# Forecasting Traffic and Toll Revenue for Kathmandu-Terai/Madhesh Fast Track Expressway

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## Abstract

*This paper presents an analysis of traffic forecasting and toll revenue projections for the Kathmandu-Terai/Madhesh Fast Track (KTFT) Expressway, which is Nepal's first expressway connecting Kathmandu to Nijgadh. The analysis involves an Origin-Destination survey, traffic assignments and projections, and an evaluation of toll earnings. Traffic assignment of the existing traffic between Kathmandu and various regional zones in Nepal shows an estimated 40% diversion of traffic to the KTFT expressway. Utilizing daily volume records of Department of Roads (DoR) for Nagdhunga and Banepa Bardibas highway sections, a projected daily traffic volume of 11957 Passenger Car Unit (PCU) was determined for the base year 2024. Traffic forecasts for 2035, 2045 and 2055 were made by projecting the base year traffic and considering a generated traffic of 30% of the diverted traffic for each subsequent year. Growth rates for different vehicle types were projected using elasticity method with GDP as an indicator. The total daily traffic projected for 2035, 2045 and 2055 is 30922 PCU, 48789 PCU, and 70724 PCU, respectively representing approximately 2.59, 4.08, 5.91 times the base year volume. A toll pricing structure, in accordance with the guidelines in the National Highway Fee Rules (NHFR-2008), has been proposed. Under this toll structure, the projected daily toll revenue for years 2035, 2045, and 2055 are estimated to be NRs 60.53 lakhs, NRs 160.62 lakhs, and NRs 251.40 lakhs, respectively. Comparison of this revenue with the construction and maintenance costs of the project indicates an estimated payback period of 35 years to break even on the construction cost.*

**Keywords:** origin-destination; traffic forecasting; toll pricing; toll revenue

## 1. Introduction

The Kathmandu-Terai/Madhesh Fast Track (KTFT) Expressway is a pivotal infrastructure project aimed at enhancing connectivity between Kathmandu, the capital of Nepal, and Nijgadh in the southern Terai region. As Nepal's first expressway, it is expected to significantly improve transportation efficiency and economic development. It is anticipated that this highway will greatly improve the existing multi-hour route by cutting the travel time to roughly an hour. The project, which is 71 kilometers long and has intricate engineering elements like tunnels and bridges, is a testament to its difficult construction. Because of Nijgadh's advantageous location near Birgunj, a key entry point into India, the KTFT will improve trade and commerce, facilitating the flow of products and fostering economic activity between Nepal and India. It also encourages the construction of the planned Nijgadh International Airport, which will facilitate better access for both local and international trade and multiply its economic impact. However, traffic forecasting is crucial for the effective management of toll operations and infrastructure planning. A sizable toll revenue stream is required for a project of this scope to

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be operational and sustainable. Toll collection is required to fund the upkeep and operations of the expressway. Furthermore, striking a balance between customer affordability and the expressway's financial needs necessitates investigation of toll pricing. Appropriate toll collection guarantees the expressway's continued economic viability while meeting user expectations for safety and service.

Following this background, the study aims to forecast the expected traffic volume along the KTFT expressway and project toll revenue collections from 2035 to 2055. The specific objectives are to estimate the anticipated traffic volume using the expressway throughout this period, propose a toll pricing scheme following the prevailing guidelines and to project toll earnings based on the toll prices and the forecasted traffic. By achieving these objectives, the study seeks to provide a comprehensive understanding of the expressway's future usage and financial sustainability, ensuring that the KTFT can maintain high standards of service and safety while meeting its economic goals, thus supporting its long-term success.

## 2. Literature Review

The initiation of the KTFT Project is poised to induce substantial transformations in travel behaviors and patterns among the road users, driven by the significantly reduced travel time offered by the expressway. Travel forecasting models are employed to anticipate shifts in travel behaviors and the usage of transportation systems in reaction to changes in regional development, demographics, and transportation infrastructure. Predicting travel demand is a complex yet essential task for effective planning and assessment of transportation networks (Kadiyali, 2016). Travel simulation often begins with trip generation at the trip generation zone and proceeds through various network links and nodes. The journey comes to a finish at the trip attraction area. Trip generation, trip distribution, mode choice, and traffic assignments are the four fundamental steps of traditional four steps transportation modeling and are also the basic elements of simulation based traffic demand forecasting techniques. Most traffic planners and modelers will concur that the traditional four step traffic demand modeling process is applicable, regardless of the software programs utilized to create the transportation demand model (Wong, 2008). Beyond these traditional steps, incorporating induced, diverted, and generated traffic is crucial for accurate forecasting. As mentioned in Litman (2001), traffic planning practices ignoring generated traffic are expected to result in inaccurate predictions.

