Chapter 10: Data and Technology

Chapter Purpose

Transportation is on the verge of a series of profound changes, many of these changes are being led by technological advancements in the areas of infrastructure management, system integration and data aggregation. As technology continue to evolve, the City of Norfolk aims to be at the forefront of understanding and anticipating the potential impact of new technologies on their transportation systems and the larger urban environment.

A significant part of the development of the Multimodal Norfolk Transportation Master Plan is being able to provide recommendations related to leading-edge innovations and emerging technology trends in the transportation industry.

In regard to recent technological improvement efforts, the City of Norfolk is currently in the process of upgrading its traffic signal system to a centralized Advanced Traffic Management System (ATMS). Using ATMS, traffic signals are connected to a central Traffic Management Center (TMC) by fiber optic and wireless networks. The use of ATMS would allow for improved vehicle detection capabilities, use of thermal imaging cameras and in-road magnetometers to report back to the TMC.

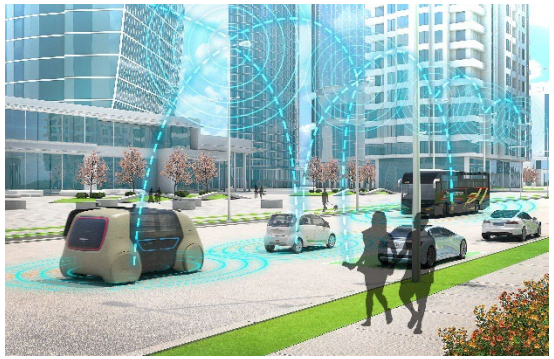
The City of Norfolk is also in the process of installing closed-circuit television (CCTV) cameras, which will allow for the monitoring of traffic conditions in real-time within the TMC. These current investments by the City are paving the way for other potential technological solutions, which can support efforts to continue to create a more efficient, sustainable and safe transportation experience for users.

Due to the constantly changing nature of technology, the purpose of this chapter is to provide general guidance and insights related to applicable types of technological solutions that align with the vision, goals and objectives of Multimodal Norfolk, as well as provide relevant technology use cases and case studies.

The recommendations provided serve as potential technological solutions for the City of Norfolk. They are deemed exploratory and a starting point for further in-depth evaluation and study prior to deciding if, how, when and where these technologies are implemented and integrated with existing systems.

This chapter provides a detailed framework for the evaluation of technology solutions, from preliminary scoping to the development of a Concept of Operations (CONOPS). Industry trends related to infrastructure management, system integration and data aggregation are provided as major considerations that impact the evaluation process. Overviews of each of the three technology areas are given including examples of technology providers in the market, specific use cases for the City of Norfolk, as well as case studies from other jurisdictions.

This chapter then concludes with a summary of major findings for technology solutions, as well as critical next steps once CONOPS for a proposed technology solution has been drafted and approved.



Emerging technologies such as Connected Vehicles and Automated Vehicles (CV/AV) will generate new opportunities to collect and analyze data to optimize transportation

Overview

Technology is an important tool leveraged by cities to address the current and future needs of transportation systems. The use of technology allows for the exponential increase in efficiency when conducting tasks (which without technology would normally take longer to complete), from inventorying assets in the field to analyzing the change in condition of assets overtime. However, the main issue is the associated risks and costs when adopting new technology. The risks vary based on the appetite for technology adoption – from those who are technology innovators (being the first to adopt) to those who are technology laggards (being the last to adopt).

Technology innovators are defined as risk takers with access to resources and the motivation to be first to try something new despite a higher probability of failure. Early adopters are defined as individuals who are excited about possibilities new technology and make decisions based on reducing uncertainty when adopting new technology. Early majority users are defined by making technology adoption decisions on having a thorough understanding of the impact of the technology. Late majority users are defined by making technology adoption decisions based on the increase presence and prevalence of technology. Lastly, technology laggards are defined as being

traditionalists who make decisions based on past experience and positive experience of others. The decision making of laggards is also partially driven by having limited economic resources to experiment or test unproven ideas.

For City of Norfolk decision makers and stakeholders, they will fall across the spectrum for technology adoption. These sensitivities towards technology adoption may also translate to the overall organizational culture. The key is to have an established framework for the evaluation of technology solutions that is informed by evidence. This can help to address the concerns of the different types of technology adopters. The framework proposed emphasizes on the systemic and iterative nature of the technology evaluation process, where new information can reshape each step. For the technology evaluation framework, the steps are as follows:

1. Preliminary Scoping
2. Refined Scoping with Stakeholders
3. Determine Potential Technology Requirements
4. Perform Market Research
5. Conduct Scenario and Impact Analysis
6. Develop Draft High-level Concept of Operations

Preliminary Scoping

The preliminary scoping process is the initial step of the technology evaluation framework and typically led by a small but key group of staff, internal to organization, who will be responsible for the overall management of the process including determining timeline, schedule and milestones for outcomes. This first step of the framework involves defining high-level objectives in considering a new technology solution.

During the initiation phase of technology evaluation framework, the aim is to develop the basis for the business case or justification of technology solution, general description of the elements of technology solution, anticipated outcomes of implementation, as well as assumptions and limitations as it relates to the technology. In addition, the preliminary scoping process includes analyzing existing

processes and workflows within the organization that would be directly impacted by technology solution.

Refined Scoping with Stakeholders

After the preliminary scoping is conducted, it can be presented to a larger group of stakeholders for further refinement. This process includes solicitating feedback and input of individuals internal and external to the organization that will be end-users of technology solution or have a vested interest, influence or importance to the implementation process. These stakeholders can include executive leadership, contracting or procurement staff and operations personnel who can provide insight on constraints and risks related to adoption of new technology from the prospective of their defined roles.

Determine Potential Technology Requirements

With technology solution scoped and business case defined, the next step is to determine potential technology and technical requirements needed for successful implementation. The main focus is transitioning from the general to more specific requirements, such as identifying and listing specialized hardware, software or equipment required. The increased involvement of IT staff and end-users is critical to this step's success.

A critical aspect of technology development and application is scope definition through consultation with key stakeholders to determine the characteristics of the minimum viable product.

Part of this step also includes distinguishing between functional requirements and non-functional requirements. Functional requirements being the elements of the technology solution that result in a minimum viable product (MVP), or version of product with just the sufficient elements to be usable, whereas non-functional requirements are elements of the technology solution that are not immediate or essential to result in a usable product. These non-functional requirements are deemed to be amenity features or capabilities that can be incorporated as part of future iterations.

Perform Market Research

Market research is a key part of the technology evaluation framework. It helps to provide an increased understanding of technology offerings, current and underdevelopment, within the industry. Market research can also aid in garnering insights from other organizations that have explored or adopted similar technology solutions being evaluated. As such, this step involves interacting with technology vendors and their customers via surveys, interviews and focus groups to learn more about the variety service offerings available on the market and associated user experiences.

This process can be as formal or informal as needed, from issuing Request for Information (RFI) through contracting and procurement office to scheduling webinar or requesting demo version(s) of technology. In addition, it is important to note that this can be a complex step and become outdated quickly as vendors frequently enter and exit the market along with vendors continually enhancing their technology solutions.

