Establishing a Cost-Effective Smart Mobility Deployment Framework (SMDF) and Association Mining

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***Abstract* - The smart city concept is widely accepted as the model for future cities to address the increasing challenges being caused by the growing population and limited city resources. Such concept advocates the leveraging of existing infrastructure and developing technologies to push for authorities' interconnectivity & coordinated efforts, and transparency & accessibility, with the intent of achieving city operational efficiency, which consequently, serves and enhances the quality of lives of the people. This paper looks at examining a variety of smart mobility initiatives undertaken by some of the leading smart cities of the world, analyze their resulting benefits, issues and challenges encountered, and propose a mitigated-risk framework for such pursuit. A proposed framework is presented to illustrate the necessary short-term and the longer-term deployment targets such as series of minor infrastructure modifications followed by road network expansion. Association mining with CN2 Rule Induction Algorithm is applied to investigate the relationship of services specially mobility among lead smart cities and finding discussed. Also, expanding the internet coverage and reducing subscription cost from the technology side, followed by adoption of emerging technologies to strengthen the smart mobility initiatives.**

Keywords—Smart city, Mobility, Sustainable Future

I. INTRODUCTION

City resources and operations management have become an increasingly challenging task due to the steadily growing population and limited resources. Therefore, there is this growing recognition to have cities of the future modelled on the concept of smart cities which advocates the leveraging of existing infrastructure and developing technologies to promote city operational efficiency and transparency of and in between the different city authorities.

This concept is largely dependent on the interconnectivity of the various information technology related devices used by the different authorities within cities. Consequently, it can support robust inter-authorities coordination to effectively manage crucial in-city services such as smart mobility which is impactful to most other if not all in-city services. For instance, hospital emergency services, commuting for work, timely deliveries, and even traveling for recreation are all dependent on mobility just to mention a few. The potentials of smart mobility are evident in cities worldwide with promising results achieved, but interestingly, varying philosophies based upon city beliefs and priorities are being followed [1]. The ultimate goal of smart cities is to leverage technologies to serve the people thus having key focus on the society, the environment and the economy, with smart mobility sitting right in the middle of them all. Smart mobility is one of the key initiatives for cities to become more functional, successful, and sustainable [2].

This paper looks at examining a variety of smart mobility initiatives undertaken by some of the leading smart cities of the world, analyze their resulting benefits, issues and challenges encountered, and propose a mitigated-risk framework for such pursuit.

Smart Mobility: It is about upgrading the quality and efficiency of the urban transportation system, which can be achieved through modern techniques such as remote tracking and video surveillance in order to monitor and manage traffic facilities and flows. The monitoring allows analysis to be conducted on the collected data to better manage pedestrian flow, traffic flow, cargo flow and prioritize emergencies in a proper manner. This also promotes the access to various transportation modes such as public transport, cycling, clean-fuel vehicles and walking.

II. LITERATURE REVIEW

A. Smart Mobility

Smart mobility is crucial to the smart city concepts and is becoming even more so with the growing urban populations and additional need for road transportations. Road congestions, restricted mobility, and delays are impacting travel time, fuel consumptions, pollution level, essential services response times, and operational efficiency. Deploying appropriate smart mobility initiatives is becoming increasingly inevitable to mitigate the aforementioned but it is not necessarily a straight forward exercise [3]. There has been arguments that the increasing traffic queues at traffic light controlled junctions are making conventionally implemented traffic management systems ineffective in mitigating road congestions . This justifies the inevitability of smart mobility including intelligent traffic management systems to be more precise. Developing technologies such as artificial intelligence (AI), Internet of Things (IoT), and Big Data Management are well positioned to support those intelligent traffic management systems deployment as they allow traffic flow to be monitored, traffic related data to be collected, transmitted, stored, analyzed and data-driven actions to be taken. This approach has shown to be effective and impacts acknowledged by even visitors in places like Singapore [4].

