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Towards Creating Smart Cities in Nepal

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ABSTRACT

Many urban centers in the world are seeking to become smart cities. Nepali city leaders are also aspiring to make their cities smart. A smart city basically has clever improvements made in three sectors of its operations: technological, human, and institutional. Globally, many cities have recently made impressive enhancements in at least one or more of these areas. Nepal's National Planning Commission (NPC) in 2016 had released a concept paper on smart cities for Nepal, defining smart cities as sustainable, information and technology-based, with high quality services and replicable (NPC 2016). As most Nepali cities still operate with limited infrastructure, services, and amenities, making them smart is a challenging task. However, some elements of a smart city can be incrementally and selectively implemented by the Nepali urban governments. This paper assesses the successes and challenges in some of the smart cities globally, and as an example assesses the pollution reduction and efficiency impact of adopting a bus-rapid transit system in Nepal. It is seen that a Bus Rapid Transit (BRT) system for the Kathmandu Valley consisting of electrical buses, will drastically reduce air pollution, and improve mobility for the residents. Urban leaders in Nepal can begin to identify such a transit related and other smart elements to be gradually implemented in their cities which will improve efficiency of urban services, enhance quality of life for the urban residents, and promote sustainability of the overall urban system.

Keywords: Air pollution, Bus rapid transit (BRT), Internet of things, Kathmandu valley, Smart city

1. INTRODUCTION

Cities that operate efficiently and in a cost-effective manner and provide amenities and services to help the residents enjoy a comfortable living in a sustainable urban system can be called smart cities. Smartness is created by a combination of technological and communication network, and passive smart planning and design approaches.

This paper assesses some smart city ideas and implementation scenarios that are relevant to Nepali cities and towns. Towards this objective, the paper briefly reviews how several global smart cities operate, and how they work. It briefly presents a transportation-related case study for the Kathmandu Valley, and identifies areas in Nepali urban management where smart city-related concepts may be applied to benefit the residents.

The UN's 2015 Sustainable Development Goal number 11 - "Make cities and human settlements inclusive, safe, resilient and sustainable" (UN 2021) relates to the topic of smart city. Specifically, its targets 11.2 and 11.3 related to transportation and urban management provide a framework for the implementation of some of the smart city functions. Lately, the concept of smart city has become popular in many parts of the world. Nepali leaders and policy makers are also regularly clamoring for creating smart cities in the country. In 2016, Nepal's National Planning Commission (NPC) – the long-term national level plan making body - created and published a concept paper on smart cities for Nepal. The Government of Nepal has since set aside funds towards creating smart cities in all geographic regions of Nepal such as the Tarai, mid hills, and mountainous regions along the east-west highways, mid-hill highways, and regional arterial roads.

As most Nepali cities conspicuously lack several basic levels of infrastructure and services, the leaders' claims to make those cities smart can sometimes sound unrealistic and even preposterous. For example, many rural areas in Nepal are annexed together to meet the government-set population thresholds to meet municipal requirements both financially and demographically. Such an ambitious approach has created many rural agglomerations often officially categorized as urban, but which can be called "ruralopolises". Residents of such "ruralopolises" are bearing the brunt of increasing taxes for officially being in an urban area while competing for the limited investments in infrastructure. This paper argues that even when some cities lack the basic amenities, selected viable smart city tools can be incrementally implemented in Nepal to help improve their livability and efficiency including with the use of smart transportation.

Smart city idea grew mainly from the smart growth movement in the United States that became popular,especially, after the 1990's. The smart growth policies were designed to promote a compact, self-sustaining mixed-land-use, and dense urban ecosystem seeking to curtail the ubiquitous urban sprawl while minimizing travel distance/time between residences, and places of work and shopping. Smart growth programs often consist of a constellation of planning principles that can result in a more sustainable and efficient urban development. A smart city includes walkable sidewalks, green open spaces, and well-regulated real time encoded transit and service systems. Smart growth is primarily an approach to achieving socially, economically, and environmentally sustainable communities. Smart cities rely on digital spatial data and internet system to support and improve urban activities and service deliveries. They are more livable, help the residents enjoy an improved quality of life, and are more sustainable. While there are no widely accepted definitions of a smart city, one good definition is provided by Nam and Pardo (2011) as follows.

"A smarter city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains (p 284)".

A smart-city approach makes use of sensors, robotics, and many other digitalized auto-control configurations to use real time data to continually manage urban functions such as traffic, energy distribution, public amenities, and vehicular parking (Adhikari & Bhattarai 2020). Using such resources, a smart city helps to reduce pollution, promote clean energy use, and improve the overall urban physical environment, quality of life, and sustainability. While providing enhanced delivery and efficient urban services, a smart city also promotes sustainable and inclusive approaches to urban development.

The smart city idea is built upon the notion of "Internet of Things" (IoT) applications, and communications networks. The IoT connects various urban elements in the physical realm such as infrastructure, equipment, buildings, and physical amenities. It digitally coordinates daily regulation mechanisms with the IoT operating in real time and encapsulates regular feedback mechanism between the urban activities and decision-making process. This regular coordination between IoTand urban administrative processes utilizing the digitalized built-in system helps in urban delivery services seamlessly in real time.

A smart city is a more organized and efficient urban system compared to a regular city and which serves its residents better. In the words of Halegua (2020), "Urban transformation from disorganized organism to ordered, streamlined, responsive layers of controlled technological systems become both the goal and the justification for smart city development" (p 42).

