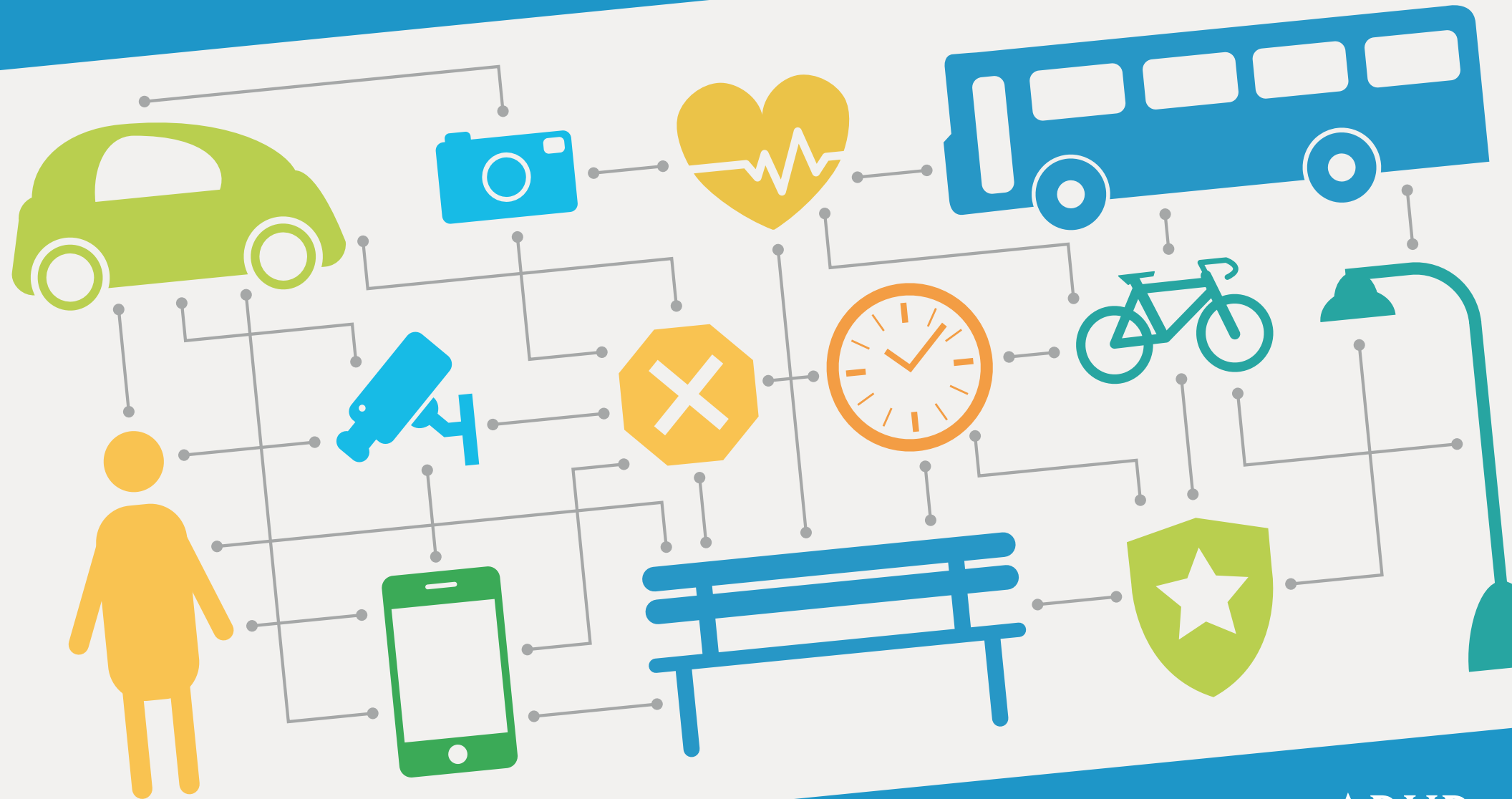# The Future of Connected Streets

An Arup Exploration in Collaboration with Qualcomm Intelligent Solutions, Inc.

ARUP

The Team*

Arup is an independent firm of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services. Through our work, we aim to make a positive difference. We shape a better world. Founded in 1946 with an initial focus on structural engineering, Arup first came to the world's attention with the structural design of the Sydney Opera House, followed by its work on the Centre Pompidou in Paris. Arup has since grown into a multi-disciplinary organization. Its works have reaffirmed its reputation for delivering innovative and sustainable designs that reinvent the built environment.

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* Qualcomm Intelligent Solutions, Inc. collaborated with Arup by sponsoring the project and participated in the workshops and research sessions utilized to develop this content.

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Special Thanks

Contents

"A truly 'smart city' ... should be a palimpsest of creative, bottom-up civic engagement. It should ... allow "hacking" by its smart denizens, empowering them to augment their collective space through the exploding constellation of urban apps."

———

Carlo Ratti - *MIT Senseable City Lab*

I. Introduction: For Smarter Cities, Look to the Streets

Tomorrow's cities will be both vastly different and yet similar to what they are today. In 2016, city governments around the world are working hard to transition to real-time operations, hoping to increase their own efficiency and make citizens' lives more convenient. But for many, the path has proven bumpier than expected.

For one, city governments are finding that the standard model of service delivery no longer works. To serve their constituencies in the era of cloud computing and autonomous cars, they must think beyond traditional departmental silos and develop new methods of collaboration.

Funding is also ripe for new approaches. Instead of placing the financial burden of infrastructure and services solely on taxpayers, municipalities are beginning to explore alternate models to effectively provide for their diverse constituencies.

Additionally, cities are also increasingly tailoring solutions to their own unique circumstances. Any given place has been shaped by its particular history, geography, and culture, with important consequences for matters such as land use patterns and transportation networks. As a result, there are no one-size-fits-all solutions for marrying physical and technological infrastructure.

Yet despite these challenges, municipalities are forging on, convinced that the potential benefits ultimately outweigh the risks. This was one of the main conclusions from research that Qualcomm Intelligent Solutions, Inc. and Arup have undertaken in New York, Shanghai, and Atlanta over the past few months: The smart city movement is here to stay.

