	74	59	65	78	1.2783
L30	85	50	129	182	2.5277	74	59	129	154	2.5238
L31	85	50	74	104	1.4444	74	59	74	88	1.4422
L32	85	50	24	34	0.4722	74	59	24	29	0.4752
L33	84	50	104	145	2.0138	71	61	104	119	2.0163
L34	70	62	31	35	0.6027	59	70	31	31	0.6027
L35	70	62	33	37	0.6372	70	62	33	37	0.6372
L36	70	62	42	48	0.8266	59	70	42	42	0.8166
Total			557	747	10.8527			557	641	10.8602

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The outputs of VISUM Model with Toll Road for the year 2025										
From Foreign Ministry to Marj al-Hamam Bridge										
Number of sections	Travelling South					Travelling North				
	% Congested	Current speed (km/h)	Free flow time (s)	Current time (s)	Distance (km)	% Congested	Current speed (km/h)	Free flow time (s)	Current time (s)	Distance (km)
L1	70	51	71	98	1.3883	158	11	71	468	1.4300
L2	77	46	21	33	0.4216	147	13	21	120	0.4333
L3	81	43	12	20	0.2388	138	15	12	58	0.2416
L4	62	57	56	69	1.0925	93	36	56	110	1.1000
L5	62	57	48	60	0.9500	93	36	48	95	0.9500
Total			208	280	4.0913			208	851	4.1550
From Marj al-Hamam Bridge to Madaba Bridge										
Travelling South						Travelling North				
L6	63	56	27	34	0.5288	92	37	27	52	0.5344
L7	63	56	14	17	0.2644	92	37	14	27	0.2775
L8	63	56	28	35	0.5444	92	37	28	54	0.5550
L9	57	61	89	102	1.7283	82	43	89	146	1.7438
L10	57	61	40	46	0.7794	82	43	40	67	0.8002
L11	57	61	23	26	0.4405	82	43	23	38	0.4538
L12	60	58	5	6	0.0933	83	42	5	8	0.0966
L13	32	70	17	17	0.3305	35	70	17	17	0.3305
L14	32	70	16	16	0.3111	35	70	16	16	0.3111
L15	32	70	42	42	0.8166	35	70	42	42	0.8166
L16	32	70	49	49	0.9527	35	070	49	49	0.9527
L17	32	70	14	14	0.2722	35	70	14	14	0.2722
L18	26	70	8	8	0.1555	29	70	8	8	0.1555
L19	26	70	109	109	2.1194	29	70	109	109	2.1194
L20	26	70	74	74	1.4388	29	70	74	74	1.4388
Total			555	595	10.7766			555	721	10.8588
From Madaba bridge to Airport										
	Travelling South					Travelling North				
L21	39	70	120	120	2.333	21	70	120	120	2.3333
L22	39	70	75	75	1.4583	21	70	75	75	1.4583
L23	39	70	162	162	3.1500	21	70	162	162	3.1500
L24	39	70	212	212	4.1222	21	70	212	212	4.1222
Total			569	569	11.0638			569	569	11.0638

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