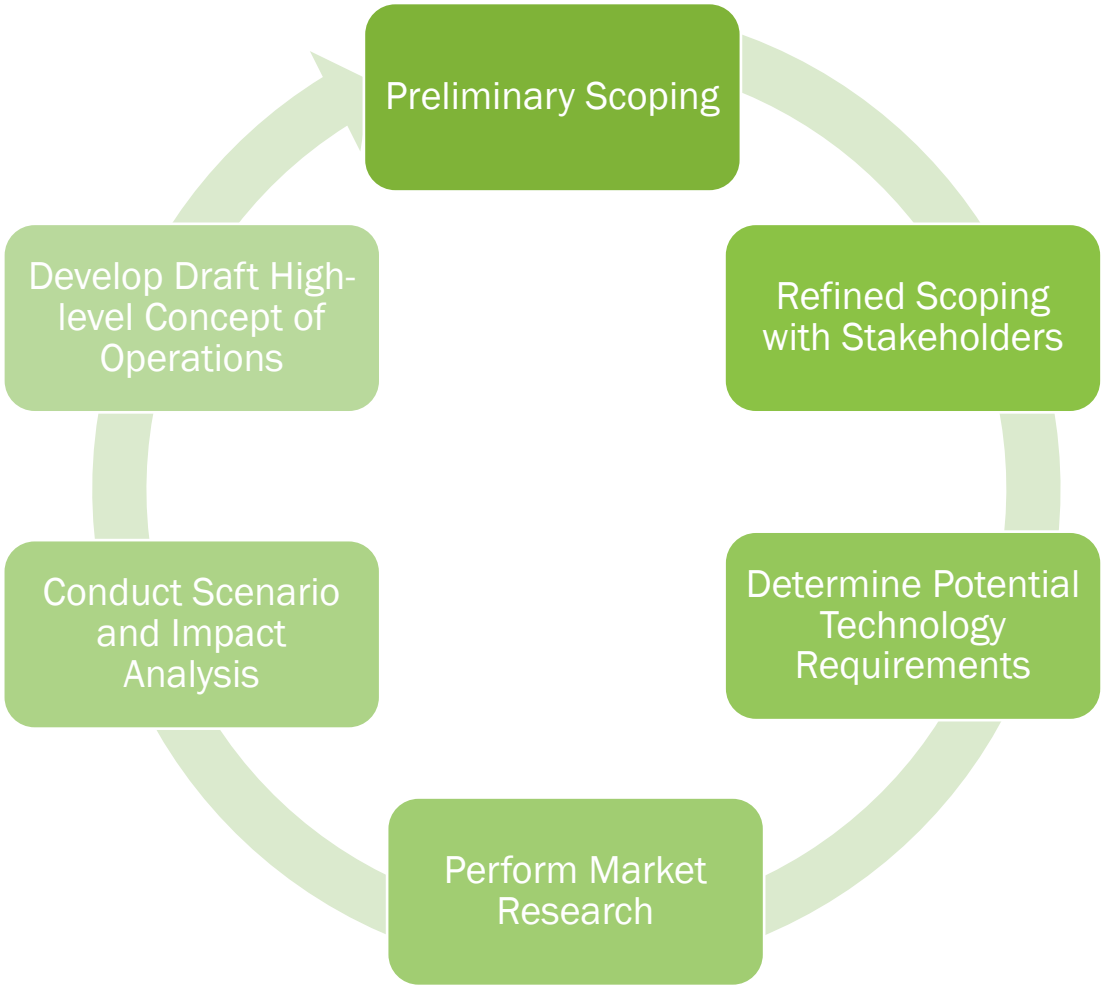
Conduct Scenario Analysis

While market research can inform how technology solutions have been implemented in previous cases or contexts, the observed outcomes from these previous cases may not necessarily

correlate to the potential outcomes for the defined business case under consideration. As such, conducting scenario analysis or using a scenario planning tool to analyze a specific technology adoption can provide a series of potential outcomes to evaluate. These outcomes can help manage risk associated with investing in new technology including likely scenarios and worse-case scenarios. Specifically, outcomes are compared to each other based on impact to resources, finances, operations and other relevant performance measures. Outcomes can include the impact of technology on traffic conditions or decision making as it relates planning construction projects.

Develop Draft High-Level Concept of Operations

Concept of Operations (CONOPS) is the intended end product when applying technology evaluation framework. Based on the work conducted in the previous steps, a CONOPS is developed which can be both a written and graphical document capturing the proposed technology solution's characteristics from the perspective of an end user of the technology solution. The CONOPS considers goals of the technology solution, polices and constraints impacting the implementation of technology solution, associated organizations, and activities of participating stakeholders, and lastly, roles and responsibilities of stakeholders. Overall, the CONOPS describes the intended users, uses and conditions for use of technology solution. It is in turn used as an input for the identification, development and procurement of the technology solution and assessing its ability to meet specified functional requirements.



Overall, the application of the technology evaluation framework is an iterative process. As more information is collected in each of the steps (from engaging with stakeholders to conducting market research), the more refined the CONOPS

and the ability to successfully identify and obtain the desired technology solution.

As part of the City of Norfolk's efforts to explore technological advancements in the areas of infrastructure management, system integration and data aggregation, initial findings that are provided in the subsequent sections can inform further in-depth evaluation of technology solutions.

Privacy Considerations

There is concern about privacy and surveillance with the Smart City applications. For instance, in Toronto a plan to create a highly connected neighborhood was canceled because of lawsuits claiming that the plan violated Canadian citizen's rights.[i] The use of video monitoring, remote sensing, and other data collection efforts to optimize the use and management of the infrastructure can also have unintended consequences if there is no clear plan on how and how long the data will be collected, used, stored and disposed of. Also, the security of the data needs to be considered to protect Norfolk's residents from potential hacks, Robust privacy policies, data use and cyber security policies and data openness will be necessary to overcome them.

Technology Procurement Strategies

For any technology solution related to infrastructure management, system integration or data aggregation, different procurement strategies can be considered along with the steps outlined within the technology evaluation framework. Whether the technology solution is developed in-house, vendor supported via custom solution or commercial off-the-shelf (COTS) product, each option has advantages and disadvantages that must be considered in terms of achieving the desired technical functionality and requirements.

Procurement Strategy	Considerations
In-House Developed Solution	• High degree of flexibility • Requires additional time and resources of City of Norfolk staff; may impact existing workflows • Retain ownership of system and intellectual property rights • High costs and extended timeline • Ability to sell product to other jurisdictions and agencies
Vendor Supported Custom Solution	• High degree of flexibility • Efforts led by vendor with the guidance from City of Norfolk • Ability to retain ownership of system and intellectual property rights • Medium costs and shorter timeline • Ability to sell product to other jurisdictions and agencies
Commercial off-the-shelf (COTS) Solution	• Least degree of flexibility • Limited ownership of system and intellectual property rights • Lower costs and quicker timeline • May not meet technical functionality and requirements for City of Norfolk • Likely high additional cost for any add-on functionality outside of COTS product

In addition, the identification, procurement and implementation of technology solutions should emphasize sustainability and resiliency. Sustainable delivery of the technology refers to the technology resulting in limited economical, ecological and societal impacts. Resilient technology refers to the technology being adaptable to disruptions, as well as changes in business case requirements. The use of open platforms that are able to accommodate third party applications will make this approach resilient and able to adapt to rapidly changing technology.

Industry Trends

While asset management for infrastructure or asset management as a concept has been around for some time, in recent years there has been an increase in leveraging technology to improve asset management operations and procedures. Using technology and data-driven processes, cities with critical transportation infrastructure have been able to develop, operate, maintain, upgrade and dispose of their assets in a more cost-effective way.

Specifically, infrastructure management trends have focused on extending the life cycle of existing facilities by using automated monitoring and sensor technology, as well as applying artificial intelligence (AI), machine learning, and business intelligence applications and tools. Used in combination, these technologies allow for the development of dynamic Decision Support Systems (DSS) and Enterprise Asset Management Systems (EAMS), which provide decision makers with the ability to make informed strategic planning and infrastructure investment choices. With constraints related to limited funding and resources, technology has been used as a stopgap by cities to address issues related to maintaining increasingly degrading infrastructure. It has also allowed for the maintenance of infrastructure while limiting disruptions to service.

In terms of system integration, industry trends emphasize the significance of the interdependences between connected infrastructure systems. To manage assets effectively, it is not only important for the people responsible for infrastructure management to communicate, but also those responsible for the physical systems to communicate with one another as well.

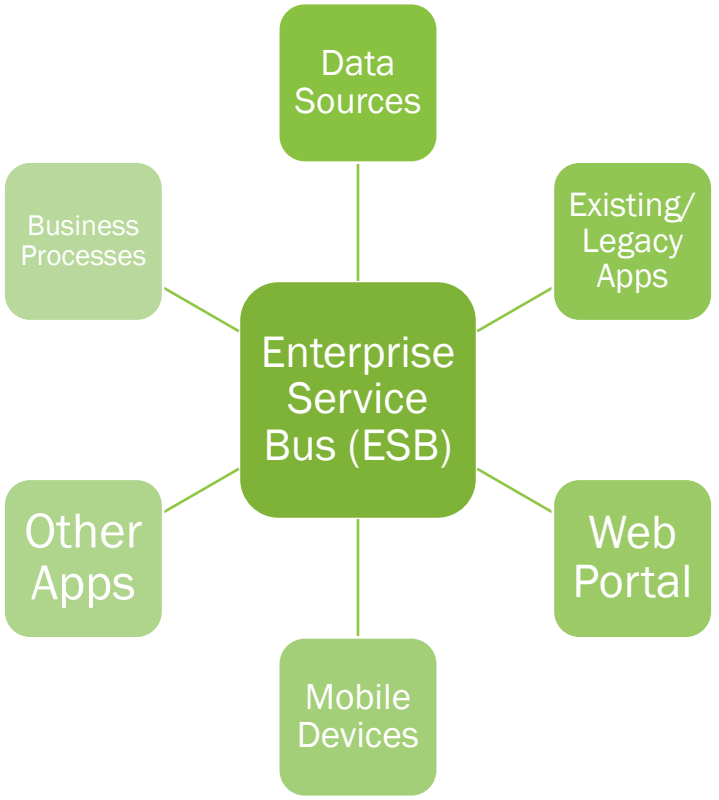
Roadways are a prime example of an asset physically located in the same right-of-way as other infrastructure, such as water mains, stormwater and wastewater systems, telecommunication and electrical lines and natural gas service. A scheduled repair or failure of the roadway can have a cascading effect on these connected systems. As such, being able to communicate impacts to the roadway in near real-time is key to the operation of the larger transportation network as well as these other connected systems. With an increased flow of information, operational costs can be reduced as well as the downtime of systems while they are undergoing maintenance or repair.