2. ELEMENTS OF A SMART CITY

Six elements play major roles in a smart city (Fig. 1). These include smart governance, smart environment, smart living, smart mobility (transit system), smart people (workforce), and smart economy, all connected autonomously to smoothly regulate multiple tasks to improve city life. Urban efficiency is achieved by mobilizing multi-data points stored in cloud with interconnected devices including the IoT. "Smart cities advance innovations in public policy and administration, which foster collaboration and partnerships focused on people-oriented policies and practices" (Dowd 2019.). For example, improving transit system while regulating traffic flow is one of the major objectives of smart cities.

Fig. 1. Ingredients of a smart city. Source: redrawn from Smart cities mandala: Giffinger et al. 2020.

When stakeholders identify the challenges in an urban system, planners, policy makers, and politicians utilize smart city ideas to help improve urban living. They explore how problems arise, what solutions are needed to resolve them, how the problems have been handled presently, and what could be done in the future.

According to Nam and Pardo (2011), the components of a smart city can be reduced to three foundational factors: human, institutions, and technology (Fig. 2).

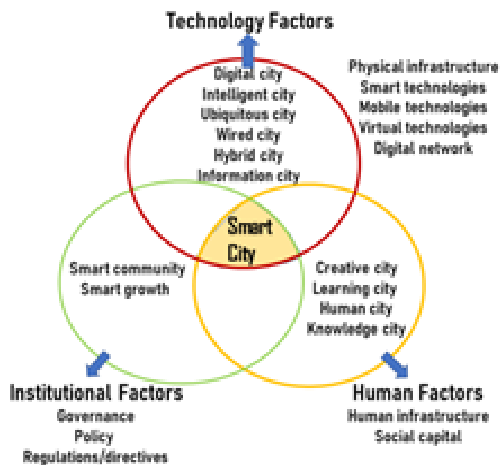

Fig. 2. Fundamental components of smart city. Source: Redrawn from Nam and Pardo (2011).

The smart city idea is also criticized by some scholars and practitioners as an elitist system that can intrude individual privacy and further divides the city by class. The privacy and practicability concerns are clear from some failed examples of smart city or smart city elements such as the abandoned Waterfront sidewalk project in Toronto (Hawkins 2020), to the unsuccessful smart and sustainable city of Masdar in UAE. Sterling (2018) hits hard on some of the promises of smart city concepts and practices as follows:

"Smart cities are a generational civil war within an urban world that's already digitized. It's the process of the new big-money, post-internet crowd, Google, Apple, Facebook, Amazon, Microsoft *et al.*, disrupting your uncle's industrial computer companies, the old-school machinery guys who ran the city infrastructures, Honeywell, IBM, General Electric. It's a land grab for the command and control systems that were mostly already there."

3. SOME EXAMPLES OF SMART CITY INITIATIVES

Several cities such as Seoul, Singapore, Taipei, Barcelona, Oslo, London, Geneva, Helsinki, Paris, Toronto, Chicago, San Francisco, Auckland, Sydney, Portland, Vancouver, and Hong Kong have planned and implemented many smart city elements. Nepal's southern neighbor India announced a "100 Smart City Mission" in 2015 (MoUD GOI 2015). The program's goal was to upgrade and make smart100 Indian cities including New Delhi, Chennai, Nagpur, Ahmedabad, Vadodara, Bengaluru, Pune, and Jaipur. The government initially promised almost one billion US dollars towards this program with an objective of upgrading the core infrastructure, improve quality of life, enhance environmental quality, and promote sustainability in the selected cities.

The reputed Switzerland-based Institute for Management Development (IMD) ranked Singapore, Helsinki, Zurich, Auckland, Oslo, Copenhagen, Geneva, Taipei, Amsterdam, and New York, respectively as the top ten smart cities in the world in 2020 (IMD 2020). The ranking is based on the assessment of the state of health and safety, mobility, activities, opportunities, and governance in the cities.

Initiated in 2009, Amsterdam has become one of the world's most innovative cities with over 150 green energy, transportation, and urban planning projects to improve the quality of urban life (Page & Miller 2019). In 2010, Chicago has become one of the smartest metropolises integrating an internet of things (IoT) system along with the installation of 270,000 sensors fitted streetlights to save maintenance and energy costs (Docksai 2013). Chicago also utilizes several internet-based apps and systems to connect its residents to city services and data.

In 2013, Spain identified Barcelona as its first smart city when it initiated urban sensor, efficient lighting, a clever waste-disposal system, and modernizing the transportation with hybrid bus system and health-friendly bike-sharing programs (Page & Miller 2019). Barcelona is also gradually consolidating its city blocks into large walk-only spaces (super blocks) eliminating cars from inside the block. This is a bold initiative for a major established city to reverse the increasing impact of auto in the city and let the pedestrian regain the control of its streets. This program furthers the goal of Barcelona in enhancing its passive city planning and design elements to support smart city functions.

Many cities in Africa are struggling to build basic infrastructure while trying to improve upon the ubiquitous slums. In the midst of these challenges, some African cities are also working to include smart elements in their urban systems. Page and Miller (2019) provide several examples of such initiatives. For example, the Rwandan government under the Kigali's "Vision City Program", has adopted solar powered public lighting and the provision of free public Wi-Fi facilities in several geographical areas. The extensive internet infrastructure now allows the residents to receive various on-line city services to help the resident enjoy on-line facilities to access vital documents and records. In 2017, AddisAbaba vastly expanded its public transportation system that includes light rail, streetcar, and regular rail lines to enhance the mobility options for the urban residents.

Toronto has deployed various sensors to improve urban transit system through the adjustment of traffic patterns using real time information. The Alphabet Company had funded a water front side walk project with an objective to develop data-centric light rail line and heated, snow-melting pavement, and self-driving delivery vehicles and free Wi-Fi throughout the city. However, the sidewalk program was abandoned in 2020 as the fear of intrusion in the privacy of the residents grew, and the public rallied against the project.