One of the greatest opportunities we identified lies in our streets, some of the most critical spaces in our communities. In redefining some of the fundamental functions of streets, municipalities can better address the diverse and dynamic concerns and desires of their citizens. Streetscapes can be reimagined so that they can flexibly adapt to meet the needs of different users at different times of the day. Light poles, for example, can also monitor air quality and traffic congestion, alerting government officials of the need to reduce pollution and commuters of alternate routes while still providing the traditional illumination.

As designers, technologists, and city administrators we don't need to limit ourselves to the physical constraints of the 20th-century. In particular, we can find ways to adapt our street infrastructure for tomorrow's needs. In this publication we've collated the expert opinions of private and public sector stakeholders who understand the many facets of streetscapes and will play an active role in shaping future design.

From this foundation, we've developed a framework for thinking about future streets from a people-centered perspective (Sec. II) and applied that framework to a set of connected street visions, bringing to life the emerging possibilities (Sec. III). With those visions in mind, we outline some of the key successes and challenges that define the current state of smart infrastructure deployment (Sec. IV) and present some practical recommendations for how best to shape the desired future (Sec. V). The end result is a practical vision for how we can begin to rethink and reclaim our streets for the benefit of everyone.

"With cities, it is as with dreams: everything imaginable can be dreamed, but even the most unexpected dream is a rebus that conceals a desire or, its reverse, a fear. Cities, like dreams, are made of desires and fears."

———

Italo Calvino - *Invisible Cities*

# II. A Model for Planning People-Centered Streets

All design, by definition, is an expression of human intent. Otherwise, it would be indistinguishable from nature. As such, everything we design, plan, or propose is a reflection of some set of embedded values, desires, or priorities that – whether stated or unstated, explicit or implicit – have shaped or influenced the design process.

Quite often, when thinking and talking about the future of connectivity, the focus quickly shifts to the technologies, infrastructure requirements, and performance benefits of the systems being built or specified. While those are essential considerations, inextricable from the conversation, in an ideal world they should all be in service of a broader set of human-centered goals: meeting the needs of people, enabling them to thrive, inspiring and empowering them, and beyond.

Our streets are no exception. For every desire, every priority, we can imagine a multitude of streets that could exist, each with a specified value serving as its center of gravity. If it was decided that the enjoyment of the citizenry was the most essential criteria for future design and planning decisions, what types of streets would be created to serve that vision? Or how about health and well-being? What would be the experience of a street that prioritizes health and what would it take to actually make that street a reality?

Thinking about the different centers of gravity and how they might express themselves in our streets provides a framework that takes a more holistic view of the human experience and the formative role that infrastructure can play in the lives of citizens. It will shift our thinking beyond simply what the technology can (or will) offer to help us honestly reflect on what people need and value and, ultimately, how those needs and values can be addressed.

Through our own research efforts and our work with cities and communities around the world, we have consistently observed that the following priorities are often emphasized when discussing the attributes of a good neighborhood, town, or city. They are some of the key elements that drive how people define 'Quality of Life.' This list is by no means exhaustive or comprehensive, but serves as a useful sample of what many people value and look for in a place. In focusing on these topics and arraying them in a circle, our aim is to put people firmly at the center of the vision process and create a structure for evaluating how our future streets can, and should, address the things that they value most.
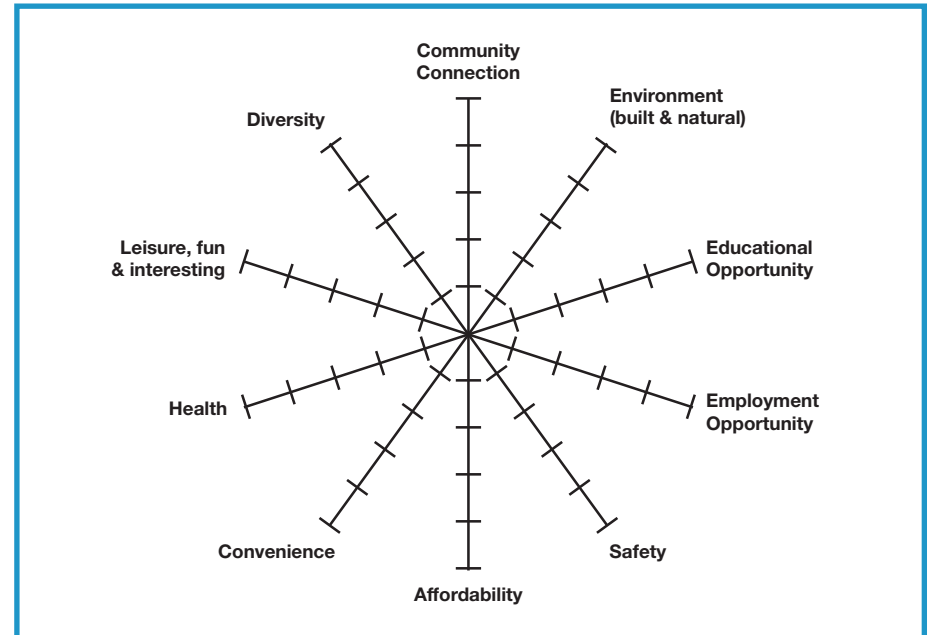
III. Connected Street Futures:
A New North Star

There are an infinite number of futures you can co-create, but which are the ones worth creating? Through a series of workshops with a broad range of stakeholders – city officials, city residents, architects, planners, engineers, designers, and lighting companies, among others – in New York, Shanghai, and Atlanta, we developed a set of possible streets that could feasibly exist in the future.   spring from the themes and concepts that came up repeatedly in our process and are based on the real-world experiences, grounded understanding, and creativity of all the talented people with whom we've had the privilege to work.

More importantly, though, each street is in some way connected to our broader ideas about what really contributes to quality-of-life for people. Instead of starting with technology and asking "What type of street or community would this technology make possible?" we can start with what people value in their lives and work to leverage digital and physical infrastructure to optimize and enable those

things, using the street as a focus point.

As the charts on the next page show, different streets directly address different values. Some of them, like The Protective Street, connect with very serious human concerns like safety and public health. Others, like The Community Inclusive Street, speak to our desires to actively engage with and shape our communities and, by extension, our society.

In the following pages six future streets will be brought to life, paying specific attention to what the experience of the streets could be, what makes them valuable or beneficial to a range of stakeholders, and what features might be developed. We hope they spark a sense of what's possible when people are at the center of our planning and design.

