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Intelligent Transportation System: Managing Pandemic Induced Threats to the People and Economy

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***Abstract*— Since the world wars, the world has not seen such a heavy and sustained negative impact on the people and economy, as is being caused by the pandemic COVID-19. Pandemic, like any other big change, is strongly disruptive, challenging authorities all over the world to reimagine services, logistics, people movement, and economic activities. For the national and local governments looking for resources to support traditional and novel solutions to mitigate, contain and control the pandemic's deleterious impact on the people and economy, Smart City's Intelligent Transportation System (SC-ITS) can be an important asset.**

Integration of the transportation advancements with artificial intelligence and information and communication technologies is interactively and dynamically empowering the ITS of Smart Cities. This integration has ushered in an era of smart city intelligent transportation services that are dynamic, adaptive and can be reconfigured to meet the smart city citizenry's changing needs in an inclusive, safe, greener, and more efficient way. We believe that by adapting and, in some cases repurposing the SC-ITS, the authorities can simultaneously increase the reach, impact, and efficacy of the solutions aimed at restarting economies while balancing both lives and livelihood concerns.

This paper builds an understanding of the pandemic and then examines the SC-ITS through its components and related applications before diving deeper into the hood to examine how these components, both now and in the future, can be adapted, reconfigured and repurposed, to address the pandemic induced challenges individually and collectively. Finally, it attempts to put a perspective by evaluating the challenges and opportunities inherent in leveraging the ITS for the deployment.

Keywords*— *Intelligent transportation system, Smart cities, Pandemic, Information technology.

I. INTRODUCTION

Transport is an essential driver of economic and social development, and transportation systems have extensive and pervasive effects on the economic and social systems that they assist. Technology, big data, and AI are a part of modern transportation systems as are the physical components such as buses, cars, and planes.

To keep the modern cities humming, their transportation systems need to dynamically respond to the traffic situation of the day and evolving living patterns, transportation tastes, and nature of freight movement.

Smart cities have invested in technology to move beyond a business relationship with its citizens through innovative solutions, integrated services, and coordinated and seamless management collectively referred to as Smart City's Intelligent Transport Systems (SC-ITS).

Managing a pandemic, even in a smart city, is challenging as every pandemic is unique, and the sudden and catastrophic disruption it causes affects multiple levels of the society and economy. There are policy challenges for the governments and authorities across the world, such as selecting an appropriate approach to respond to the pandemic with speed, scale, and equity while balancing lives and livelihood concerns if the pandemic prolongs. Another critical challenge is in identifying, gaining, and deploying required medical, economic, people, and technical resources within already constrained budgets and timelines.

There are similarities in managing transportation systems and a pandemic. For both, decisions need to be made under rapidly changing, uncertain conditions, with limited (if any) prior experience, which calls for the availability of rich information, decision support technology, and integrated systems.

In this paper, we first understand the pandemic through pandemic induced challenges, their impact on people and the economy, pandemic response approaches, and related technology. Next, we present, review, and analyze key components of the SC-ITS and related applications to assess how the components and applications, both now and in the future, can be adapted, reconfigured and repurposed, for the pandemic response.

II. PANDEMIC INDUCED CHALLENGES

A global pandemic causes immense social and economic pain leaving scars both on the people and economy that take a long time to heal. Regardless of the level of awareness, planning, and preparation, both the authorities and people have a steep learning curve for adapting and responding to the unique challenges of a pandemic.

A. Evaluating Impact of the Pandemic on People and Economy

Disruption caused by pandemic affects multiple levels in the society and economy. The most visible and disturbing impact is a significant, widespread increase in morbidity and mortality

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and a disproportionately higher mortality impact on vulnerable populations such as the elderly and low and medium-income groups. This, coupled with the adverse impact of the mitigative actions such as social distancing and lockdowns, leads to individual behavioral changes, such as fear-induced aversion to workplaces and other public gathering places [1].

The restrictions placed on movement, behavioral changes, and fear lead to the collapse of demand in multiple sectors, which in turn amplifies the hardships faced by individuals. The local and national governments face an enormous financial burden of additional expenditure to support people, affected industries, and healthcare systems even as they struggle to cope with a large drop in their tax collections.

