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ROLE OF IOT (INTERNET OF THINGS) IN TRAFFIC MANAGEMENT IN KATHMANDU METROPOLITAN CITY

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ABSTRACT

Kathmandu, the capital of Nepal, faces significant traffic congestion due to rapid urban growth, impacting residents' daily lives and hindering economic and environmental sustainability. This study investigates the global implementation of IoT in traffic management, drawing lessons for Kathmandu and identifying associated challenges. Using a mixed-methods approach, primary data were collected via surveys and interviews with traffic authorities, urban planners, and residents, while secondary data came from existing traffic reports and studies.

The findings reveal positive perceptions of IoT's role in traffic management, with high optimism for its effectiveness (Mean = 2.05) and low standard deviations indicating consensus. Significant correlations were found between IoT, smart infrastructure, public awareness, and traffic management. Regression analysis shows a strong model fit (R-squared = 0.759), highlighting the positive impact of public awareness and infrastructure on traffic management. However, caution is advised in generalizing the findings, and further research is recommended to explore additional factors influencing traffic management in Kathmandu.

Keywords: *IOT, traffic management, Kathmandu*

Introduction

Kathmandu, the historic and bustling capital of Nepal, has undergone a profound transformation in recent years. Its rapid urbanization and population growth have ushered in an era of unprecedented change, presenting both opportunities and challenges for the city and its residents. As the urban landscape expands and evolves, so too does the need for a modern, efficient, and sustainable transportation system that can cater to the burgeoning demands of its populace (Ishtiaque et al., 2017).

The exponential growth of Kathmandu's urban population has given rise to a multitude of concerns, chief among them being the escalating problem of traffic congestion. The city's once-unhurried streets now find themselves in a state of

perpetual gridlock, as vehicular traffic swells and maneuvering through the labyrinthine roads becomes increasingly time-consuming and frustrating for commuters. What was once a short journey from one point to another has, for many, become a daily ordeal of prolonged travel times, stress, and diminished productivity (Ojha, 2019).

However, the implications of this traffic congestion extend far beyond mere inconvenience. The consequences of congested roadways permeate virtually every facet of urban life in Kathmandu (Timsina et al., 2020). Environmental pollution, a byproduct of vehicles idling in traffic for prolonged periods, has surged to alarming levels, jeopardizing the health and well-being of Kathmandu's inhabitants. The air quality has deteriorated to the extent that it is now a pressing public health concern, leading to respiratory ailments and diminishing the overall quality of life.

Furthermore, the economic vitality of the city is threatened by the inefficiencies wrought by traffic congestion. Businesses suffer from delayed deliveries, increased transportation costs, and reduced access to potential customers, while individuals grapple with diminished leisure time, disrupted schedules, and the stress of navigating chaotic streets (The Kathmandu Post, 2015).

However, Nepal could integrate the ICT for the purpose of traffic management. Perhaps the first area that some large Nepali cities can adopt smart city concepts is in real-time traffic management. In place of the traffic signals that operate on pre-programmed cycle for fixed duration, smart traffic signals can sense the actual traffic movement at the intersection and adjust immediately to optimize the traffic flow. The human traffic police sometimes do that in the street of Kathmandu, but it is an unsafe and tedious task. Smart traffic control system can automatically manage the traffic and help it flow better (Bhattarai & Adhikari, 2020).

This paper aims to provide a comprehensive response to this question by exploring the role of the Internet of Things (IoT) as a potential solution. IoT, a burgeoning technological paradigm, holds immense promise in revolutionizing urban infrastructure and services.

The primary objectives of this study are as follows:

- To explore the traffic management system in the Kathmandu Metropolitan City.
- To identify the challenges and barriers associated with the implementation of IoT-based traffic management solutions in the city.

Research Hypothesis

H_1: There is a significant relation between the use of IoT devices in traffic flow management.