THE LEISURE STREET

Radar chart axes: Community Connection, Environment (built & natural), Educational Opportunity, Employment Opportunity, Safety, Affordability, Convenience, Health, Leisure, fun & interesting, Diversity

THE PROTECTIVE STREET

Radar chart axes: Community Connection, Environment (built & natural), Educational Opportunity, Employment Opportunity, Safety, Affordability, Convenience, Health, Leisure, fun & interesting, Diversity

THE COMMUNITY INCLUSIVE STREET

Radar chart axes: Community Connection, Environment (built & natural), Educational Opportunity, Employment Opportunity, Safety, Affordability, Convenience, Health, Leisure, fun & interesting, Diversity

THE ECO-OPTIMIZED STREET

Radar chart axes: Community Connection, Environment (built & natural), Educational Opportunity, Employment Opportunity, Safety, Affordability, Convenience, Health, Leisure, fun & interesting, Diversity

THE PARTICIPATORY STREET

Radar chart axes: Community Connection, Environment (built & natural), Educational Opportunity, Employment Opportunity, Safety, Affordability, Convenience, Health, Leisure, fun & interesting, Diversity

THE ADAPTIVE COMMERCE STREET

Radar chart axes: Community Connection, Environment (built & natural), Educational Opportunity, Employment Opportunity, Safety, Affordability, Convenience, Health, Leisure, fun & interesting, Diversity

The Leisure Street

The Story of This Street

According to Psychology Today, "Recreational deprivation has been linked to criminality, obesity, and declining creativity."[1] Encouraging leisure and play is critical to the physical and emotional health of society.
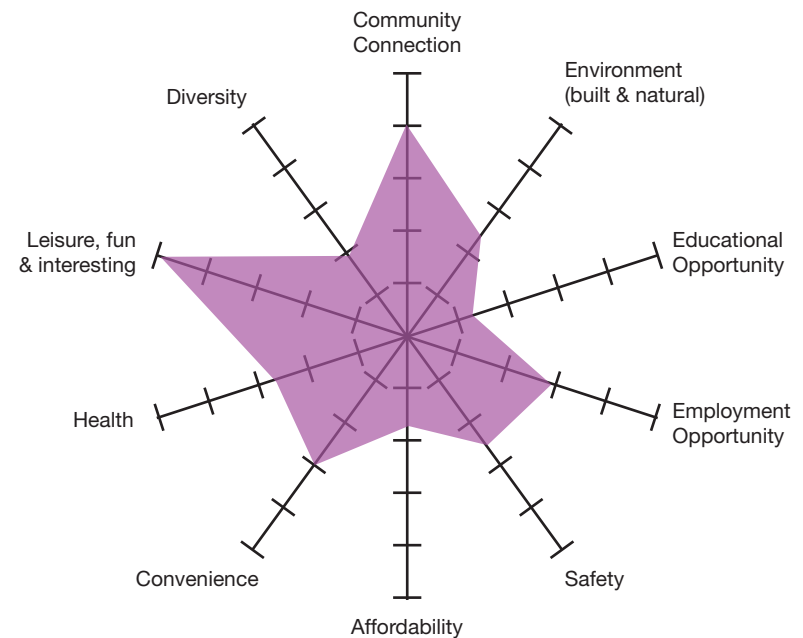
Imagine a street that seamlessly coordinates after work drinks with your friends. Embedded technology that notifies you of an impromptu basketball game forming at your local court so you can reserve a spot. A street that adjusts the light and sound environment to optimize for your favorite leisure-time activities. The Leisure Street leverages the power of sensors, real-time processing, high-speed connectivity, and adaptive lighting and sound to optimize personal enjoyment every day.
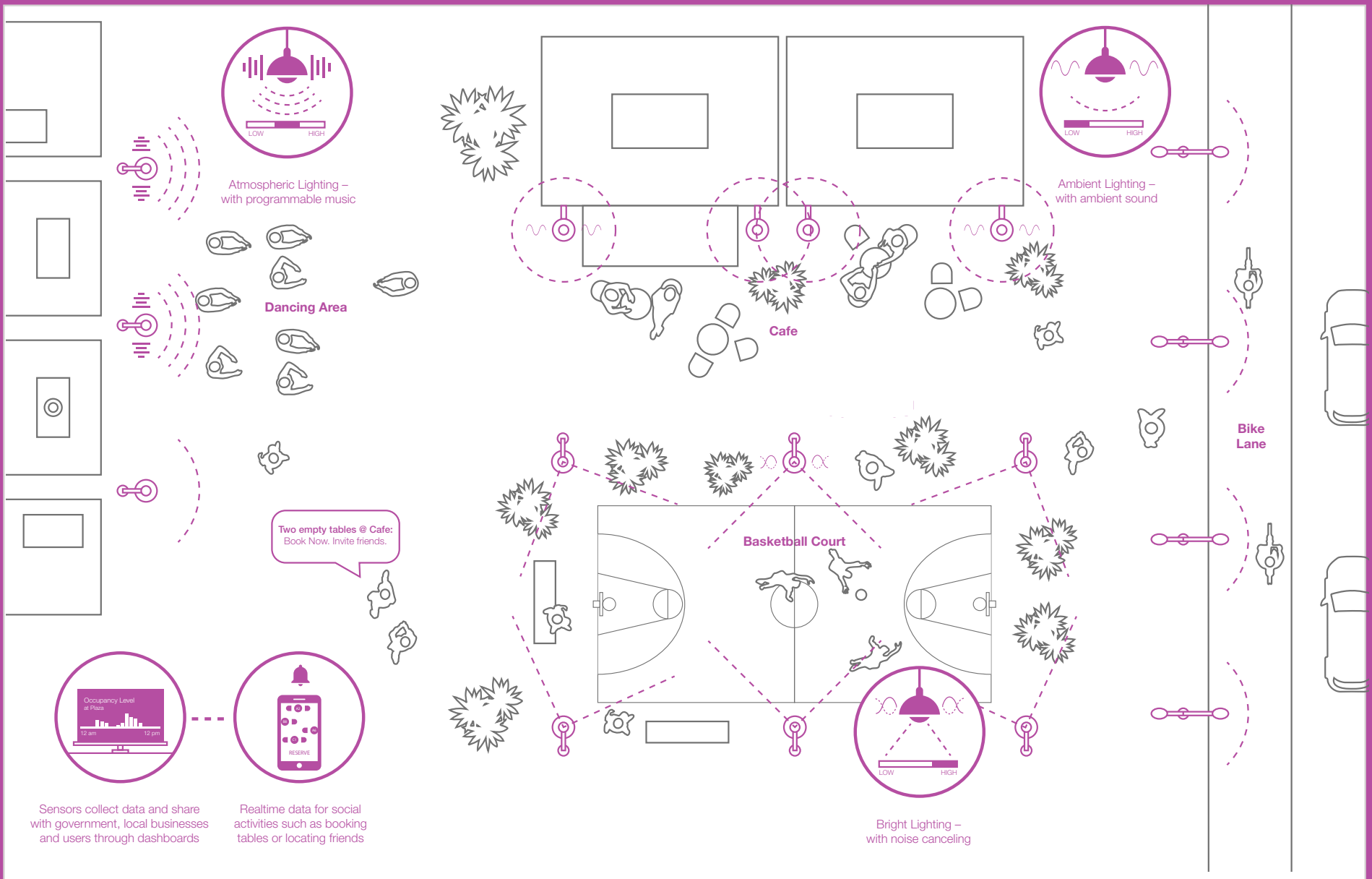
What Needs Does it Meet