The daily collected traffic related data can easily be fed into online virtual platforms that gives the authority access to traffic status in real-time. Additionally, it enhances the capabilities for early detection of in-city traffic related incidents with swift and appropriate responses, or to predict and be as pro-active as possible to mitigate such incidents. Relevant apps are reducing unnecessary movements by bringing smart mobility services to the fingertips of the public including paying bills, calling a taxi, accessing public transport schedules, tracking packages, vehicle registration, or reporting road incidents. Smart street lights and parking sensors are also commonly seen services resulting from smart city concept. It is estimated by Juniper research that smart cities will bring about 19 billion dollars of saving a year and the global smart city market is estimated to attract more than 15 billion dollars by 2021 just for software. This explains the growing interest from major software development companies such as Microsoft, Cisco, Siemens, and Huawei [5].

Expanding road infrastructure only has proven to be very costly and a fairly slow deployment strategy to alleviate city mobility issues, while smart mobility through the leveraging of the existing infrastructure and developing technologies offer better options. Providing earlier exits around roundabouts to avoid roundabout queues or traffic lights enhances traffic flow which is quite apparent in Oman. Other smart mobility initiatives like traffic information status, effective public transport, vehicle-sharing, and easy parking finding, can assist with traffic flow. These are very citizen-focused strategies [6].

The need for road transportation be it for people or for goods, keeps increasing and so the relative impact on congestion, air pollution, road accidents and climate change. The growing demand for mobility continues and so is the exploration for smarter mobility. Smart mobility can promote environmental friendliness through the use of electric vehicles, provide alternatives public vehicles for people movement, and deploy intelligent traffic lights to better manage traffic flow. Figuring out appropriate approaches to rolling out smart mobility initiatives together with their associated infrastructures in a more sustainable way is imperative. As a result, it will assist in building greener, smarter and more livable cities [7].

As mentioned earlier, smart mobility including smart traffic management systems are essential for realizing the potentials of smart cities concept. The increasing road accidents, delays, and road user frustrations due to growing traffic congestions are negatively impacting the socio-economic progress and the environmental friendliness. The conventionally implemented traffic management systems that are underperforming against heavy traffic queue built-ups during peaks hours need to be replaced by more suitable intelligent traffic management systems so to strive for more free-flowing traffic. The concept of Internet of Things (IoT) has added a new breadth to the possibilities of implementing more efficient and effective traffic management systems. It offers excellent features for automated tracking and monitoring of vehicles, collecting and processing of traffic data, and management of the processing outcomes to provide valuable real-time traffic-related services to road users. This can well reduce traffic congestions [8].

B. Issues and challenges relating to smart mobility initiatives

Despite the praises and potentials of smart mobility, it comes with its own issues and challenges. Smart mobility is not only about implementing emerging technologies but also careful thinking about possible issues and challenges that the general public may face because of it. Particular attention needs to be given to our tendencies of identifying and solving problems as the emerging ones of the 21st century have varying degree of complexity [10]. Anna and Miltiadis (2019) discussed and mapped the social, political and economic risks and threats of smart cities and mobility. They identified governance and democracy, readiness and applications of technologies, and unified model or framework to be some of the complex challenges that need attention [9].

In line with their theories, it is noticed that the exponential growth in urbanization and population are the causes of many if not most of the challenges to cities, and one of the key challenges is mobility. The worldwide efforts to re-imagining transportation are evident of that. One of the most soul-destroying things is traffic and it affects people in every part of the world. Sometimes, it is almost impossible to response to incidents be it minor or major due to simple instances of traffic delays. Smart and thoughtful approaches for alleviating congestions must be devised, with effective plan for moving people around the city and appropriate investments with consideration of public health and safety. Intelligence transportation systems and available technologies can be used to help families out of poverty by connecting them to employment [10].