H_2: There is a significant relation between Data Analytics in traffic flow management**.**

H_3: There is a significant relation between Smart Infrastructure and traffic flow management.

H_4: There is a significant relation between Policy Interventions and traffic flow management.

Literature Review

The Internet of Things (IoT) encompasses a network of interconnected physical devices, equipped with sensors and actuators, that communicate and exchange data over the internet. These devices, ranging from smart home gadgets to industrial machinery, collect information from their surroundings and utilize communication protocols to transmit data for processing, which may occur at the device itself (edge computing) or on centralized cloud servers. IoT applications span diverse sectors, including smart homes, industrial processes (IIoT), healthcare, and smart cities, offering benefits such as automation, efficiency, and improved decision-making (Sethi & Sarangi, 2017). However, challenges such as security, privacy, and interoperability must be addressed for the continued growth and successful integration of IoT into various domains.

Adhikari and Bhattarai (2020) discussed the concept of smart cities and its potential benefits for Nepal. It explains that smart cities use information technology, sensors, and real-time data to improve urban functions such as traffic, energy distribution, and public amenities. The benefits include reduced pollution, increased efficiency, and a more sustainable urban environment. The article highlighted that smart cities integrate information and communication technologies to optimize urban infrastructure and services. It mentions examples like traffic management and energy grid optimization. Smart cities also focus on efficient use of public spaces and parks. However, the article acknowledges that implementing smart cities in Nepal faces challenges due to inadequate infrastructure and services. Despite this, it suggests that starting with partial implementations, such as real-time traffic management, could be a practical approach for Nepali cities. The article concluded by noting that the development of smart cities is an evolving process, and that Nepal can benefit from implementing certain smart city elements like traffic management, parking, and energy transmission. It also highlights the need for a cost-benefit analysis and addresses potential concerns about privacy.

Bhusal et al. (2021) stated that Motor cars are more prevalent on the highways of major cities like Kathmandu as a result of the raging increase in urban population. As a result, the residents of this city are accustomed to experiencing frequent traffic jams. The fact that every person is forced to spend an average of 120 hours a year doing nothing productive due to traffic congestion makes this very clear. Evidently,

identifying the problem does not always result in a fix. However, creating intelligent traffic management systems with intelligent traffic signals and early warning systems could be a successful substitute. Furthermore, creative road engineering, as demonstrated by features like road diet and roundabouts, is a popular treatment. However, the primary issue is the preference for private vehicles over public transportation. It can definitely help to reduce these worries to cultivate a society-friendly mentality along with effective, inventive approaches (Bhusal et al., 2021).

Dziuba (2021) discussed how IoT can enhance traffic control, improve road safety, and reduce congestion. The potential applications of IoT in toll and ticketing systems, connected cars, public transport management, and traffic management are explored. The article also outlines the benefits of IoT-based traffic monitoring and management systems, including safety, efficiency, and environmental improvements (Dziuba, 2021).

Dixit and Shaw (2023) explored the emerging concept of Smart Cities in Nepal, aiming to address urban challenges and enhance citizens' quality of life through technology and innovation. This transformation is driven by urbanization, sustainability goals, and technology's potential. Nepal prioritizes sustainability and smart technology integration within its development objectives. While Smart City indicators have been established, this study recommends flexibility in these indicators, a holistic approach to interconnected Smart City components, and greater transparency and accountability to maximize quality of life and economic growth potential (Dixit & Shaw, 2023).

The literature on smart cities in Nepal, as discussed by Adhikari and Bhattarai (2020), Bhusal et al. (2021), Dziuba (2021), and Dixit and Shaw (2023), collectively underscores the potential advantages and challenges of integrating information technology, sensors, and real-time data to enhance urban functions. Adhikari and Bhattarai emphasize reduced pollution, increased efficiency, and sustainability benefits, while acknowledging infrastructure challenges. Bhusal et al. propose intelligent traffic management systems and advocate for a shift in the societal preference for private vehicles. Dziuba explores the transformative role of IoT in traffic management, emphasizing its potential in safety, efficiency, and environmental improvements. Dixit and Shaw address Nepal's rapid urbanization, advocating for flexible smart city indicators, a holistic approach, and increased transparency to maximize the quality of life and economic growth potential. Together, these studies highlight the evolving nature of smart city development in Nepal and the need for strategic, flexible, and innovative approaches to address urban challenges.