Oslo, Reykjavik, Zurich, San Francisco, and Portland are some more examples of implementing various smart and sustainable city elements in urban services, energy, and transportation arenas.

Singapore introduced in its city center an innovative congestion pricing system in 1975. The program worked by reading the license plates of the cars that entered the downtown area and based on the time of the day and the duration when the cars were there, the municipality would bill the car owners a congestion price. The program discouraged the entry of the auto into the downtown and central business areas and encouraged residents and visitors to reach the areas by public transit. The program not only reduced the number of autos in the congested areas, but also helped reduce air pollution, and made the area safer for the pedestrians and bicyclists. The congestion pricing system can be considered one of the early mechanisms of creating a smart city.

Paris is a leader in bike-sharing programs, mass transit and walk able streets. Many vehicular streets have been converted to walking only areas, and the biking network has been vastly expanded across the city. Its metro system, long a city pride, has enhanced its reach and services to the residents and visitors alike.

Hong-Kong has implemented artificial technologies in the central business districts and port areas to help the municipality provide real-time digital security information and to regulate traffic and inform about the weather (Falcioni 2020). Municipal utilities such as water, energy, and other basic needs including emission and temperature are monitored and regulated through IoT. Hong Kong is an Avant Garde city to utilize drones to monitor the performance of the city's various activities including the autonomous vehicles for mobility.

Singapore has some of the best public health, public housing, safe streets, sustainable energy, water conservation, and public transportation systems in the world. As the city-state continues to advance its business ecosystem, internet connectivity, clean energy, and transit programs, it has become a test bed for many smart operations. Results from these initiatives have elevated Singapore in the top rank among the smart cities. Singapore is also well known for its therapeutic gardens, water harvesting programs, clean energy technologies, defensible (safe) spaces, and smart transit system.

The healing powers of nature such as forests, landscapes, flowers, and water features are well known. Many cities are including natural features in their parks and open spaces sometimes known as "therapeutic open spaces or gardens" or "healing gardens or landscape" as spaces for people to relax. Although this concept has been in existence for a long-time, the recent global pandemic brought about by the Covid-19 virus has rekindled planners' interest on such landscapes. For example, Singapore has created several therapeutic gardens and open spaces in many parts of the city to help its resident visit them and feel relaxed. In the desert setting of Phoenix Arizona, there are several artificial ponds, lakes, fountains, green areas, public arts, and flowering landscape integrated in parks and opens paces that provide a healing environment to the users. Planners and residents are also seeing urban forestry with increased interest as an important passive element to enhance the smartness of a city. For example, the City of Tempe in the Phoenix Metropolitan area in the United States adopted an Urban Forestry Master Plan in 2017 that seeks to increase tree crown cover to 25% by 2040.The resulting shade, reduction in urban heat island effect, increase in biodiversity and reduction in pollution, improvement in the aesthetics and enhanced ecological system will

Table 1 provides a comparative overview of some leading global smart cities used technological and smart passive elements to improve the efficiency of urban systems and enhance livability.

City	Examples of Technological Elements Used (planned)	Examples of Smart Passive Elements Used (planned)	Remarks
Amsterdam	Use of IoT, sensors, smart transportation, many real-time data points	Bike-sharing, bike-lanes and bike expressways, green energy programs	Considered a top-ranking smart city
Auckland	Smart street lighting, public Wi-Fi, extensive use of IoT, waste bins with sensors	Smart road crossing (scrambles), smart parking, green elements, shaded sidewalks	Considered a top-ranking smart city all around
Barcelona	Extensive use of sensors, smart waste disposal system, open and e-governance	High walk score, consolidating big city blocks for pedestrian only areas	Considered a top-ranking smart city all around, and highly walkable
Chicago	Extensive sensor installation, smart transit, a leader in hyper-connectivity, open data for citizens, "residents watching the city vs the city watching them"	Walkable downtown, healing gardens and water features, big investment on digital infrastructure	Considered as a rapidly evolving smart city, rich history of innovative design and planning
Helsinki	Mobility-on-demand, extensive sensor use, open and e-government	High walk score, High livability score, smart public spaces	Considered a top-ranking smart city overall
Hong Kong	Real time traffic and weather monitoring system, drone use to monitor vehicles	High density, rich transit, high walk score, high livability score, attractive streets	Considered a rapidly evolving smart city
London	Pioneer (after Singapore) in congestion pricing, extensive sensors and mobile-app applications, e-governance, real-time air pollution monitoring and info dissemination	Very high walkable score, high density, pioneer in public transit, therapeutic open spaces, smart-city friendly urban design	Considered a top-ranking smart city overall
New Yok	Smart lighting, smart water metering, smart waste management, e-governance leader, real-time air pollution monitoring	Bike-sharing, extensive transit system, high walk score, high density, mixed uses, iconic Central Park	Selected areas are considered as rapidly evolving smart city areas; the city is one of the smartest in the USA
Paris	Extensive IoT use, real-time data on parking availability, smart lighting, smart energy plans, extensive use of sensors to track real-time data, ubiquitous charging stations,	High walk score, extensive public transit, pedestrian friendly and shaded walkways, an early bike-sharing adopter, smart transit	Considered a rapidly evolving smart city, a top tourist destination, high aesthetics, and a leader in smart city programs
San Francisco	High level technological innovation, e-governance, ride-sharing apps, extensive installation of sensors, cameras, or crowdsourcing tools	Parklets, transit, high walk score, green energy use, bike transport, smart open spaces, protected viewsheds	Considered a top-ranking smart city overall
Seoul	Almost a free "data city", smart, moving towards a free Wi-Fi city, extensive IoT implementation, smart transportation	High walk score, high density, smart public transit, green and healing open spaces, passively controlled microclimate, and microenvironment in the city center	Considered a top-ranking smart city all around

Singapore	Extensive application of IoT, Wi-Fi, transit-related apps, smart transit, use of apps to help in public health	Therapeutic gardens, safe spaces, rainwater harvesting, extensive use of solar power and geothermal energy	Considered a leader and top-ranking smart city all around
Nepal (including in Syangja, Lumbini, Dadeldhura)	Smart people, governance, infrastructure, and economy (planned elements)	Green infrastructure, energy, and business systems (planned)	Nepal has initiated a plan to create smart cities in ten towns.