Disruptions to the transportation system can be mitigated using active traffic and congestion management tools based on open platforms that ingest various streams of data and take third party application. Integrating existing information and data systems such as the Norfolk Police Department's Computer-Aided Dispatch system and roadway cameras of critical intersections and throughputs allow for the proactive management of local traffic congestion. The mobilization of traffic enforcement officers, deployment of traffic control measures such as barriers and Variable Message Signs (VMS), as well as the broadcasting of alerts on advisory radio channels in response to incidents can be done more efficiently with system integration. During non-emergency situations, increased information sharing also aids in coordinating everyday workflows. For example, system integration can help to avoid the situation where a roadway surface is repaved before the required replacement of a water main underneath.

System integration allows for increased transparency and information sharing. However, effective system integration is dependent on the accuracy of the information shared. Data aggregation allows for the compiling information from disaggregate databases with the intent of combining those databases for processing. The industry trend has been the increased use of data aggregator software and tools to conduct predictive analytics and identify outliers and trends within the data in near real-time. The results of data aggregation can serve as an input for Decision Support Systems, which are used to manage infrastructure systems. However, data aggregation can result in the discarding of

valuable information that may be necessary for other applications. In addition, there are cost and efficiency considerations to account for related to the collection, transmission, storage and retrieval of data, as well as data security and ownership concerns. As such, the specific algorithms or methodology used for aggregating different datasets is based on business case requirements, as well as size, frequency and other characteristics of the datasets.

Infrastructure management can be enhanced by integrating across different systems. Each system communicates with one another or communicates to a central system, such as an Enterprise Service Bus (ESB), to provide a holistic overview of the larger connected network of infrastructure. The integration of each individual system involves the appropriate data aggregation methodology being applied to meet scoped business case.



Infrastructure Management

The City of Norfolk is responsible for the provision of transportation services to its residents. These services rely on infrastructure and include sidewalks, streets, lighting, sewerage, bus stops and shelters, signage, fiber among others.

The Department of Information Technology provides the support framework for customer-focused services. Its three focus areas are providing enterprise-wide technology support and solutions to enhance efficiency, strengthening cybersecurity, and powering data-informed decision-making.

One of the department initiatives is the **Smart City Plan or Smart Norfolk** which seeks to:

1) create a digitally connected public and infrastructure;
2) develop new business opportunities to drive growth;
3) encourage tech-savvy individuals to make Norfolk their home;
4) lead to greater efficiency and productivity; and
5) offer a higher quality of life for residents.

The Department of Transit through its Transportation Engineering division is responsible for the **Traffic Operations Center and Traffic Management Center** that operate and maintain the traffic signal and traffic management systems, maintain all street signs and pavement markings (including 312 traffic signals, 120 school and pedestrian crossing signals, 22 continuous and activated flashers, over 31,000 streetlights, 700 miles of traffic lane lines and 813 crosswalk locations) and assist with special events.

The Parking Division under the General Services Department operates over 19,000 public parking spaces located in 14 garages, 10 lots and more than 500 on-street spaces.[ii] To facilitate parking, the city has launched **ParkNorfolk Mobile Pay** to pay with credit card, extend parking sessions, and access discounted parking. Other organizations that require information on the conditions and status of the infrastructure in Norfolk include the Emergency Preparedness and Response, Office of Resilience, Public Works, Utilities, Norfolk Data and City Planning.

To manage their infrastructure effectively, cities rely on system integration and data aggregation to support infrastructure management. Each infrastructure element has systems that were created to facilitate its operation, monitoring and management. These applications tend to be proprietary and specific to a technology that over time may not be as responsive as needed.

Smart Cities

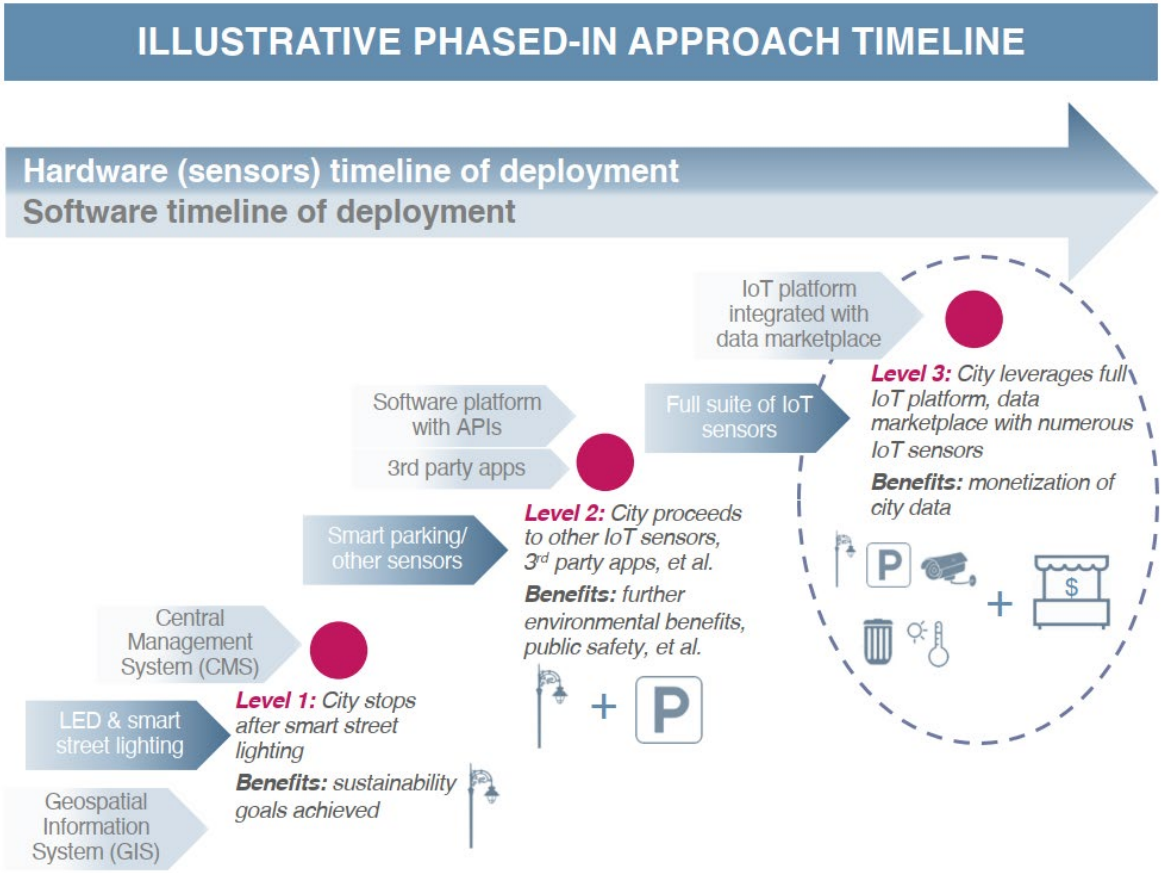
Smart Cities are defined as areas where technology applications (communicating devices and sensors) provide direct benefits to the city and provide data points that can be used in the future. This technology application provides clear financial (cost reduction), environmental (reduce consumption and increase efficiency), and health & safety benefits (real time information, faster response to incidents).

Applications can include:

- Street Lighting,
- Smart Parking,
- Video Monitoring,
- Air Quality Monitoring,
- Public EV Charging,
- Smart Waste Bins, and
- Open Data Apps among others.

Internet of things (IoT) platforms include unified dashboards, open standards for devices, analytics and "as-a-service" models that allow for new devices, services, and applications to be added with minimal additional cost.[iii]

The image to the right is an illustrative phased-in approach to exemplify a potential application implementation.



