Smart Cities--Smart Futures Idea

Connecting the Milwaukee of Tomorrow: The Smart Streetcar Corridor for Greater Community Health, Equity, Livability, and Prosperity (HELP)

Business Plan

NAME OF CONCEPT: Smart Streetcar Support

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Executive Summary

Our idea is to tap the power of emerging technologies--including 5G wireless, 8K video, cloud computing, and Internet-of-things--to support Milwaukee's streetcar, The Hop, with a smart network to help to improve the quality of life for the community. Ideas about smart cities emphasize the need to serve urban areas with transit, particularly in knowledge-based economies. Transportation research literature shows that in order to encourage development along a streetcar route, a streetcar needs to operate well as a transit service, and yet research on streetcar transportation, as integrated within a smart transit corridor, is lacking. Our idea builds a framework for data-gathering and research to achieve this aim of supporting the capabilities of a streetcar as used for transportation. Based on a concept of smart nodes creating a 5G wireless and 8K video network along the route, the streetcar and its environment could be placed in real-time wireless communication with cloud-based data collection, storage, and software. Transportation analysis methodologies that we have studied could be applied to support goals of safety and efficiency within this multimodal corridor. Data on

performance, passengers, safety issues, traffic, events, and systems could be gathered in real-time and stored securely in the cloud. Partner agencies or manufacturers could gain access to this real-time data and analysis. This smart network and cloud-based data could be used to develop transportation methods and products using the "digital twin" concept from Industry 4.0 to continuously support and improve the system and advance transportation research. The aim of this concept, ultimately, is to support The Hop's goal of serving the community.

This smart network would serve as a framework for streetcar support as well as further Internet-of-things development and community benefits along the route. By including 5G service along this smart corridor to the public, the streetcar's role in motivating development and connecting communities could be strengthened. Supporting the streetcar helps the community by providing emissions-free vehicles (at street-level), connecting people with community resources, supporting walkability, and increasing access to transportation. This support works within goals for transit-oriented development, affordable housing, mobility choices of the Milwaukee Environmental Collaboration Office, the Milwaukee Pedestrian Plan, and the Southeastern Wisconsin Regional Planning Commission's VISION 2050 plan. For the community, this smart network could provide a corridor for business development in a range of industries that 5G wireless, 8K video, and Internet-of-Things may enable.

The market for this concept includes partners and stakeholders in transportation, manufacturing, research, and community groups. The operators, owners, and industry partners of the 376 streetcar systems worldwide (and more than 70 in the construction or planning or proposal stages) may benefit from our idea. Interested investors or partners would include the manufacturers of streetcar vehicles and equipment, engineering and design firms, operators, transportation management companies, and the municipalities and agencies at all levels involved in the ownership and development of streetcar systems or 5G/8K and related technology products. Our concept could attract partners that are seeking to gain experience in smart corridor and vehicle-to-anything (V2X) development, including players such as Google, Microsoft, vehicle manufacturers, 5G wireless manufacturers and providers, transit system operators, or transit research organizations. The revenue potential would come from the added value our concept brings to the safe and efficient operation of the streetcar for the stakeholders as well as the value of the smart corridor for business and the community. The initial financial return could come from delivering cloud-based diagnostics and streetcar safety and performance reporting as an initial-stage development of the system.

A risk assessment shows that the novelty of employing and integrating these technologies on a streetcar route would pose up-front development costs, risks, and engineering challenges. However, the existing Hop streetcar as the basis for deployment gives a considerable head start in developing this concept. Also, the methodologies used for transportation analysis have a track record of transportation improvements and are within the expertise of the local Center for Urban Transportation Studies at the University of Wisconsin—Milwaukee. With potential partners in other academic units involved in network technologies and massive data processing, the expertise available locally represents a significant strength of our idea.

Our goal is not to replace current partners on the streetcar, but to collaborate with them to create new tools to gather data, develop methodologies, perform empirical research, and begin to answer questions about urban transportation that have never been asked before. Our goal is not just to dream of a smart city, but to visualize a path and begin building one.

Concept Description

The City of Milwaukee, Wisconsin has built, tested, and now operates a streetcar system in its downtown area. Opened on November 2, 2018 as "The Hop," the streetcar includes 3.4 km of track and five Brookville Liberty Modern streetcars capable of running off-wire on batteries using an onboard energy storage system [1]. The Hop's Main Line connects 18 boarding areas of various configurations [2]. Extensions of this system include the Lakefront Line (partly built) and lines planned to the Bronzeville and Walker's Point neighborhoods [3]. The City's vision is a streetcar system that could serve many neighborhoods with transit-oriented development and with emissions-free (at street-level) vehicles [3, 4]. The streetcar and passengers interact with Milwaukee's existing multi-modal transportation choices along its route which is a setting for transit, commerce, housing, tourism, entertainment, and economic development [5, 6].

Research into streetcar systems shows that while the aim of motivating development has seen results [7] , achieving these results requires high levels of service as a transportation system [8].   The desire to encourage building and property along the route is a strong motivator to build a streetcar system [9, 10] and is a motivator for Milwaukee's Hop [5].   However, researchers Brown and Mendez caution that the function of the streetcar system as transportation is key: "the more effective a streetcar is as a transportation service, and the more widely used it is by patrons, the more likely it is to have development effects" [11].

In research and promotion, the transportation role of a streetcar is not often emphasized. A multiple-case study of streetcar transit found that "there is remarkably little work on the streetcar's role as a transportation service" [8]. Further, in examining the stated motivations for the streetcar, it was found that "transportation objectives were largely afterthoughts with the notable exception of Portland" [8]. However, stakeholders expect both the development benefits as well as the transportation benefits. Mendez and Brown examined the "expected transportation benefits relative to indirect benefits through economic development" and found "that approximately three-quarters of all expected benefits from streetcar projects accrue to property development with the remaining expected benefits assigned to transportation" [7].

While researchers have shown that building a streetcar for transportation is usually not a primary motivation [12], an argument can be made that improving the streetcar as a transportation mode helps development goals. A multiple case study shows the importance of this in the case of Portland:

> When assessed as transportation, Portland's streetcar emerged as the clear standout performer with the highest ridership and service productivity and the second-most cost effective service. Portland was also the only city in which streetcar performance (service productivity and cost effectiveness) measures surpass that of the average local bus. Planners' decisions to locate the streetcar lines in an area with strong ridership potential combined with decisions to provide frequent service that is well integrated with other transit services help to explain Portland's strong performance. These decisions reflected a view that the streetcar was not just a development tool, but that it also needed to function effectively as a transit service that catered to a broader ridership. [8]

Our concept is to address this need to support the streetcar's transportation capabilities. Using emerging technologies and transportation analysis methodologies that have a track record of improving service, our goal is to create a data-gathering and communications network along the streetcar corridor and use empirical research methods to inform and support streetcar operations.

Our concept is to provide what we call "smart node" devices along the streetcar corridor to form a network. These smart nodes could be mounted on infrastructure and contain 5G communications equipment, 8K video cameras, small computers, and a connection to a terrestrial high-speed Internet cable. These smart nodes would constitute the smart network and would be the wireless interface between the vehicles and cloud-based data collection, storage, software, communication, and analysis. Because the data gathered would be so voluminous, 5G wireless communication would be essential to offer 20Gbps downlink and 10Gbps uplink per mobile base station [13]. A big technical challenge would be processing the large amounts of data produced.