Table 1: Comparative review of elements in some smart cities.
Prepared and adapted by the authors from various books, articles, and newspaper articles (including Page & Miller 2019) and authors'personal observations and on-site experiences.

4. EXAMPLES OF A SMART CITY ELEMENTS

A smart city is designed to improve the efficiency of urban functions. This can be achieved by a combination of smart elements that use technology features such as sensors, cameras, internet, Wi-Fi, and IoT, and passive planning and design elements such as walk able streets, shaded walkways, transit nodes, parks and park lets, therapeutic or healing spaces and clean energy installations.

Smart city helps not only to regulate the smooth traffic flow, minimize traffic congestion, maintains a balance between the various modes of traffic while minimizing the overall travel time for the urban transit users but it also provides safe, comfortable, and attractive environment with generous landscaping for the pedestrian (Fig. 3), cyclists, and transit riders (Adhikari & Bhattarai 2020). Though this model is difficult to implement in most existing streets in the Nepali cities due to the limited width of the right-of-way, newly annexed and some reorganized and re-purposed streets in urban areas can follow this technique.

Fig.3. A shaded, active, and safe sidewalk in downtown Tempe, AZ, USA. (Photo by Ambika P. Adhikari)

Smart cities provide attractive sceneries while they focus primarily on the increased intelligence capacity of the digital system with extensively networked cameras and sensors. These technologies are embedded into the digitalized infrastructure to monitor different activities in the urban areas. They use real-time data to improve the management of pedestrian and vehicle traffic, weather preparedness and energy use. However, more cameras and sensors can also infringe on people's privacy rights. (Adhikari & Bhattarai 2020)

A safe and comfortable pedestrian environment is an important part of smart cities. For example, sidewalks can be detached from the vehicular roads by means of landscaping buffers, and a double row of trees above sidewalk can shield the pedestrian from the sun at most times (Fig. 4), reduce dust pollution, reduce heat island effect, and promote walkability in the city. During the latter part of the twentieth century, many American cities were designed mainly for the cars and had unsafe sidewalks. Recently, more cities are working to correct past mistakes by adopting the principles of New Urbanism that promote walkability, pedestrian safety, mixed uses and compact development.

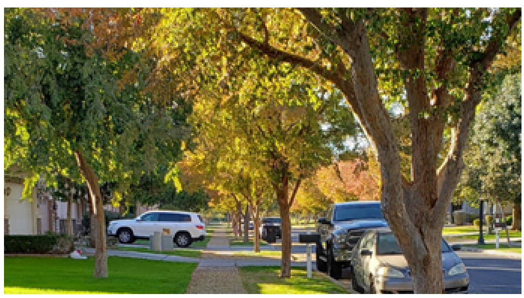

Fig.4. Residential street with a detached sidewalk shaded by double rows of trees in Gilbert, AZ, USA. (Photo by Ambika P. Adhikari)

The development of a smart city takes the cost effectiveness into consideration. Since various cost involves in developing digital infrastructure, high speed internet, fiber optics cables and wireless internet systems, every smart city needs to take them into consideration. Further, digitizing components e.g., transportation, home energy systems, parks use, sidewalk use, traffic lights, water supply and wastewater sensors will add to the costs. If properly designed, smart cities can overcome such cost from reduced traffic congestion, optimal use of parks, parking areas, sidewalks, streetlights, water supply, sewerage, less pollution, and other services. The biggest gain can be a better quality of life for the residents. While loss of personal privacy can be an individual cost unacceptable to some, the enhanced sustainability could be a social benefit (Adhikari & Bhattarai 2020).

Nepali cities can utilize some of these models and principles of planning to create smart city elements in the new or existing urban developments.

5. CHALLENGES FACED BY SMART CITY INITIATIVES

Especially, in Western countries, many smart city projects have often been plagued by the fear by the residents about loss of privacy even if urban efficiency was gained. Also, gains in efficiency of urban functions often invite maintenance challenges. Further, cities find it hard to keep up with rapidly emerging technologies, while also dealing with the changing demand for transportation, and evolving preferences of the young generation. In many Western countries, residents often harbor apprehension against large technology companies, and they fear loss of control of their surroundings and lives. Smart city initiatives can also be thwarted by the lack of trained personnel and limited available budget for high technology installation. Several communities also yearn for a simple and stable lifestyle they have enjoyed in the past, and push-back on high technology-based urban systems.

Since cost effectiveness and meeting increasing needs of urban dwellers are emerging challenges of smart cities, it is hard to fully complete a smart city project on time. As a result, several smart cities projects have not met the initial goals that were put forward. For example, work on Masdar City in the United Arab Emirates (UAE) (Fig. 5) began in 2008, but the work still continues. Planned as a smart and sustainable city with compact development and zero carbon emissions, it is only partially occupied, and it has not met many of the smart and sustainable city goals such as the reduction in carbon emission, and enhanced walk ability. Anthony Flint (2020) sums up the current state of Masdar City as "For a Masdar City tourist, an Uber ride in an air-conditioned white Lexus it was. Visiting (it) is like having a kale salad for lunch but reverting to a Big Mac and fries for dinner."

