Evaluating Traffic Dispersal to and from Kathmandu Terai Fast Track Expressway within Kathmandu Valley's Road Network

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Abstract

The Kathmandu Terai Fast Track (KTFT) Expressway aims to bolster connectivity between Kathmandu valley and Nepal's Terai region. Despite its potential benefits in enhancing economic development and accessibility, the project poses challenges due to the existing poor road network and traffic congestion in Kathmandu valley. This study assigns projected KTFT traffic to and from the road network in Kathmandu valley based on detailed origin-destination information. It discusses potential transport infrastructure interventions to facilitate traffic dispersion and analyzes link performance using flow and volume-to-capacity (v/c) ratios with and without such interventions for the projected traffic in the next three decades. Assignment results indicated potential heavy congestion in the western area of the valley road network, particularly along Dakshinkali road, Khokana-Nakkhu Road, Kalanki-Gongabu Road, and Kalanki-Thankot Road in the coming decades. Improvements of the Dakshinkali road, corridor roads and links to Thankot and Nakkhu along with addition of a tunnel in Chobhar area showed significant improvement in the performance of the network links.

Keywords: origin-destination; traffic assignment; volume-to-capacity (v/c) ratio

1. Introduction

The Kathmandu Terai Fast Track (KTFT) Expressway, spanning approximately 71 kilometers, aims to enhance connectivity between Kathmandu valley and the Terai region of Nepal. This national pride project is designed to boost economic development, improve accessibility, and reduce travel time between Kathmandu and Terai region of the nation. Planned to start from the Khokana area in Kathmandu valley, the expressway has a significant potential to facilitate regional freight transport in the country. Kathmandu valley, the capital region of Nepal, comprises 18 municipalities and hosts over three million residents (NSO, 2021). The core areas exhibit high population densities, with Kathmandu metropolitan city recording the highest density of 166.92 people per hector (NSO, 2021). Despite having a dense road network of 5800 km or more (JICA, 2018; KVDA-UNDP, 2016), many of these roads are narrow (less than 3.5 m width) local roads. The number of registered vehicles in the valley is consistently increasing at an average rate of 12% annually, with the total in Kathmandu valley/ Bagmati zone reaching 11,72,413 in 2018 which is about 36% of the total vehicles registered in Nepal (DoTM, 2018). Given the dense population, increasing vehicular numbers, and uncontrolled urbanization, Kathmandu valley currently faces significant traffic congestion and related challenges, which are expected to worsen with the influx of traffic from the KTFT expressway.

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The projected increase in vehicular movement necessitates effective traffic dispersal mechanisms to manage the additional load efficiently. This study addresses this challenge by assessing the projected KTFT traffic from its starting point, Khokana, to the valley's road network based on detailed origin-destination information. Proposed interventions to improve traffic dispersion in anticipation of future traffic include strategic addition of link roads, bridges, and a tunnel, and also the improvement of existing roads. The analysis uses traffic flow and volume-to-capacity (v/c) ratios as performance measures to evaluate link performance with and without these interventions. By providing a comprehensive analysis, this study aims to inform policymakers and urban planners, helping to devise strategies to lessen the impact of KTFT traffic to the road network within the Kathmandu valley.

2. Literature Review

Traffic congestion in the Kathmandu valley is a chronic problem primarily stemming from haphazard urban growth, inadequate transportation infrastructure, and ineffective management practices. The roads are typically narrow and winding, making them ill-equipped to handle the heavy traffic load, exacerbating the problem. Inadequate parking facilities, insufficient traffic signals and signage, and the presence of diverse traffic types including vehicles, pedestrians, and street vendors further compound the issue. Moreover, improper parking and roadside vending exacerbate the chaos, resulting in substantial delays and congestion (Thapa et al., 2008).