Creating a smart transit route has precedents in several pilot projects. In Finland, the LuxTurrim5G project seeks to build the “world's smartest road” [14]. This project is building a 5G network using “smart light poles with integrated antennas, base stations, sensors, screens and other devices” [15, 16, 17]. The Smart Transport Corridor from Helsinki to St. Petersburg seeks to identify and address mobility problems in a corridor, exchange data, and work toward the interoperability of data and services [18].

There is emerging interest in 5G wireless services focused on transit corridors. Japan-based operator KDDI completed the first 5G demonstration on a moving train in October, 2017 [19]. The UK government called for 5G connectivity on a rail route [20]. Millimeter wave frequencies provide high data rates for vehicle communications [21] and fast machine learning [22]. The interaction along a multimodal corridor can be complex, but as Erik Josefsson, Ericsson’s head of advanced industries, has said, “I think the industry has high hopes that this [5G] can help simplify complex environments” [23].

Our concept would use hardware that could be specialized to work with the unique needs of streetcar operation. The fixed nature of The Hop’s tracks provide known locations for line-of-site communication to the streetcars and thus a good testbed for 5G communications. Most significantly, 5G provides real-time tracking through low-latency (1 millisecond) signals and possibilities for sensors in a density of up to 1 million devices per square kilometer [13]. Current technologies for vehicle communications run into problems where “[t]he effectiveness and efficiency of a TSP [Transit Signal Priority] implementation quickly degrades as the communication latency increases" [24].

The Hop's main line (and extensions) could be covered by a smart node network. The LuxTurrim5G project places smart poles about every 50 meters along the route [17]. Our smart nodes might not necessarily be on light poles. These smart nodes might be placed on infrastructure, such as city-owned light poles or streetcar infrastructure supporting the catenary cables. Based on this rough estimate, The Hop's Main Line of 3.4 km might be covered with approximately 70 smart nodes to form the smart network. Connections and communication could be made wirelessly to corridor traffic signals for automotive and bicycle traffic, streetcar, and pedestrian signals.

By positioning these smart nodes along the streetcar route, the smart network could track the streetcars, monitor the route, collect data, provide wireless communication, and send data to and from the cloud. The small computers in these nodes would serve to control the system as well as work specifically to process and direct the 8K cameras whose data output would be too voluminous even for transmitting by terrestrial cable, but require data-reduction techniques, machine vision, and selective image and video clip upload.

The purpose of this smart communication network would be multifold:

- First, it would provide an opportunity to apply analytic methods in cloud-based software for smart signaling, decision support systems, and integrated corridor management techniques that are supported by a body of transportation research. These methods could control signals for streetcars, automobile traffic, and pedestrian signal lights. Further methods could be developed to address operational issues such as weather, snow, route blockages, or special events or conditions.
- Second, it would serve as a collector of incident reports, statistics, and streetcar systems diagnostics that could serve to inform decisions about improving the system. For example, battery, brakes, wheels, and other systems could be monitored in real-time and statistics stored in the cloud. 8K video monitoring could continuously check for damage from vehicles or objects and be able to be directed by machine vision to identify objects striking the vehicle, for example, and their source, with redirected cameras photographing the source of objects striking the streetcar in a video buffer that would be able to "look back in time" at the activity on the route that caused the incident.
- Third, the 5G base stations could provide 5G wireless services to the communities and passengers along the route, further strengthening the streetcar's aim to spur development. Extending the 5G coverage to planned route extension and neighboring areas--even ahead of route construction--could serve to collect data such as traffic patterns, corridor conditions, and air quality. Extending the 5G zone to special areas, such as the convention center and the Fiserv Forum might provide valuable support or entertainment activities for major conventions or events occurring in Milwaukee. Services based on 5G could extend to advanced methods of fare payment, information delivered to streetcar informational or platform screens, or rider satisfaction surveys and studies.
- Fourth, it would constitute a framework for further integration with internet-of-things services and features such as air quality monitoring, business activity, as well as integration with local bus and regional transit. Other agencies or organizations might be able to build off this network for other

purposes.

- Fifth, it would serve as a testbed for further transportation research. Methodologies and decision support systems for operations including events like festivals, conventions, or emergencies could be developed. Further research into rider satisfaction based on data could also be done. The impact of smart parking management techniques along the corridor could be tested for reducing blockages and delays. This research could be used for analyzing and informing proposed design configurations of extensions.
- Sixth, it could serve as a network for delivering information and route guides to passengers and advertising from sponsors. High-resolution video might be transmitted to the streetcars or platforms for display on high-resolution monitors quickly, in response to conditions, route guidance, or advertising.

This smart network and cloud-based data and software employ a concept from Industry 4.0 literature that seeks to create a virtual model of a system from a physical one [25, 26]. The resulting "digital twin" [27, 28] of the streetcar system then would be available for analysis of its operations, testing designs of future expansions, or testing hypothesis regarding signaling or decision support systems algorithms. Continuous gathering of data along the route would model the entire streetcar corridor and set probabilities and parameters in the digital twin for conditions such as traffic, weather, obstructions, people, activities, and special events. Development of concepts on the digital twin and measurements on the real-world system could work to continuously improve the system. Data, displays, and communication and control operations might be provided in a control center similar to the State Traffic Operations Center at Milwaukee's Intermodal Station.

Central to our concept are research methodologies that can improve transportation:

- Smart signaling, based on mathematical models, has improved the performance of transportation systems. Transit data can be analyzed and provide real-time responses to problems based on vehicle position [29]. Traffic signal timing has shown to reduce streetcar travel time [30]. Smart signaling has improved the reliability of service and reduced travel delays [31], reduced travel time in congested traffic [32], reduced bus delays [33], and decreased passenger travel time in Bus Rapid Transit [34].
- Transportation analysis can improve managing transportation routes in emergencies. Passenger demand management techniques can estimate demand patterns of a transit route [35], and realtime information for mobile phone users can help with accurate information for transit choice [36].
- Decision support systems enhance the ability to plan traffic flows in a specific time period, such as in an emergency evacuation or unusual traffic condition [37, 38, 39]. Critical real-time issues can be supported with advanced

traveler information [40] and for dilemma-zone intersections [41].

- Integrated corridor management (ICM) approaches aim to make the best use of transportation infrastructure, facilities, and equipment [42]. ICM has been applied to mitigating congestion [43] and for a diversion control model for incident management on I-94 from Milwaukee to Waukesha [44].

Concepts could be developed in a digital twin of the system under a proposed methodology. Then, the hypothesized methodology could be deployed in the real-world with measurement and analysis of the actual results versus null case applications of the method. Similarly, other studies could be done of passenger demand modeling and affects on corridor business operations and residential patterns. The digital twin could be used to research transportation operations and provide tools to analyze design tradeoffs of expansions. There could be a range of ways the streetcar's operation and impact could be scientifically studied because data would be continuously gathered.

The importance of continuous data-gathering cannot be overstated: conclusions could be drawn from data recorded and rates of incidents and events. Anecdotal accounts of incidents, such as observations of ride-sharing vehicles parked on the tracks, parked cars blocking the route, and other events cannot be used to make claims about the rate of these occurrences without a continuous record of observations. Simply put, data has to be gathered on an ongoing basis to inform scientific methods or to draw conclusions that could inform procedures or public policy.