Fig. 5. Image a building in Masdar City near Abu Dhabi, UAE.

Similarly, the 2017 multi-billion-dollar smart sidewalk project funded by the Alphabet Company for the waterfront of Toronto encountered many problems (D'Onfro 2019) before it was even completed. The smart street enterprise had budgeted US$1.3 billion to build housing with timber, incorporate heated sidewalks to automatically melt snow when needed, and provide public Wi-Fi in the area. The project had merely begun to install cameras, sensors, and electronic devices to monitor and regulate vehicular and pedestrian movements. However, the existing residents of the area were concerned about the impact of the endeavor in their privacy, and vehemently opposed high-tech devices that could intrude in their activities. The project was unceremoniously abandoned in 2020.

According to news reports, several other smart city projects such as Santander, Spain; Plan IT Valley in Portugal; and Lavasa, India, also failed in their stated missions. The programs did not live up to the expected objectives, had difficulties mobilizing investment, faced serious privacy concerns, and were generally considered to be overpromised and under-delivered.

6. TOWARDS CREATING SMART CITIES IN NEPAL

Almost all Nepali cities are characterized by the lack of good planning, implementation and required resources. With the jarring deficit in infrastructure and services, the talk of making them smart can sometimes appear to be paradoxical. When citizens experience pot-hole laden streets, half-dug sidewalks and pavements and overflowing sewer lines, the idea of a smart city can look like a distant goal. However, Adhikari and Bhattarai (2020) argue that there are several benefits of gradually and incrementally adopting some smart city elements in Nepal even if they are partial and selectively applied initially to areas such as traffic management and parking.

In 2016, the National Planning Commission (NPC) of Nepal released concept paper on smart cities (NPC 2016). The concept paper refers to the government's intention of initiating to create 10 smart cities including in Palungtar,Waling, and the districts of Lumbini and Dadeldhura. Subsequently, the government proposed four more smart cities, making the total number of planner smart cities to 14. Land pooling integrated urban development, and One-City-One Identity (OCOI) concept based on their socio-economic characteristics are some of the approaches proposed to make this endeavor a success. In addition, the rapidly emerging municipalities deserve to have a full assurance for food sufficiency while maintaining adequate levels of open spaces in the cities. Towards this goal, the emerging smart cities should embrace the concept of Food Green City (FGC). Further, urban dwellers may apply the hydroponic technology on roof top gardens (Shrestha 2019) where applicable. These approaches would help maintain needed ecosystem services, and a sustainable urban development. In the increasingly digitalized world, smart cities also would emphasize four areas of urban management - smart residents, governance, infrastructure and economy - that would propel a city towards becoming smart. Karki and Dahal (2020) argue that if Nepal wishes to pursue smart city objectives, it must invest resources in the installation of information and communication technology system, smart infrastructure and in creating skilled human resources. In 2019, the Nepali government, through the Kathmandu Valley Development Committee, created plans for at least four new smart cites in the Valley that may need a total investment of staggering US$ 5.5 billionat sites including Gundu, Balkot, Dadhikot, Duwakot and Changu Narayan (Kathmandu Post 2017). In the midst of what the residents experience every day in the Valley related to traffic congestion and limited urban services, the idea of new towns with brand new infrastructure, planned subdivisions and smart urban qualities appears attractive. Further, new towns also provide the planners to start from scratch to start with any new model and provide adequate open spaces, parks, and modern urban amenities.

However, without improving the situations of the urban systems of Kathmandu Valley, merely adding four cities may overshoot the physical and environmental carrying capacity of the Valley (Adhikari & Bhattarai 2020). The bowel shaped Valley has been suffering from pollutants due to the severity of high wind speed during the winter. For example, the environmental pollution observed in the last week of March 2021 with the accumulation of hazardous haze blankets in the Valley can be taken as a message for planners to be careful while adding new settlements in the Valley (HNS 2021). This cloud was also observed in 2009 (Pandey *et al.* 2009) and 2019 (Poudel 2019), which indicates that brown cloud incidences can be regular hazards for the residents of the Kathmandu Valley. The authors believe that the planners should carefully assess the success and failures and lessons learnt in implementing new towns and smart cities in situations similar to that in Nepal.

6.1 Infrastructure

Residents of many Nepali cities and towns still experience rural conditions where the limited infrastructure can hardly meet the increasing needs of the growing population. The highly congested roads, lack of sidewalks, and unsafe road crossing in many places such as Tin Kune between the

Tribhuvan International Airport and Naya Baneshwar in Kathmandu are risky to the users. Open space, water supply, sanitation, drainage, and parking are very limited. Though it was touted that water from the nearby Melamchi river brought through tunnels and aqueducts to the Kathmandu Valley (Mandal 2021) would be sufficient not only for drinking but also to freshly drain the most polluted water bodies of Bagmati and Bishnumati rivers. Unfortunately, the big flood of August of 2021 washed away much of its infrastructure constructed in three decades since the 1990s.

Many components of a smart city are lacking in the Nepali cities. For example, surveillance cameras are non-existent almost anywhere. Overall, the urban management is also generally considered needing improvement. The energy supply, broadband, and other technology services are often not well-managed. Some dramatic examples can be seen in the overhead electrical and data cable lines in the cities, which appears to be completely muddled up, knotted and messy. (Adhikari & Bhattarai 2020).

6.2 Energy Efficiency

Energy conservation in the cities is facilitated by passive solar design of the buildings, by using solar photovoltaic panels on roofs (Fig. 6), above public walkways, and on covered parking and utilizing energy efficient appliances and systems. A smart way to obtain shade over walkways, parking lots, and green roofs is the installation of solar photovoltaic panels over the shade structure. The panels will not only provide shade for pedestrians and the users of the space below, but also produce electricity for use by the adjoining building. Green roofs, green walls, and shaded windows, door, and balconies (Fig. 7) can help buildings conserve energy and make living more comfortable for the residents of the building.