The severity of traffic congestion is influenced by several factors, including the demographic, social dynamics and economic conditions. However, it is noted that the development of a well-planned and robust highway network can significantly mitigate this issue. Other effective mitigation measures include promoting the use of non-car transport modes such as bicycles and public transit, fostering traffic demand management strategies, developing well-planned communities, increasing urban density, and fostering favorable socioeconomic conditions (Rahman et al., 2021). Hence, the introduction of major infrastructures necessitates an analysis not only of its economic viability but also of its social and traffic impacts on the surrounding areas.

Transportation planning commonly employs the four-step transportation modeling framework, comprising trip generation, trip distribution, modal split, and traffic assignment, which is valuable for evaluating traffic impacts. Trip generation involves predicting the number of trips originating and ending in different areas as a function of land use, household demographics, and other socioeconomic factors. Trip distribution determines where these trips are headed. Modal split assesses the choice of transport modes, such as cars, buses, or bicycles. Traffic assignment then forecasts how these trips will spread across the transportation network, aiming to achieve user equilibrium (UE). In the state of UE, no driver can reduce their travel time by choosing a different route. Frank-Wolfe (FW) algorithm is a commonly used algorithm to solve traffic assignment problems. Introduced in 1956 for quadratic programming, the FW algorithm is particularly effective in this context. Each iteration of the FW algorithm involves minimizing a linearized version of the objective function, which entails directing all traffic flows to the paths with the lowest costs. These costs are influenced by the current traffic distribution across the network. As the algorithm iterates, it gradually adjusts the flows to find an equilibrium where travel times cannot be further reduced by changing routes (XU et al., 2008).

Under the KTFT project initiative, this study takes steps to explore the impact of the traffic to and from the planned KTFT expressway and identifies interventions essential for mitigating these impacts. Utilizing the FW algorithm, the study conducts time-based traffic assignment to explore the potential traffic dispersion pattern from the expressway to the road network in Kathmandu valley and evaluates link performance in terms of flow and volume/capacity ratios.

3. Methodology

The methodological framework of the study revolves around three main components: the assignment of the projected KTFT traffic to the Kathmandu valley road network, analysis of traffic dispersion, and performance evaluation with and without transport infrastructural interventions.

3.1 Origin Destination Survey

A 24-hr Origin-Destination (OD) survey was conducted at Nagdhunga checkpoint to collect detailed origin or destination information of regional trips to the Kathmandu valley. This survey aimed to gather comprehensive data on trip origins and destinations within the valley, providing insights into potential origins and destinations of KTFT trips within the valley. To capture comprehensive OD information, the valley was divided into 7 zones based on geographic and demographic factors. The regional trip OD information was used for traffic forecast of the KTFT expressway as well as for assignment of daily traffic between Khokana (the expressway point) to various locations in the Kathmandu valley.

3.2 Traffic Assignment

Traffic volume along KTFT was forecasted for the base year 2024 and subsequent thirty years 2035 to 2055 considering potential diversion of regional traffic currently using Nagdhunga and Banepa Bardibas highway sections obtained from Department of Roads (DoR, 2024), a generated traffic equal to 30% of the diverted traffic and growth rates of different vehicle types estimated using elasticity method. For traffic assignment of the KTFT traffic in-out Kathmandu, it was assumed that 90% of the trucks will stay in the dry port and will follow their final destination within Kathmandu valley during night time. Similarly, 90% of the large bus, 75% of the minibus and 50% of the microbus are assumed to be stationed at the planned bus terminals to be located near the Khokana point of the expressway. It was assumed that the further trips to end locations would be carried out on smaller vehicles. So equivalent increases in smaller vehicles are considered based on carrying capacity (for trucks) or occupancy (for passenger vehicles) of vehicles. Following are the assumptions made to calculate the in-out traffic from/to the KTFT to Kathmandu valley.

a. 1 large bus is equivalent to 1 minibus plus 1 microbus.
b. 2 minibus is equivalent to 1 minibus, 1 microbus and 1 car/taxi.
c. 2 microbus is equivalent to 1 microbus and 4 cars/taxis.
d. 1 heavy truck is equivalent to 3 mini trucks.
e. 1 truck is equivalent to 2 mini trucks.
f. 1 mini truck is equivalent to 2 utility vehicles.