Continuous data-gathering is key to building a database of statistics on the operation of the streetcar. Events, incidents, or more serious incidents can be looked at in terms of their occurrences, lessons can be learned, and procedures updated. This corresponds to a historic phrase used in rail transportation safety—rules and regulations are "written in blood" [45], that is, as a result of an incident, rules are codified. A record of the conditions of incidents and events could evaluate risks associated with different procedures. Further, known events in the corridor, such as expected traffic conditions for season, time-of-day, day-of-week, and the occurrence of festivals could be gathered. Weather events and snowfall amounts that lead to blockages of the track due to parking issues could be quantified so that procedures put in place to reduce delays and reduce conflicts.

Data gathered might include:

- Telemetry on vehicle position, speed, systems status (batteries, breaks, etc), passenger count, vehicle operations, auditory data, video clips or still images, traffic events or signals, and current weather and environmental conditions could be gathered.

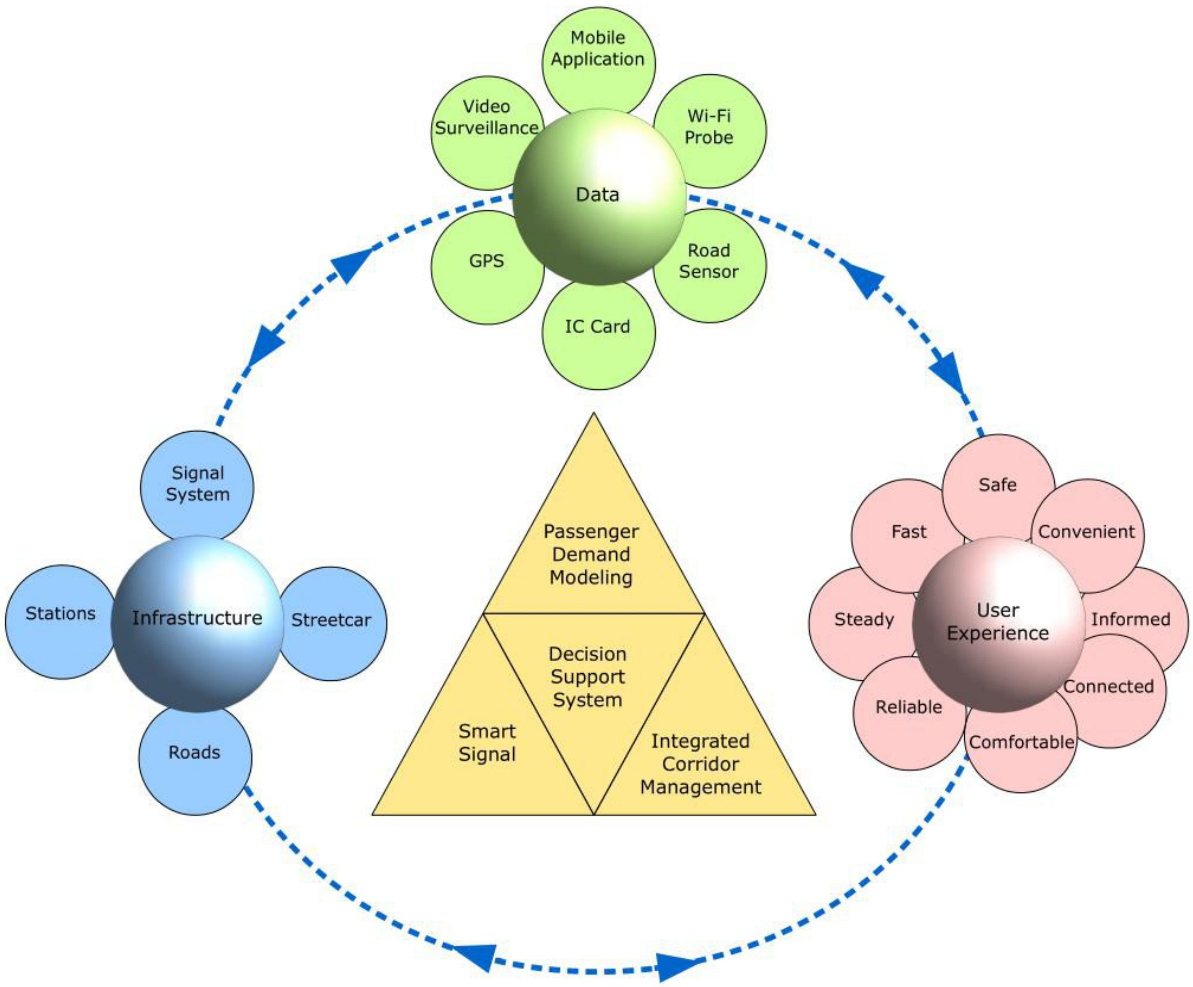
- Event recording, on particular events of interest such as sounding the horn, braking, speed changes, delays, passenger levels, including automatic capture of video and other data could be recorded. In particular, any incident which constitutes a potential safety issue could be examined so that procedures could be developed to prevent, mitigate, or understand the situation.
- Systems operation could be recorded, particularly in conditions of interest. For example, during polar vortex conditions, the battery drain rate and status could be tracked. For delays, the cause, proximate traffic, blockages, and other factors that led to it could be examined.
- Passenger loads throughout the trip could be recorded and sent to the cloud in real-time (to possibly avoid the streetcar door count data that was lost in February-March 2019, for example [46]).
- Passenger surveys might be developed through an app to measure, at various times through their ride, the level of satisfaction or specific questions, including perhaps tracking volunteer passengers throughout their trip on and off the streetcar. This data could yield insights into passenger behavior and satisfaction and, for example, passenger behavior when fares are collected.
- Maintenance events including downtime, system failures, and probabilities associated with part replacements required could be gathered comprehensively.
- Video observations along the route could be gathered in a manner that uses data reduction techniques to make use of the high-resolution video and the selective upload of video frames. Procedures for blockage detection and resolution, ahead of the streetcar's arrival at a blockage, might be developed.
- Corridor state, including traffic and parking levels, pedestrian levels and movement could be gathered continuously to set parameters and probabilities for the digital twin of the system.

The goals of safety and efficiency can be supported through empirical research that can inform and shape procedures. Algorithms and decision-support could be developed for bridge openings (the Main Line crosses the Milwaukee River at St Paul Avenue), special events requiring special traffic flows in the Third Ward (such as Summerfest) or along the route (Veteran's Day Parade) based on observed statistics and performance goals.