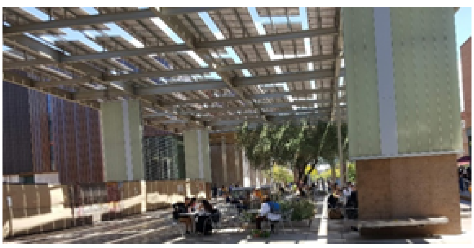

Fig. 6. Solar panels over walkways at ASU Tempe Campus, AZ, USA.

Several streets in the Kathmandu Valley towns deploy solar panels to power streetlights. Rooftop solar photovoltaic panels and water heating panels are becoming more ubiquitous in Kathmandu and several other Nepali cities as Nepal's geospatial location within the latitudinal range between 260 – 300 N offers opportunities to harness solar power with biannual solar oscillation of ± 0.07 (Monteith & Unsworth 2013) where in average a day receives 8.4 hours of sun light.

Fig.7. Green roof and green walls. Optima Homes in Scottsdale, AZ, USA.

6.3 Introducing Smart Urban Elements

As discussed above, if properly managed, there are benefits of moving towards smart cities even if it is partial and applied only to selected services such as traffic and parking. A most practical approach for the Nepali cities could be the start of the adoption of real-time traffic management. The current traffic lighting system used in most intersections is obsolete. In place of the traffic signals that operate on pre-programmed cycle for fixed duration, traffic lights can be organized using artificial intelligence programs to sense signal of the actual traffic movement at the intersection and adjust immediately to optimize the traffic flow. The human police officer sometimes do that in the street of Kathmandu, but it may involve human bias while also being a tedious task. Smart traffic control system can automatically manage the traffic and help it flow better thus reducing congestion.

The Nepali urban leaders and planners can review and identify a series of smart urban interventions to create the building blocks of a smart city. These will likely include transportation services, street lighting, energy use in public buildings, utilization of public amenities including public spaces, information on the status of parking facilities, and making urban services, infrastructure, and amenities more efficient.

7. A CASE STUDY; BUS RAPID TRANSIT IN NEPAL

The Kathmandu Valley has poor air quality. One of the major factors of emitting air pollutants is from hundreds of single occupancy vehicles than high occupancy vehicles (Fig. 8). Additionally, road construction and maintenance activities also emit various pollutants. Since low occupancy vehicles are affordable for personalized transport and can travel through narrow roads and spaces even during peak traffic time, knowingly or unknowingly commuters extensively use them. Unfortunately, the high per capita amounts of carbon monoxide (CO), nitrous oxides (NOx), and unburnt hydrocarbons including particulate matters they emit negatively affect human health. Figs. 9 (a-e) show the amount of air pollutants (broken down by major pollutant types) emitted by the various modes of transportation such as buses, micro and minibuses, taxis, and motorcycles in the Kathmandu Valley. The data is also broken down by the levels of pollutants emitted when the vehicles run on optimal speed (> 25 kilometers per hour) and suboptimal speed (< 25 kilometers per hour).The data shows both historical and projected pollution yields. The analysis shows that pollutant yields are higher when vehicles run at a sub-optimal speed. These graphs are created by the authors based on the data by Shrestha et al (2013).

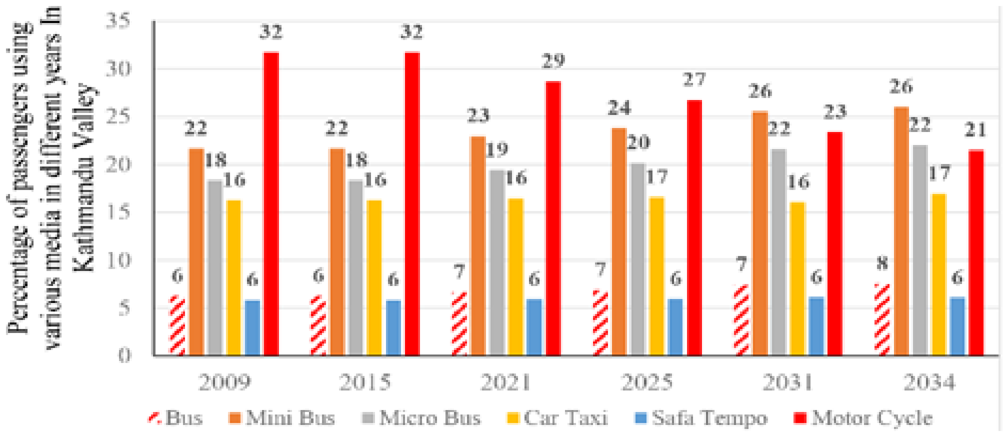

Fig. 8. Percentages of people in the Kathmandu Valley travelling by various modes.

The vehicular emissions vary with the level of road surface roughness measured according to the international roughness index (IRI) in meters per kilometer (m/km) (Bhattarai *et al.* 2019). The Highway Design and Maintenance Standards Model (HDM-4) (Bhattarai & Conway 2021; Watanatada *et al.* 1987) suggests that in an average, an IRI for the urban Kathmandu ranges between 4.0 m/km and 6.0/km. A vehicle emits relatively high amounts of pollutants when the road IRI is high. Air pollution has negatively impacted public health in the Valley. Further, because of limited road length, narrow streets and poorly managed transit system in the Kathmandu Valley, traffic congestion is routine making mobility a challenge.