The longer the pandemic lasts, and the greater the lockdowns and movement restrictions exist, the personal and economic shocks which affect the society tend to bring long term changes to relationships, supply chains, production, and consumption [1].

B. Selecting the Pandemic Response Strategy

The guiding principles for the pandemic response are *speed*, *scale*, and *equity*. The response itself is calibrated to the stage of the pandemic. At the initial stage, when the pandemic alert has been issued but has few or no known local cases, the response approach is to improve situational awareness and provide reliable communication about symptoms, known cures and care, and actions needed to be taken by the people to avoid the infection. Resources are focused on preparation as well as surveillance, testing, and tracing.

Once the pandemic has set in, the authorities try to slow down transmission, reduce mortality, and eventually get to a steady state of low-level or no transmission. At this stage, we see authorities taking one of the following two approaches - *strict control* actions such as lockdowns or *containment* through guided voluntary actions [2].

The *strict control* approach uses complete lockdowns where high restrictions over large areas are placed on people movement with significant controls on goods' movement. The *containment* approach is to retain normal life with limited restrictions and established precautionary and preventative actions to be followed voluntarily by people. Both approaches retain continued focus on surveillance, testing, and tracing.

When the pandemic extends over longer periods, and no specific treatment or vaccination exists, limitations of both the approaches get exposed. A third approach increasingly discussed is where the city and local authorities are encouraged to adopt a more dynamic stance, identifying and placing smaller *containment zones* under differential restrictions over varying periods based on the situation and available system capacity. In a variation of this approach, the authorities additionally identify *buffer zones* around containment zones with relatively fewer restrictions [3]. The appreciation for this approach comes from the fact that it can significantly alleviate the adverse economic and social shock, especially to the vulnerable industries and communities.

One of the reasons we have seen less adoption of the third approach, or limited success where this has been adopted, is the failure to understand that this approach is more knowledge-driven and requires robust integration of information sources with decision-making processes and extensive communication capabilities, something that cannot be started from the scratch.

C. Developing New Technology Solutions

To effectively slow down pandemic transmission and eventually get to a steady state of low-level or no transmission, a necessary condition is coordinated containment and mitigation processes, including surveillance, testing, contact tracing, and strict quarantine.

A technical solution to tracking, tracing and mapping individual movements is a must. Sensitivity with respect to individual privacy and rights becomes an important requirement for authorities aiming for voluntary adoption [5].

A simple, low-cost option of leveraging smartphone applications has been widely used and, in many cases, mandated by the authorities. However, this solution concerns privacy violations and faces significant challenges on the adoption front [6][7].

An emerging alternative to mobile applications for contact tracing is the use of anonymous physical token devices. Tracking and tracing technologies for logistics using physical tokens is well developed and deployed, therefore reliable, and the tokens appear to address the privacy concerns and have a greater likelihood of voluntary adoption [8].

III. ITS COMPONENTS

A smart city with ITS has ready availability of information architecture, technology infrastructure, and solutions, such as business intelligence and AI, that can meaningfully capture and integrate data generated by the applications and token devices to present an enriched picture to authorities. This ensures dynamic decision making through robust analysis.

To identify opportunities of harnessing SC-ITS for dynamic and differential approaches to the pandemic, we deep dive into the details. Since ITS has evolved from multiple organizations, technology, and services constructs, we have used a componentry analysis to map its potential for use in different areas of pandemic management. As smart city services and SC-ITS continue to evolve differentially across different countries and states, we believe that this approach will enable authorities to quickly identify, select and integrate available and applicable solutions to their pandemic response frameworks and strategies.

The componentry analysis method is inspired by the Component Business Model approach of IBM. We have identified four unique components of the transportation management system that are innately relevant and provide a deeper understanding of the whole system. These four components are a) Transit and Mobility Management, b) Arterial and Freeway Management, c) Freight Management, and d) Emergency and Incident Management.