The daily volumes of KTFT were converted to peak hour volume and were assigned to the various zones of Kathmandu valley following the proportion observed in the OD survey. Using these OD matrices, a mesoscopic traffic assignment was carried out within the Kathmandu valley and the expected traffic conditions with and without infrastructural interventions were analyzed. A static assignment model with user equilibrium method using the Normal Frank-Wolfe Algorithm with a time-based cost function as given in equation (1) was applied.

$$\text{Travel Cost} = \text{Time} \times \text{VOT} \quad ...(1)$$

Where,

Time: Current estimate of link traversal time

VOT: Value of time

The value of time was taken as Rs. 130/hr which is an average value of time obtained for work trips for public and private vehicles in the context of Nepal as mentioned in Gautam (2020). For the traffic assignment, a network of major road links in Kathmandu was considered. This includes parts of national highway and feeder highway sections, strategic urban roads and corridor road sections.

3.3 Proposed Interventions to Facilitate Traffic Dispersion

Several transport infrastructure improvements are proposed to facilitate the traffic dispersion. This includes addition of a link road from Khokana to the Dakshinkali road and dry port (L1), expanding the Dakshinkali road link (L2), expanded and improved Bagmati corridor links L3 (four-lane) and L4 (double-lane), expanded/improved linkage roads from Chobhar to Thankot check post (L5), linkage roads from corridor roads to F103 (L6, L7, L8, and L9, i.e., Nakkhu Jalbinayak marg, Jal Binayak marg, Nakkhu corridor left and right roads, respectively) as shown in Table 1. To address the challenging terrain in the Chobhar Galchhi area, a tunnel (TL) with a length of 0.42 kilometers was suggested to connect the corridor roads L3 and L4. Two new bridges B1 and B2 to facilitate traffic movement between Khokana and Chobhar dry port were also proposed. In an effort to reduce stress on Kathmandu Ring Road (KRR), the enhancement of two additional links: L10, connecting Kirtipur to Naikap in Prithvi highway (H02) via Kirtipur road and Salyanthan Road; and L11, connecting L5 and L10 to a 7m carriageway double-lane road were also proposed. Figure 1 shows the locations of the proposed interventions.

Table 1: Proposed transport infrastructure improvements

SN	Transport Infrastructure	Existing Status	Required Addition/Improvement
1	T: Terminal	-	Addition
2	B1: Bridge to Dakshinkali road and Chobhar dry port	-	Addition of 4 lane 15 m carriageway
3	B2: Bridge from Chobhar dry port	-	Addition of 7 m carriageway
4	TL: Tunnel	-	Addition of 7 m carriageway
5	L1: Link road to Dakshinkali road and dry port	-	Addition of 4 lane 15 m carriageway
6	L2: Dakshinkali road expansion link	4 lane	Widening to 6 lane 22.5 m carriageway
7	L3: Bagmati corridor link	-	Addition of 4 lane 15 m carriageway
8	L4: Bagmati corridor link	Track in some places	Improvement to 7 m carriageway
9	L5: Link to Thankot check post	Two way >=5.5m carriageway	Improvement to 7m carriageway
10	L6: Link to F103	Two way >=5.5m carriageway	Improvement to 7m carriageway
11	L7: Secondary link to F103	Two way >=5.5m carriageway	Improvement to 7m carriageway
12	L8: Nakkhu corridor left to F103	Two way >5.5 m carriageway but no linkage to F103	Connection of the corridor to L4 and F103
13	L9: Nakkhu corridor right to F103	Two way >5.5 m carriageway but no linkage to F103	Connection of the corridor to L4 and F103
14	L10: Link to Naikap in Prithvi Highway	Two way >=5.5m carriageway	Improvement to 7m carriageway
15	L11: Link road between L5 and L10	Two way >=5.5m carriageway width	Improvement to 7m carriageway

Figure 1: Proposed transport infrastructure interventions

3.4 Traffic Dispersion and Performance Measures

To distribute traffic from the expressway across the road network of Kathmandu valley, varying capacities and speeds were allocated to different roads. By presuming that 50% of the road capacity can be utilized for the KTFT traffic on existing roads, capacities were assigned following NURS 2076 guidelines. Table 2 presents the adopted capacity and speed values for different roads. Subsequently, traffic assignment was conducted for two scenarios: the current road network and with transport infrastructure interventions. The link performance was measured in terms of traffic flows and volume/capacity (v/c) ratios.