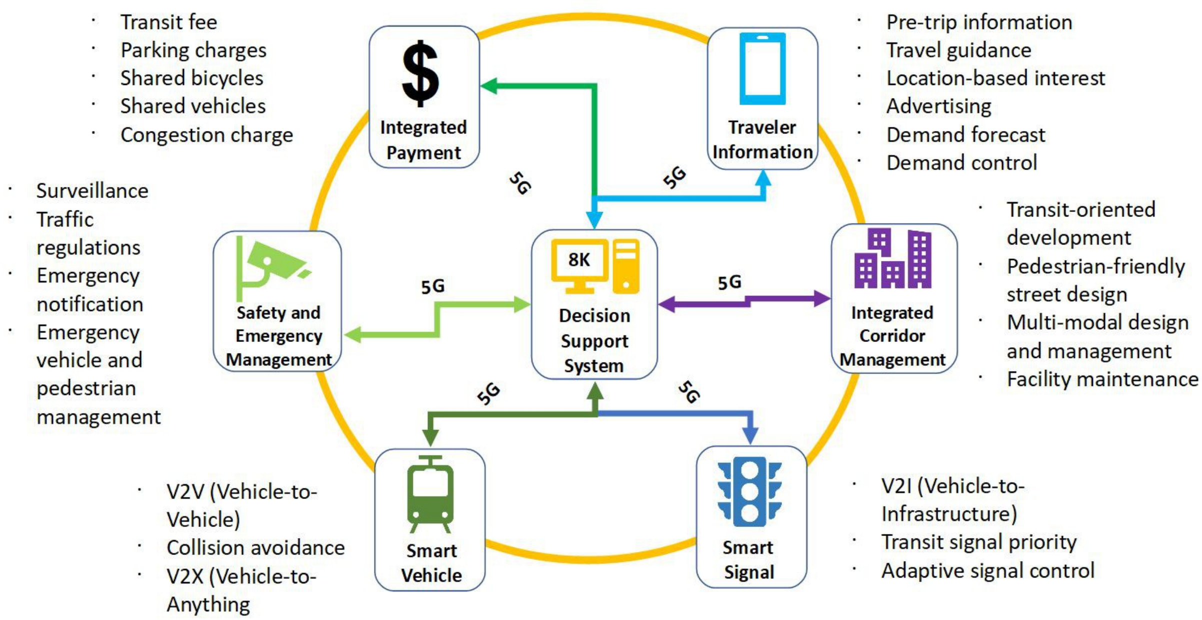
This massive data recorded could then be used to simulate operations on a digital twin of the system. For example, analysis could be done to see performance for 10-minute vehicle service intervals versus 15 or 20 minute intervals for varying conditions or events. Cost analysis could be done to see the value of adding another streetcar to the route for the day or permanently to the fleet. Studies could be done to see how to serve expected large crowds for a convention or special events, and data collected during their actual occurrence. Cost analysis could be done on expected extensions, with detailed data on how street configuration (one tracks on a street or two, street widths, car-clearance distances) affect safety and efficiency. Digital twin scenarios could be developed in a virtual model, and then tested in the real world, along with null case conditions, to test hypothesis about algorithms or procedures that are under consideration.

This continuous data-gathering and advanced transportation analytics can capitalize on the massive data content produced by 5G and 8K systems and harness the power of these technologies to improve streetcar transportation. 5G wireless and 8K video along the Hop's route would provide the data feed to the cloud for these analytics, improve operational safety and efficiency, and serve as a setting for economic development by businesses and residents wishing to make use of the 5G network. These data feeds could be monitored and signals sent to and from the streetcars wirelessly and to cloud-based data storage and computing. The resulting smart corridor for The Hop could be a setting for improved transportation and services to enhance the life of the community.

This diagram summarizes the analytic research framework showing the focus on methodologies, shown in the central pyramid, with the spheres representing the focus areas of infrastructure, data, and user experience.



This diagram summarizes functions of our concept that could be developed, including integrated payments, traveler information, integrated corridor management, smart signals, smart vehicles, and safety and emergency management:



This diagram shows a visual conception of the smart corridor with some key locations, technologies, and analysis methods identified:

Smart Cities of the Future

Relevancy: Connecting the past, present, and future of cities

Our concept connects the historic roots of cities with current efforts to create the future of urban transportation in Milwaukee.

Cities over human history have shown their function as an assembly area for the exchange of goods [47] and have been shaped by the transportation infrastructure that moves people and materials through the space of the city [48]. Urban transportation has become more specialized, as reflected in Milwaukee. Electric streetcar service in the city of Milwaukee operated from 1890 under the Milwaukee Street Railway Company through its successor companies, The Milwaukee Electric Railway & Light Company and The Milwaukee Electric Railway and Transport Company, until 1958 [49]. The extent of the system through the city of Milwaukee grew to as much as 289 km (180 miles) of track and an estimated fleet, peaking in numbers approximately around 1930, of over 400 streetcars [49, 50]. Today's Hop is a distinctly different vehicle from those times [1], and it now connects Milwaukee's downtown neighborhoods [2]. Streetcars worldwide have also continued into the 21st century, with 376 streetcar systems operating and more planned [51].

As the needs of cities have changed, the transportation type and use of space in urban areas has changed. Within urban areas, observations show that density leads to productivity gains through the concentration of knowledge workers [52, 53]. People gain benefits from accessibility to activities and to each other [54]. This concentration of people and activities may lead to traffic congestion through motor vehicle trips. Further, researchers have shown automobile parking and storage policies have an impact on the utility of urban land [55]. To mitigate this spatial competition, the State Smart Transportation Initiative (SSTI), based at the University of Wisconsin-Madison, describes a transportation demand management (TDM) approach to achieve the purpose of cities [54]. The SSTI report, "Modernizing Mitigation: A Demand-Centered Approach," calls for improved transit infrastructure, subsidized transit, and high-capacity transit [54]. This report makes the case that adding motor vehicle trips to dense urban areas "degrades the accessibility of cities" and could lead to results counterproductive to winning the productivity increases that come from density [54].

With increasing urbanization [56, 57] and the growing public awareness of the needs of the densely settled areas of cities [58], the spatial distribution and the amount of vehicles in an urban area might need to flex to accommodate the goal of providing higher levels of productivity for urban land. Streetcar transportation has been shown in the past to serve the needs of cities for precisely this reason—to reduce vehicle trips and connect walkable areas. It remains to be researched if streetcars fill a niche in providing transit in dense areas in a manner that reinforces both the need for higher density and productivity as well as the human-centered knowledge economy. However, contemporary awareness, as reflected in the Cities Issue of *National Geographic* of April 2019, notes the loss of urban rail transit: "We didn't have to rip up all the streetcar lines. We didn't have to forget that cities are for people—and we don't need to do it again" [58].

Contemporary transportation planners have recognized the need to support transit with new technologies. Southeastern Wisconsin Regional Planning Commission's VISION 2050 plan calls for "improving and expanding public transit" [59]. Kansas City has implemented technology along its streetcar line [60, 61, 62] and set goals to include public WiFi, smart streetlights, and sensors [63]. The US Department of Transportation's Smart City Challenge recognizes the importance of technology for the future of urban transportation [64].

Our concept is a step toward building a framework for supporting and researching urban transportation within worldwide and Milwaukee's history. Cities are becoming the pattern of settlement [56, 57], crucial connectors of people engaged in the work of the modern economy, and "the defining artifacts of a civilization" [47]. In Milwaukee's history, the culture has embraced entrepreneurial civic-mindedness and has shown a continuous series of changes in cultural geography [65]. Bringing The Hop and its corridor to a level of integration with smart city trends connects Milwaukee's urbanism to the fourth industrial revolution. Milwaukee has a tremendous head start, with The Hop, in a worldwide movement to have the kind of urban fabric that future cities may need.

Usefulness: Improving the Quality of Life

Our concept's aim is to improve the quality of life along the streetcar corridor and throughout Milwaukee. We summarize the areas of quality improvement with the abbreviation HELP = Health, Equity, Livability, and Prosperity.

Health. Our smart streetcar corridor improves health through supporting emissions-free vehicles and reinforcing walkable urban places. The electric-powered nature of the streetcar vehicle makes it emissions-free in operation at street-level. Production of electricity in Wisconsin involves only a fraction of solar or wind sources at the present. Other streetcar systems, however, have taken this further, such as Nottingham Trams Ltd in England, which, as of April 2019, will buy power for its electric tram system from 100% "green [renewables] electricity" [66]. Advances in implementing renewable-energy production sources or special programs could increase The Hop's green electricity use. The City of Milwaukee sees The Hop as one component of overall goals for environmentally-sustainable systems. The Milwaukee Environmental Collaboration Office recognizes The Hop as an important choice in multi-modal, ecologically-sound transportation modes [67].