The following sections present an overview of the components and then provide an insight into their unique challenges and opportunities through a review of the recent study and research activities. Finally, we assess how the component, now and in the future, can help authorities increase reach, impact, and efficacy of the solutions aimed at managing pandemic and, where applicable, restarting economies to balance both lives and livelihood concerns.

A. Transit and Mobility Management

ITS Transit & Mobility (T&M) management component enables coordination among transit services across transportation alternatives to provide cost-effective, safe, and convenient mobility options for all social segments. T&M management's focus is on designing the services around people and their specific needs and supporting them with the required information and features in an easily accessible fashion.

ITS T&M provides an integrated information backbone to both public and private mobility solution providers to facilitate secure data sharing for planning as well as for dynamic, efficient, and responsive scheduling.

Advancements in T&M technologies are increasingly enabling the integration of payment systems, digital communications, and route planning to enhance commuter choice sets while reducing costs for the operators [9].

1) Review

In our review, we see that the recent research in the ITS T&M area is integrating AI and Deep Learning developments to attend to the challenges associated with mobility in today's environment where several organizations and public transport, are coming together for overall seamless service.

Mobility-on-Demand is a network of reliable and affordable multimodal options for personal mobility. New research in the mobility is helping improve traditional approaches to scheduling, routing, and operations, optimizing outcomes such as fleet fuel consumption and overall network efficiency [10][11][12]. Smart cities are also gearing up for the challenge in the near future where Connected and Automated Vehicles (CAV) will become a larger part of the traffic. Many studies in our review evaluate the potential impact of CAVs on smart city traffic management and suggest potential solutions [13][14]. We are already beginning to see the auto industry integrating AI to improve driver safety, lane adherence, crash avoidance, accident risk prediction while adding features and comfort for the drivers [15][16].

2) Discussion and Proposition

The biggest weapon against the spread of pandemic is limiting contact between people to slow, reduce, and potentially eliminate the spread. Once pandemic has set in, mobility requirements significantly change, commutes and regular travels are cut down, and shopping trips become limited to essentials. The authorities, too, tend to focus more on system-wide outcomes. Simultaneously, the mobility challenge becomes more complex as the capacity of available and safe transit options reduces significantly as safety norms are applied. People tend to favor the public transit options as a safer option even as private players, especially shared services, reduce or limit coverage. There is a need for reliable and accurate information.

Smart city T&M is an invaluable resource for authorities to manage the response to the situation in a dynamic and differential fashion, with flexibility, creativity, and empathy. It enables them to tune the mobility services to the policy and people’s needs. Equipped with integrated information services that provide shared, real-time, integrated, and richer information to travelers and service providers, both public and private, ITS T&M would, on the one hand, improve utilization of mobility assets in service during the pandemic. On the other hand, it would provide the people with rich and accurate information such as the current situation, voluntary actions recommended by authorities, health advice, restrictions, zoning protocols, and available mobility options.

We believe that with some repurposing, the ITS T&M media (applications, portals) can be used to relay reliable information on the nature of the pandemic, precautions, and best practices. An innovative extension can be to use the channels for feedback from the people and understand their issues and challenges.

Integrating the preliminary screening solutions such as digital thermometers and thermal cameras with mobility solutions is a low-cost way to effectively cover large populations. The social norms would support early and quick adoption. Public mobility solutions can host readers for the token devices and relay the same to central applications for real-time alerts and advice.

B. Arterial and Freeway Management

ITS Arterial and Freeway management (A&FM) component enables integrated, and holistic management of the people and freight flows through the interconnected arterial and freeway network.

A&FM helps minimize congestion and its side effects by leveraging integrated monitoring, communication and control technologies to improve safety, direct and modify traffic flows, detect incidents, deploy traffic management strategies and controls, share information with users, and partner with other agencies to remediate disruptions and emergencies.

1) Review

Recent research in A&FM is focused on reducing and managing congestion. In Canada, which has 82% of the population living in urban centers, commuters in Toronto, Montreal, and Vancouver combined are spending more than 10,000 years of extra time stuck in traffic. In the US, the annual congestion cost for an urban commuter is $166 billion [17].