Methods and Procedure

This study employed a quantitative research design, using surveys to collect data from 325 residents of Kathmandu. The research aimed to integrate IoT within traffic management by developing a relevant model. Data collection involved distributing questionnaires to gather insights into residents' perceptions and experiences. Data analysis utilized quantitative methods, employing statistical tools such as chi-square tests to identify associations between categorical variables, ANOVA to evaluate differences in group means, and p-values to determine the significance of results. The conceptual framework focused on traffic management as the dependent variable, influenced by independent variables including IoT devices, data analytics, smart infrastructure, and policy interventions. The model's formula was

This will be calculated by the following formula:

$$TM = a + P1\ IOT + P2\ SI + P3\ PI + P4\ CN + P5\ PA + e \quad \text{(i)}$$

Where,

TM = Traffic Management, IOT = Internet of Thing, SI = Smart Infrastructure, PI= Policy Intervention, CN= Communication Network, PA= Public Awareness, a = constant term, e= error term,

P1, P2, P3, P4,P5= Beta coefficient of variables

Results

Analysis of the Traffic Management in Kathmandu

Table 3

The major traffic issues in Kathmandu Metropolitan City

Traffic Issues	Frequency	Percentage
Congestion	250	76.92%
Air pollution	180	55.38%
Lack of parking spaces	120	36.92%
Traffic accidents	200	61.54%
Other (Specify)	30	9.23%
Total	325	100%

Source: Field Survey, 2023

The survey results reveal that 76.92% of respondents in Kathmandu Metropolitan City identify congestion as a significant issue, highlighting prevalent concerns about traffic flow and delays. Additionally, 55.38% of participants recognize air pollution as a major traffic-related problem, emphasizing environmental impacts. The lack of parking spaces is noted by 36.92% of respondents, indicating

infrastructure deficiencies. Traffic accidents are a critical concern for 61.54% of participants, underscoring the need for improved road safety measures. Lastly, 9.23% of respondents mention specific concerns under the "Other" category, necessitating further analysis to understand additional traffic management challenges in Kathmandu.

Table 4

Effectiveness of Current Traffic Management

Effectiveness of Current Traffic Management	Frequency	Percentage
Very effective	0	0
Somewhat effective	60	18.46
Not effective at all	265	81.54
Total	325	100%

Source: Field Survey, 2023

The survey on the effectiveness of current traffic management in Kathmandu Metropolitan City reveals three distinct levels of perceived effectiveness among respondents. Notably, no respondents rated the current system as "Very effective," indicating a unanimous lack of strong endorsement. In the "Somewhat effective" category, 18.46% (60 respondents) expressed moderate satisfaction, suggesting some acknowledgment of effectiveness but highlighting that most find the system suboptimal. The predominant sentiment, with 81.54% (265 respondents), categorized the traffic management as "Not effective at all," underscoring widespread dissatisfaction. This overwhelming majority indicates a shared perception that the current measures are inadequate for addressing Kathmandu's traffic issues. The distribution of responses points to a general dissatisfaction, emphasizing a need for improvement and innovative solutions. These findings provide valuable feedback for policymakers and urban planners, signaling a call for more robust and efficient traffic management strategies in the city.