Source: IoT Software and Platforms (2020). Northeast Group, LLC and Signify

Electric Vehicle Charging Stations and SMART Streetlights

Smart City Solutions for Norfolk can include **Electric vehicle charging stations** for both commercial (fleet and public service) and residential applications (for example - ChargePoint+).

For **residential applications**, an EV Charging Station Program will be needed to guide the permitting and installation of EV chargers in house garages, private parking lots and curb spaces that meet the permitting office and the department of transportation requirements (including determining appropriate location, and if on public space, ensure that there is sufficient parking availability, and permanent underground conduit installation).

There are several companies that offer these chargers for Level 1 (120 volt) or Level 2 (240 volt) applications. Level 2, 240-volt EV charging stations charges any EV up to 9 times faster than normal wall outlet.

For **commercial applications**, there are Level 2 and Level 3 (DC Fast) chargers can be deployed by private companies. These companies offer LCD screen, single or double chargers, support services such as configuration and activation, maintenance, and management services plus ability to see available chargers and pay through a service app.

The City of Norfolk has several contracting options to offer charging:

1) charging-as-a-service (similar to any other utility, with no CAPEX and only pay for its use),
2) purchase the chargers and offer the service itself with management and maintenance service contracts, or
3) develop and deliver all aspects itself.

The implementation of the charging stations would require coordination with the Permitting Department to create a process to guide design and construction, and review applications for commercial purposes.

Company: -ChargePoint+

Established: 2007

Headquarters: California, USA

Technology: Electric Vehicle (EV) charging stations (residential and commercial)

Website: www.chargepoint.com

Residential Electric Vehicle Charger (ChargePoint +)

Commercial Electric Vehicle Charger (ChargePoint +)

SMART GRID enabled LED streetlight applications aim at reducing energy costs and increase efficiency on its service provisions (companies include Interact City (Signify) and OSRAM). The system is anchored by software applications that manage the connected lighting systems and the data these systems collect. The system also conducts asset management through monitoring of function, energy consumption and performance. It also allows the energy optimization through dimming, scheduling (time of day, season, or event) and zoning (plazas, parks) of the lighting based on traffic and pedestrian use. An additional benefit includes the potential of incident detection as the lampposts uses sensors to monitor traffic, sounds and crowd noise. The applications consolidate the operation and information collected on dashboards and offer APIs.

An example of the benefits of implementing Smart Lighting is the City of Guadalajara in Spain where 13,500 connected LED light points and 187 cabinets controlled by Interact City software were installed as part of an upgrade to improve the efficiency in city lighting (see box to the top right). Lighting accounted for nearly 50% of the energy consumption of the city. The smart lighting program was able to reduce energy consumption by 68%, eliminated 4,200 tons of CO2 emissions annually. It has also improved the service to citizens with a reduction in failure complaints to less than 1% per year with its increased to safety. The lighting management software monitors performance, energy consumption and fault detection.[iv]

Another example of the potential of Smart Lighting comes from AMS-OSRAM in Switzerland where the city of Biberstein, as part of an extensive renovation project, replaced their luminaries with LED luminaries equipped with an interface for communication and sensing (see box to the right). The luminaries were placed on roads, paths and places to be illuminated efficiently and economically. One of the benefits of this application is the control over the intensity of the luminaries. To reduce light pollution, the luminaries are dimmed if there are no pedestrians and as soon as a pedestrian enters the path, the lighting comes on completely.[v]

Company: Interact City (Signify)

Established: 1891

Headquarters: Netherlands

Technology: Connected lighting software, lighting, IoT

Website: www.interact-lighting.com/global

Company: AMS-OSRAM

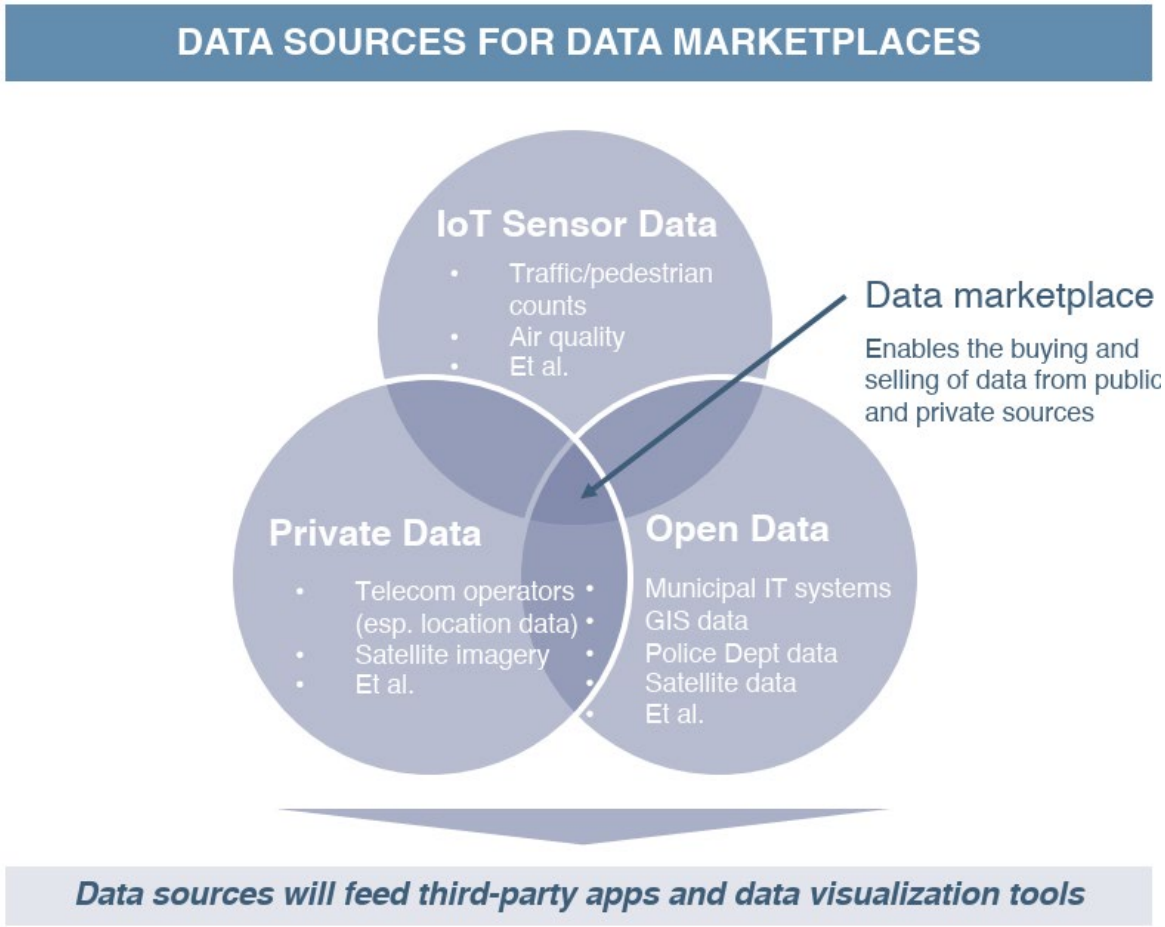
Established: 1906

Headquarters: Munich, Germany

Technology: Sensing, Illumination and Visualization

Website: www.osram.com/cb/

The image below shows the various data sources and potential data marketplaces.