Ramp metering is an important demand management tool for A&FM. It helps to regulate traffic entering the freeway. Advancements in the traditional ramp metering approach are being made. One research provides a solution to distant downstream bottlenecks using linear-quadratic-integral regulators using measurements from a significant distance before the ramp [18]. Artificial intelligence is also being used to replicate human knowledge about the traffic flow problem control strategies. Yang et al. [19] propose a deep reinforcement learning-based ramp metering control framework to reach the optimal control target within a short training time. Another AI approach, using multi-task deep reinforcement learning for adaptive metering without model calibration, is enabling precise adaptive metering [20].

Predicting traffic volumes is another area of active research work; the deep learning approach for lane-based short-term traffic volume prediction at signaled intersections proposes the use of both spatial and temporal features. A combination of the traditional approach with new schemes of variable speed limit implementations is also proving to be effective [21].

Another deep learning approach, reinforcement learning, is being used for traffic optimization. More effective lane allocations can be achieved through coordinated learning-based solutions that enable dynamic configuration of lane directions [22]. Other artificial intelligence-based solutions such as real-time validation of commuters in HOV (High Occupancy Vehicle) lanes improve compliance to the rules deployed for traffic management [23].

2) Discussion and Proposition

Context-based tracking, using the enhanced data from roadside infrastructure and leveraging the same for dynamic decision making, is an essential component of smart city A&FM. We believe that this capability of A&FM coupled with smart city big data and the contact tracing solutions deployed for the pandemic response can prove to be an effective solution.

Communication infrastructure within A&FM, such as dynamic messaging signs (DMS), highway radios, can be easily integrated into the overall response and communication strategy to increase both reach and efficacy of the communication around avoidance, prevention, and treatment solutions available.

A combined approach of containment contact tracing and real-time evaluations using the decision support applications embedded in A&FM can help control the spread of the disease and be an essential tool to protect soft spots such as critical markets ports, and essential public services and facilities. In the event of any incident, the integrated information from tracing solutions can enable A&FM to provide a quick response while minimizing the risk of infections.

C. Freight Management

ITS Freight Management (FM) component enables the flow and delivery of goods and related information through the various transportation modes and networks in a safe, timely, and efficient manner. It makes use of advancements in technology for monitoring, improving, and managing the transportation infrastructure and traffic flows, and providing a seamless exchange of information to facilitate planning and coordination among various stakeholders and agencies.

FM combines artificial intelligence and robotics with solutions for real-time collection and dissemination of detailed information. It enables the application of innovative strategy and solutions to the first mile and last mile challenges, increased demand for urban freight movement as well as congestion around major international trade gateways and hubs, and at major distribution centers.

New challenges, such as increased online shopping adoption during the pandemic, keep evolving and put the focus on the already congested infrastructure.

1) Review

Recent research has pointed to a steep drop in non-essential travel during the current pandemic, especially for shopping. The preference is now for receiving deliveries at home requiring new techniques and solutions to enable smooth movement of the additional freight traffic through urban locations. Using community resources for combining last mile and first mile has gained attention, and improvements in crowd logistics, crowdsourcing, and peer-to-peer platforms are being looked at for efficient management of Freight Loading Zones [24][25]. Utilizing new technologies, research links driver's state and efficiency with vehicle route planning for improving safety.

As governments and communities become sensitive to transportation's environmental impact, there is increasing scrutiny on the modes of freight movement from that aspect. Trucks being the single largest contributor to freight-related air pollution [17], researchers suggest improving intermodal mix and shifting freight to more efficient rail or water modes through the incentives [26]. Artificial intelligence is also enabling appropriate allocation of charges and fees among the users of transport infrastructure [27].

2) Discussion and Proposition

Smart city ITS ensures that a finely tuned chain of stakeholders, authorities, and participants, including transportation operators, can manage and recover from disruptive shocks such as a pandemic. In smart cities, ITS FM leverages rich real-time data for analytics and AI to provide an appropriate signal to authorities for managing congestion. Many features of these solutions, such as predicting the availability of parking, dynamic rerouting of trucks, and coordination of freight movement within cities, are extremely useful to freight operators. Other solutions from FM enable innovation and efficiency by real-time matching of shippers with truckers, coordinating and enabling automated deliveries, improving flows through ports, and easing border crossings.