The success of a toll road project hinges significantly on the precision of traffic forecasting, which directly impacts revenue projections (Indra Dharmawan et al., 2019). International studies evaluating toll road traffic estimates in various countries have revealed an initial overestimation ranging from 20% to 30% during the early years of operation. Baeza Muñoz & Vassallo Magro (2008) suggest that the inclination to overestimate traffic volumes is a strategic choice made by investors during the toll road project auction process. This strategy is not a result of systematic errors in transportation modeling but because the investors anticipate that if actual traffic falls well below projections, the government will consider renegotiating the project terms. For the functionality of the expressway, it is necessary to introduce a suitable toll pricing based on the forecasted traffic. The toll pricing ought neither to be too high nor too low. If it is too high, the expressway will not be able to serve to its capacity and if it is too low the expressway will not be able to sustain its operation & maintenance cost leading to the failure of the project. Also, the toll rate should be affordable for travelers. According to Roe & Hopkins, (1987), the toll rate should be less than one-third of the total benefit that travelers gain from using the toll road.

The toll pricing is a subject of great interest to the researcher. Different countries all over the globe have different strategies regarding toll pricing. In the case of China, toll rates are generally set by toll road authorities based on their previous experiences and the methods employed in comparable locations (Jia & Tian, 2002). However, KTFT being the first expressway project of Nepal, the toll pricing based on previous experiences and methods cannot be executed. In order to set the toll rates based on traffic volume while taking into account both quantitative

and qualitative datasets, an elasticity-based model has also been developed. Furthermore, some studies such as Chu & Tsai (2004) created models for congestion charges based on the kind of vehicle and the amount of harm that various vehicle classes generate. To determine the minimal toll rate, Vajdic et al. (2012) developed a linear equation that took into account both technical and financial limitations, such as the concession time and construction lifespan. This equation incorporates various costs, including construction, operation, maintenance, interest rates, debt maturity, and inflation rates. The weighted average toll charge based on construction, annual operation costs expenses and annual average daily traffic is suggested. In India, the National Highway Fee (Determination of Rates and Collection) Rules 2008 is used to determine the toll rates (Bari et al., 2023).

The above literature emphasized how crucial travel forecasting models and simulations are in predicting travel demand and behavior changes associated with the commencement of new infrastructure. It also stressed on how important it is to generate toll revenue in order to maintain the viability of high-volume transportation infrastructure projects like expressways, as well as to pay for operating and maintenance expenses. It also provides insights regarding the selection of appropriate methods for toll pricing.

## 3. Methodology

Figure 1 shows the methodological framework of the study. An Origin Destination (OD) survey was conducted at the Nagdhunga check point to assess the regional origin/destinations of trips to and from Kathmandu valley. A macro simulation traffic assignment was carried out to estimate the percentage diversion of traffic to KTFT. Traffic for the base year along the KTFT was then projected using Department of Roads (DoR)' Annual Average Daily Traffic (AADT) data for the Nagdhunga station and Banepa Bardibas highway, another point of regional connectivity within the valley considering both diverted and generated traffics. The elasticity approach was used to calculate the traffic growth rates for different vehicle classifications, with GDP serving as an indicator. The anticipated future traffic was then forecasted using the base year traffic information and growth rate factors. Based on the forecasted volume , the potential revenue collection