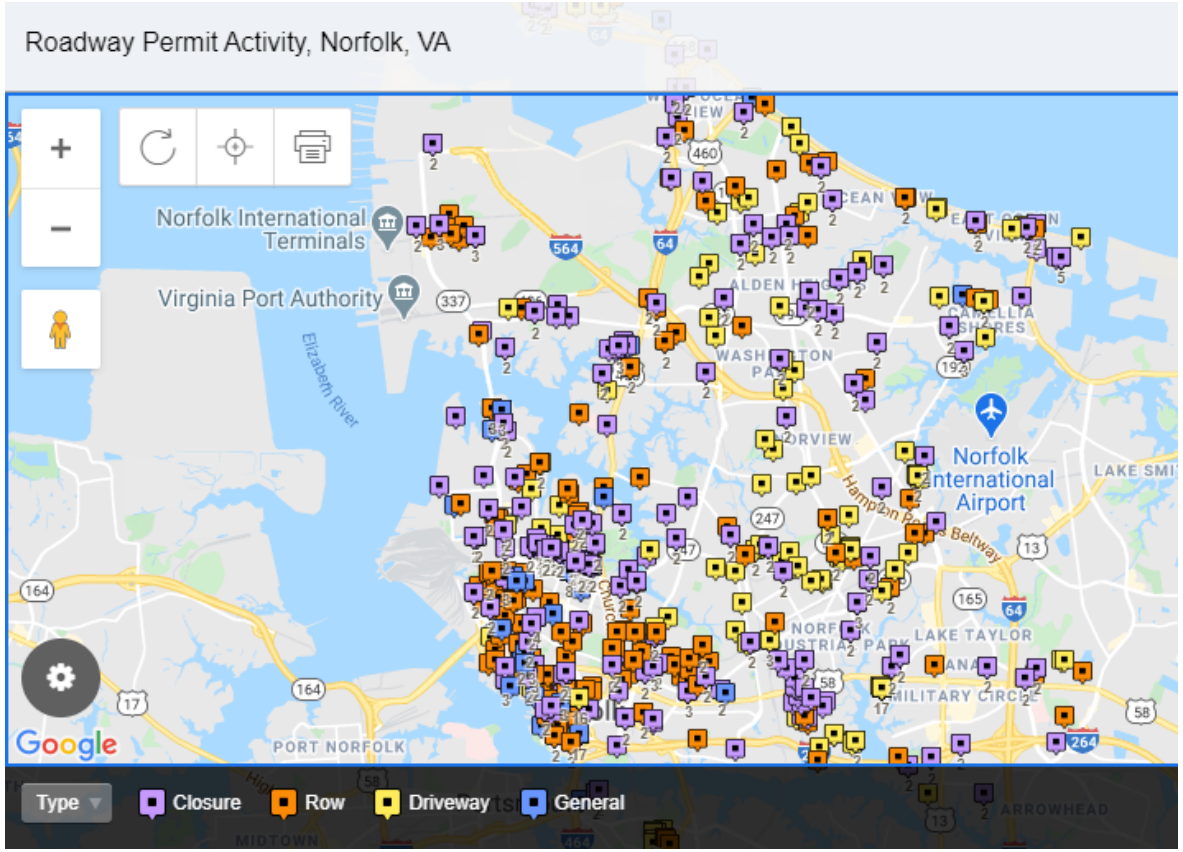
Source: IoT Software and Platforms (2020). Northeast Group, LLC and Signify

System Integration

Technology related to system integration can be leveraged to more effectively manage connected infrastructure systems.

The City of Norfolk Department of Transit is responsible for planning, developing, and maintaining a multi-modal transportation system that supports all modes of transportation. There are inherent interdependences between each of the transportation options made available to users. For instance, many share the same right of way.

The Division of Right of Way Management within the Department of Public Works coordinates, permits, and inspects construction and other activity within the roadways and serves as the liaison to developers, contractors, and private utility companies. It currently provides a GIS-based report of road and lane closures for the City, which includes the street address, X and Y coordinates, applicant, type, and start and end date of permits issued. It is powered by BatchGeo, a technology provider that allows for the copying of data, validating data and setting options for display, and mapping of locations. The information collected and visualized via BatchGeo is critical for coordinating work with other agencies, such as other divisions within the Department of Public Works that maintain physical facilities, and the



Department of Emergency Preparedness and Response when responding to incidents.

In addition, the lane closure application can be leveraged by the City of Norfolk Department of Transit's Traffic Operations Center and TMC systems for managing congestion on the roadway, including integrating with other systems tracking special events and special traffic advisories. BatchGeo is an example of technology that the City of Norfolk can use to support system integration efforts.

As the City continues to identify opportunities for increased integration between infrastructure systems, there are technology solutions related to active traffic and congestion management, parking and curbspace management, and mobility-as-a-

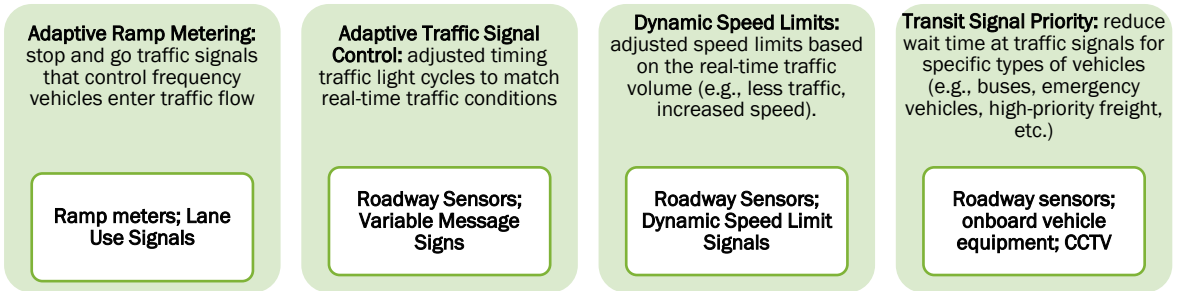
service that can inform these efforts as well as associated case studies.

Active Traffic and Congestion Management

Active traffic management (ATM) refers to the dynamic management of recurrent and non-recurrent congestion based on the underlining and predicted traffic conditions. The intent of ATM is to influence traffic behavior via user choices and operation of transportation facilities. ATM strategies include adaptive ramp metering, adaptive traffic signal control, dynamic speed limits, and transit signal priority (TSP) among others. With the implementation of each of these strategies, there are active technologies that must be deployed, installed and monitored (as shown in the graphic to the right).

With the various technological components utilized for each individual ATM strategy, it is beneficial to have a system that can integrate existing and new technologies within a single platform.

HERE Technologies is a global company that provides platform-based solutions for connected driving, fleet management, supply chain, urban mobility and consumer engagement (see box to the right). Their platforms allow for creation, development and scaling of location-centric data, editing data in real-time, and the licensing and exchange of data. HERE Traffic platform



enables cities to map, analyze, predict, and react to real-time road traffic. It enables for more informed decision making as it relates to road-engineering, traffic flow, road network management, and land use. As such, it has both traffic operations and traffic planning applications.

In terms of operations, HERE Traffic combines reported data and automated data, such as GPS probes points (road sensors and connected vehicles) to enhance operational capabilities. Through the combined data sources and technologies via HERE Traffic Dashboard, up-to-date areas of congestion, travel times on roadway variable message signs, as well as reports on performance measures such as reliability are provided. In terms of planning, HERE Traffic collects data from real events, incidents and congestion, which overtime becomes a sizeable repository of historical traffic data that can be used for predictive travel patterns and to inform infrastructure development.

Company: HERE Technologies

Established: 1985

Headquarters: Netherlands

Technology: Tracking and positioning, traffic, mobility

Website: www.HERE.com

HERE Traffic technology solution has been utilized in the City of Ebersberg, Germany where the majority of the transportation network is located in forested areas which has high incident of vehicular accidents due to animals crossing the road. The issue of safety for drivers and animals was a high priority for the Ebersberger Road Authority (ERA) responsible for road safety. In collaboration with HERE, ERA utilized intelligence traffic technology to enhance road safety by optimizing the location of existing and new animal crossing signs, as

well as communicate via VMS real-time danger of animal crossing to drivers utilizing data streaming catalog of incidents. For the City of Norfolk, a similar approach can be taken in regard to recurring flooding incidents with optimizing the placement of "Road May Flood" signs along specific corridors as well as providing alerts for the potential for flooding via VMS.

Cubic Transportation Systems, Inc is a technology-focused company that provides transportation management technology solutions for public transit operations including but not limited to fare payment and surface transport management (see box to the right). Cubic Surface Transport Management platform solution supports data analytics and visualization across multiple modes of travel for a single operational view or common operating picture. The solution is able to integrate with legacy systems and third-party products, as well as scale based on the need.

Cubic Surface Transport Management serves as the base integration platform that can integrate existing systems into one customizable platform that allows for operators to strategically manage the individual traffic and transportation elements in a holistic manner. Cubic Surface Transportation Management customers include the Highways England, Transport for London (Tfl), Transport Scotland, and Transport for New South Wales. For Tfl, Cubic has been providing traffic control equipment maintenance, capital works and related services since 2014 with focus of work being in South East London. Cubic supports Tfl with the management of traffic control infrastructure including supply, installation, maintenance, modification and monetization of traffic signals and associated equipment, over-height vehicle detectors, and VMS.

For the City of Norfolk, systems integration can be across various operations including light rail and bus via Hampton Roads Transit, road traffic, ferry, traditional taxi cabs via Hampton Roads Transportation, Inc and environmental monitor systems. The solution allows collaborative data analytics as well as business-wide management reporting; all of which can done via cloud-hosting with platform being accessible using desktop, mobile devices as well as a public website for data sharing. The solution would provide map-based access with integrated situational awareness across all systems including implementation of signal plans, dissemination of transportation information, and predicative modeling for identifying potential incidents in advance.