Table 5

Descriptive Summary

	N	Min	Max	Mean	Std.
IoT Devices	325	1.50	3.00	2.00	.5252
Smart Infrastructure	325	1.25	2.25	1.550	.3679
Policy Intervention	325	1.33	2.33	1.866	.3404
Communication Network	325	1.25	2.25	1.800	.3679
Public Awareness	325	1.33	2.33	1.866	.4529
Traffic Management	325	1.50	2.50	2.050	.33217

In summarizing the findings from the survey assessing various aspects related to the role of IoT in traffic management in Kathmandu Metropolitan City, it is evident that respondents generally hold positive perceptions across the evaluated variables. In terms of IoT Devices, respondents express a moderate to high level of confidence

in the reliability and impact of these devices on traffic management (Mean = 2.00, Std. = 0.52521). Smart Infrastructure, Policy Intervention, Communication Networks, Public Awareness, and Traffic Management also received favorable responses, showcasing overall agreement among participants. Notably, Traffic Management, in particular, received a high mean score (Mean = 2.05, Std. = 0.33217), indicating a positive outlook on the effectiveness and efficiency of IoT in improving traffic conditions in Kathmandu. The relatively low standard deviations across variables suggest a degree of consensus among respondents, highlighting a generally optimistic perspective regarding the integration of IoT technologies in the context of traffic management in the city.

Table 6

Correlation Analysis

	IOT	SI	PI	CN	PA	TM
IOT	1					
SI	.527*	1				
PI	.471	.708**	1			
CN	.367	.659**	.840**	1		
PA	.593*	.602*	.596*	.751**	1	
TM	.619*	.755**	.742**	.719**	.755**	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The correlation matrix indicates the relationships between the variables IOT (Internet of Things), SI (Smart Infrastructure), PI (Public Infrastructure), CN (Data Communication Networks), PA (Public Awareness), and TM (Traffic Management). The correlation coefficients reveal statistically significant associations between these variables. Specifically, IOT demonstrates a positive and moderately strong correlation with SI ($r = 0.527$, $p < 0.05$) and PI ($r = 0.471$, $p < 0.05$), indicating that as IoT adoption increases, so does the importance of system integration and public infrastructure. Additionally, strong positive correlations exist between SI and PI ($r = 0.708$, $p < 0.01$) as well as SI and CN ($r = 0.659$, $p < 0.01$), highlighting the interdependence of system integration with both public infrastructure and data communication networks. Furthermore, PA exhibits a significant positive correlation with IOT ($r = 0.593$, $p < 0.05$), emphasizing the role of public awareness in influencing IoT implementation. Lastly, TM is positively correlated with all other variables, with particularly strong associations observed with SI ($r = 0.755$, $p < 0.01$) and PA ($r = 0.755$, $p < 0.01$), underscoring the integral role of system integration and public awareness in the effectiveness of IoT-based traffic management systems. These findings collectively suggest a complex network of relationships, emphasizing the multidimensional nature of factors influencing the successful integration of IoT in traffic management.

Table 7

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.357	.580		-.616	.553
	PA	.311	.276	.347	1.127	.289
	CN	-.025	.561	-.019	-.045	.965
	PI	.440	.544	.286	.808	.440
	SI	.446	.393	.284	1.137	.285
	IOT	.145	.249	.136	.583	.574

a. Dependent Variable: TM

The regression coefficients also provide insights into the direction and strength of the relationships. For instance, the constant term is negative (-0.357), suggesting a baseline negative impact on TM when all predictors are at zero. However, the non-significant p-value indicates that this effect is not statistically reliable. Overall, this analysis suggests that, within the given predictors, public awareness and public infrastructure play more substantial roles in influencing traffic management outcomes. Nevertheless, caution should be exercised in generalizing these findings, and further research may be needed to explore additional factors that contribute to the complex dynamics of traffic management in this context.

System Description

The proposed smart parking system leverages IoT technology to streamline the parking experience in Kathmandu. It integrates sensors, communication devices, and data analytics to provide real-time information, helping drivers find optimal parking spots based on location, budget, and time preferences. Key components include a mobile app interface, parking lot sensors, a central database, a smart parking algorithm, navigation integration and a user notification system.