During the pandemic, there is a significant disruption of supply chains, causing shortages of not just much needed medical supplies at hospitals and pharmacies but also of essential food items and goods for individuals. The vulnerable population is at most risk from such disruptions. Leveraging smart city ITS FM and coordinating with authorities to streamline national and state approvals, prioritize flow, and last-mile delivery can cut down shortage induced distress.

For authorities, adopting dynamic and differential stance and zoning approaches, ITS FM communication and control infrastructure can be used to allow adjustment in logistics from suppliers as well as to ensure a high level of compliance by the logistics providers. During the pandemic, consumers prefer home deliveries, and ITS FM can help suppliers consolidate, streamline and coordinate deliveries to ensure minimal exposure and enable strict adherence to zonal controls. Depending on the situation and availability, this process can be further extended to integrate autonomous delivery robots and drones.

D. Emergency and Incident Management

ITS Emergency and Incident Management (E&IM) integrates the solutions for early and automatic detection, quick identification, effective isolation and evacuation, and coordinated multi-disciplinary management of emergency situations. With ITS E&IM, the speed of response is vastly improved, which in turn minimizes the primary and secondary losses and exposure and enables early restoration of services and return to normalcy.

ITS E&IM solutions help to detect disruptions, reduce incidents, and restore traffic capacity as safely and quickly as possible while reducing the possibility of secondary crashes [28].

1) Review

ITS E&IM enables the coming together of multiple agencies and stakeholders. Therefore, timely, accurate and detailed information sharing among agencies is essential for its effectiveness.

The delay caused by an incident is strongly correlated to the time required to verify a given incident [29]. For emergency situations, visual verification, surveillance, and monitoring become crucial. These, when coupled with advanced and traditional communication means such as electronic messages, signs, and highway advisory radios, enable effective sharing of information. New techniques are being used for early identification and prediction using the available information and past experiences. Enhancing the data by combining heterogeneous urban data, Yuan [30] proposed a methodology for predicting traffic accidents. Another research proposed a technique for using a state-space model [31].

AI and deep learning tools have further enabled extracting more patterns in the data. Biocchi et al. recommend using Vehicular Ad-Hoc Networks sampling protocols for traffic monitoring for incident detection [32]. Related research aims to automate incident detection by combining video and other data. The use of floating data collected by probe vehicles and passive data collected from smartphones via machine learning algorithms is proposed by Asakura et al. [33]. To enable emergency teams to reach the site much faster, a new traffic signal scheme has been proposed [34].

2) Discussion and Proposition

In the time of the pandemic, the incident response process becomes more complex as new equipment and protocols are necessary to prevent exposure to the response team. By integrating the contact tracking and testing data with their ITS E&IM, smart cities can cut the delays and minimize exposure events while handling incidents.

ITS E&IM helps to improve the level of information provided to health caregivers, transportation, and emergency managers during emergencies and incidents. The availability of richer data sources coupled with information on the level and potential for pandemic exposure, enables coordination and combining of resources even more effectively and, thus, reducing the cost and time of the response.

We have seen that the front-line staff, such as police and sanitation workers, are at most risk of exposure. Resources available with ITS E&IM, such as Unmanned Aerial Vehicles (UAVs) can be repurposed by authorities, in the containment and buffer zones, for monitoring protocol adherence such as quarantine and isolation, thermal scanning, alerts, communication and can even be extended to spray disinfectants.

IV. ITS SERVICE APPLICATIONS

ITS is a dynamic solution to an evolving smart city ecosystem. The proactive stance of ITS is enabled by the integrated set of applications that collectively address the different dimensions of tasks placed on transportation systems by the smart city authorities. In this section, we feature select applications or user-oriented solutions for each of the components discussed in the previous section. While we discuss these solutions and applications as a feature of the components to facilitate understanding, we believe ITS components and different applications should not be considered as separate and distinct elements, but as an integral element of all types of solutions to transportation issues, including the pandemic challenges.