Table 2: Capacity and speed values assigned to various roads dedicated to KTFT traffic

Road	Capacity (PCU/hr)	Speed (kmph)
Ring Road (Kalanki-Satdobato-Koteshwor)	2000	45
Ring Road (Kalanki-Gongabu-Koteshwor)	1000	35
Dakshinkali Road	2500	35
Koteshwor-Bhaktapur	1500	40
New proposed Link Roads	1000	30
Proposed Tunnel	2000	45
All other existing roads	500	20

4. Results and Discussion

4.1 Traffic Assignment In-Out Kathmandu

Table 3 illustrates traffic growth rates according to various vehicle types. GDP growth rates, sourced from a previous DPR report projecting up to 2031, were utilized. For later years up to 2055, a constant GDP growth rate of 4.3% was applied (CMS, 2013). Growth rates for utility vehicles were determined using the elastic method due to the lack of specific data in the report. Projections spanned 30 years up to 2055, with growth rates calculated for each five-year period. Notably, heavy trucks exhibited the highest growth rate at 8.3%, while utility vehicles demonstrated the lowest at 3.69% for the year 2024.

The base year traffic along the KTFT expressway for year 2024 was obtained with 40% diversion of existing traffic from Nagdhunga and Banepa Bardibas highway sections. Traffic forecasts for the years 2035, 2045, and 2055 were established using the base year traffic of 2024, along with a generated traffic of 30% of diverted traffic and using growth rates for different vehicles. Table 4 presents the base year and forecasted traffic for the next thirty years by vehicle type. The anticipated total daily traffic volumes are 30,922 PCU, 48,789 PCU, and 70,724 PCU, respectively indicating approximately 2.59, 4.08, and 5.91 times the volume estimated for the base year.

Table 3: Traffic growth rates for different vehicle types

Vehicle Type	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%

Table 4: Traffic forecast along the KTFT expressway

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

Tables 5 and 6 depict the expected daily passenger and freight traffic between KTFT and Kathmandu valley, including equivalent increases in smaller vehicles for end-point travel/transport. Table 7 displays the total classified peak hour volume (excluding the percentage of trucks continuing at night) obtained as 15% of the daily volume as recommended in NURS, 2076. And Table 8 shows the peak hour volume according to the OD zones, up to 2055.

Table 5: Expected daily passenger traffic in-out between KTFT and Kathmandu valley in 2024

Vehicle type	Total KTFT traffic (VPD)	Vehicles that will continue as it is		Vehicles that will continue as smaller vehicles to and from Khokana	Equivalent smaller vehicles		
					Mini bus	Micro bus	Car
Large bus	566	10%	57	509	509	509	
Mini bus	53	25%	13	39	20	20	20
Micro bus	478	50%	239	239		120	478
Car	724	100%	724	0			

Table 6: Expected daily freight traffic in-out between KTFT and Kathmandu valley in 2024

Vehicle type	Total KTFT traffic (VPD)	Park & continue at night		Vehicles that will continue as smaller vehicles to and from Khokana	Equivalent smaller vehicles	
					Mini truck	Utility vehicle
Heavy Truck	1398	90%	1258	140	419	
Truck	858	90%	773	86	172	
Mini Truck	93	90%	83	9		19
Utility Vehicle (4 wheel drive)	380	0%	0	380*		380

*continue as it is

Table 7 Expected peak hour traffic in-out between KTFT and Kathmandu valley in 2024