The Hop reinforces a healthy activity, walking, by connecting neighborhoods with high walk scores [69], and thus gives people the opportunity and motivation to move within these areas to access resources in close proximity. The nature of streetcar transportation requires walking to and from stations and destinations. The walkshed of transit is often recognized to extend to 400 meters [69, 70] from the streetcar stops and thus take in wide range of features and activities to motivate walking, including fitness, parks, and health-related destinations [6]. The City of Milwaukee is developing a pedestrian plan [71], and walking is recognized as a healthy activity [72].

Equity. By creating a smart corridor through which vehicles designed and built for all can operate, reducing the demand for single-vehicle trips, we support The Hop's goal to increase equity. Our concept is that transportation that can be affordable, accessible, and accountable to civic goals.

The Hop as a form of transit is affordable to all for its first year of operation with free fares provided by a sponsorship with the Forest County Potawatomi Community with Potawatomi Hotel & Casino as the presenting sponsor of the city's streetcar system [73]. Depending on how an eventual fare structure is devised, it may involve tiered rates such as used on the Milwaukee County Transit System [74] or on a multiple-systems card or phone app such as Portland's Hop Fastpass [75]. These rate structures are in contrast to ride-hailing or car-sharing services which may insitute surge pricing for special events or large demand. Further, ride-hailing services during large events could congest streets with automobiles, blocking access to the flow of people at special event sites or sites of interest. The vehicle capacity of The Hop, accommodating up to 150 people onboard each streetcar, is Americans with Disabilities Act (ADA) accessible [2]. Even during times of large numbers of people using the system, the level boarding provides a way for people of all abilities to get on and off The Hop through two sets of double doors open at each station.

Another aspect of equity involves accountability to Milwaukee communities. The goal of addressing the need for expanding the reach of the streetcar to the Historic King Drive and Bronzeville and Walker's Point neighborhoods has been done with an Equitable Growth Planning Study [3]. These plans included input from citizens, stakeholders, and market analysis which looked at how transit-oriented development can help spread the value of the streetcar extensions. The resulting plans work toward "attracting investment, enhancing connectivity and reinforcing neighborhood identity" in the Historic Dr. Martin Luther King Jr. Drive (King Drive) and the Bronzeville Cultural and Entertainment District as well as the Walker's Point and the Harbor District [76, 77].

The expansion plans of the streetcar are to support affordable housing [3]. The frequency and permanence of streetcar service works well to support affordable housing by reducing the cost burden of minimum parking requirements near transit, a strategy that is being used to increase the supply of affordable housing [78, 79].

Our concept could create a framework for measuring the implementation of these plans, bolster business formation through availability of 5G wireless, and work to make sure that the operations of the streetcar are safe, efficient, and harmonious with the goals for the communities. The smart network could measure and maintain the accountability of the streetcar corridor to assure stakeholders that the best practices will be pursued, data collected for learning from incidents, and continuous improvement followed to garner trust from citizens and decision-makers.

Using transit to support community understanding and equity has a precedent. A project on Israel's public transit light rail system, Dissolving Boundaries, seeks to foster dialogue and understanding between Israeli and Palestinian residents. This project shows how "In a city full of contested spaces, Jerusalem's light rail can function as a neutral ground" [80].

Livability. Our next aim is to support livability through urban-specific and human-centered design because the smart streetcar corridor we propose reinforces transit-oriented development and the walking environment around the streetcar stops. As the plans for streetcar extensions describe[3], transit-oriented development is a settlement pattern that seeks to specifically leverage the gains that transportation provides. Our concept for a smart corridor for the streetcar provides transit. Dense housing and transit described by architect Peter Calthorpe [58] seeks "to reinvent the old streetcar suburb, where you had fabulous downtowns and you had walkable suburbs, and they were linked by transit" corresponds, in many ways, to The Hop operating now in the "Walker's Paradise" areas of East Town and the Third Ward [68].

Transit Oriented Development (TOD) is a goal of the planning for The Hop and its extensions [3]. The basic idea of TOD is to make the best use of space around transit stops [81, 82]. A case study analysis of a TOD development in New Jersey has shown that "In each case, these communities have been able to add populations to largely build-out landscapes, expand the variety of its housing stock, and create locations where residents can satisfy their needs without personal vehicles" [83]. TOD has been recognized as a way to capture the demand for housing near transit through development [84]. Chris Persons, CEO of Capitol Hill [Seattle] Housing says, "The more we can locate affordable housing around transit, the better it is for the low-income individuals [and] the better it is for the resilience of our environment" [85].

Prosperity. The smart streetcar corridor would be built around the streetcar route itself, with the design aim of intending to serve concentrations of residents, jobs, and visitors in a density that leads to increased economic productivity of the urban land. As observed [52, 53], the density of jobs and residences increases productivity, encouraging more jobs and growth. The hop-on-hop off purpose of The Hop itself extends walkable access to 51 buildings over 10 meters tall along its Main Line [86], creating a corridor for collaboration and worker and residence density. Density fosters specialization, knowledge spillovers, competition, efficiency, larger labor markets, and economies of scale [52]. Density is important for "enhancing economic productivity, encouraging more sustainable patterns of travel, facilitating a more suitable mix of new dwellings and increasing occupational densities to support a more productive workforce" [53].

Impact: Empirically Measuring, Supporting, and Researching Streetcar Transit in Milwaukee

The aim of our concept is to build a smart network to measure, model, and research the operations of the streetcar and the environment through which it travels. At the heart of this concept is data-gathering that can measure how business, the environment, and residential life is impacted.

Quantities such as the amount of people moved and where, air quality monitoring through the smart nodes, access to 5G services for business and residents could become available. Streetcar vehicle performance, speed, systems could be measured in real-time and stored in the cloud. These measurements could quantify the efficiency and safety of operations and provide statistics on interaction with the corridor traffic, bicyclists, and pedestrians.

Business development along the corridor has already been motivated by the transportation line itself [5]. Measurements and work to improve the reliability of the streetcar strengthens its function as transportation to businesses and residences. The addition of 5G service along the route could foster business formation.

For residents, our concept seeks to measure the value of the corridor itself for aspects of living. With surveys based on measurements from the smart nodes and surveys of activity, this value could be quantified in terms of sales at businesses, health outcomes, and new business activity and formation.

Other parameters are directly measurable, such as air quality, transportation efficiency, and traffic flow and incidents. The environmental goals of air quality could be quantifiable with air quality monitoring through the smart nodes [17]. The movement of people would be quantified by the smart network, both on the streetcar as well as through sensors monitoring traffic. Incident reports could be gathered, and quantified in terms of how automobile traffic is calmed and streetcar operations work within the multimodal environment.

Market Opportunity

Our concept could attract partners who are seeking to gain experience in smart corridor development, including players such as Google, Microsoft, vehicle manufacturers, 5G wireless providers, or transit system operators. The revenue potential would come from the added value our concept brings to the safe and efficient operation of the streetcar for the stakeholders and the community and the business value of the smart corridor. The initial financial return could include delivering cloud-based diagnostics that support obstruction resolution services and streetcar safety, product, and performance reporting.