A bus rapid transit (BRT) may help to efficiently improve transportation and to drastically reduce air pollution in the Kathmandu Valley. According to the information provided by the Association of Central Oklahoma Governments (ACOG) in the US, "compared to single occupancy vehicles, public transportation produces 95% less carbon dioxide, 92% fewer volatile organic compounds, 45% less carbon dioxide, and 48% less nitrogen oxide" (ACOG, 2013). Trains emit even less pollutants per person-kilometers. However, any type of train service in the Kathmandu Valley is not being implements immediately.

A BRT system can be made user friendly by using a Transit Tracker App (TTA) that is operable on a mobile phone or hand-held tablet. Using a TTA with routing real time algorithm a potential rider can locate a bus, traffic conditions, where it is parked, how long it takes to arrive at certain location, what bus or connection would be best to use to reach certain location. This information will help a rider to make a change between different transport modes, and how to reach the destination quickly and conveniently. It will use live traffic data and estimations of arc (distance) travel times; suggest paths to the users and public transport modes; and the optimal path decision.

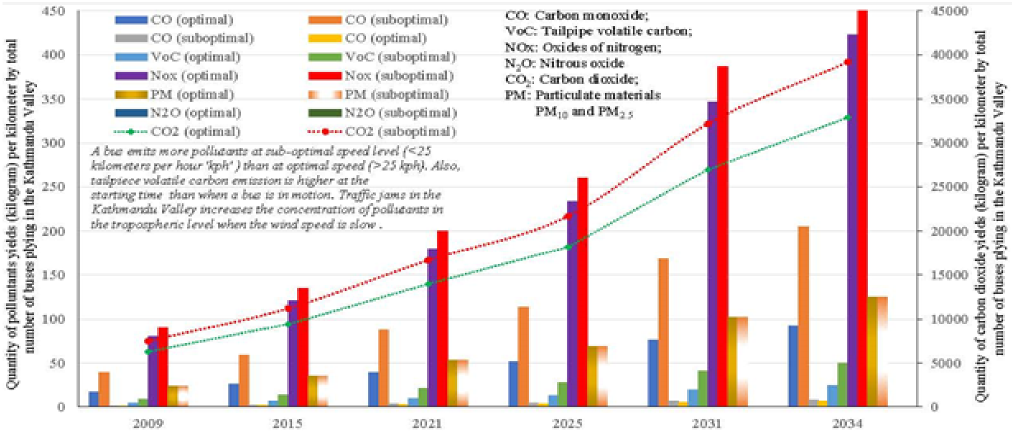

Fig. 9a. Pollutants yield in kilogram by all buses per kilometer in the Kathmandu Valley

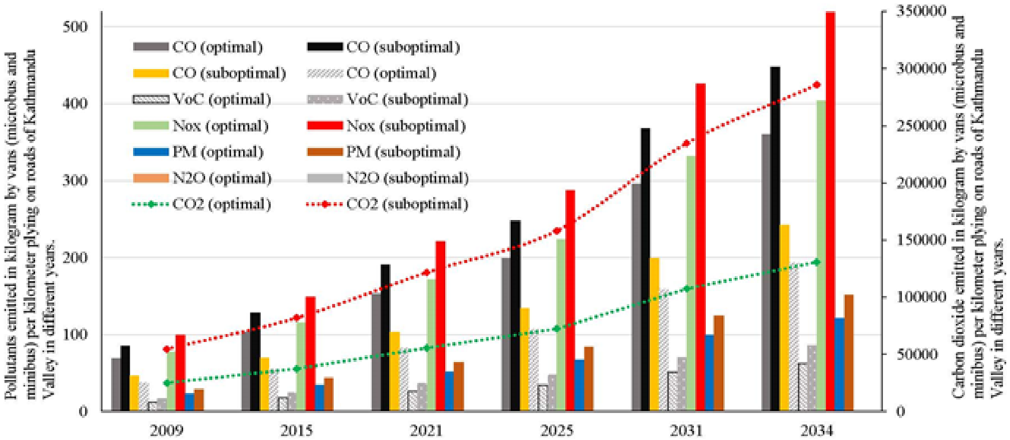

Fig. 9b. Pollutants yield in kilogram by all vans (microbuses and minibuses) per kilometer in the Kathmandu Valley

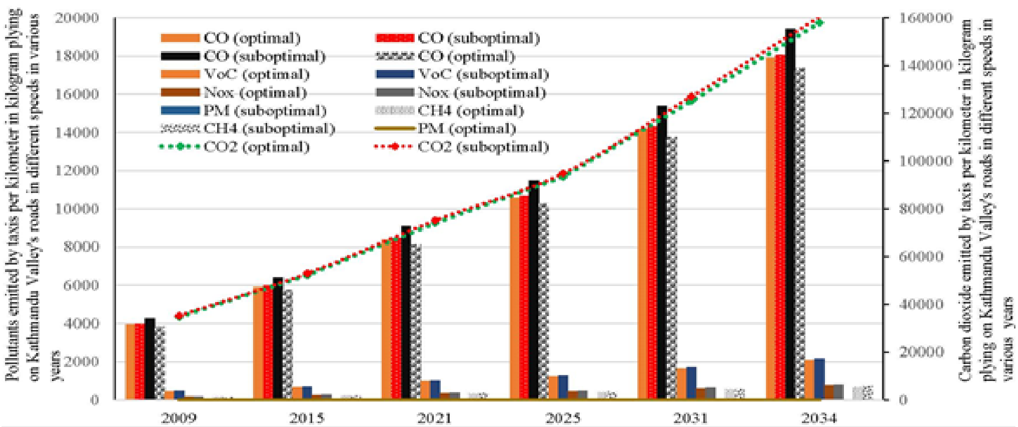

Fig. 9c. Pollutants yield in kilogram by all taxis per kilometer in the Kathmandu Valley