Moreover, Governments are facing issues of having intelligent operations hype such as physical and virtual portals that allow for data and resources sharing across all levels instantly and lack of major disaster response systems. The absence of machine learning algorithms that can assist in improving reliability and emergency response time to disasters, which can also be part of congestion reducing solution, vehicle decreasing incidents at intersections, and pollution reduction. Cities with less developed infrastructures or with older technology infrastructures tend to find it harder to embrace the smart cities concept and so smart mobility. The use of sensor technology is a key component of the smart initiatives for assisting in collecting and analyzing data, and for providing relevant information required to improve the residents' quality of life [11].

Cars sharing or exchanging data and information with each other can enhance efficiency. Better mobility will need better systems where traffic signals needs to communicate with cars, while cars needs to communicate to other systems and devices to determine traffic count or density in real-time 24/7. However, the final traffic information updates have to be provided to the road users and so these [12] in such a way to do just that .

Advocating the use of public transportations over personal transportations can very much help with issues such as road congestions that leads to further needs for expanding road networks and for creating additional parking spaces which are very costly. Getting people out of personal transportations and into public transit also brings great social benefits. It promotes the community values that encourages people to interact and communicate with each other thus enhancing human care which is currently on the decline. Cities have a great opportunity to be at the forefront of testing and trying these new ideas. By fully realizing such transformations and transportations, environmental benefits will also be on the rise as low-carbon or even zero-carbon energy will be in use. As cities become greener, so will the world. The use of sensors to collect data for the IoT-Clouds platforms and other relevant applications can ensure profitable decisions and actions always [13].

The smart city index of 2019 and 2020 which was based on the perceptive rating of sub components of each of the key areas were aggregated to represent the perceptive ratings of the key areas under each pillar. Ranking was then used on the resulting perceptive ratings of the key areas to determine the prioritization whch is illustrated in the figure below. It may be noted that mobility is not high on the priority [14].

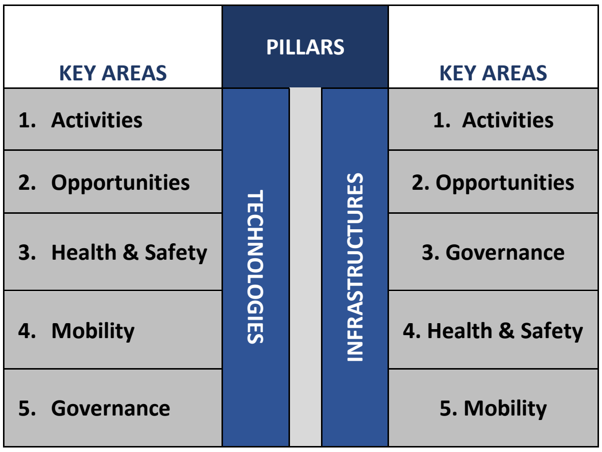

Figure 1: Key area as Pillars of Technologies & Infrastructure.

III. Mobility Initiatives by Few Smart Cities

Smart City Name: Barcelona

- ***Smart Cities Initiatives:*** Pioneered smart cities initiatives such as low carbon solutions. Among the first worldwide to introduce solar thermal. Overall city municipality services are smart.
- ***Resulting benefits (Economic, Social, Environmental):*** Essentially systematizing electronics and analytics to solve many issues like traffic congestion saving billions of dollars from having to build more roads in the process.
- ***Issues/Challenges:*** According to Barcelona City Council, some of the issues and challenges explain the shift from first to second generation smart city policies. Few urban challenges such as traffic congestion, resource consumption, employment generation, wage inequality, climate change, housing, data rights etc. were in need to adequately address in the smart city strategy [15].

Smart City Name: Berlin

- ***Smart Cities Initiatives:*** Highly innovative in use of green technology initiatives. Strong collaborations and support from BMW for the implementation.
- ***Resulting benefits (Economic, Social, Environmental):*** Technology and digitalization helped in providing both short-term and long-term solutions to building more resilient ecosystem - Berlin Innovation Agency (BIA). Benefited with balanced utilization of public mass transportation. Characteristics of resilient city of Berlin - socially inclusive, eco-friendly and digitized services. Their mobility model is smart, shared and intermodal [16].