Size & Positioning

A market analysis shows 18 streetcar systems operating in the USA, 376 systems worldwide, and more than 70 in the construction or planning stages [51, 87]. *Metro Magazine* observes that streetcars "are making an unprecedented resurgence across the U.S. and around the world" [88]. Figures available from the American Public Transportation Association (APTA) show a capital expense in the US of $3.5 billion in 2013 for both light rail and streetcar (streetcar was not separated out from the total) [89]. The APTA also shows proposed federal capital investment grant funds of $454 million for streetcars during the fiscal year 2016 [89]. Our positioning within this market would be in operations, support, and research. Our ability to show value-added results for these activities would be the key to gaining partners.

Target Customer

Our goal is not to replace current partners on the streetcar, but to collaborate to create new tools to gather data, develop methodologies, perform empirical research, support operations, and begin to answer questions about urban transportation that have never been asked before.

Our target partners include stakeholders in the range of operations, support, governance, manufacture, maintenance, supplies, and staff involved in streetcar operations worldwide. Our goal would be to collaborate to build and operate a system that gives value for current operations and develops products and methods that can be proven to show improvement of the streetcar system.

Major transportation solutions providers may have research and development efforts or operations research departments that would be interested in our concept. Major operators who have a presence in US transit systems include:

Transdev--operators of The Hop. Transdev is an "operator and global integrator of mobility." As of December 2017, Transdev operates in 19 countries, has 74,309 employees, and has an annual revenue of €6,643 million ($7.4 billion). The Transdev Web site explains their efforts: "we are building an ecosystem of partner companies to ensure the best service at the best cost." (https://www.transdev.com)

Bombardier Transportation--a global mobility solution provider. Its fiscal year 2018 revenue was $8.9 billion with 40,650 employees. Their efforts are for "rail solutions, ranging from global mobility solutions to a variety of trains and sub-systems, services, system integration and signaling to meet the market's needs and expectations." (https://www.bombardier.com)

RATP Group--a multimodal operator in urban mobility, with a core business in the Paris, France region. Their 2015 revenue was €5.56 billion ($6.2 billion) with 59,667 employees. Their efforts are to "deploy innovative systems to meet the new uses and expectations of our customers and an urban population that is on the rise and increasingly connected." RATP Smart Systems works in Intelligent Transport Systems and of mobility-enhancement services. (https://ratpgroup.com)

Manufacturers of streetcar vehicles may be interested in our concept in order to provide support for their vehicles to customers and to identify and develop new features.

The US streetcar manufacturer, **Brookville Equipment Corporation,** the builder of The Hop, is a privately-held corporation, and has these modern streetcar projects:

- Dallas Area Rapid Transit (DART)
- QLINE Detroit
- City of Oklahoma City
- City of Milwaukee, The Hop
- Portland, Oregon (orders)
- Tacoma Link (orders)
- Tempe Streetcar (orders)

Brookville Equipment Corporation has provided restored heritage PCC streetcars to the City of El Paso, the San Francisco Municipal Transportation Authority, New Orleans Regional Transit Authority , and the Southeastern Pennsylvania Transportation Authority. (https://www.brookvillecorp.com)

Manufacturers or developers of specific sub-systems also might have an interest in real-time monitoring. For example, **vehicle battery developers** [91] might be interested to know the battery drain performance in polar vortex conditions, as experienced in January of 2019 in Hop operations.

Engineering firms working in transportation projects might make use of the analytic tools we might develop for mobility designs.

The engineers of The Hop, **HNTB Corporation**, is a "infrastructure solutions firm serving public and private owners and contractors." HNTB has employees worldwide and an office in Milwaukee. (http://www.hntb.com).

Further customers or partners could potentially include **specific transit agencies** involved in streetcar operations currently or proposed streetcar projects. Here is a table compiled from agency profiles at https://www.transit.dot.gov and publicly-available financial reports showing systems, operators, and revenue from the parent company operators of urban rail systems in the US.

State: Name of System Location	Operators	Revenue
Arizona: Sun Link (Tucson Streetcar) Tucson (second era)	RATP Group	€ 5,399.1 million ($6 billion) (Transport revenue) (2016) (Annual report p. 8)
Arkansas: Metro Streetcar Little Rock (second era)	Rock Region Metro	$17,330,796 (Actual Total revenue) (2017) (Annual Report p. 30)
California: Metro Rail(Blue, Expo, Gold and Green lines) Los Angeles	Los Angeles County Metropolitan Transportation Authority	$4,093,649 (Total program revenues) (2017) (Annual Report p. 21) $52,570,228 (Fare revenues for light rail) (2017) (transit agency profile)
California: San Diego Trolley San Diego	San Diego Trolley, Inc. (SDTI)	MTS is effectively an umbrella agency. MTS owns the assets of San Diego Trolley, Inc. (SDTI) and San Diego Transit Corporation (SDTC), the area's two largest transit operators. $362,200,347 (2018) (Total revenue of MTS) (Annual Report)
California: Muni Metro San Francisco	San Francisco Municipal Railway	$1.2 billion (2018) (Annual Report) $ 5,746,779 (2017) (Street car Fare Revenue) (agency profile)
California: Port of Los Angeles Waterfront Red Car Line San Pedro	Port of Los Angeles	$490,760,000 (2018) (Annual Report p. 16) (operating revenue)
Colorado: RTD Light Rail Denver (second era)	Regional Transportation District	$147,376,000 (2017) (total operating revenue) (Annual Report p27) $ 38,157,473(2017) (Light rail Fare Revenues) (agency profile)
District of Columbia: DC Streetcar Washington(second era)	RATP Group	€ 5,399.1 million (Transport revenue) (2016) (Annual report p. 8)
Florida: TECO Line Streetcar System Tampa (second era)	Hillsborough Area Regional Transit	$16,537,331(2016) (Total operating revenues) (Annual report p88) $ 1,697,447 (2017) (Fare revenue of street car rail) (agency profile)
Georgia: Atlanta Streetcar Atlanta (second era)	Metropolitan Atlanta Rapid Transit Authority	$457,788,000 (2017) (Operating revenue) (Annual report p. 6)

Massachusetts: MBTA Green Line Ashmont–Mattapan High Speed Line Boston	Massachusetts Bay Transportation Authority	$764,421(2018) (total operating revenue) (Annual report p. 9) $ 83,191,624 (2017) (fare revenues for light rail) (agency profile)
Michigan: QLine Detroit (second era)	Transdev	€6,643.2 millions (2017) (Revenue from ordinary activities) (report p. 8)
Missouri: KC Streetcar Kansas City(second era)	Kansas City Streetcar Authority	$4,150,350(2015) (revenues) (Annual report p6)
New Jersey: River Line (New Jersey Transit) Camden (second era)	Bombardier Transportation	$8,915 Million(Transportation) (2018) (Annual report p.153)
New York: Buffalo Metro Rail Buffalo (second era)	Niagara Frontier Transportation Authority	$64,898,000(2018) (Charges of services) (Annual report p14) $ 5,625,487 (2017) (light rail) (agency profile)
North Carolina: Lynx Charlotte (second era)	Charlotte Area Transit System	$125,250,665(2015) (operating revenue) (Annual report) $ 0 (2015) (fare revenue) (agency profile)
North Carolina: CityLynx Gold Line Charlotte (second era)	Charlotte Area Transit System	$125,250,665(2015) (operating revenue) (Annual report) $ 0 (2015) (fare revenue) (agency profile)
Ohio: Cincinnati Bell Connector Cincinnati (second era)	Transdev	€6,643.2 millions (2017) (Revenue from ordinary activities) (report p. 8)
Oklahoma: Oklahoma City Streetcar Oklahoma City	Herzog Transit Services	$593 million (2016) (revenue) (Craig-Eversold-Herzog-presentation-2016)
Oregon: MAX Light Rail Portland (second era)	Tri-County Metropolitan Transportation District of Oregon	$574,197,000(2017) (total revenue) (Annual report) $ 49,384,596 (2017) (fare revenue) (agency profile)
Oregon: Portland Streetcar Portland (second era)	Tri-County Metropolitan Transportation District of Oregon	$574,197,000(2017) (total revenue) (Annual report) $ 49,384,596 (2017) (fare revenue) (agency profile)
Pennsylvania: SEPTA Subway–Surface Trolley Lines Philadelphia	Southeastern Pennsylvania Transportation Authority	$467,901,000 (2018) (operating revenue) (Annual report) $ 25,710,304 (2017) (Fare revenue) (agency profile)

