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Smart Infrastructure for Sustainable Public Transportation

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Abstract
This research work is an attempt to understand how public transportation is inefficient in Kathmandu and the ways to improve the service. The focus of the research lies in the social dimension of Sustainability in public transportation. The research is problem driven, with an aim to understand different smart infrastructure that makes the Public Transportation (PT) sustainable and the smart solution to the existing problem in PT in Kathmandu. The component of analysis of smart infrastructure for Sustainable PT are Bus, Bus stop, IoT and System.
With the ontological claim that the development in smart infrastructure will aid in making PT sustainable, a methodology was prepared to find the epistemological reasoning. Nature of the research is exploratory with inductive approach. The research uses mixed method falling under sequential exploratory design. Data collection was done by interviews, questionnaire and participant observation. The data analysis helped in identifying intervening and extraneous variable in the ontological claim.

Keywords
Public Transportation, Sustainable Transportation, Smart infrastructure, Public bus

1. Introduction

1.1 Background

With a population of 2.5 million people, the Kathmandu Valley is growing at 3.9 percent per year, one of the fastest-growing metropolitan areas in South Asia, and the first region in Nepal to face the unprecedented challenges of rapid urbanization and modernization at metropolitan scale [1]. Rapid population growth, urban sprawl, and increasing motorization in Kathmandu valley are creating complexity of traffic congestion, poor public transport system, pedestrian and vehicular conflict, and poor air quality. In past 10 years, the number of registered vehicles in Kathmandu valley increased 3.75 times to reach 570,145 till 2010/2011. The composition of motorcycle is highest with 73.% among registered vehicles in Kathmandu valley followed by car/ jeep/ van with share of 18.5%.1 Public transport constitutes only 2.5% of total passenger vehicles in Kathmandu valley [2]. Local public transport in the Kathmandu valley includes micro bus, minibuses, tempos, bus, rickshaws and taxis with and without meters. Some of the larger bus have been introduced in the past few years. The public transportation in the valley, such as micro buses, minibuses and buses are normally crowded and uncomfortable. Moreover, there is no well-defined travel schedule and proper bus stops

1.2 Smart mobility

Traffic congestion is becoming a major problem in many global cities and cities are investing in public transport as one of the most efficient ways to move people around the city. Providing riders with information on the status of the system along with the arrival and travel times (i.e. dynamic information) will encourage transit use [3].

European public transport systems are actively adopting new, ICT-enabled user navigation, routing, booking and ticketing applications. These provide users with real-time timetabling and route optimization, seamless travel and digital ticketing. Smart public transport services and systems can provide the backbone for future integrated smart mobility [4].

1.3 Problem Statement

A brief investigation of public transport in the Kathmandu Valley identified core problem as duplication of routes, with multiple uncoordinated operators, large numbers of low-capacity vehicles

operating on high volume routes causing traffic congestion and environmental degradation, congestion in the city centre from the multitude of Public Transport terminals and loading areas, poor quality of service to users, inadequate passenger facilities, weak regulation resulting in old, poorly maintained vehicles and an oversupply of vehicles on some routes [5]. (Khokali, 2017). In reference to the survey conducted by World Bank Group in October 2013, noted that 80% of women and 70% men noted overcrowding as their main concern. The overcrowding is also the reflection of inefficiency in transportation system to deliver the service according to demand.

1.4 Objective

1.4.1 Main objective

- To determine the relation between smart infrastructure development and public transportation sustainability in context of Kathmandu, Nepal.

1.4.2 Specific objective

- To identify components of smart infrastructure in public bus transportation
- To identify all variable i.e dependent, independent, intervening and extraneous variable for establishing relation between smart infrastructure development and public transportation sustainability

2. Literature Review

2.1 Sustainable Transportation

Sustainable transportation provides access to all groups of people in the city in a manner that is within the environmental carrying capacity of the city and is affordable to both the providers and the users of the system. A sustainable transportation system also requires the provision of a diverse, integrated and balanced public transportation services. The transportation needs of different groups are different due to the distances they need to travel, their trip purpose, income, age, gender, physical ability etc. According to the dimension of sustainability, indicators for sustainable urban transport index if given in Table 1.

The assessment of public transport sustainability requires specific focus on elements that are relevant to public transport, ensuring that environmental, social and economic aspects are addressed. Table 2 provides a summary of indicators proposed in the literature for the assessment of public transport sustainability, based on a review undertaken by Miller et al.