Company: Cubic Transportation Systems, Inc

Established: 1951

Headquarters: San Diego, CA

Technology: Fare collection and revenue management, road user charging, surface transport management

Website: www.CUBIC.com

Parking and Curb Space Management

The increase in shared mobility options, such as e-scooters, e-bikes, and Transportation Network Companies (TNC) like Uber and Lyft, along with traditional taxicab services, has resulted in additional demand on the limited parking and curbside space for the City of Norfolk. Partly due to the COVID-19 pandemic, there has also been increased demand for online commercial and food delivery services. With these competing demands for the curb, there is a need for the City to be able to have a holistic view of the curb space from both an operational and infrastructure perspective.

In terms of operation of the curb space, technology provider, curbFlow has service offerings that enable its customers to determine real-time curb space availability for on-demand and commercial delivery operators to execute delivers in a more efficient and safer manner (see box to the right). Rather than the existing typical practice of vehicles double parking and blocking traffic, curbFlow can support the city in better managing parking spaces through vehicle counting, vehicle dwell-time detection and illegal parking detection technology. These enhancements can be used to determine trends for vehicle movements, reduce congestion by identifying idling vehicles as well as support law enforcement efforts and actions for vehicles double parking and blocking traffic. The technology leverages network of computer vision devices located on private property, machine learning to detect real-time availability and smartphone app and interface that shows inventory of parking. The use of this type of technology benefits both drivers as well as merchants and retail vendors. It can increase productivity of the curb, increase turnover of parking spaces and reduce circling time for drivers seeking parking.

In Washington DC, a curbside research pilot project was implemented by curbFlow in partnership with the District of Columbia Department of Transportation (DDOT). The pilot focused on analyzing the demand at the District's curbside spaces, with particular emphasis on designated pickup dropoff (PUDO) zones; a total of nine PUDO locations were evaluated. For the pilot, "ambassadors" (curbFlow employees) showed drivers and merchants how the system works and counted, classified users and measured benefits (this was done as part of the pilot with DDOT and may not represent their direct-to-market services). During the course of the pilot, which occurred over a period of three months, drivers reserved spaces over 15,000 times. Major findings of the pilot included a 64 percent decrease in double parking and illegal U-turn incidents, as well as an average of two and half minutes per PUDO activity. Using a similar approach, the City of Norfolk can identify streets that experience the most curb space activity and create designated zones. These zones can be then dedicated for drivers to reserve parking spaces, which can be paid in advance through technology platform.

Company: curbFlow

Established: 2018

Headquarters: San Francisco, CA

Technology: Curb space management for loading/unloading

Website: www.curbflow.com

While commercial delivery is one important element of managing the curb space, the demands on the curbside are also a function of time, community needs as well as public policy priorities, so having dynamic or evolving curb space regulations is important capability for City of Norfolk.

Using mapping technology tool provider, Kurb, the City of Norfolk can have a map-driven collaborative approach for designating the use of curb space from physically drawing space boundaries, utilizing virtual collaboration tools (e.g., chat function, file sharing, etc.) for providing and giving feedback between users as well as sharing and reviewing published maps (see box to the right).

It can save time and resources as it relates to allocating curb space for parklets, bus stops, bicycle corrals and more. The tool can be leveraged by the public for advanced reservation of curb space for specific activities as well as the permitting of space by other city agencies (enforcement or compliance is still required; DC effort used “curbFlow Ambassadors” that served as “parking attendants”).

The management of Park and Ride facilities can also be enhanced by analyzing their effectiveness as it relates to usage and their proximity to major employment or residential areas.

AECOM has also developed a concept of operations for dynamic or flexible curb space named FlexZones, which would allow for the adjustment of curb space designations in real-time based on the City’s priorities. The focus is on safety and efficiency and utilizing digital wayfinding signage – displaying usage and associated price – notifying drivers of current availability.

Usage of spaces can change in real-time to meet curb space demand. In combination with roadway sensors, CCTV cameras, dashboarding tool and mobile app, space allocation can be optimized based on availability along with price varying based on demand.

Space usage can also be restricted in the event of emergency incident, ensuring access for first responders. This type of forward-thinking can greatly enhance the management of the curbside space in the future.

Company: Kurb

Established: 2020

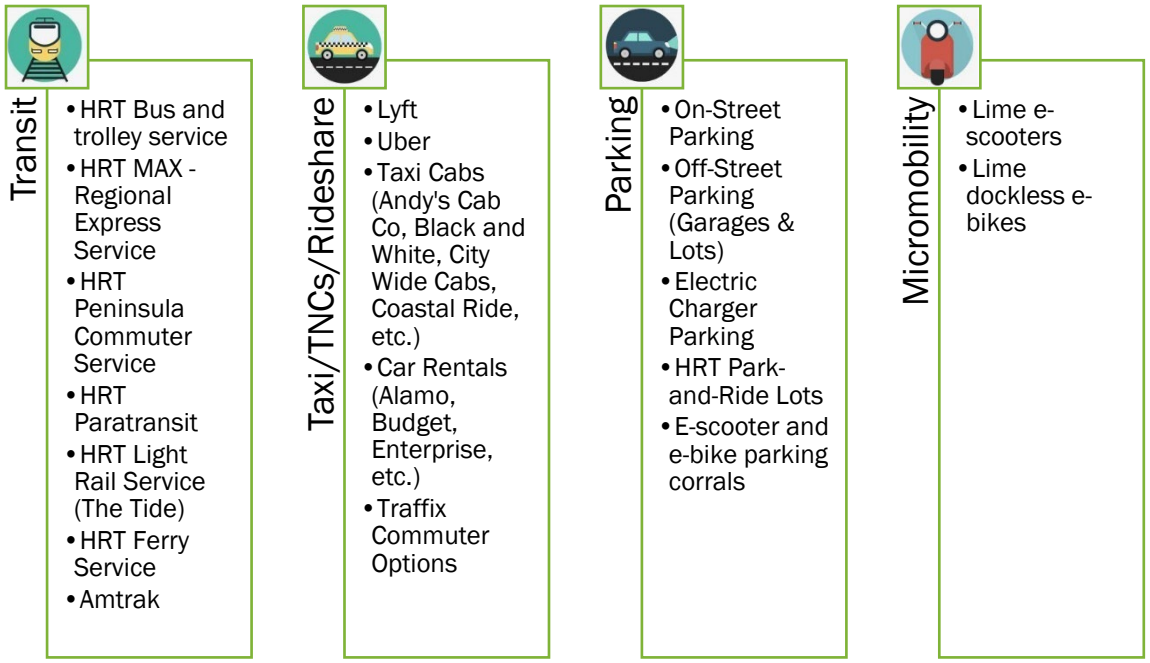
Headquarters: Pittsburgh, PA

Technology: Map-driven collaboration tool for planning outdoor space

Website: www.kurb.io

Mobility-as-a-Service

Integrated mobility efforts have been increasing in cities across the country that leverage the use of technology to enable contactless payment, transfer between different mobility options as well as end-to-end trip planning. Mobility-as-a-Service (MaaS) is the type of service that connects all these various functionalities through a single digital solution that allows for the travel and payment of various mobility service options. With the increase in the variety of mobility options, MaaS can increase efficiency and allow users to more easily navigate the larger transportation network. For the City of Norfolk, the Multimodal Transportation Master Plan includes several key initiatives that can be integrated through a MaaS solution.



With the City installing bike-pedestrian counters, the current electric-assisted dockless bike share program, the current electric scooter share program, the scooter/bike parking corral program, and bike shelter improvements (which can include real-time digital message signs with transit alerts), there is the opportunity to integrate the information and service offerings across these modes onto a single platform.

Beyond these mobility options, there would be the need for interagency collaboration with Hampton Road Transit (HRT) bus, light rail, and ferry service and the private mobility sector such as TNCs and Lime (scooter and e-bike operator) for a truly multimodal platform. The MaaS solution can also include a regional mobility service option such as the Williamsburg Area Transit Authority (WATA) buses integrated with Amtrak service or potential future mobility options such as microtransit. However, the development of an initial platform integrating parking, e-scooters and e-bikes and is under the direct management of the City of Norfolk, would be a step in the right direction and serve as a proof-of-concept.

While mobility-as-a-service has not be fully realized in the US, there are several technology vendors and jurisdictions that have made efforts towards this.