The mobile app serves as the primary user interface, offering real-time parking availability, navigation, and reservation services. Camera placed in the Parking lot identifies the number of incoming and outgoing vehicles and calculate spot occupancy, transmitting data to a central database, which stores both real-time and historical data. The smart parking algorithm processes this data, incorporating user preferences to suggest optimal parking spots based on its current location. It also considers alternate parking lot if the current nearest location is full.

The system's workflow involves vehicle detection by camera, data aggregation and analysis, mobile app usage for parking spot selection. Parking lot owners benefit from a dashboard providing real-time occupancy rates and performance insights, aiding in effective management.

Limitations

The study's scope is limited to Kathmandu Metropolitan City and may not fully represent the traffic challenges of surrounding areas. Data collection may be affected by logistical challenges and the willingness of respondents to participate.

The model system was developed to navigate the user to the nearest parking space with the help of digital system. IoT were used to identify the parking space and based on it the recommendation of nearest location.

Discussion

The findings of this study align with existing literature on the potential benefits and challenges of integrating IoT in traffic management, particularly in the context of smart city initiatives. The high optimism for IoT's effectiveness in Kathmandu, reflected in the study's mean score of 2.05, mirrors Dziuba's (2021) discussions on IoT's transformative potential in traffic control and safety. Similarly, Bhattarai and Adhikari (2020) highlighted the advantages of smart traffic signals in optimizing flow, a sentiment echoed by our study participants. The strong correlations between IoT, smart infrastructure, and public awareness, with an R-squared value of 0.759, reinforce Bhusal et al.'s (2021) and Dixit and Shaw's (2023) emphasis on these factors in addressing urban traffic challenges.

However, the study also reveals significant implementation challenges, consistent with the literature. Adhikari and Bhattarai (2020) and Bhusal et al. (2021) noted issues such as inadequate infrastructure and the need for a shift towards public transportation. Our study participants underscored similar concerns, highlighting the need for robust infrastructure and effective policy interventions. The regression analysis, showing critical roles for public awareness and smart infrastructure, suggests that addressing these areas could mitigate some challenges, aligning with recommendations by Dixit and Shaw (2023) for enhancing smart city initiatives in Nepal.

This study contributes valuable context-specific insights for Kathmandu, complementing the broader global perspectives found in existing literature. The empirical evidence gathered through surveys and interviews provides a robust foundation for the theoretical benefits of IoT, offering concrete data to guide practical implementation strategies. By adopting a holistic approach, considering factors like IoT devices, smart infrastructure, policy interventions, communication networks, and public awareness, the study supports the comprehensive planning needed for effective smart city development. These findings offer a clear roadmap for policymakers and urban planners to harness IoT's potential in transforming traffic management in Kathmandu, paving the way for more efficient, sustainable, and safe urban mobility.

Conclusion

In conclusion, the survey examining the role of IoT in traffic management in Kathmandu Metropolitan City provides a comprehensive and insightful understanding of public perceptions. The demographic profile illuminates key age groups and occupational backgrounds, revealing a diverse and engaged respondent base. Major traffic issues such as congestion, air pollution, parking challenges, and traffic accidents underscore the complex challenges faced by the city's residents. Importantly, the expressed dissatisfaction with the current effectiveness of traffic management highlights a clear call for improvements.

On the positive side, respondents exhibit a generally optimistic outlook toward IoT-related variables, with strong endorsements for smart infrastructure, policy interventions, communication networks, and public awareness. The high mean score for Traffic Management suggests a belief in the potential of IoT to positively impact traffic conditions in Kathmandu.

The correlation and regression analyses unveil intricate relationships between these variables, emphasizing the crucial roles of Public Awareness and Smart Infrastructure in influencing Traffic Management outcomes. These insights provide a valuable roadmap for policymakers, urban planners, and stakeholders to strategically enhance traffic management strategies in Kathmandu.