Table 1: Final set of indicators for Sustainable urban transport index

Indicators	Dimensions	Strategies	SGD Targets
Extent to which transport plans cover public transport, intermodal facilities and infrastructure for active modes	System	Shift	(11.2)
Modal share of active and public transport in commuting	System	Shift	(11.2)
Convenient access to public transport service	Social.	Shift	11.2
Public transport quality and reliability	Social.	Shift	11.2
Traffic fatalities per 100,000 inhabitants	Social.	Improve	3.6
Affordability – travel costs as part of income	Economic. / Social.	Improve	(11.2)
Operational costs of the public transport system	Economic.	Shift/Improve	(9.1)
Investment in public transportation systems	Economic	Shift	(11.2, 9.1)
Air quality (PM10)	Environmental.	Avoid/Shift/Improve	11.6
Greenhouse gas emissions from transport	Environmental.	Avoid/Shift/Improve	7.3/13.2

Table 2: Indicators used for the assessment of public transport sustainability

ID	Indicator	Units	Desirability
A	ENVIRONMENTAL		
A1	Quantity of energy consumed	MJ/pkm	Lower is desirable
A3	Mass of total pollutants emitted (e.g., NO_x, VOC, CO_2)	kg/ha	Lower is desirable
A5	Land area consumed by public transport facilities	% of urban area	Lower is desirable
B	SOCIAL		
B1	System accessibility	pkm/capita	Higher is desirable
B4	Average user trip distance	km	Lower is desirable
B5	Affordability	10^{-4} per capita GDP/trip	Lower is desirable
B9	Public transport related deaths	fatalities/billion-pkm	Lower is desirable
C	ECONOMIC		
C1	Annual operating cost	$US/pkm	Lower is desirable
C4	Cost recovery (proportion of costs recovered)	% of total costs	Higher is desirable
C6	Passenger km travelled per unit GDP	pkm/$US	Higher is desirable
C8	Average time per trip	min	Lower is desirable
D	SYSTEM EFFECTIVENESS		
D1	Average occupancy rate of passenger vehicles	% of seated capacity	Higher is desirable
D3	Annual public transport trips per capita	trips/capita	Higher is desirable
D4	Public transport mode split	% of all trips	Higher is desirable
D5	Public transport fleet size	vehicles/million people	Higher is desirable

2.2 Smart Mobility and Public transportation

Smart Mobility is largely permeated by ICT, used in both backward and forward applications, to support the optimization of traffic fluxes, but also to collect

citizens' opinions about live ability in cities or quality of local public transport services. (Benevolo and Dameri, 2015). Traffic congestion is becoming a major problem in many global cities and cities are investing in public transport as one of the most efficient ways to move people around the city. Providing riders with information on the status of the system along with the arrival and travel times (i.e. dynamic information) will encourage transit use. The information reported for each stop must contain at least the arrival of the next vehicle/train/etc. It is also encouraged to provide travel times to other destinations. The information can be provided at the stop itself through screens or through other electronic means such as the official website or a mobile application. The information should be dynamic such that it is current and updated regularly rather than simply being posted as static timetable [3].

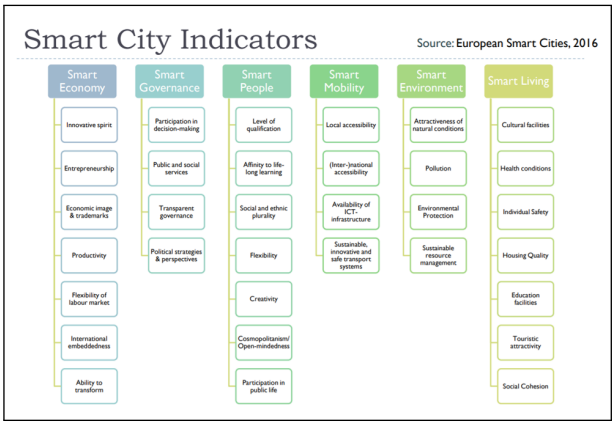

Figure 1: Smart city indicators

2.3 Smart Infrastructure in Public Transportation

Infrastructure is crucial for the operation of a smart city (lighting system, water distribution network, etc.). Moreover, transport infrastructure is placed at the chore of such smart city by making a smooth mobility of people and goods, especially with the possibility of regulating traffic congestion, providing up-dated and in time information for the public transportation user, developing green means of transportation (bike and car sharing for instance), etc. Consequently, smart transport infrastructure and smart transport are a key component of the Smart City [6].