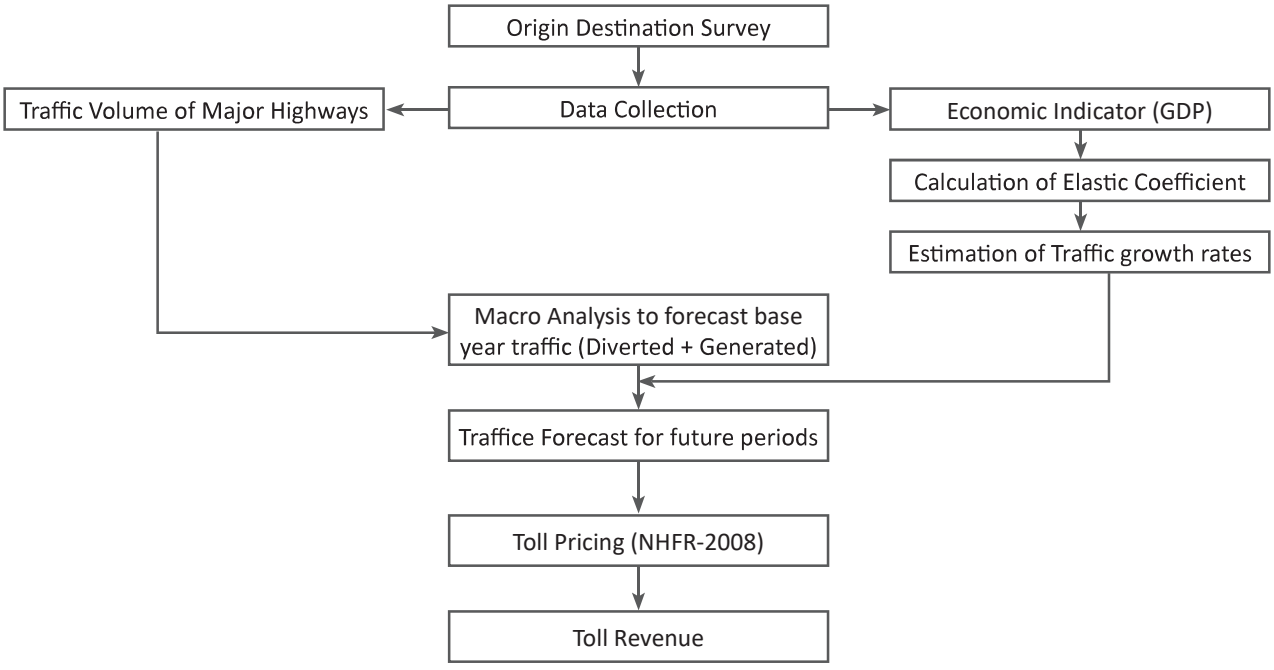


**Figure 1 Methodological framework**

was then assessed.

### 3.1 Origin-Destination Survey

A 24-hour Origin-Destination (OD) survey was conducted at Nagdhunga check point, a major entry or exit point to the valley to understand current regional traffic patterns and potential diversion to the KTFT expressway. The survey employed a rigorous sampling approach, ensuring a representative sample of over 400 vehicles per direction, based on a 5% margin of error and a 95% confidence level. Vehicles were randomly stopped, and drivers or occupants were surveyed using a meticulously designed questionnaire. The questionnaire collected detailed information on travel direction, vehicle type, origin and destination locations, freight type, travel frequency, passenger count, and travel time. Data collection was facilitated through the Kobo Toolbox platform, ensuring efficient and secure data handling. The survey data provided insights into regional traffic movement to and from Kathmandu valley. This data was essential for classified traffic projection along KTFT in different years.

### 3.2 Traffic Projection

A macro analysis was performed using this OD data to predict the percentage of traffic using Nagdhunga expected to divert to KTFT. The network included major highways to Kathmandu and an additional KTFT link with a speed of 100 km/h. All highway links except the KTFT link were set to 40 km/h speed. A static assignment model with user equilibrium, applying the Normal Frank-Wolfe Algorithm and a time-based cost function, was used to estimate the traffic diversion. The anticipated classified traffic volumes along KTFT for the base year and future time periods from 2035 to 2055 were then projected considering potential traffic from the Nagdhunga and Dhulikhel check points, as well as the additional generated traffic.

Traffic growth rate was determined by an elasticity method. In the elasticity method, traffic growth rate can be determined in relation to the changes in economic factors. Traffic growth rate for the project was analyzed using Gross Domestic Product (GDP) indicator. The econometric model used is shown in Equation (1).

$$\text{Log}_e P = Ao + A_1 \text{Log}_e GDP \quad \ldots (1)$$

Where,

P: Traffic volume of a year

GDP: Gross Domestic Product for the same year

Ao: Regression Constant

A1: Regression Coefficient

The growth rates for various vehicle types were determined using Equations (2).

$$\text{Traffic growth rate} = E_m * R \quad \ldots (2)$$

Where,

Em: Elasticity coefficient

R: Average growth rate of GDP

### 3.3 Toll Pricing

Nepal does not have a toll rate collection policy for expressways since KTFT is the country's first expressway. Roads Board Nepal has previously introduced toll pricing to some highways. However, there is a lack of specific guidelines for toll collection or pricing specifically for different vehicle categories. Therefore, a toll pricing scheme based on the Indian Guideline National Highway Fee (Determination of Rates and Collection) Rules, 2008 known as NHFR-2008 (MoRTH, 2008) is proposed considering similarity in vehicle types in the two countries.