Dallas Area Rapid Transit (DART) Go Pass program allows for the payment and riding of transit service without the need of cash via mobile app or reloadable transit card (see box to the right). The mobile app offers real-time trip planning tools, integrated maps, and the card allows for simple tap boarding on both buses and trains. Fare can be reloaded on both mobile app online or via card at hundreds of retail locations across North Texas. The trip planning capabilities leverages Good Transit features and allows for the creation of personalized trips plans for DART buses, DART Rail, Trinity Railway Express, Tulsa Transit and Denton County Transportation Authority A-train allowing for travel between jurisdictions. DART also allows for the leasing of their app to other jurisdictions to develop their own mobility app solutions which can be leveraged by the City of Norfolk in partnership with HRT.

Another mobility app solution is Cubic Mobile Suite. In addition to the Cubic Surface Transport Management platform solution that supports data analytics and visualization across multiple modes, there is also Cubic Mobile Suite which provides a range of integrated functionality including enabling multimodal transport, multiple payment offices from single account, connection with merchant and retail network to sell tickets as well as ability to support inspectors with validating tickets as well as processing ticket purchases via mobile device. Technology allows for the integration with parking, ride hail, care service, bike share and other third-party vendors with real-time alerts and trip planning via Google Maps. These services are provided through a collection of mobile apps including Merchant App, Inspector App, and Traveler App and allows for individual branding and logo design. Cubic currently provides these services throughout the US including Boston, New York, Washington DC, Chicago, Los Angeles and San Francisco. The City of Norfolk can leverage one or all three applications for their multimodal planning needs.

In terms of other multimodal transportation app solutions, there is Transit App which provides free consumer app for trip planning as well as Transit+ app for cities and transit agencies that allows for mobile payments across bike and scooter share programs as well as ridehailing and carsharing services (see box to the lower right). The platform provides alerts for arrival and departure of transit service based on user GPS location, trip planning and comparison of mobility options all at once, customer communication integration and alert system for service change as well as rider dashboard for data related to ridership and level of service. The data collection can provide insights as it relates to popular destinations and origins, most frequently used of mode of service as well as changes to trip planning choices. Transit app is currently being used by Kansas City Regional Transit (RideKC), Santa Clara Valley Transportation Authority (VTA) and the Montreal Transit Corporation (STM) in Canada

Company: Dallas Area Rapid Transit (DART)

Established: 1983

Headquarters: Dallas, TX

Technology: All-in-one travel tool to buy transit passes

Website: www.gopass.org

Company: Transit

Established: 2012

Headquarters: Montreal, Quebec

Technology: Aggregation and mapping of real-time public transit data

Website: www.transitapp.com

System integration in the form of active traffic congestion management, parking and curb management and mobility-as-a-service solutions can all be used to more effectively manage connected infrastructure systems. There are inherent

interdependences between each of the transportation options made available to users, and the City of Norfolk can leverage technology to eliminate the barriers the exist between these different mobility options.

Data Aggregation

Infrastructure management can be improved through system integration which includes the aggregation of data across the individual systems. As such, data is the foundational building block supporting infrastructure management and system integration.

The City of Norfolk has an adept understanding of the importance of quality data that meets standards of accuracy, completeness, consistency, timeliness, validity and uniqueness. Through Norfolk Open Data portal (powdered by Socrata and Tyler Technologies), the City of Norfolk offers free and easy access to data about Norfolk across the categories of education, environment, government, maps, permits, public safety, real estate, recreation and transit. However, the existing data available is limited to only 43 datasets.

The current transportation related datasets that are available are as follows:

- Fleet
- Mowing Schedule
- Parking Citations
- Parking Permits
- Permits – Right of Way
- Scooters and e-bikes
- STORM | System to Track, Organize, Record, and Map
- Street Lights and Outages Reports
- Towing
- Bike-Pedestrian counters

As such, the portal needs to be reviewed and evaluated for considering the expansion of available datasets as well as improved categorization, increased data types as well as detailed tagging. In addition, the inclusion of links to key datasets not maintained by the City but are available through Virginia state agencies and Federal departments would be beneficial.

Leveraging Socrata capabilities, the Norfolk data portal can be enhanced to provide additional analytic and app development capabilities, as well as data and citizen engagement features (see box to the right). The current version allows for the creation of an account profile and that allows user to track own data sets as well as dataset shared with user. The platform also allows new datasets to be suggested.

While there is room for improvement as it relates to the sharing of publicly accessible datasets, there is the internal process and procedures for the exchange of data between Norfolk departments and external agency partners. Using the Connected Government Cloud feature, data can be shared internal with government partners in a modern, secure, cloud-based infrastructure with self-service access. As such, it eliminates the need of sharing data back and forth via e-mail and ensure a common operation picture of datasets. The streamlined access allows data to be readily available to support government initiatives, polices and decisions. The Socrata Connected Government Cloud provides secure access, internal data-sharing and collaboration for data query and analysis, financial analysis and reporting, performance management, operation analysis as well as open data programs.

Company: Socrata

Established: 2007

Headquarters: Seattle, WA

Technology: Open data, government performance management, government financial insights, data-driven government

Website:
www.tylertech.com/products/socrata

The City of Norfolk current collects, formats, processes and maintains various data

sources according to data standard specifications. As part of Norfolk Multimodal Transportation Master Plan, an inventory of data collection is organized into six categories:

1) Demographics
2) Land Use
3) Transportation Facilities
4) Traffic
5) Transit
6) Safety

These existing conditions data is being used to support a broad and in-depth analysis of Norfolk's transportation system. There are also privately available data and vendor technologies related to data sources and collection, data management and incident management that can be procured to support related efforts.

Data Sources and Collection

Exploring additional data sources and collection in combination with existing data can enhance the City's understanding of their infrastructure. The use of crowdsourced and location-based services (LBS) data specifically can be beneficial. As it relates to crowdsourced data, there is the increased trend for users to report incidents or impacts on the transportation network via social media applications such as Twitter or Facebook. In terms of location-based services data, this relates to data that is retrieved from mobile devices and can provide population movement analytics at trip origins, destinations and points of interest (POI) such as grocery stores, healthcare facilities and others. Both crowdsourced and location-based services data is usually in the form of Big Data, or data that is too large or complex to be dealt with by traditional data-processing. In addition, crowdsourcing data can help City of Norfolk obtain increased data points without requiring additional resources.

In synthesizing crowdsourced data, a tool that can be leveraged is Dataminr, which is a New York-based company that specializes in artificial intelligence to provide real-time information alerts to clients (see box to the right). The company use artificial intelligence and machine learning systems for real-time event detection. These events are synthesized from micro-blogs and social media posts which are accessed based on the credibility of the source, the occurrence of similar online posts and cross-checked with verified sources such as government agencies and news organizations. Dataminr's First Alert product for the public sector alerts first responders to breaking events, enabling the fastest real-time response. This tool can be utilized within a TMC or Emergency Operations Center (EOC) to provide additional data sources for incidents. This is especially useful for areas with large populations or during high-incident events such as hurricanes or winter storms.

Company: Dataminr

Established: 2009

Headquarters: New York, NY

Technology: Artificial intelligence to provide real-time information alerts to client

Website:
www.dataminr.com

Public agency clients of Datminr include the United Nations and the New York City Office of Emergency Management (NYCEM). For NYCEM, Dataminr is used in Watch Command – New York City's incident management monitoring central hub which operates 24 hours a day, seven days a week. It serves as an alert and notification tool for Watch Commanders and agency executives of major events. Once an alert is received, Watch Commanders verify incident with law enforcement agencies and releases public warning message via Notify NYC, which is the City's public source for information about emergency alerts and important city services.

In terms of crowdsourced data that is specific to transportation, Waze, a Google company and GPS navigation software, collects data from users via app related to traffic (moderate, heavy, standstill), crashes (minor, major, other side), hazards (on road, shoulder, weather), road closures among other types of reports (see box to the right). There is also the ability to report incidents with comments as well as pictures. This wealth of information can be ingested by TMCs and EOCs, where it can be verified using law enforcement, CCTV cameras and other verified sources. With the quick reporting of incidents via Waze, responding agencies can quickly formulate mitigation and action plans. Other crowdsourced data-driven application are Spot Angels, which digests public data on public availability, and Gas Buddy, which uses user reports to confirm gas availability at gas stations.

In terms of location-based services data, there are several companies that have business agreements with major telecommunication companies, such as AT&T and Verizon, and aggregate and anonymized data to provide insights on populations movements.

Most popular LBS data providers are Replica, SafeGraph and Streetlight, which is described in the table to the right based on data sources ingested methodology and outputs.

Location-based services data provides both historical trends on population movements as well as real-time analytics that can be used for various analyses from recurring traffic congestion to adherence of stay-at home orders.