Pedestrians / People. In our modern world decompression time is a commodity. This space allows people to effortlessly inhabit a space and to focus on interacting and connecting with others.

Local Businesses. Businesses thrive from the purchasing power of their local economies. By attracting more people into public space and generating useful, anonymous data, businesses will develop new insights into their local markets.

Municipal / City Agencies. Sensor-enabled data collection, controllable interactive lighting, and real-time information allows city governments to better understand and meet the needs of their communities, while ensuring their safety.

Radar chart with axes: Community Connection, Environment (built & natural), Educational Opportunity, Employment Opportunity, Safety, Affordability, Convenience, Health, Leisure, fun & interesting, Diversity.

Atmospheric Lighting –
with programmable music

LOW   HIGH

Dancing Area

Ambient Lighting –
with ambient sound

LOW   HIGH

Cafe

Bike
Lane

Two empty tables @ Cafe:
Book Now. Invite friends.

Basketball Court

Occupancy Level
at Plaza

12 am   12 pm

RESERVE

Sensors collect data and share
with government, local businesses
and users through dashboards

Realtime data for social
activities such as booking
tables or locating friends

Bright Lighting –
with noise canceling

LOW   HIGH

Enhances the leisure experience, from fit-to-purpose lighting and sound to real-time, geo-sensing, social connectivity.

The Protective Street

The Story of This Street

According to Bloomberg Philanthropies, the laws of roughly 85% of countries globally are inadequate to counter their growing number of traffic injuries and fatalities. As such, 20-50 million traffic-related injuries and ~1.24 million deaths occur each year.[2]
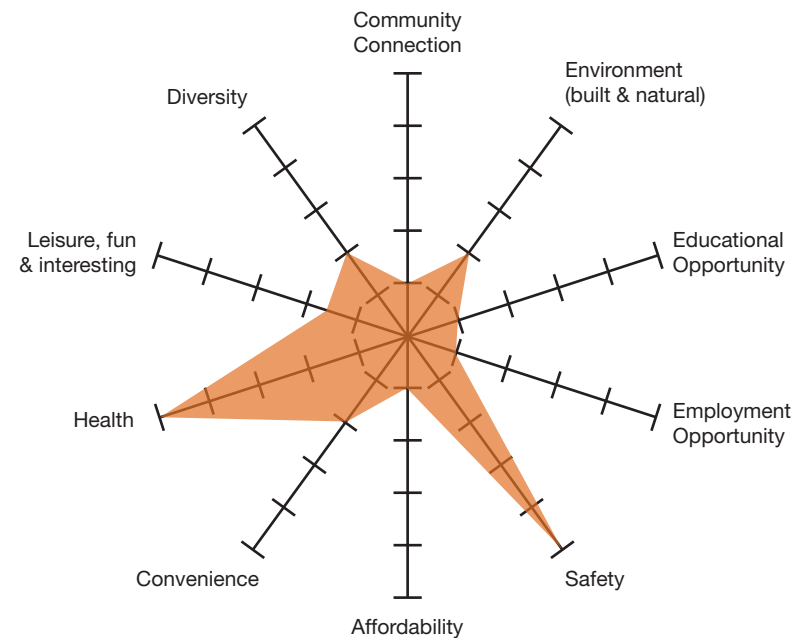
Imagine a street that perpetually works to protect you and the people you care about the most. A street where you can feel 100% at ease. The Protective Street senses and helps to synchronize movements by signalling in real-time between motor vehicles, pedestrians, and cyclists to heighten awareness and prevent collisions. It monitors and cleans the air you breath and could even reward or incentivize responsible, proactive behaviors like walking or taking the stairs.
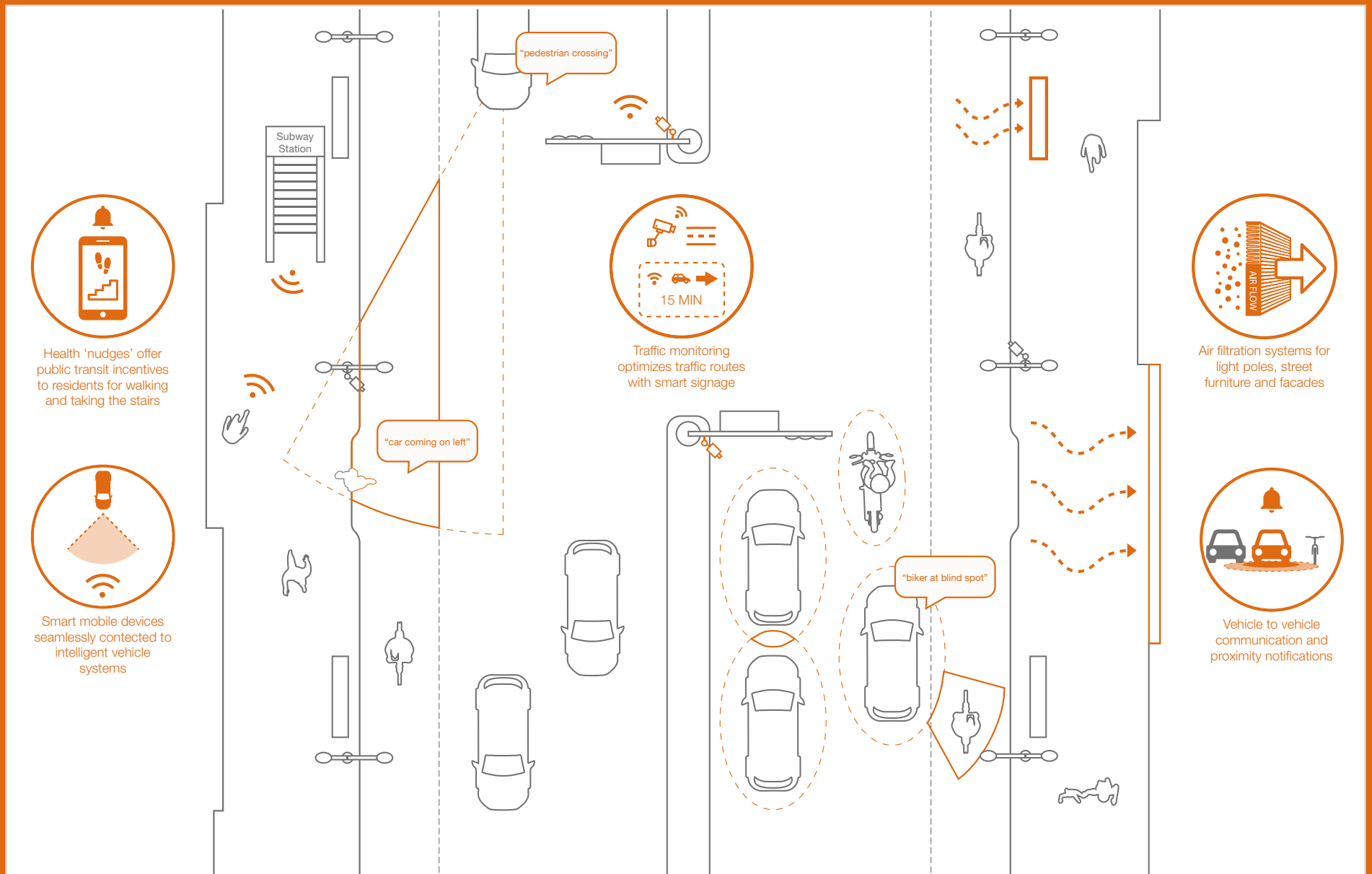
What Needs Does it Meet