As the city grapples with the complex dynamics of urban traffic, this survey serves as a foundational resource for evidence-based decision-making. Policymakers are encouraged to focus on targeted public awareness campaigns and the development of smart infrastructure to harness the full potential of IoT in transforming and optimizing traffic management practices. The findings collectively illuminate a path forward for Kathmandu, where thoughtful integration of IoT technologies can contribute to more efficient, sustainable, and safer urban mobility.

References

Adhikari, A. P., & Bhattarai, K. (2021). Towards Creating Smart Cities in Nepal. *Nepal Journal of Science and Technology*, *20*(2), 1–16. https://doi.org/10.3126/njst.v20i2.45769 (Accessed. 10 Feb, 2024)

Alahi, M. E. E., Sukkuea, A., Tina, F. W., Nag, A., Kurdthongmee, W., Suwannarat, K., & Mukhopadhyay, S. C. (2023). Integration of IoT-Enabled Technologies and Artificial Intelligence (AI) for Smart City Scenario: Recent Advancements and Future Trends. *Sensors*, *23*(11), Article 11. https://doi.org/10.3390/s23115206 (Accessed. 10 Feb, 2024)

Bhattarai, K., & Adhikari, A. P. (2020, June 28). *How Nepal can make its cities smart*. My Republica. http://myrepublica.nagariknetwork.com/news/95660/

Bhusal, A., Jha, A., Khanal, A., Awasthi, A., & Mahato, A. K. (2021). Evaluation And Mitigation Of Traffic Related Concerns In Kathmandu Valley. *ARXIV*, *12*(1).

Damadam, S., Zourbakhsh, M., Javidan, R., & Faroughi, A. (2022). An Intelligent IoT Based Traffic Light Management System: Deep Reinforcement Learning. *Smart Cities*, *5*(4), Article 4. https://doi.org/10.3390/smartcities5040066 (Accessed. 10 Feb, 2024)

Dixit, A., & Shaw, R. (2023). Smart Cities in Nepal: The concept, evolution and emerging patterns. *Urban Governance*. https://doi.org/10.1016/j.ugj.2023.08.003 (Accessed. 10 Feb, 2024)

Dziuba, A. (2021, December 16). *IoT in Transportation: All You Need to Know About Smart Traffic Control System Using IoT*. Relevant Software. https://relevant.software/blog/iot-in-transportation-smart-traffic-control-system/ (Accessed. 10 Feb, 2024)

Frąckiewicz, M. (2023, April 28). IoT for Smart Parking: How It Helps to Improve Parking Management and Reduce Congestion. *TS2 SPACE*. https://ts2.space/en/iot-for-smart-parking-how-it-helps-to-improve-parking-management-and-reduce-congestion/ (Accessed. 10 Feb, 2024)

Ishtiaque, A., Shrestha, M., & Chhetri, N. (2017). Rapid Urban Growth in the Kathmandu Valley, Nepal: Monitoring Land Use Land Cover Dynamics of a Himalayan City with Landsat Imageries. *Environments*, *4*, 72. https://doi.org/10.3390/environments4040072 (Accessed. 10 Feb, 2024)

Kheder, M. Q., & Mohammed, A. A. (2023). Real-time traffic monitoring system using IoT-aided robotics and deep learning techniques. *Kuwait Journal of Science*. https://doi.org/10.1016/j.kjs.2023.10.017 (Accessed. 10 Feb, 2024)

Ma, Q., & Liu, L. (2005). *The Technology Acceptance Model*. https://doi.org/10.4018/9781591404743.ch006.ch000 (Accessed. 10 Feb, 2024)

Marikyan, D. (2003). Unified Theory of Acceptance and Use of Technology. *A Review. In S. Papagiannidis*.