To estimate the revenue generation, the base toll rate per km for different vehicle classes is taken as per NHFR-2008 under Rule 3 Sub-Rule I. The base toll rate is converted into Nepali Rupees and further, revised annually based on the Wholesale Price Index (WPI ) of the consecutive years as shown in equation 3. The WPI data is extracted from the Nepal Rastra Bank website (NRB, 2023). The WPI for the years 2035, 2045, and 2055 were projected using linear regression. Toll rates for different vehicle types were obtained adjusting to the similarity of vehicle classes in the Nepalese context to the classes defined in the above-mentioned code. A pricing framework for the KTFT expressway is proposed for different vehicle types based on this analysis as shown in Table 1.

Applicable rate of fee = base rate + base rate × ((WPIA-WPIB) / WPIB)*0.4 (3)

Where,

WPIA: Wholesale Price Index of nth year

WPIB: Wholesale Price Index of (n-1)th year

**Table 1: Proposed KTFT expressway toll fee for different vehicle classes**

Toll Fee (NRs)

| Year | Car | LCV | Bus/ Truck | Three Axle CV | Heavy Com |
|---|---|---|---|---|---|
| 2035 | 150 | 250 | 530 | 580 | 820 |
| 2045 | 160 | 260 | 550 | 610 | 860 |
| 2055 | 170 | 270 | 570 | 630 | 900 |

## 4. Results and Discussion

The project traffic for the expressway, both for the base year 2024, and the subsequent next thirty years period was determined by estimating the expected diversion of traffic volume currently using the Nagdhunga and Banepa Bardibas highway sections, along with an additional expected generated traffic volume along the expressway. Anticipated annual toll revenues up to 2055 were evaluated and were compared with the annual operation and maintenance costs alongside the total construction cost of the project.

### 4.1 Anticipated Traffic Diversion

To facilitate the analysis of expected traffic diversion to KTFT, the surveyed OD locations were classified under six distinct regional zones of Nepal, namely West-West, West-North, West-South, East-South, and East-North, South. Figures 2 and 3 illustrate the percentages of vehicles leaving and entering the Kathmandu valley via. Nagdhunga check point to various distinct regional zones of Nepal, respectively. Following the Origin-Destination patterns to and from Kathmandu and using the DoR's AADT information at Nagdhunga section, the expected AADT in Passenger Car Unit (PCU) in and out between the OD zones and Kathmandu valley via. Nagdhunga in the base year 2024 was determined as shown in Table 2.