Vehicle Type	Total Volume In-Out Kathmandu Valley			
	ADT Excluding Night Trucks (VPD)	Peak Hour Traffic (VPD)	PCU factor	Peak Hour Traffic (PCU)
Heavy Truck	0	0	4.0	0
Truck	0	0	3.0	0
Mini Truck	591	89	1.5	133
Large bus	57	8	3.0	25
Mini bus	542	81	2.5	203
Micro bus	888	133	1.5	200
Car	1222	183	1.0	183
Utility Vehicle (4 wheel drive)	398	60	1.0	60
TOTAL				**805**

Table 8 Expected peak hour in-out traffic between KTFT and Kathmandu valley according to OD zones

Inbound to Kathmandu valley					
Destination zone	Percentage	Peak hour traffic (PCU)			
		2024	2035	2045	2055
1. Bhaktapur	8%	66	159	239	335
2. Core Area	4%	36	87	131	184
3. Gongabu	16%	125	301	454	635
4. Kalanki	13%	106	255	384	538
5. Kirtipur	0%	1	3	5	7
6. Lalitpur	5%	39	93	141	197
7. Gokarneshwor	4%	30	71	107	150
Outbound from Kathmandu valley					
Origin zone	**Percentage**	**Peak hour traffic (PCU)**			
		2024	**2035**	**2045**	**2055**
1. Bhaktapur	7%	59	143	216	302
2. Core Area	3%	26	62	94	131
3. Gongabu	20%	161	387	584	816
4. Kalanki	10%	84	203	307	429
5. Kirtipur	0%	3	8	12	17
6. Lalitpur	6%	44	107	161	225
7. Gokarneshwor	3%	24	59	89	124
Total	**100%**	**805**	**1939**	**2925**	**4089**

4.2 Expected Traffic Dispersion with and without Transport Interventions

Figures 2 and 3 illustrate the expected traffic distribution to and from Khokana in 2035, 2045, and 2055, with and without transport infrastructure interventions. Without interventions, the results indicate large volumes and severe traffic congestion (v/c ratio > 1) primarily in the western area of the valley road network, particularly along Dakshinkali road, Khokana-Nakkhu Road, Kalanki-Gongabu Road, and Kalanki-Thankot Road in the coming decades. The assignment result in Figure 3 shows that the proposed interventions specially the expansion of the Dakshinkali Road, addition of tunnel section and links L3, L4, L5 and L6 can significantly help in dispersing the traffic. The results also indicate the pressing need for expansion of ring road section from Kalanki to Gongabu area.