  Issues/Challenges: Research reveals that participatory practices, collaboration of several types of stakeholders and digital strategy to tackle smart city challenges in the near future, was main focus in Berlin. Issues and challenges were mapped against social, political and economic risks and threats [17].

Smart City Name: Tokyo

- ***Smart Cities Initiatives:*** Created small towns in the suburbs in partnership with Panasonic, Accenture, and Tokyo-Gas. Eco-burb homes integrate solar panels, storage batteries and energy efficient appliances with all connected to smart grid.
- ***Resulting benefits (Economic, Social, Environmental):*** Most successful metropolis city referred to as Earth's model Smart City due to its Virtual vertical farming and energy efficient appliances key initiatives. These initiatives are providing opportunities for having environmentally and economical spaces. Collecting and recycling drain water for better utilization, enriched agriculture and transportation.

  Issues/Challenges: Recent research on Smart City as a case of Tokyo depicts that application of IoT creates engineering, scientific and other such issues to be resolved. More ingenious research needs to be done [18].

IV. Proposed Framework and Justification

The smart mobility proposed framework is based on the Infrastructure and Technology pillars. The figure below is the authors' own illustration of the proposed framework.

Figure No. 2: Proposed Framework of Smart Mobility

The proposed framework illustrates the short-term and the longer-term deployment targets. For instance, the immediate focus for the Infrastructure should be on series of minor junction modifications that can significantly reduce queue build-ups and enhance traffic flows around roundabouts. Such targets would be less expensive, require less time, and other resources. In the longer-term, the more expensive road network expansion could be rolled to provide alternate routes.

The immediate focus for the Technology should be on expanding internet coverage and reducing subscription cost to enable easy access to the variety of traffic information provision apps which can in turn allows road users to plan their traveling or avoid congested areas. This can also reduce traffic congestion and enhance traffic flow. Additionally, it could further enhance the effectiveness of junction modifications under the Infrastructure. In the longer-term, the adoption of emerging technologies to strengthen the smart mobility initiatives could be gradually implemented. Such incremental deployment may be quite suitable for financial cautious decision-makers. The framework is proposed for the first time and so there is no similar work.

V. Methodology and Analysis

The study has been conducted based on the smart city index measured across different indicators which are technology, urban planning, strategy & governance, environment, cohesion, economy, mobility, human capital and transportation. An open source mobility dataset is used, as part of secondary data i.e. October 2020 worldwide survey of 118 world smart cities as population and 10 leading smart cities as a sample. Data was normalized to use for investigation purpose using Orange tool.

The data used the mobility data from a sample of 10 leading smart cities. We applied Association Mining Rule(AMR) from the data mining domain. Below are the analysis results.
Figure 3 is an illustrations of the framework based on the mobility data using the model-classier (CN2 Rule Induction). The rule induction algorithm was used to detect the probabilities using association. Efficiency was measured by the highest probability.

Laplacian error estimate was employed as an alternate estimation function. Also, the way to generate both ordered and unordered rules is illustrated. Additionally, Beam width 5 was identified as the most appropriate of the rules to use and so the others were ignored.

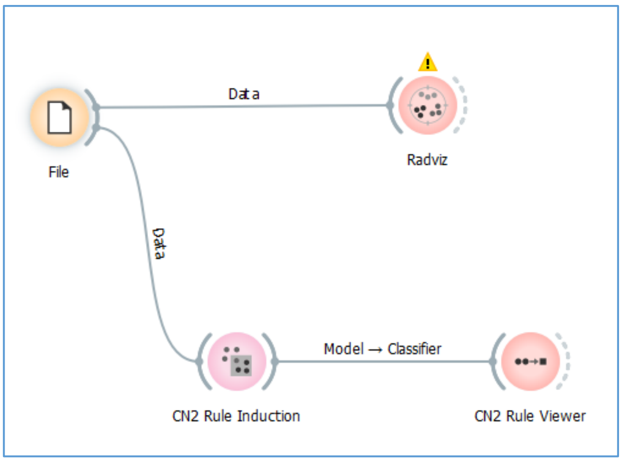

Figure No. 3: System Framework (Data & CN2 RI & V)

Table No. 1 demonstrates the result of the Rule Induction algorithm (RIA) including conditions used and the calculated probabilities for the six mobility variables.