Municipal / City Agencies. Increases reputational capital. Reduces the need (and cost) of storing and operating emergency vehicles and protecting the public. Enhances operational efficiency.

Pedestrians / People. Enables better physical health and quality of life for local residents. Creates safer and more livable neighborhoods by diminishing the risk of accidents and increasing accountability. Also has mental health implications, potentially reducing anxiety and stress associated with safety concerns.

Local Businesses. Safer streets are more conducive to foot and vehicular traffic and thus good for increasing business traffic and commerce.

"pedestrian crossing"

Subway
Station

Health 'nudges' offer
public transit incentives
to residents for walking
and taking the stairs

"car coming on left"

Smart mobile devices
seamlessly contected to
intelligent vehicle
systems

15 MIN

Traffic monitoring
optimizes traffic routes
with smart signage

"biker at blind spot"

AIR FLOW

Air filtration systems for
light poles, street
furniture and facades

Vehicle to vehicle
communication and
proximity notifications

Improves street-level safety and physical well-being for all street users, from pedestrians to motorists.

The Community Inclusive Street

The Story of This Street

In her seminal work *The Death and Life of Great American Cities*, acclaimed urban theorist Jane Jacobs wrote: "Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody."[3] The Community Inclusive Street embodies this idea.

Imagine a street designed specifically to foster and support the local community. Hyper-local issues could be easily identified through sensors and digital feedback portals and efficiently addressed. Open, decentralized platforms would allow people to participate directly in budgeting and decision making. Residents could use reliable, high-speed, and secure IT to share and engage with each other, while local businesses could connect with and understand their customers more intimately.

What Needs Does it Meet

Pedestrians / People. Inclusion in the process of actively shaping their community and environment. Better connectivity to services and each other. Increased safety. Convenient access to pertinent community information.

Local Schools. Provide more learning opportunities for their students. Affordable connectivity and technology resources.

Local Businesses. Hyper-local market knowledge and direct communications. Technology infrastructure and data for start-ups to leverage.

Municipal / City Agencies. Granular understanding of community needs and access to relevant community-level data.
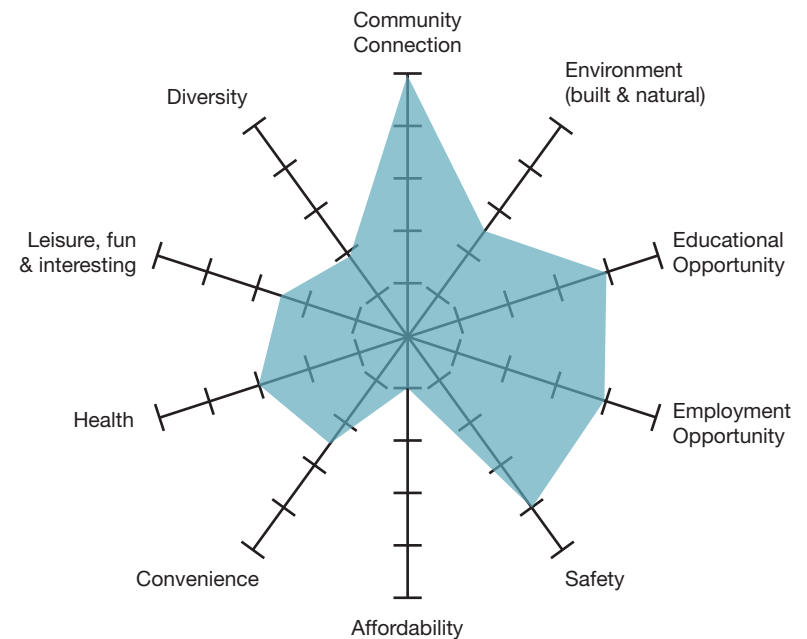
Sensing and Input
Information about the neigborhood is sent to cloud by people, sensors, and organizations, then to government agencies to address
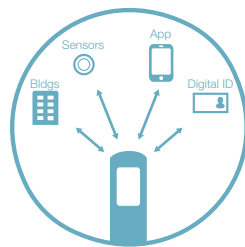
Neighborhood Beacon
Communicates local updates and notifications to residents through Neighborhood Passport App