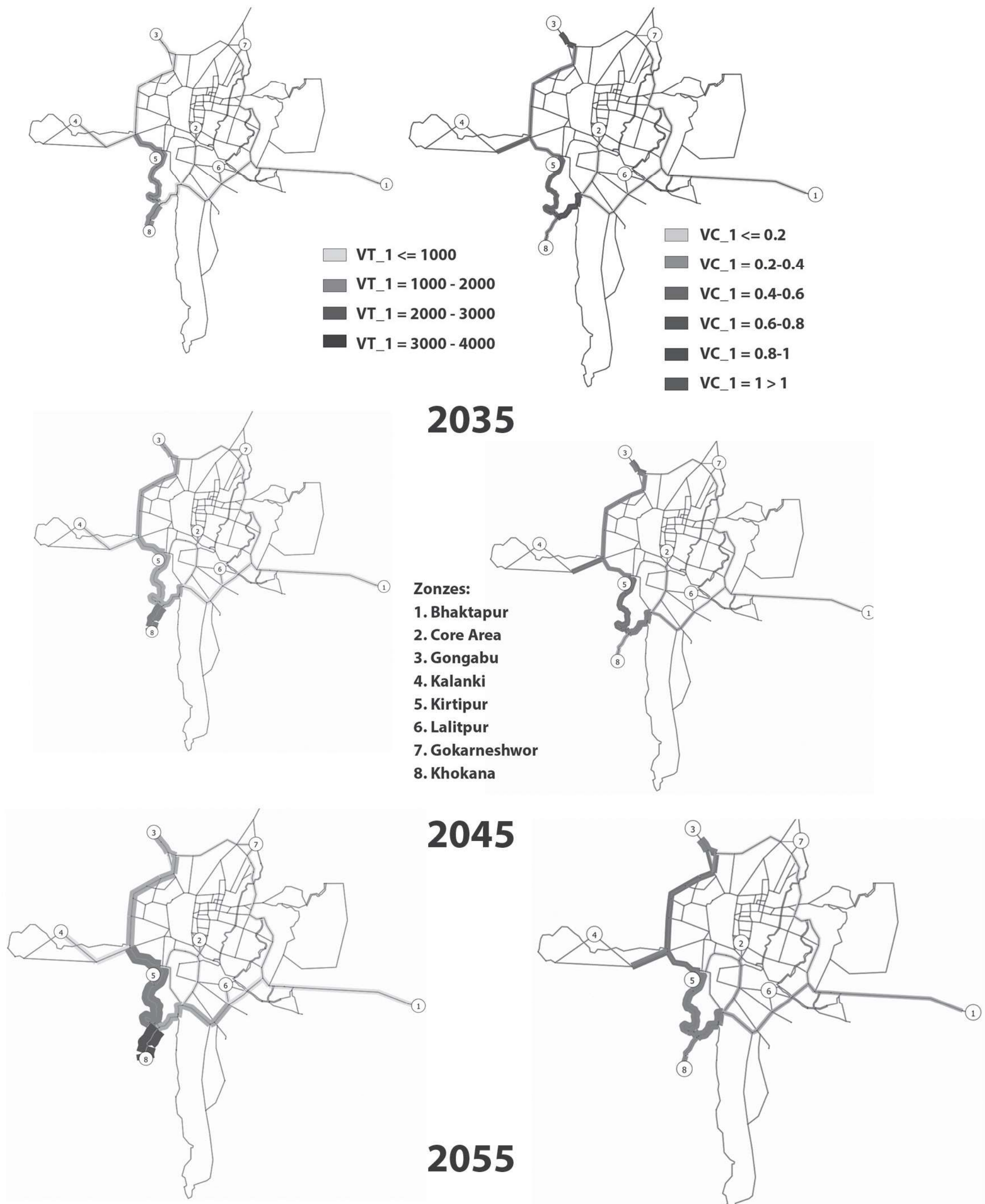

Figure 2: Expected traffic dispersion in 2035. 2045 and 2055 without transport infrastructure intervention