There cannot be a Smart City without Smart Mobility, and no Smart Mobility is possible without Smart Infrastructure. The four key attributes of the Smart Transportation Infrastructures of the Future include Mobility, Intelligence, Safety and Security and Sustainability [7].

3. Methodology

With the ontological claim that the development in smart infrastructure in Kathmandu will aid in making PT sustainable, a methodology was prepared to find the epistemological reasoning. Nature of the research is exploratory with inductive approach. The research uses mixed method falling under sequential exploratory design.

The research required identification variables involving sustainability of public transportation through smart infrastructure. The dependent and independent variables were identified through literature studies. While intervening variable and extraneous variable in the ontological claim was identified through case study research.

For contextual study of Kathmandu, a road strip from Narayan Gopal Chowk- Satdobato chowk was taken to analyze status of Bus stops and Road. To understand about public bus service, Sajha Yatayat co operative bus organization was taken. Data collection was done by interviews, questionnaire and participant observation.

4. Findings

To identify the specific components (context based), an ethnographic study was done with the help of 10 respondents who were the subject in the study and whose reflection were the source of data collection. The 10 respondents involved 5 private vehicle users and 5 public vehicle users.

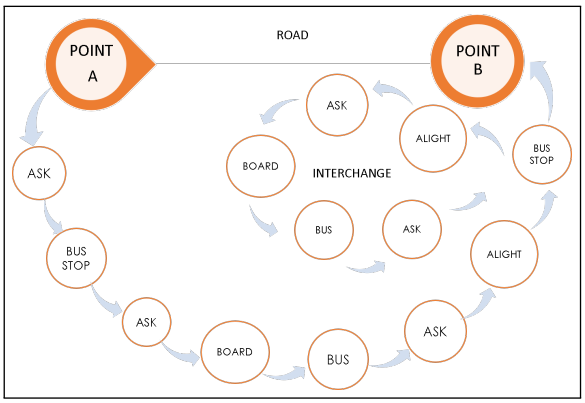

Figure 2: General Travel Plan

The main theme of this study was to understand how the people travel from point (A) to point (B) in public transportation. With help of their response and their travel reflection, general the travel behaviour was extracted which in shown in Figure 2.

From the literature review, the parameters of socially sustainable components were identified as accessibility, reliability, safety and security.

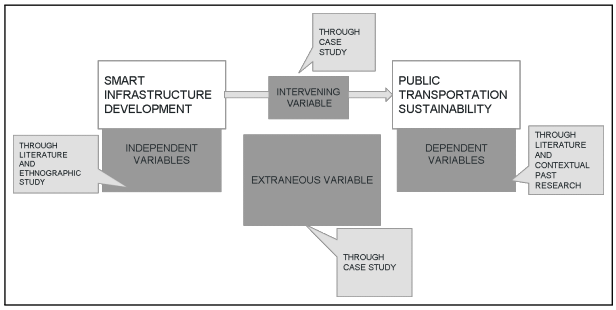

Figure 3: Relation between smart infrastructure development and public transportation sustainability

For contextual understanding of situation of bus stops and road in Kathmandu, a strip of road from Narayan Gopal chowk- Satdobato Chowk was taken. The findings are organised under the subheading of Road and Bus stop with the analysis in terms of accessibility, reliability, safety and security

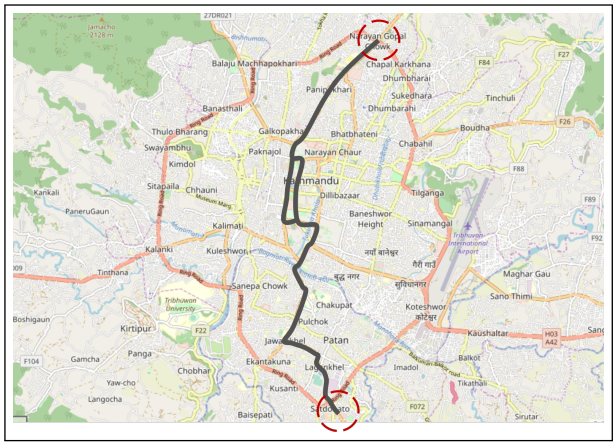

Figure 4: Study of bus stop and road in strip of road from Narayan gopal chowk to Satdobato chowk

1. Road:

The chosen strip of road is black toped. The characteristic feature of the chosen strip is that, it covers diverse zone like, administrative, corporate, commercial, heritage, hospital, industrial and sports and recreation zones. The sectional street view is also diverse, with variation in size of footpath and accessibility.