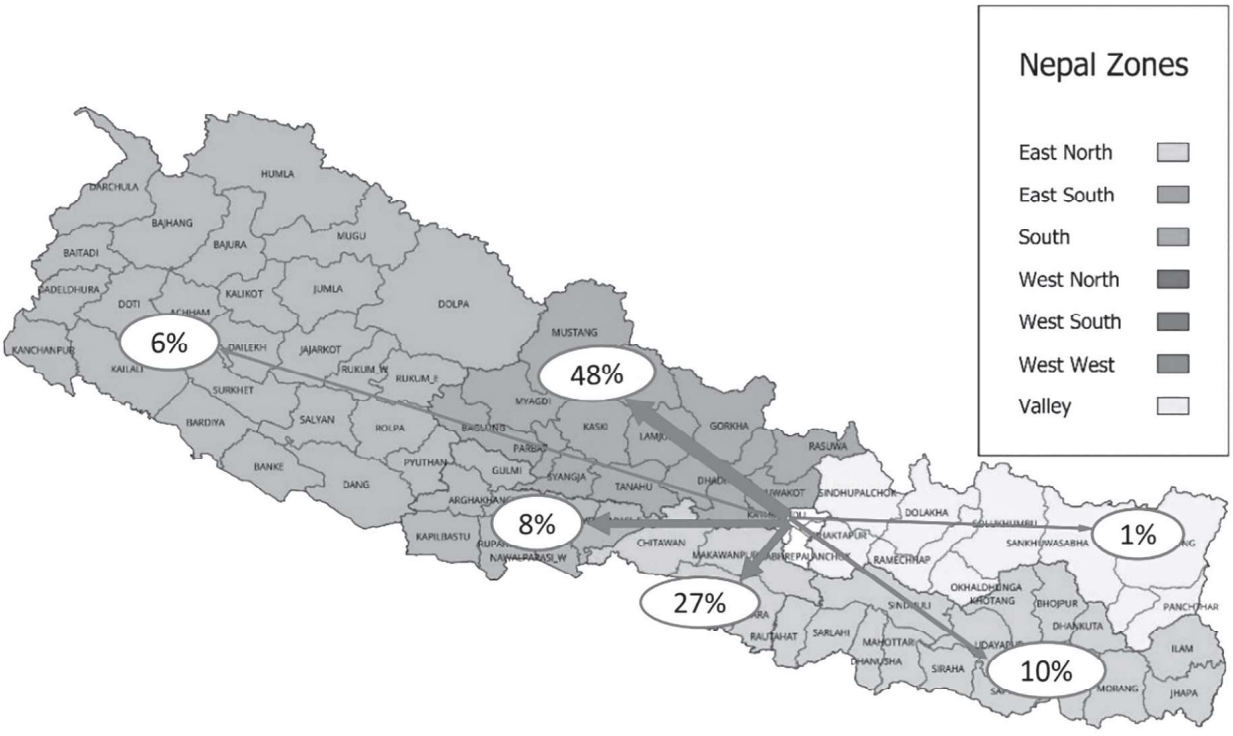


Figure 2: Desire lines of travel of vehicles entering Kathmandu valley via. Nagdhunga

Table 2: Expected traffic in-out Kathmandu valley via. Nagdhunga from and to regional zones in 2024

| | Zonal code | AADT (PCU) | |
|---|---|---|---|
| | | From Kathmandu (Zone 5) | To Kathmandu (Zone 5) |
| West-North | 1 | 5656 | 5025 |
| West-West & West-South | 2 | 2178 | 3574 |
| East-South | 3 | 1613 | 1267 |
| East-North | 4 | 169 | 173 |
| South | 6 | 4272 | 3836 |
| **Total** | | **13888** | **13876** |