Neighborhood Passport
Real-time updates and relevant notifications sent to residents through the app
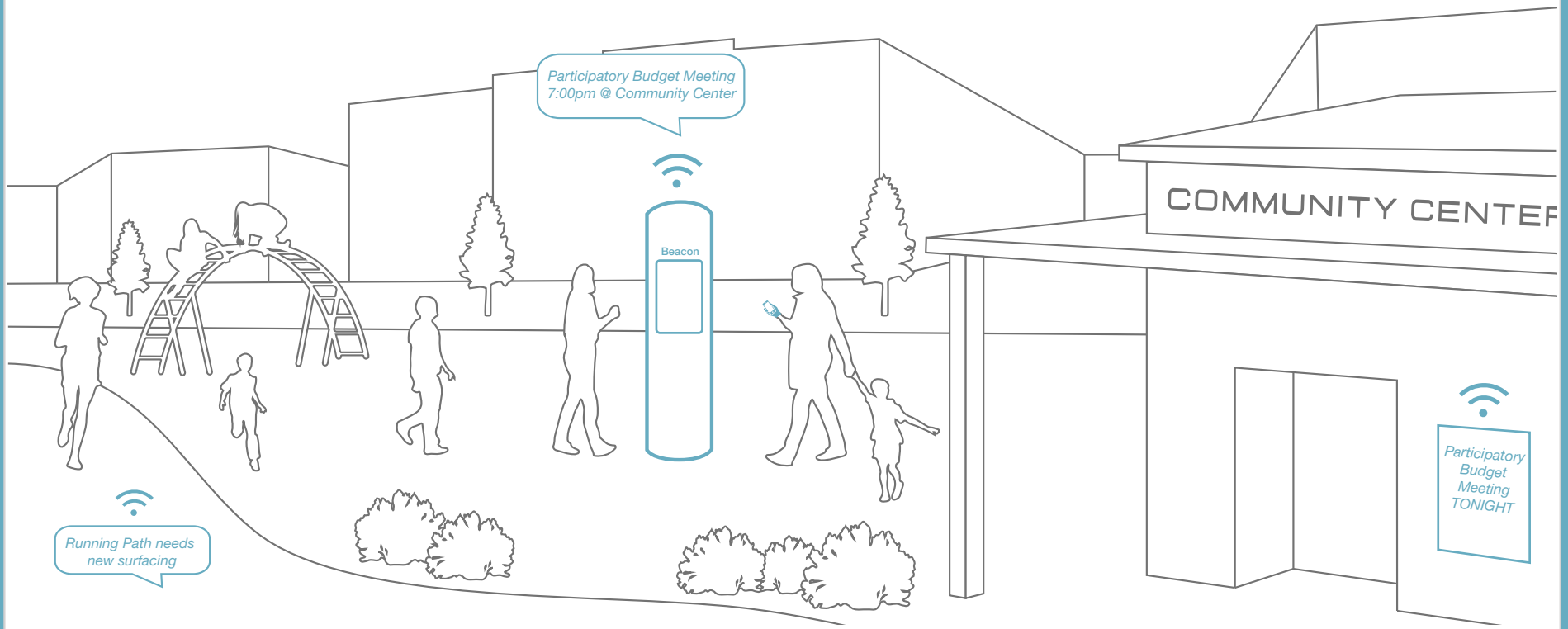
Facilitates belonging and participation and reveals opportunities for all community members.