Table 3: Analysis of road

Accessibility	Reliability	Safety & security
Not pedestrian friendly as numerous pedestrian crossover overhead bridge.	Road faces a lot of congestion due to high traffic which affects the travel time of all commuters thus affecting reliability in travel time	Unsafe footpath
Design not considering differently abled group of society	Quality of road r	Traffic lights for pedestrian only at 2 section

2. Bus stop:

There are 29 bus stops in the route and all are nearby within the distance of 500m. The is variance in type of bus stop, 9 of bus stop have bus turnout while some had shelter and some was open to air with only pole and signage.

Table 4: Analysis of Bus stop

Accessibility	Reliability	Safety & security
Not accessible to differently abled group.	No proper information of the vehicle route, schedule, name of bus, etc	No proper lighting in the bus stop area thus, problem during late evening
Platform height is not raised, thus inconvenience in boarding the bus	No information about the time of availability of public bus service.	Bus stop behaviour like not stopping in designated place, and passengers rushing in and out during boarding and alighting is not safe.

3. Bus infrastructure:

For the detailed information on bus infrastructure, a case of Sajha Yatayat has been taken which is a corporative organization operating public bus service with aim of improving public bus service quality. The

company owns 71 buses, and covers 9 different routes inside the valley.

Table 5: Analysis of Public bus- Sajha bus

Accessibility	Reliability	Safety & security
Company has recruited new buses with low floor platform	The company only covers 9 routes inside the valley so, cannot be relied on its service everywhere.	The interior of the bus has cctv camera for safety
Bus has a ramp that folds from the steps for the access of wheelchair users	The company owns only 67 buses that runs in the Kathmandu valley, so the reliability is a big issue.	There is safety belt and strap for the wheelchair users

4. Information and system:

Some of the smart practices has been adopted by Sajha Bus by incorporating cctv, and GPS system for location. There is also online application called 'Sajha app' which shows the location of the bus.

Table 6: Analysis of Public bus- Sajha bus

Accessibility	Reliability	Safety & security
Information of the route is not updated in the website	Since the information is not updated, the bus route information is not reliable.	Since there is lack of updated information, sense of security of accessing the bus during late hours is an issue.
Sajha app can been downloaded in android and ios version of cell phone. And since Kathmandu valley have only 50% of smartphone users, the information accessibility is only limited to certain user group.	No information about the operating hours of bus. The updated information is only shared through local news but, news about halt of night bus service were not notified.	

5. Analysis

From the case study, it is clear that the status infrastructure of public transportation is leading to poor service of the whole public bus transportation system. Also, it is evident that, the initiative has been taken by some of the transportation company like Sajha Yatayat to improve the service by ensuring accessibility and improving safety and security sector. But, it still stands behind in meeting its objective as result of lack of infrastructure planning. The smartness in terms of smart ticketing, disability friendly bus, smartphone application has been developed, but it is still facing difficulty in meeting the purpose as the infrastructure like bus stops and road are not designed well concerning differently-abled group. there are numerous bus operators whose data about route information, bus number and schedule are not integrated to provide a reliable information to the public.

6. Conclusion

The research objective was to figure out the relationship between smart infrastructure development and public transportation sustainability by figuring out dependent, independent, extraneous and intervening variables. The components like bus, bus stop and information were found out as independent variables representing infrastructure while reliability, accessibility and safety and security was established as dependent variable representing social sustainability of public transportation. The extraneous variable in this relation was the identification of stakeholders whose role can aid in this relation. The stakeholders identified were, DoTM, Public transportation operators, Metropolitan traffic and potential ITS companies to work in transportation sector for traffic management. The intervening variable in this relation was identified as 'integrated infrastructure planning'. Thus, unless the infrastructure is not integrated and planned together for smart mobility, the sustainability of PT will still be a question as development of only certain infrastructure solely without integration will defy the whole purpose of its development in the first place.

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