A. Transit and Mobility Applications

Transit and mobility applications in smart cities aim to integrate public and private solutions to urban mobility challenges, expand choice sets, simplify ridesharing and multimodal coordination, enable dynamic planning and selection, provide guidance, and provide seamless trip management and payment experience to the commuter population based on their needs.

To enhance user experience and utility, the mobility applications are increasingly integrating other smart city services such as traffic information, weather updates, and parking availability. By combining transit signal priority and transit operation applications, automated vehicle location, computer-aided dispatch, automatic passenger counters, and fleet management, the smart city transit and mobility applications also contribute to improving effectiveness in transit demand and supply management [35]. As the dynamics of supply chain and demand frequently change during the pandemic, through these applications, transit management can prioritize (or provide exclusive fleet) the essential workers, peak-time commuters, and specific population (seniors).

Improvements in the transit experience are expected to lead to a cleaner environment, increases in the use of public transit, and mobility for all [10]. This can help in creating a commuting bubble for the long, uncertain pandemic period.

Integrated mobility in smart cities will be further supported by Advanced Traveler Information Services. During the pandemic, commutes, especially the essential workers, can rely on this system for scheduling while avoiding containment/buffer zones. This can also benefit travelers by matching the government's peak-time management policy (office and school commuters) during the pandemic.

B. *Arterial and Freeway Applications*

Traffic detection, identification, and tracking is a major focus area for arterial and freeway applications. These applications integrate the data feeds coming in from the vehicle detectors, sensors, traffic probes, and cameras with network surveillance and traffic detection layer to provide rich information to the integrated network of Traffic Management Centers (TMC). When integrated with contact tracking and tracing solutions, these applications can help authorities identify, isolate, and contain pandemic vectors.

TMCs, in turn, are enabled by the traffic management solutions such as smart signals ramp metering, dynamic, reversible, and HOV lane management and variable speed limits that reduce congestion, enable effective use of capacity and help minimize wait times [36]. Smart city authorities can leverage these applications to prioritize response, containment, and emergency supply traffic.

Automated enforcement applications such as in-vehicle systems for speed warning and lane enforcement can be leveraged for quarantine and zone controls. Information dissemination solutions like DMS, highway advisory radio can help increase both reach and efficacy of communications around avoidance, prevention, and treatment solutions available.

C. *Freight Management Applications*

ITS Freight Management solutions improve delivery performance and reliability while making freight operations safer and more economical. By digitizing the information flow, these solutions enable seamless movement at potential bottlenecks.

Freight network planning and management benefit from visibility through integrated GPS and other solutions for remote monitoring of in-transit freight as well as integrated traffic information sourced from public and private applications. Consumers having better control over the information to the goods flow are better placed to make tradeoffs in favor of environmentally sustainable modes and product packaging. This supply chain visibility is crucial during the pandemic for planning, such as when and where to end quarantine based on the present and future availability of the medical supplies.

Freight operators leverage FM solutions for dynamic operations planning. An integrated operations platform with visibility to carrier status enables operators to offer features such as flexible pricing for just in time delivery space booking.

Challenges from increasing complexities of last mile and first mile urban freight transit, delivery, and coordination with authorities are more efficiently handled in smart cities as authorities and operators can come together for a coordinated movement of freight through major traffic bottlenecks and advance booking of parking spaces.

Increasingly freight operators leverage FM solutions coupled with smart city multimodal mobility choices for consolidation of inward freight movement and disaggregation closer to delivery locations. The inward movement of essential goods and kits to quarantined individuals and facilities, and outward movement from production facilities located in containment zones, can be managed using this approach.

To control congestion and timely handling of the priority medical supplies, smart cities will look at minimizing dry runs and wasted miles, as well as spreading out truck arrivals at intermodal terminals throughout the day through next generation drayage optimization applications that combine container load matching and freight information exchange systems [37].