The Eco-Optimized Street

The Story of This Street

The quality of the surrounding environment – built and natural – has a tremendous physical and mental impact on people. For example, a 2015 study by the Centre for Research in Environmental Epidemiology found that kids exposed to more nature and greenery had better attention and memory development.[4] The Eco-Optimized Street leverages nature and technology to create a cleaner, healthier, more livable place.
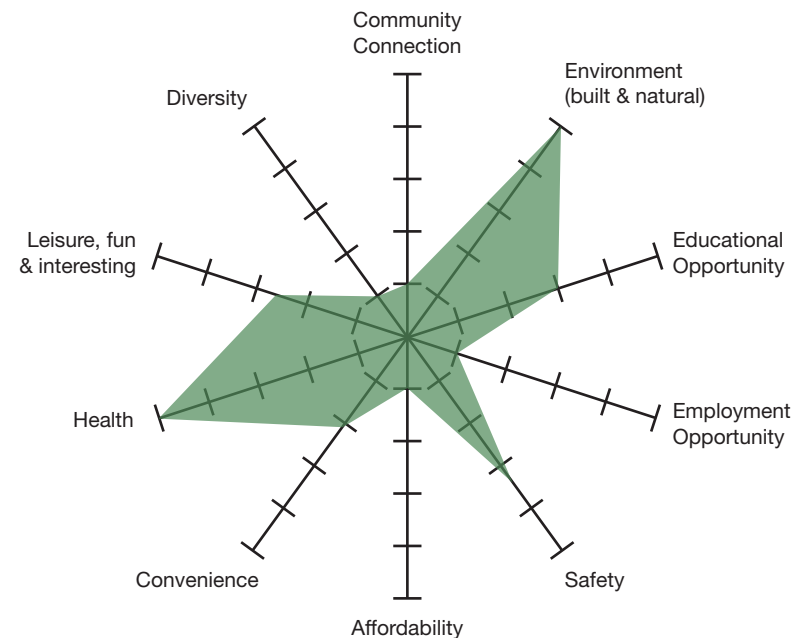
Sensors monitor environmental quality and autonomously activate air filters and mitigating systems as needed. They also deliver real-time updates to motorists, pedestrians, and city agencies for "air quality action days," landscape maintenance, and other applications.
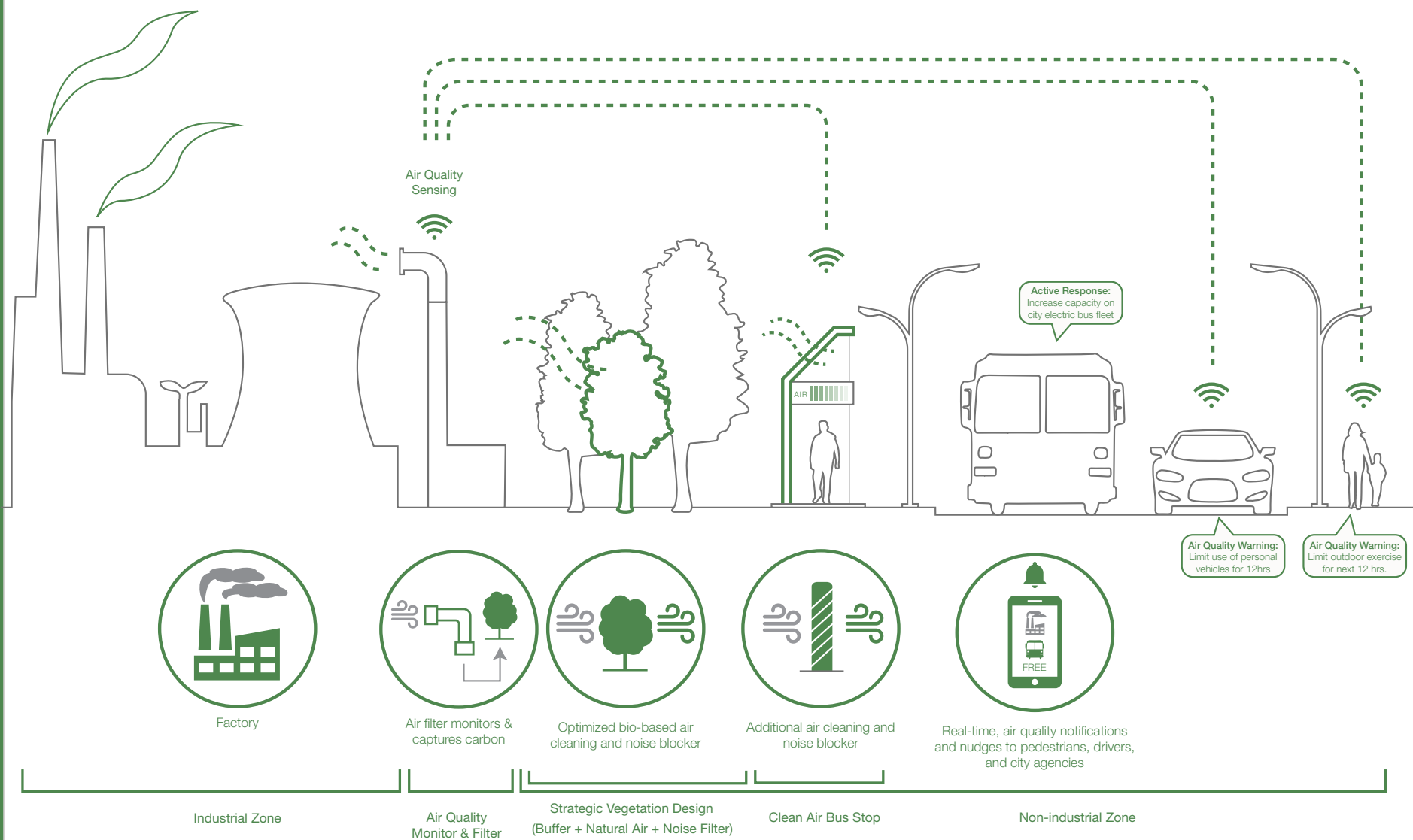
What Needs Does it Meet

Pedestrians / People. Real-time monitoring and active mitigation foster a healthy environment that people can trust. Green spaces enliven the senses and create pleasing surroundings.

Municipal / City Agencies. Sensors and data help agencies generate actionable insights and make better decisions more efficiently. Transport strategies can be implemented to curtail emissions without significant disruptions. Regulators can also keep a closer watch on their environmental metrics, geo-located, in real-time.

Local Businesses. Centralized data infrastructure helps industry monitor operations and emissions more efficiently.

Air Quality Sensing

Active Response:
Increase capacity on
city electric bus fleet

AIR

Air Quality Warning:
Limit use of personal
vehicles for 12hrs

Air Quality Warning:
Limit outdoor exercise
for next 12 hrs.

Factory

Air filter monitors &
captures carbon

Optimized bio-based air
cleaning and noise blocker

Additional air cleaning and
noise blocker

FREE

Real-time, air quality notifications
and nudges to pedestrians, drivers,
and city agencies

Industrial Zone

Air Quality
Monitor & Filter

Strategic Vegetation Design
(Buffer + Natural Air + Noise Filter)

Clean Air Bus Stop

Non-industrial Zone

Creates a cleaner, healthier environment through air-quality sensing, automated mitigation, and real-time updates.

The Participatory Street

The Story of This Street

People are unique, but have historically been forced to accept mass-market products and services. Our individual ability to shape streets to suit our own needs has similarly been limited. Yet technological advances have enabled individual tailoring in physical and digital products and experiences (from hotels to sneakers), ushering in an era of personalization, particularly in the West.

The Participatory Street encourages citizen involvement in shaping the street experience for all. Imagine waiting at a bus shelter on a cool day and using your phone to adjust the seat height and the ambient temperature. Beacon technology allows you to vote on how to fill a vacant storefront. And location awareness allows you to leave geo-tagged restaurant suggestions for your friends.

What Needs Does it Meet

Pedestrians / People. Enables people to adapt the street to suit their individual preferences. Encourages a greater sense of civic engagement and empowerment. Creates a vibrant, diverse, engaging environment.

Local Businesses. Deepens the relationship between businesses and individuals. Creates an effective feedback loop to optimize products and services. Greater flexibility to shape the street-level experience for their business.