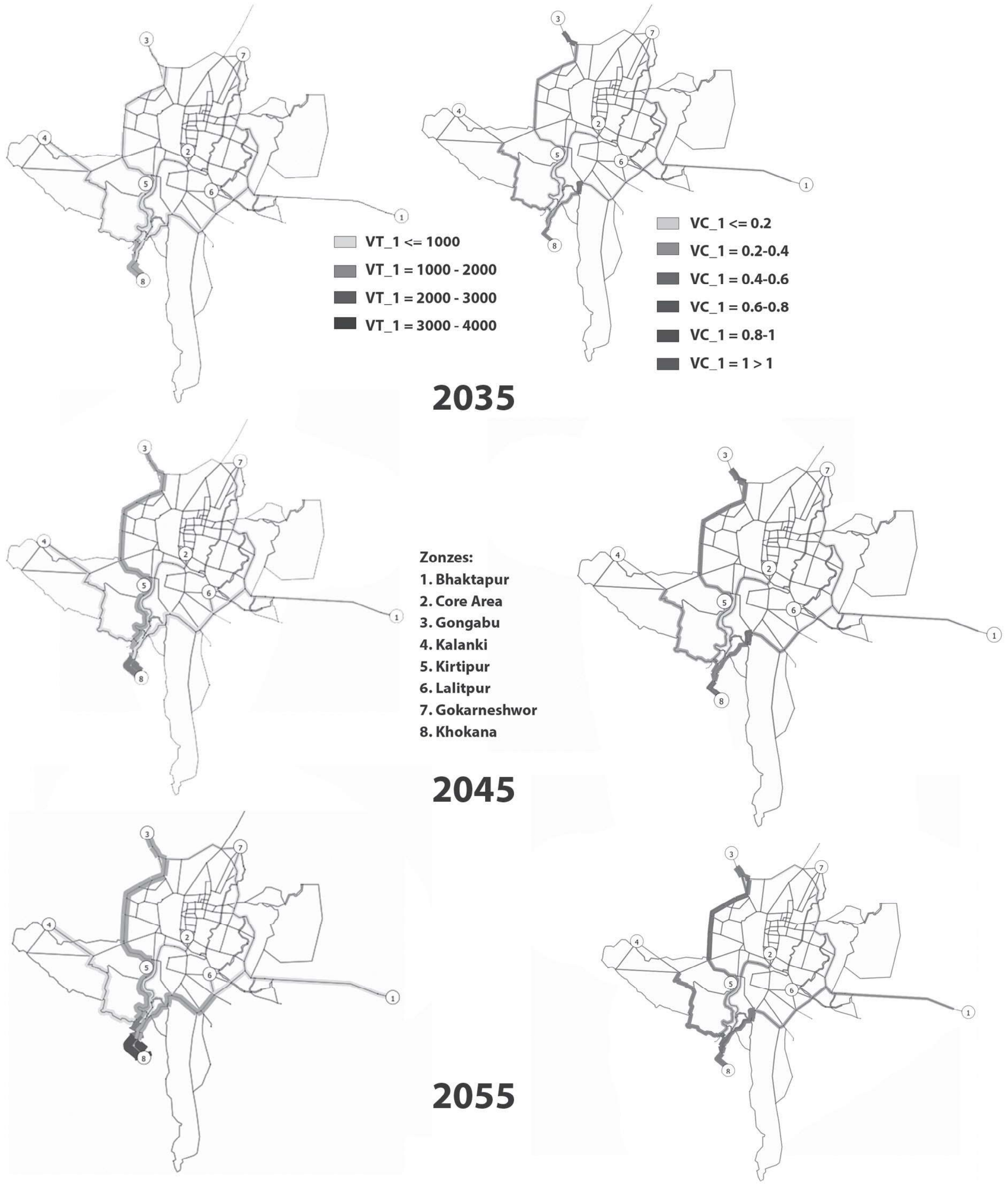

Figure 3: Expected traffic dispersion in 2035. 2045 and 2055 with transport infrastructure intervention

5. Conclusion and Recommendations

The Kathmandu Terai Fast Track Expressway project aims to significantly enhance connectivity between Kathmandu valley and Nepal's Terai region. Given the dense population and increasing vehicular numbers in Kathmandu Valley, this study investigates how to manage the anticipated traffic influx from the KTFT expressway effectively. Utilizing an origin-destination survey, traffic assignment models, and volume-to-capacity (v/c) ratio analyses, the study assesses current and future traffic conditions with and without proposed infrastructure interventions. Following are the key findings of the study:

a. Heavy trucks show the highest growth rate at 8.3% whereas utility vehicles have the lowest growth rate at 3.69%.

b. Traffic volumes from KTFT are expected to increase significantly, reaching up to 70,724 PCU by 2055, which is about 5.91 times the base year volume (2024).

c. Significant congestion is projected on Dakshinkali Road, Khokana-Nakkhu Road, Kalanki-Gongabu Road, and Kalanki-Thankot Road.

d. Infrastructure improvements such as road expansions, new link roads, bridges, and a tunnel are expected to alleviate congestion, especially on Dakshinkali Road, Khokana-Nakkhu Road, and Kalanki-Thankot Road.

To manage the anticipated traffic influx from the KTFT Expressway and mitigate congestion within Kathmandu Valley, immediate actions should be taken to upgrade the existing infrastructure. Priority should be given to expanding and improving critical routes such as Dakshinkali Road and Khokana-Nakkhu Road. Implementing smart traffic management systems can regulate traffic flow and alleviate congestion during peak hours. Future research should refine origin-destination zones for more precise traffic forecasting, analyze commuter behavior, and evaluate the impact of both infrastructure and policy interventions.

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