D. *Emergency and Incident Management Applications*

E&IM applications support early event detection, flexible multi-channel communication, joint response, and evacuation planning with various agencies.

By incorporating information from the latest drone-mounted solutions, E&IM applications improve the range and sensitivity of detection platforms, which in turn helps improve the speed of delivery of first response while minimizing human exposure [38].

Roadway service patrol support systems, early warning systems, and infrastructure monitoring systems enable early identification of emergency situations. Wide area alert applications provide support for mayday and alarms, emergency call taking, and identification and delivery of first response [38]. Here, when coordinated with the contact tracking and testing data, smart cities can reduce the delay and, thus, minimize the exposure while handling pandemic incidents.

Smart city E&IM applications also provide a framework and a flexible multi-mode, interoperable system, including a bridge between commercial and government agencies, that allows various agencies to communicate on a uniform, base platform. Emergency route guidance applications integrated with information on location, nature, and characteristics of vulnerable populations help smart cities support people with special needs during emergency situations such as a pandemic. E&IM communication platform enables the development of coordinated response strategies for evacuation, relocation, and, if necessary, rehabilitation of people from care homes and special needs facilities. Transit signal priority, and emergency vehicle preemption applications help speed passage of emergency or transit vehicles.

V. SMART TO SMARTER

Many authorities, even within smart cities, have traditionally approached pandemic as public health emergency only and have focused their attention on hospitals, medical supplies, and health care personnel. We believe that this approach though necessary misses the big picture.

We see smarter cities taking the lead in re-envisioning their charter to include responsibility towards protecting their people and businesses from social and economic shocks induced by the pandemic. Such re-envisioning should result in redrawing of smart city's continuity and disaster recovery plans in coordination with the businesses and communities, possibly at much granular levels than today.

To move towards this new vision, smart cities would need to prioritize investment in integrating their information backbone with the technical solutions that have emerged in response to the pandemic. It is here we believe that the technical and knowledge infrastructure already existing for smart city ITS, as discussed in this paper, can prove to be a great asset and help minimize additional investments needed for the new scope. A smart city approach to become smarter should be to leverage what we have and integrate well.

SC-ITS's integration into planning vision of smart cities as a necessary component of the solution to the pandemic will bring focus and encourage necessary cooperation, coordination, and consensus-building needed to address conflicting technology choices, such as 5G vs DSRC, that have stalled further investments and development of ITS.

A key challenge is ensuring cybersecurity for smart city's digital infrastructure, including the ITS. As businesses, people and governments adopt more digital options, the possibility and potential impact of cyberattacks have multiplied. The latest research suggests that smart city and ITS applications, including ones used for contact tracing, and sensor or the IoT layer of infrastructure, are vulnerable to privacy and security threats. We believe a widely adopted, comprehensive, and implementable cybersecurity framework is necessary before we see pervasive benefits of the smart city's ITS both during the pandemic and after.

VI. CONCLUSION

Regardless of the level of awareness, planning, and preparation, the authorities, businesses, and people have a steep learning curve for adapting and responding to the social, economic and medical challenges of the pandemic. For the authorities, there is an additional challenge of identifying, gaining, and deploying resources to handle the multifaceted challenges on the one hand and, on the other hand, select a response approach and stance to balance lives and livelihoods at stake.

The requirement that selected approaches and pandemic response strategies place on smart cities is that of the ability to deliver and amplify communication, collect information, and dynamically adjust response by moving people and resources in response to the situation. Something that is at the core of the ITS in smart cities.

As we have presented in the paper, smart cities have, in their ITS, access to the muscle of well-coordinated transportation services and the knowledge through AI and big data-enabled integrated information backbone. The ITS systems and processes are people-centric, have access to rich data, provide multiple communication avenues, and are dynamically responsive. Leveraging ITS people, processes, technology, and systems are relatively easy, and by taking the next step of integrating the contact tracking and tracing technologies, the smart city can have a rich understanding of evolving challenges and ensure effective coordination of the response plans.

We see smart cities becoming smarter and setting an example for others by holistically planning for and addressing the health, economic and social questions posed by the pandemic.

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