Table No. 1 Rule Induction Algorithm – Conditions (CN2 Rules)

Induced rules

	IF conditions		THEN class	Distribution	Probabilities [%]	Quality	Length
	Helsinki=Low	→	Feature 1=M3	[0, 0, 1, 0, 0, 0]	14 : 14 : 29 : 14 : 14 : 14	-0.00	1
1	Zurich=Medium	→	Feature 1=M5	[0, 0, 0, 0, 1, 0]	14 : 14 : 14 : 14 : 29 : 14	-0.00	1
2	Singapore=Low	→	Feature 1=M1	[1, 0, 0, 0, 0, 0]	29 : 14 : 14 : 14 : 14 : 14	-0.00	1
3	Helsinki≠High	→	Feature 1=M4	[0, 0, 0, 1, 0, 0]	14 : 14 : 14 : 29 : 14 : 14	-0.00	1
4	Auckland=High	→	Feature 1=M6	[0, 0, 0, 0, 0, 1]	14 : 14 : 14 : 14 : 14 : 29	-0.00	1
5	Singapore=Medium	→	Feature 1=M2	[0, 1, 0, 0, 0, 0]	14 : 29 : 14 : 14 : 14 : 14	-0.00	1
6	TRUE	→	Feature 1=M1	[1, 1, 1, 1, 1, 1]	17 : 17 : 17 : 17 : 17 : 17	-2.585	

Mobility variables

M1	Traffic congestion is not a problem.
M2	Public transport is satisfactory.
M3	Car-sharing Apps have reduced congestion.
M4	Apps that direct you to an available parking space have reduced journey time.
M5	Bicycle hiring has reduced congestion.
M6	Online scheduling and ticket sales make public transport easier to use.

Figure No. 4 shows the RadViz generated based on the same mobility dataset. RadViz is popular in representing the multidimensional data [19]. Following visualization is displaying dots as association of smart city services in terms of mobility. All mobility variables as M1 to M6 are depicted in the following figure 4 as data visualization using RadViz utility of Orange.

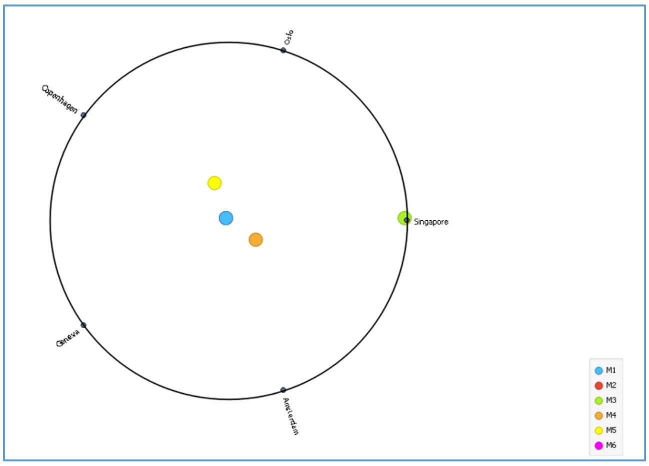

Figure No. 4: Data Visualization using RadViz

VI. Conclusion and Future Work

It is obvious that the perception of quality of living may differ from city to city and this research has attempted to establish a standardized view of how smart mobility initiatives could be rolled out gradually to better control associated financial burdens. Both pillars should be given similar emphasis though the technologies pillar may to some extent depend on the structures pillar. Association mining with CN2 Rule Induction Algorithm is applied to investigate the relationship of services specially mobility among lead smart cities and finding discussed. Having some short terms solution such as increasing coverage of IT, in the longer run adapting emerging technologies like AI, IoT, Cloud Connectivity etc. By doing so, it will allow an incremental budget to several parallel activities. Though mobility appears to be less emphasized upon among the key areas from the structures pillar, issues relating to traffic congestions keeps growing and they are becoming key challenges to smart cities realization. In the future work, most appropriate intelligent traffic management system and also expansion of the road network would be required. Advance applications would be used to develop smart transportation system.