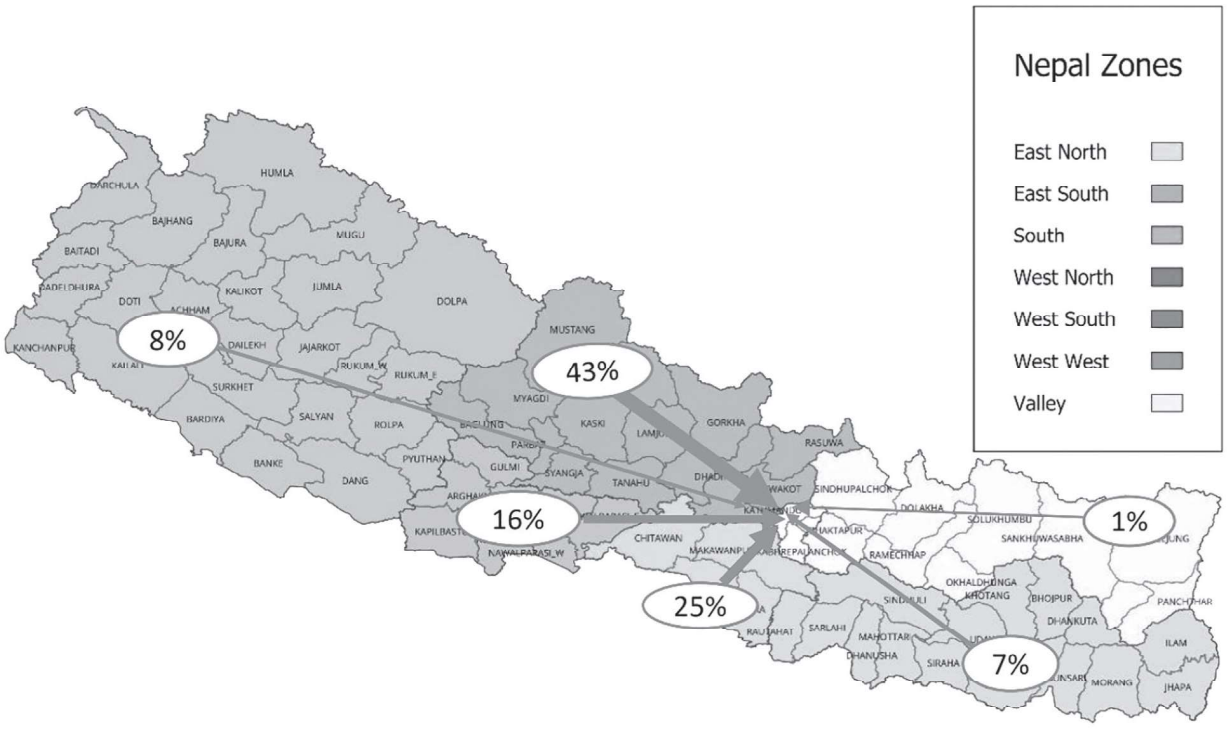


Figure 3: Desire lines of travel of vehicles leaving Kathmandu valley via. Nagdhunga

Figure 4 shows the result of a macroscopic traffic flow assignment, based on the data provided in Table 3, incorporating a new KTFT expressway link between Kathmandu and Nijgadh. The expected assignment was investigated considering users' choice to minimize the travel time. The black numbering denotes the expected AADT using the respective links. In contrast, the red numbering denotes the AADT of respective links using the KTFT expressway. Traffic assignment result shows a total of 10,988 daily PCU (mainly from Birgunj to Biratnagar area as origin/destination) that is 40% of the expected total 27,674 daily PCU via. Nagdhunga can be anticipated to be diverted to the KTFT expressway in the base year 2024.

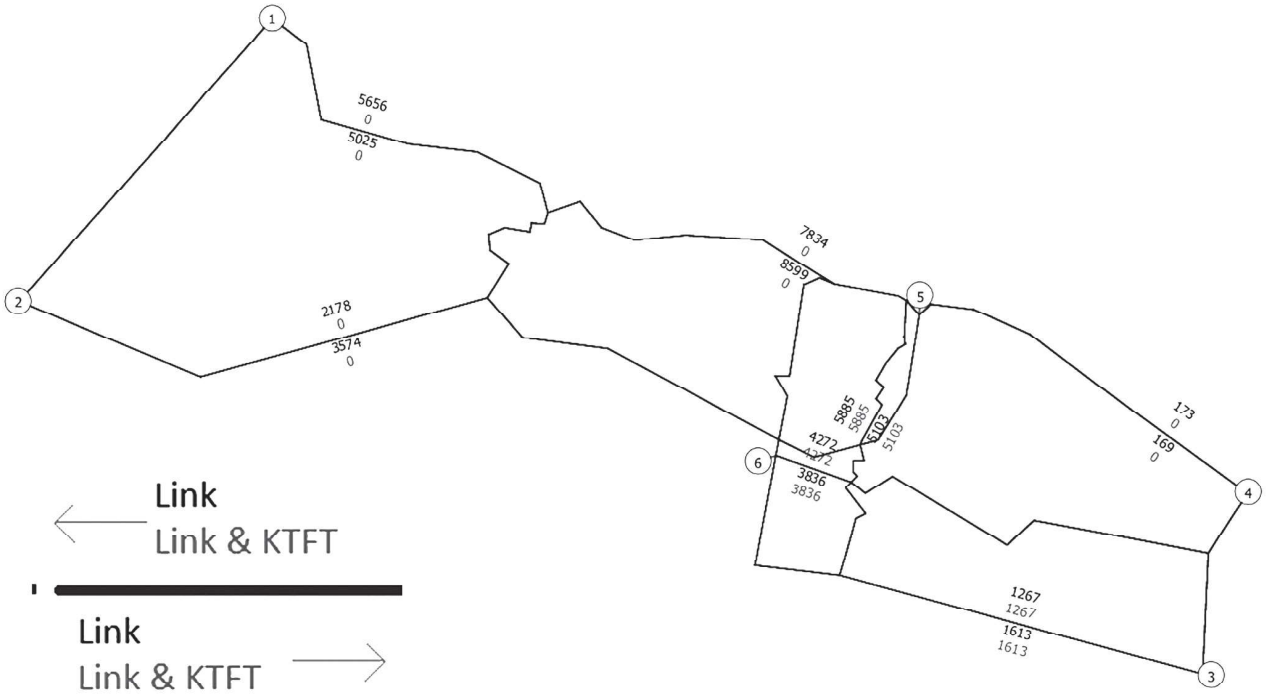


Figure 4: Anticipated traffic assignment of the vehicles via Nagdhunga with KTFT expressway