Mohamed, E. (2021). *Intelligent Traffic Management System Based on the Internet of Vehicles (IoV)*. *15*. https://www.hindawi.com/journals/jat/2021/4037533/ (Accessed. 10 Feb, 2024)

Ojha, A. (2019, September 19). *Why are Kathmandu's traffic jams notorious?* The Kathmandu Post. http://kathmandupost.com/valley/2019/09/19/why-are-kathmandu-s-traffic-jams-notorious (Accessed. 10 Feb, 2024)

Oladimeji, D., Gupta, K., Kose, N. A., Gundogan, K., Ge, L., & Liang, F. (2023). Smart Transportation: An Overview of Technologies and Applications. *Sensors*, *23*(8), Article 8. https://doi.org/10.3390/s23083880 (Accessed. 10 Feb, 2024)

Pradhananga, R., Pandit, A., Bhattarai, A., Chaudhary, A., Rawal, A., & Adhikari, B. (2021). *Effectiveness of Reversible Lane Systems in Kathmandu Valley: A Case Study of Jadibuti-Koteshwor Section*.

Sahin, I. (2006). Detailed Review of Rogers' Diffusion Of Innovations Theory And Educational Technology-Related Studies Based On Rogers' Theory. *The Turkish Online Journal of Educational Technology*, *5*(2).

Sarrab, M., Pulparambil, S., & Awadalla, M. (2020). Development of an IoT based real-time traffic monitoring system for city governance. *Global Transitions*, *2*, 230–245. https://doi.org/10.1016/j.glt.2020.09.004 (Accessed. 10 Feb, 2024)

Sethi, P., & Sarangi, S. (2017). Internet of Things: Architectures, Protocols, and Applications. *Journal of Electrical and Computer Engineering*, *12*. https://www.hindawi.com/journals/jece/2017/9324035/ (Accessed. 10 Feb, 2024)

Shakya, A. K. (2017). *Economic Importance of Public Transit Investment in Kathmandu Valley* [Thesis]. https://elibrary.tucl.edu.np/handle/123456789/2098 (Accessed. 10 Feb, 2024)

Sharma, S., Patel, K., Deol, N., Mani, V., Begum, V., & Raj, D. (2021). IOT Based Traffic Management System. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 184–187. https://doi.org/10.32628/CSEIT1217451 (Accessed. 10 Feb, 2024)

Shrestha, B. (2023, July 31). *Nepal's struggle with unorganised and unstable public transportation crowds*. Online Khabar. https://english.onlinekhabar.com/nepal-poor-public-transportation.html (Accessed. 10 Feb, 2024)

Singh, H., Bhatia, J. S., & Kaur, J. (2011). Eye tracking based driver fatigue monitoring and warning system. *India International Conference on Power Electronics 2010 (IICPE2010)*, 1–6. https://doi.org/10.1109/IICPE.2011.5728062 (Accessed. 10 Feb, 2024)

Thakur, A., Malekian, R., & Capeska Bogatinoska, D. (2017). *Internet of Things Based Solutions for Road Safety and Traffic Management in Intelligent Transportation Systems* (p. 56). https://doi.org/10.1007/978-3-319-67597-8_5 (Accessed. 10 Feb, 2024)

The Kathmandu Post. (2015, December 29). *The next big thing*. The Kathmandu Post. http://kathmandupost.com/opinion/2015/12/29/the-next-big-thing (Accessed. 10 Feb, 2024)

Timsina, N. P., Poudel, D. P., & Upadhyaya, R. (2020). Trend of urban growth in Nepal with a focus in Kathmandu Valley: A review of processes and drivers of change. *Cities Urban Risk in Transition*, *15*(2).

White, J., Thompson, C., Turner, H., Dougherty, B., & Schmidt, D. C. (2011). WreckWatch: Automatic Traffic Accident Detection and Notification with Smartphones. *Mobile Networks and Applications*, *16*(3), 285–303. https://doi.org/10.1007/s11036-011-0304-8 (Accessed. 10 Feb, 2024)