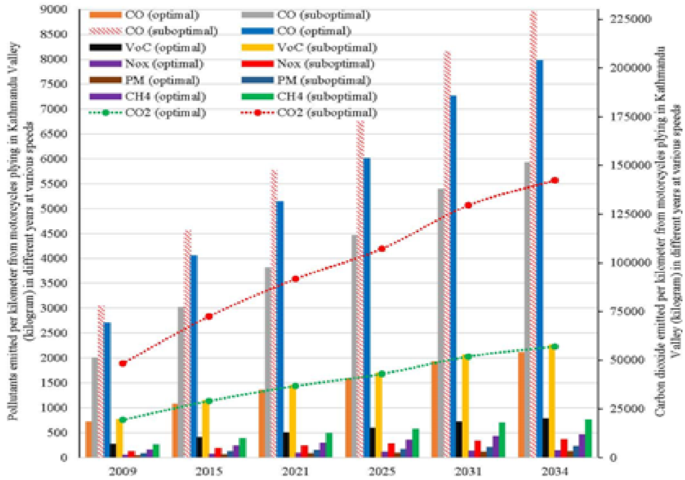

Fig. 9d. Pollutants yield in kilogram by all motorcycle per kilometer in the Kathmandu Valley

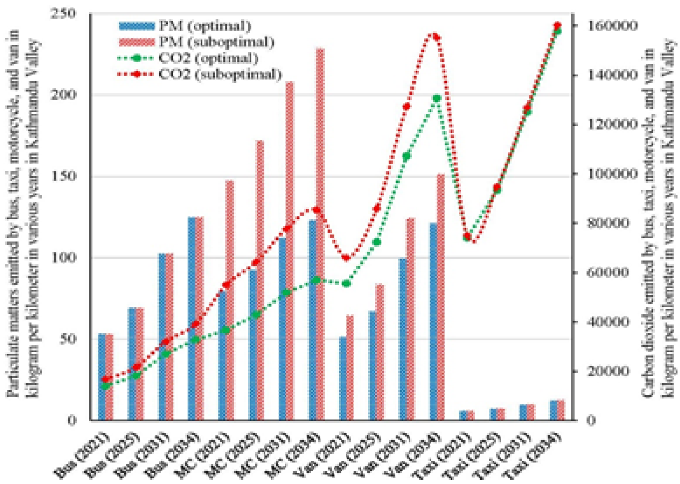

Fig. 9e. Amounts of particulate matters emitted by various vehicles in the Kathmandu Valley.
Note for Figure 9a-e. Graphs by the authors based on data from Shrestha *et al.* (2013).

If low occupancy vehicles are replaced by high occupancy vehicles, congestion will decrease, and traffic flow will improve. This will help to operate high occupancy vehicles at an optimal (>25 kilometer per hour, 'kph') speed level, and the pollution emitted by the vehicles will decrease compared to when they run in sub-optimal speeds. Figs. 9 (a-e) show how the generation of various pollutants will decrease if high occupancy vehicles running at optimal speeds are used for public transportation.

Replacing low and high occupancy vehicles that run on petroleum-based fuel by electric buses on the main roads and limiting currently operating vehicles to the interior roads will help to minimize the emission of various pollutants in the Kathmandu Valley. Operating electric buses and establishing infrastructure needed for its operation such as charging infrastructures/stations ubiquitously can be expensive at the very beginning. Such a BRT system will help improve the traffic flow, mobility, and accessibility, and drastically reduce air pollution in the Kathmandu Valley; it will help to significantly improve public health.

8. CONCLUSION

Making Nepali cities smart is a potentially long and challenging process. First, the basic infrastructure and planning of the Nepali cities needs to be improved. Many studies related to improving urban efficiency have already been completed. Nepal also has prepared several plans to enhance the working of the cities and to manage growth. All these documents can be valuable references in preparing comprehensive implementation mechanisms to improve the smartness of Nepal's urban areas. Even more important are the lessons learnt in the implementation of Nepal's urban plans, so that the future planning and implementation can be improved.

Globally, many cities have already gathered rich experience in implementing smart city ideas and principles. A study of their experience and lessons learned can be valuable in planning for smart cities in Nepal. Some relevant best practices can be seen in the experience of neighboring India in its smart city projects.

While a smart city project can be a time consuming and gradual endeavor, many urban governments globally have experienced good results in the smart cities field. We have provided several examples of these in this paper. Nepali cities are also good candidates for implementing selective smart elements as the planners and residents are keen to adopt programs and processes that can improve daily urban living. The first and easy possible interventions are in the passive systems areas, such as creating safe sidewalks, implementing urban forestry and urban agriculture programs, water harvesting, and building rain gardens, passive buildings that are energy efficient and safe.

Nepali cities can benefit by incremental and selective use of smart technologies, for example, to help in traffic and parking management and improving walkability and increasing the deployment of clean energy. Another potential area of improvement is utilizing a Bus Rapid Transport (BRT) system to replace low occupancy vehicles for public transportation. Using electrical buses in place of petroleum-fueled vehicles would further help in the reduction of air pollution. Uses of high occupancy vehicles will also provide a positive feedback loop by reducing congestion and allowing vehicles to run at optimal speeds which will reduce emissions even more.

Planners and urban leaders in Nepal will need to work on identifying smart elements that are the low hanging fruits for the urban areas to begin enjoying the benefits of improved urban services, amenities, and infrastructure. Nepali cities will need to perform cost and benefit analysis and review their management capacity and explore how the capacity could be enhanced. Nepali planners and policymakers can begin to assess, identify, and gradually implement selected smart city ideas. These activities should be accompanied by education, research and training related to advancing related knowledge and ideas and deployment of selected smart city elements in Nepal.

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