Company: Waze

Established: 2006

Headquarters: Palo Alto, CA

Technology: GSP navigation software and trip planning

Website: www.waze.com

Location-Based Services	Data Sources	Methodology	Output
Replica	Publicly available census data; mobile location data, and point-of-interest (POI) transaction data	Advanced modeling and algorithms to create synthetic population that matches the characteristics of a region's real population, and applying travel behavior model to synthetic population	Synthetically generated representation of the activities and movement; data download and dashboard
SafeGraph	Telecommunication device-based data	Analyze GPS location data with POI geofences to determine if a device visited a place, brand, or type of store	Store visitor demographics; data download and dashboard
Streetlight	Data from SafeGraph; major navigation-GPS data supplier, INRIX, and one LBS data supplier provider Cuebiq	Pull de-identified data in bulk batches from data suppliers followed by data cleaning, creating trips and activities, Quality Assurance (QA), storing, aggregating and final QA	Travel pattern metrics; interactive maps and charts within the platform, or downloaded

More conventional data source and collection technology would be the deployment and utilization of field sensors. Roadway sensors for temperature and pressure, strain gauges, Bluetooth devices, and other types of sensors can be used to monitor traffic patterns and the condition of infrastructure.

Sensor companies such as Sensor Solutions and DeepBlue can offer technologies for City of Norfolk to instrument the most critical transportation facilities, intersections and roadways.

DeepBlue provides Bluetooth detection hands-free sets and devices, as well as Wi-Fi based devices that can be mounted on streetlights or electric poles and transmit data wirelessly (see box to the right).

Mobilitynow is DeepBlues' data-as-a-service (DaaS) solution offering temporary data and origin-destination matrix collection for before and after studies, traffic and event planning. TrafficVision and Verizon Network Infrastructure Services are companies that can provide supplementary infrastructure monitoring services in the form or CCTV surveillance systems and upgraded telecommunication networks for the transfer of data.

Company: DeepBlue Sensor

Established: 2002

Headquarters: Barcelona, Spain

Technology: ITS traffic management solutions

Website: www.deepbluesensor.com

Data Management

Data management for accessing, storing, exporting and sharing data is key for public transparency as well as supporting infrastructure management coordination between the City of Norfolk departments and divisions. Through Norfolk Open Data portal, powered by Socrata and Tyler Technologies, the City of Norfolk offers free and easy access to data about Norfolk. By leveraging The Socrata Connected Government Cloud provides secure access, the City of Norfolk can benefit from internal data-sharing and collaboration for data query and analysis, financial analysis and reporting, performance management, operation analysis as well as open data programs.

Another open data portal and data management platform provider is Mapbox Studio. Mapbox's suite of technology solutions can help the City of Norfolk get a better sense of their data through visualization and analysis (see box to the right). Mapbox Quick Launch platform allows for dashboard development, which connects users to internal data sources, supports collaborative annotated mapping tools as well as information sharing between stakeholders. Mapbox's content tagging solution creates a database of location assets that are tagged, stored and retrievable by end users' searches. The NYC Department of Information Technology and Telecommunications' Gov Lab & Studio in partnership with Mapbox designed the NYC Open Data website which stores NYC data by categories (e.g., education, environment, etc.), view types (e.g., datasets, files and documents, maps, etc.), curated data collections of related datasets such as COVID-19 Heath Data, agency and content tags. The data portal allows users to filter, map and export data, with new datasets being published frequently. Other data portal and data management platforms include ESRI ArcGIS Open Data, which software-as-a-service (SaaS) solution allows for the sharing of spatial (i.e., maps) and non-spatial (i.e., tables) data, and Google Maps Platform via Google Cloud, which allows for highly customizable map creation with customer markers, overlays and photos.

Company: Mapbox Studio

Established: 2010

Headquarters: San Francisco, CA

Technology: Custom online maps for websites and applications

Website: www.mapbox.com

Incident Management

The City of Norfolk daily operations, from traffic management to construction work, requires the use of critical transportation and infrastructure data. In the event of an incident or emergency situation, it is even more critical that these datasets are reliable and provided in near real-time. There are various technology solutions within the marketplace that can support incident management coordination and information sharing between the City of Norfolk's departments from law enforcement to utilities. These technologies are deployed to support the identification, analysis, correction and the prevention of emergency incidents.

Waycare Technologies is a map-based incident management solution that provides users with real-time data and information to address roadway and traffic related incidents. Using the Waycare platform, users are able to receive notifications and updates on road and traffic conditions, stalled vehicles, debris, traffic stops, or areas identified as risk zones; obstructions by patrols can be reported and work order requests by maintenance dispatchers can be submitted in the field via mobile devices; first responders can receive the precise location of incidents for route navigation; and on-time performance of transit systems can be monitored to support route planning and schedule adjustments due to incidents. The different incident activity types are tracked and documented to be accessible by other agencies. It also allows for interoperability with agency operation centers' existing incident management systems, such first responder Computer-Aided Dispatch systems. With more interagency partnership and coordination as it relates to the sharing of data, the more accurate and precise the data would be within the Waycare platform. Also, the platform ingests a variety of data sources that are both private and publicly accessible, such as weather conditions and forecast data, CCTV camera feeds, and General Transit Feed Specification (GTFS) via Application Programing Interface (API). This platform can be leveraged by the City of Norfolk to respond to recurring flooding incidents using historical flooding data, current weather reports, as well as field observations.

Data integrated through the Waycare platform can help to decrease response time to incidents as well as notify first responders of the potential for incidents to occur (see box to the right). In 2018, Waycare partnered with the Nevada Highway Patrol (NHP) to improve incident identification, response time and interagency coordination. By leveraging the platform, NHP was able to see an average nine-minute reduction time in incident identification. The platform provides a single common operating picture for NHP with their partner agency the Regional Transportation Commission of Southern Nevada's (RTC) Freeway and Arterial System of Transportation (FAST) allowing for quicker response times. An alternative or complementary incident management platform that can be utilized is WebEOC. It is the preferred emergency management software that is used by the Federal Emergency Management Agency (FEMA). The software is able to support a variety of operations including emergency vehicle tracking, asset and inventory management, incident command and notification, volunteer responder management, as well as mutual aid resource tracking and requesting.

Company: Waycare Technologies

Established: 2016

Headquarters: Palo Alto, CA

Technology: Traffic management systems leveraging predictive analytic

Website: www.waycaretech.com

Chapter Conclusion

The variety of the technology solutions that exist in the marketplace as it relates to infrastructure management, system integration and data aggregation is countless and constantly evolving. Each of the technology solution described offers features that can meet the needs of the City of Norfolk including asset management, smart city solutions, active traffic management, curb space management, data collection and management, as well as incident response. However, there are trade-offs as it relates to cost, scalability and adoptability.

It is important that when developing CONOPS for any technology solution, as part of the proposed evaluation framework, that there are definitive objectives which are scoped with stakeholders, potential technology requirements are clearly defined, and the evaluation is supported by scenario and impact analyses. Scenario planning tools, such as Sustainable Ways to Integrate Future Transportation (SWIFT) platform developed for the Texas Department of Transportation with AECOM, can help to analyze potential impacts of technology adoption prior to implementation. The SWIFT platform developed future build scenarios based on changes in land use, user behavior, technology adoption and transportation policies, which provide broader insights on the implications of specific transportation planning decisions.

With a fully developed draft CONOPS for a technology solution, there are subsequent next steps that can be taken by the City of Norfolk towards successful implementation. These next steps are as follows:

- Conduct testing of technology solution and pilots
- Determine performance measures for evaluation of technology solution
- Execute scaled implementation
- Incorporate proposed technology into existing workflows
- Support ongoing maintenance and upgrades

The testing of technology solution and pilots will provide specific information on the ability of technology to meet defined objectives. It will allow for the documentation of limitations and inform areas of improvements prior to proceeding with the go-live implementation. As part of testing and pilot, there should also be specific performance measures or targets that can be used to evaluate if the technology adequately performed intended functions, conducted any unintended functions, and in general whether the technology can be deemed a success or failure.

Once the testing and acceptance has been completed, with points of failure addressed, plans for scaled implementation can get underway. This scaled implementation can be based on specific user type or geographic areas depending on the type of technology. In addition, as technology is being implemented, the impact on existing workflows can be accessed from roles and responsibilities of staff to the need for additional personnel support. Lastly, the evaluation of the technology solution is a perpetual process, along with maintenance and upgrades to ensure that the solution is sustainable. It is important that the technology is able to adapt with changes in the needs of the City of Norfolk and demands on the larger transportation network.

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