### 4.2 Anticipated Traffic Growth Rate

The growth rate calculation was carried out using relevant information from the DPR report of KTFT expressway (DPR KTFT, 2015). Therefore, elasticity coefficients and growth factors given in the report were used. However, the values are available only for up to year 2031. Therefore, the elastic coefficients for future years 2032 and above were obtained by projecting the values following a similar trend in the DPR report. Additionally, the DPR report does not provide values for vehicle type utility vehicles. Therefore, the elasticity coefficients of utility vehicles were calculated performing an elastic analysis of the national GDP (Nepal Rastra Bank, 2022) with traffic volume data of Nagdhunga section from 2011 to 2021 (DoR, 2024). Table 3 and 4 present the anticipated elastic coefficients and growth rates for various vehicle types across various projected periods.

**Table 3: Elasticity coefficients**

| Vehicle type | Elasticity coefficients | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2017-21 | 2022-26 | 2026-31 | 2032-36 | 2037-41 | 2042-46 | 2046-51 | 2052 and above |
| Car | 1.63 | 1.47 | 1.32 | 1.19 | 1.07 | 0.96 | 0.87 | 0.78 |
| Mini bus | 1.67 | 1.51 | 1.36 | 1.22 | 1.10 | 0.99 | 0.89 | 0.80 |
| Bus | 1.34 | 1.21 | 1.09 | 0.98 | 0.88 | 0.79 | 0.71 | 0.64 |
| 2A-Truck | 0.82 | 0.74 | 0.67 | 0.60 | 0.54 | 0.49 | 0.44 | 0.39 |
| 3A-Truck and LCV | 1.65 | 1.48 | 1.33 | 1.20 | 1.08 | 0.97 | 0.87 | 0.79 |
| MAV | 1.85 | 1.67 | 1.50 | 1.35 | 1.22 | 1.09 | 0.98 | 0.89 |
| Utility vehicle | | 0.74 | 0.66 | 0.60 | 0.54 | 0.48 | 0.44 | 0.39 |

Table 4: Anticipated traffic growth rates for different vehicle types

| Vehicle Type | Growth factors | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2017-21 | 2022-26 | 2026-31 | 2032-36 | 2037-41 | 2042-46 | 2046-51 | 2052 and above |
| Heavy Truck | 8.20% | 8.30% | 7.50% | 6.10% | 5.22% | 4.70% | 4.23% | 3.81% |
| Truck | 7.20% | 7.40% | 6.70% | 5.40% | 4.64% | 4.18% | 3.76% | 3.39% |
| Minitruck | 3.60% | 3.70% | 3.30% | 2.70% | 2.32% | 2.09% | 1.88% | 1.69% |
| Large bus | 5.90% | 6.00% | 5.40% | 4.40% | 3.79% | 3.41% | 3.07% | 2.76% |
| Mini bus | 7.40% | 7.50% | 6.80% | 5.50% | 4.72% | 4.25% | 3.82% | 3.44% |
| Micro bus | 7.40% | 7.50% | 6.80% | 5.50% | 4.72% | 4.25% | 3.82% | 3.44% |
| Car | 7.20% | 7.30% | 6.60% | 5.30% | 4.61% | 4.14% | 3.73% | 3.36% |
| Utility vehicle | | 3.69% | 3.32% | 2.99% | 2.42% | 2.08% | 1.87% | 1.69% |

### 4.3 Anticipated Traffic Volume Along KTFT

Traffic volume along the KTFT expressway for the base year 2024 was estimated considering expected diversion of traffic currently using Nagdhunga and Banepa Bardibas sections. The expected daily KTFT traffic in the base year 2024 considering a diversion of 40% of traffic, as indicated by the assignment result from both the sections is shown in Table 5. The traffic forecasts for future years 2035, 2045, and 2055 were carried out using the base year traffic, the expected growth rates for different vehicle types given in Table 4, and considering a generated traffic of 30% of the diverted traffic for the year. The base year and forecasted traffic for the next thirty years by vehicle type are also given in Table 5. The total daily traffic projected for 2035, 2045 and 2055 are 30922 PCU, 48789 PCU, and 70724 PCU, respectively which are approximately 2.59, 4.08, 5.91 times that of the base year.