Pennsylvania: SEPTA Routes 101 and 102 Philadelphia	Southeastern Pennsylvania Transportation Authority	$467,901,000 (2018) (operating revenue) (Annual report) $ 25,710,304 (2017) (Fare revenue) (agency profile)
Pennsylvania: SEPTA Route 15 Philadelphia	Southeastern Pennsylvania Transportation Authority	$467,901,000 (2018) (operating revenue) (Annual report) $ 25,710,304 (2017) (Fare revenue) (agency profile)
Texas: DART Dallas	Dallas Area Rapid Transit (DART)	$79,587,000 (2017) (Operating revenue) (Annual report) $ 0 (fare revenue of street car rail) (2017) (agency profile)
Washington: Tacoma Link Tacoma	Sound Transit (ST), officially the Central Puget Sound Regional Transit Authority	$86.5 million (2016) (Total operating revenue) (annual report 2016) $ 0 (fare revenue of street car rail) (2017) (agency profile)
Wisconsin: The Hop Milwaukee	Transdev	€6,643.2 millions (2017) (Revenue from ordinary activities) (report p. 8)

Manufacturers of equipment used could have a strong interest to participate in developing partnerships. **8K video and 5G wireless equipment manufacturers** could have an interest in the manufacture of the smart nodes and equipment needed for our concept.

Our concept also might attract partners who are seeking to participate in vehicle-to-anything (V2X) development, including players such as **Google, Microsoft**, and others who are currently looking at autonomous vehicles, although our goal is not to develop autonomous vehicles. Our challenge would be to show to these potential partners that immediate gains in intelligent vehicle operation may come from corridor-based systems, as we describe, that support fixed-route vehicles in dense urban settings (streetcars). This form of transportation support--corridor-based--may be an approach that produces results more quickly than the pursuit of autonomous vehicles.

Competition

Currently, no streetcar systems have been identified that utilize millimeter wave technology as proposed in our idea. For example, RTAChicago shows that GPS & Wi-Fi is used for vehicle communication [90].

Our use of 5G and 8K combined is a new approach to a smart corridor, although the Finnish LuxTurrim 5G [15] project uses 5G communication developed on smart light poles.

Revenue Potential & Financial Return

Key Revenue Streams

Our key revenue streams would be in partnerships with transit agencies and transit system operators who wish to become involved in research and development in a smart streetcar corridor. Another area of key revenue would come from manufacturers of streetcar vehicles and equipment who wish to become involved in product testing and research. The third key stream would come from research grants from academic, government, and think-tank organizations who seek to advance transportation research.

Revenue Potential

Our revenue potential would be based on the research and development budgets initially, and then operating budgets of transit operators and agencies.

Product Positioning & Sales/Growth Strategy

Our sales positioning and growth would arise from a staged approach to the project's implementation. The aim would be to grow in scope starting from a focus on the smart node, and then to smart control, and then to a smart corridor. The table below summarizes this strategy with steps continuing along each phase.

	Step 1	Step 2	Step 3
Smart Node	• Integrated corridor reinventing • 5G deployment • 8K camera • CPU • sensors	• Facility maintenance • Data collection	• Facility maintenance • Data collection
Smart Control		• Control center deployment • Traveler information service • Integrated payment • Smart signal and scheduling	• Traveler information service • Integrated payment • Smart signal and scheduling
Smart Corridor			• Smart vehicle • Multi-modal management • Safety and emergency management

Initial Financial Return

We expect our initial financial return to come from forging partnerships regarding operations support and product development. Initial returns might be from specific products such as delivering diagnostic data that the smart nodes are able to collect to partners, including manufacturers, to improve their projects.

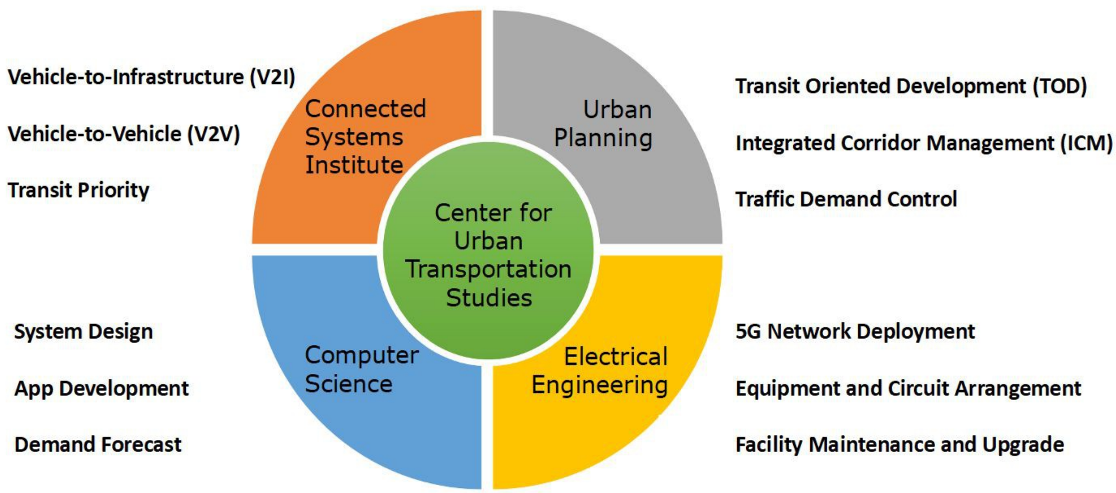
Risk Assessment

To evaluate the risk of our concept, we performed a SWOT analysis, which seeks to disclose and analyze our strengths, weaknesses, opportunities, and threats to implementing our concept.

Strengths

- The expertise at Center for Urban Transportation Studies (CUTS), University of Wisconsin--Milwaukee (UWM) is fully capable and experienced in transportation analysis and projects which have withstood peer-review and have been used in operations worldwide, including in southeastern Wisconsin. Colleagues in the transportation field worldwide might also be interested in participating.
- The Hop is an existing streetcar that is operating, is funded for years ahead, is new enough so that the operators may be eager to see ways to measure performance, and is small enough that placing a smart network on its entire route length might be feasible; it also displays a diversity of street configurations and interactions with a variety of neighborhoods.
- We have potential partners to provide the needed engineering and research expertise to develop the concept to reality. UWM is a Tier 1 research institution. UWM's College of Engineering and Applied Science has experts in engineering, computer science, and networking. UWM itself has experts in Connected Systems (CSI) and experts in urban planning at the School of Architecture & Urban Planning.