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VII. REFERENCES

[1] T. Bakıcı, Almirall and J. Wareham, "A smart city initiative: the case of Barcelona.,"," *Journal of the Knowledge Economy,* vol. 4, no. 2, pp. 135-148, 2013.

[2] P. Lam and W. Yang, "Factors influencing the consideration of Public-Private Partnerships (PPP) for smart city projects," Evidence from Hong Kong., Cities Report, Hong Kong, 2020., 2020.

[3] O. Kodym and J. Unucka, "Smart life in smart region," in *2nd EAI International Conference on Management of Manufacturing Systems (p. 1). European Alliance for Innovation (EAI).*, 2017.

[4] A. Kurzhanskiy and P. Varaiya, "Traffic management: An outlook.," *Economics of transportation,* vol. 4, no. 3, pp. 135-146, 2015.

[5] P. Fan, "Catching up through developing innovation capability: evidence from China's telecom-equipment industry.," *Technovation,* vol. 26, no. 3, pp. 359-368., 2006.

[6] R. Xie, W. Wei, Q. Wu, T. Ding and S. Mei, "Optimal service pricing and charging scheduling of an electric vehicle sharing system," *IEEE Transactions on Vehicular Technology,* vol. 69, no. 1, pp. 78-89, 2019.

[7] A. Razmjoo, M. M. Nezhad, L. G. Kaigutha, M. Marzband, S. Mirjalili, M. Pazhoohesh and G. Piras, "Investigating smart city development based on green buildings, electrical vehicles and feasible indicators.," *Sustainability,* vol. 13, no. 14, p. 7808, 2021.

[8] P. Figueiras, Z. Herga, G. Guerreiro, A. Rosa, R. Costa and R. Jardim-Gonçalves, "Real-time monitoring of road traffic using data stream mining," in *IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, 2018.

[9] T. Besker, A. Martini and J. Bosch, "Managing architectural technical debt: A unified model and systematic literature review.," *Journal of Systems and Software,* vol. 135, pp. 1-16, 2018.

[10] A. Obayelu and I. Ogunlade, "Analysis of the uses of information communication technology (ICT) for gender empowerment and sustainable poverty alleviation in Nigeria," *International Journal of Education and Development using ICT,* vol. 2, no. 3, pp. 45-69, 2006.

[11] G. Riecken and U. Yavas, "Improving quality of life in a region: A survey of area residents and public sector implications.," *International Journal of Public Sector Management.,* 2001.

[12] Z. Khan, A. Anjum, K. Soomro and M. A. Tahir, "Towards cloud based big data analytics for smart future cities," *Journal of Cloud Computing,* vol. 4, no. 1, pp. 1-11, 2015.

[13] S. Williams and N. Williams, The profit impact of business intelligence, Elsevier, 2010.

[14] Anon, "Smart City Index 2020," IMD, 2020.

[15] H. March and R. Ribera-Fumaz, "Barcelona: From corporate smart city to technological sovereignty," Routledge., 2018.

[16] L. Zvolska, M. Lehner, P. Y. Voytenko, O. Mont and A. Plepys, "Urban sharing in smart cities: the cases of Berlin and London," *Local Environment,* vol. 24, no. 7, pp. 628-645, 2019.

[17] A. Visvizi and M. Lytras, "Smart cities: Issues and challenges: Mapping political, social and economic risks and threats.," 2019.

[18] T.-h. Kim, C. R and S. M, "Smart city and IoT," *Smart Cities,* pp. 159-162, 2017.

[19] M. Angelini, "Towards enhancing radviz analysis and interpretation," in *IEEE Visualization Conference (VIS).*, 2019.