Table 5: Forecasted traffic along KTFT

| Vehicle type | Daily traffic | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2024 | | 2035 | | 2045 | | 2055 | |
| | VPD | PCU | VPD | PCU | VPD | PCU | VPD | PCU |
| Heavy truck | 1398 | 5591 | 3877 | 15510 | 6378 | 25511 | 9541 | 38162 |
| Truck | 858 | 2575 | 2197 | 6591 | 3423 | 10269 | 4900 | 14700 |
| Mini truck | 93 | 139 | 170 | 254 | 212 | 317 | 254 | 381 |
| Large bus | 566 | 1698 | 1278 | 3834 | 1838 | 5513 | 2466 | 7397 |
| Mini bus | 53 | 132 | 136 | 341 | 214 | 534 | 308 | 770 |
| Micro bus | 478 | 717 | 1236 | 1855 | 1941 | 2911 | 2794 | 4191 |
| Car | 724 | 724 | 1834 | 1834 | 2846 | 2846 | 4062 | 4062 |
| Utility Vehicle (4-wheel drive) | 380 | 380 | 703 | 703 | 887 | 887 | 1062 | 1062 |
| **AADT** | **4550** | **11957** | **11432** | **30922** | **17738** | **48789** | **25386** | **70724** |

### 4.4 Toll Revenue Projection for KTFT

Table 6 shows the expected daily revenue, calculated based on the toll rate provided in Table 1 and the traffic forecasts outlined in Table 5, for different vehicle types for 2035 to 2055. Considering DoR's prevalent maintenance costs for similar infrastructure, the average annual maintenance costs for the expressway and the tunnels along KTFT are expected to be NRs 69 lakhs/km, NRs 284 lakhs/km respectively. Throughout all projected periods, the annual toll revenue surpasses the annual operation and maintenance costs. The initial construction cost of the expressway, NRs 2130000 lakhs, is estimated to be offset by the cumulative annual surplus within a payback period of 35 years under the proposed toll pricing framework.

**Table 6: Estimated daily revenue from different Vehicle types in lakhs**

| Year | Daily Toll Revenue in Lakhs | | | | | |
|---|---|---|---|---|---|---|
| | Car | LCV | Bus/ Truck | Three Axle CV | Heavy Com | Total |
| 2035 | 2.75 | 4.85 | 8.40 | 12.74 | 31.79 | 60.53 |
| 2045 | 4.55 | 7.35 | 12.45 | 20.88 | 54.85 | 160.62 |
| 2055 | 6.91 | 10.41 | 17.26 | 30.87 | 85.87 | 251.40 |

## 5. Conclusion and Recommendations

This study presents traffic forecasts along the KTFT expressway and assesses the anticipated toll revenue generated by the expressway project. Traffic projections were made using a time-based assignment considering the Origin-Destination patterns of existing trips between Kathmandu and various regions of Nepal. A toll fee structure for different types of vehicles was proposed, aligning with the toll rate guidelines outlined in NHFR-2008 but adapted to suit the current Nepalese context. The anticipated toll revenues were subsequently calculated and analyzed considering the construction and maintenance costs of the expressway. The numerical findings are as shows:

1. Origin-Destination survey data indicated significant traffic movement between Kathmandu and various regional zones, with the West-West & West-South zones contributing notably to traffic entering and leaving Kathmandu.
2. Time-based traffic assignment shows approximately 40% of the total traffic from the Nagdhunga, equating to 10,988 PCU, is expected to be diverted to the KTFT expressway in the base year 2024.
3. Heavy trucks are anticipated to have the highest traffic growth rates of 8.2% (2022-2026) to 3.81% (in 2052 onwards).
4. Cars are expected to have growth rates starting from 7.3% (2022-2026), gradually decreasing to 3.36% ( in 2052 onwards).
5. By 2055, the total daily traffic volume is projected to reach 70,724 Passenger Car Units (PCU), approximately 5.91 times the base year traffic of 11,957 PCU in 2024.
6. Projected daily toll revenue under the proposed toll structure are NRs 60.53 lakhs, Nrs 160.62 lakhs, and Nrs 251.40 Lakhs from years 2035, 2045 and 2055, respectively..
7. The payback period based on the annual revenue collection and the construction and maintenance cost of the project is estimated to be 35 years.

The toll revenue analysis in this study focuses on uniform single entry fee structure for various vehicle types. Subsequent research could explore alternative fee structures tailored to frequent users, and incorporate intermediate exits, which were not considered in this analysis. Moreover, exploring dynamic pricing strategies and adopting advanced toll collection technologies are essential steps for enhancing efficiency and ensuring financial sustainability. It is also advisable to develop a toll collection guideline specifically designed for the Nepalese context.

## 6. Acknowledgement

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