The following diagram summarizes some of the potential close partnerships among academic units at UW-Milwaukee and areas of work:



- We are operating in a city, Milwaukee, which has many educational institutions and technology companies. The Milwaukee School of Engineering, on the route of The Hop itself, is building an Artificial Intelligence research center, focused on artificial intelligence and cloud computing, housing a GPU-powered supercomputer [92].
- We feel strongly in the merit of our concept, as proven by past transportation analysis, and that we could contribute to the streetcar's success in known ways and by future research because data collection--a key aim our concept--is the lifeblood of research itself.

Weaknesses

- Considerable engineering expertise would have to be applied to integrate emerging technology with the physical systems, infrastructure, networks, computing, cloud communication, cloud computing, and ongoing research and development while delivering results to partners.
- A novel application of emerging technologies carries risk because technologies could change rapidly or have disconnects in integration.
- The concept involves many players and stakeholders including government at all levels, transit agencies, transit operators, telecom companies, business improvement districts, academic units; complex agreements, permissions, and coordination would need to be negotiated.

- Cloud-based computing and data storage, while promising, is a particularly crucial component for this concept and an emerging field; this would require a partner with strong experience in this area.
- Stakeholders may not see the benefit of the concept in light of its costs (the ROI) because of the up-front infrastructure and deployment costs of the physical and network systems; stakeholders might see the current methods of operation as sufficient and immediate results not sufficient for the effort and costs. Without an operating smart network system, of course, specific results could not be shown.
- There is difficulty of showing benefits of the smart corridor on business incubation or formation. Use of the 5G technology could be quantified, but a causal link of business formation to streetcar operation might not be provable.

Opportunities

- The major opportunity is tremendous: research leading to results. Data availability is crucial for testing various transportation analysis methods, and a working system would provide detailed performance metrics so that hypotheses could be developed on the virtual twin of the system and then tested in real-world operation.
- The novel idea of implementing an actual, working model of what might termed a "smart streetcar corridor" could boost the city's profile in the technology field and in streetcar transportation. Currently, the Kansas City Streetcar provides smart services (which, from what we can tell, doesn't involve the 5G communication we envision [63]).
- The 5G network along the route and in the vehicles itself could be a benefit to the city's businesses, residents, and profile in the world. A 5G zone near the Fiserv Forum might be very helpful for the 2020 Democratic National Convention in Milwaukee.
- The fundamental goal of our concept--supporting the streetcar operations for safety and efficiency--could lead to an increase in positive results so that the continued successful operation of the streetcar is made even stronger.
- The data collection and research could inform and justify public policies that support the harmonious operation of the streetcar with other traffic and transportation in a fair and equitable way.
- There would be opportunities for research into data-driven rider satisfaction models that could be used to build rider loyalty similar to Starbucks loyalty plan concept—using data on customer preference and behavior to tailor the service to their needs. Further passenger studies might explore the concept that the streetcar showcases businesses along the route—through high visibility through The Hop's big windows and the visual presence of The Hop

on the street to explore how “the presence of the streetcar is producing additional development stimuli that are contributing to heightened activity” [7].
- While focused on The Hop for deployment, our concept might be used on some of the 376 streetcar systems around the world and more in development. Many such systems face scrutiny because their results and benefits are hard to quantify. Many proposed systems, such as The BQX in New York, NY [93], struggle to gain acceptance in the planning stages. A promise of a kind of "streetcar operating system" ready to work toward corridor-based continuous improvement of the system's safety and efficiency, might help convince stakeholders to build a system.

Threats

- The cost of developing a smart network may not be seen as viable within the priorities in funding neither at a government or at a commercial level. The ROI may not be clear or compelling enough.
- Contingency plans could be adopted that don't collect sufficient data to show results, which would make a weak case for providing the smart network in full.
- The financial and political support for the streetcar itself, a complex technical and political accomplishment, may erode in the face of perceptions, fair or unfair, of its operations.
- While the complex integration of emerging technologies shows a high barrier to entry, such work may become commonplace soon. Competitor projects could emerge over time. This is mitigated by the particular expertise of the Center for Urban Transportation Studies, located in Milwaukee, which is essential for success.

Contingency plans

A set of plans could be developed to deal with lack of funding or limited funding or lack of interest by potential partners.

- Develop a plan for data collection that is sufficient to develop a "digital twin" of the system for methodological development and testing.
- Develop a minimum viable product (MVP) [94] version of the smart node for demonstration purposes.
- Develop a test-run case of the smart nodes to measure simple statistics and metrics on a particular stretch of the track with perhaps one signal to show at least the feasibility of the system.
- In the case of withdrawn support for the streetcar in Milwaukee, the project

might continue on another system.
- The system could be studied academically using some mathematical models showing how hypothetical, estimated, or gathered statistics would be used.

Risk Assessment Conclusion

A risk assessment shows that our concept has considerable strengths in the areas of analytic capability in the methodologies used for transportation analysis. Our project also has a domain of application—The Hop streetcar—that is established and running in Milwaukee. The opportunities that could result from the concept implementation would be manifold: support for the streetcar's safety and efficiency and data collection to support further transportation research. The smart network could be a framework for many kinds of measurements and community involvement in things like air quality monitoring, traffic safety, business formation and activity monitoring, and community-based communication and collaboration. The goals of the streetcar itself—supporting our HELP areas (Health, Equity, Livability, and Prosperity)—would aim to provide community benefits.

However, there are significant risks and threats to success. The use of many components of infrastructure, hardware, software, networks, cloud storage, cloud computing, and the analysis involved all require a range of technical and organizational expertise. The complexity of project partnerships and management could make it difficult to gain consensus or move forward.

For competitors, the risk in integrating a system of hardware, software, and networks using emerging technologies creates a fairly large barrier to entry. Further, a competitor would have to possess the academic knowledge to apply transportation analysis. The co-location of the UWM Center for Urban Transportation Studies (CUTS) in Milwaukee provides expertise for the methodologies employed in analysis which have a proven track record of giving insights to improve transportation. CUTS, established in late 1970s, is an internationally-recognized transportation research, education, and technology transfer/training/outreach center with a focus on combining academic knowledge and extensive real-world experience in developing innovative, implementable solutions for all modes of transportation. Our concept might be distributed world-wide to potential large customers. Organizations and partners in streetcar manufacture, operation, or governance may gain greatly from the support and analysis this concept provides.

The pursuit of this concept would need further development to move forward:

(1) The concept would have to be scrutinized for engineering and technical

feasibility by experts in the systems it involves. This process would examine, revise, and validate the basic concepts by engineers and experts.

(2) The organizational structure for combining partners and stakeholders would have to be determined. A project management structure might involve a collaboration among academic, industry, public, community, and research organizations that would participate. For example, the Finnish LuxTurrim5G project involves, “9 companies and 3 research institutes, with project volume of 15 M€ from Business Finland and the companies” [15]. A flexible structure, contingent on funding and interest, would have to be developed.

Conclusion

Our idea is to support safe, efficient, beneficial, and user-friendly streetcar operations with a unique approach. We propose applying the massive data capabilities of 5G and 8K and cloud-based data-gathering and analytics in a smart network corridor.

Our vision is to help the unique community of Milwaukee--and perhaps the world--through smart transportation. The benefit would be safe, efficient, and harmonious operations that provide support for business incubation and attraction, advancement of transportation research, and opportunities to improve the quality-of-life--health, equity, livability, and prosperity--along the smart corridor.

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