Municipal / City Agencies. Promotes a greater awareness of public space utilization and the likes and dislikes of their local constituencies (through data collection).
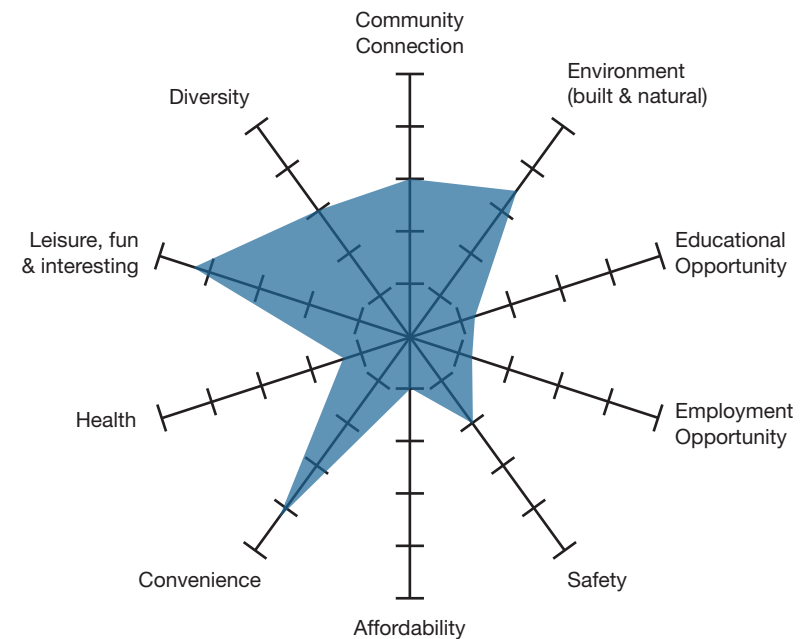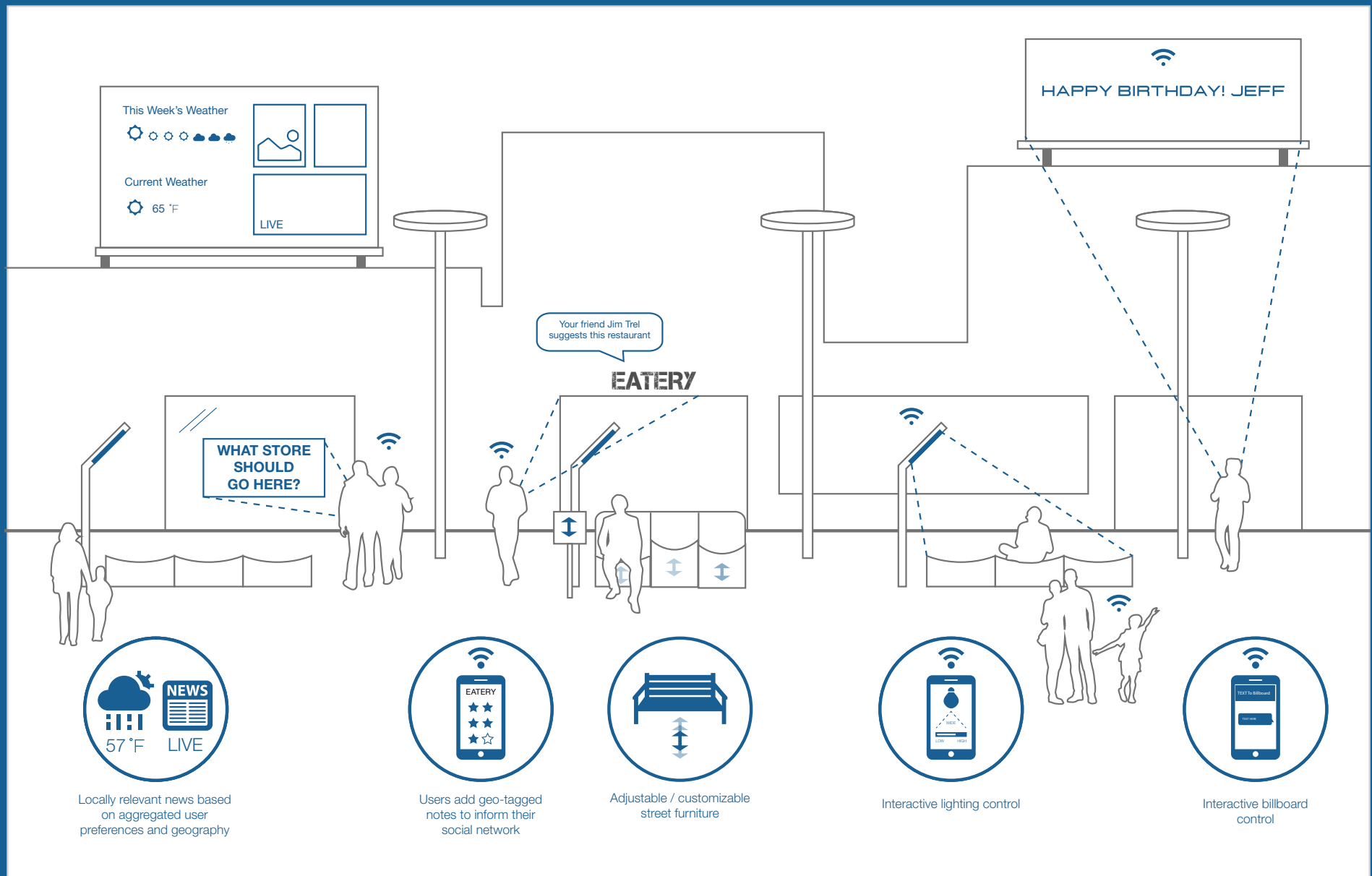
Adaptive and controllable street components create a highly participatory, customizable streetscape.

This Week's Weather

Current Weather

☀ 65 °F

LIVE

HAPPY BIRTHDAY! JEFF

Your friend Jim Trel suggests this restaurant

EATERY

WHAT STORE SHOULD GO HERE?

57 °F | NEWS LIVE

Locally relevant news based on aggregated user preferences and geography

Users add geo-tagged notes to inform their social network

EATERY ★★ ★★ ★☆

Adjustable / customizable street furniture

Interactive lighting control

WIDE LOW HIGH

Interactive billboard control

TEXT To Billboard

The Adaptive Commerce Street

The Story of This Street

Commerce is an essential activity in cities and towns globally. According to a 2014 report from the National League of Cities, "Small businesses are an integral part of every community, and are responsible for roughly half the nation's economic output," concluding that it is essential to be business friendly.[5]

The Adaptive Commerce Street uses flexible digital and physical infrastructure to optimize for commerce and visitor experience. At peak times, it turns into a dynamic public mall and promenade (with adjustable lighting and sound control) where local vendors use sensors, communication technology, data, and analytics, to understand, connect, and serve their customers in new ways.
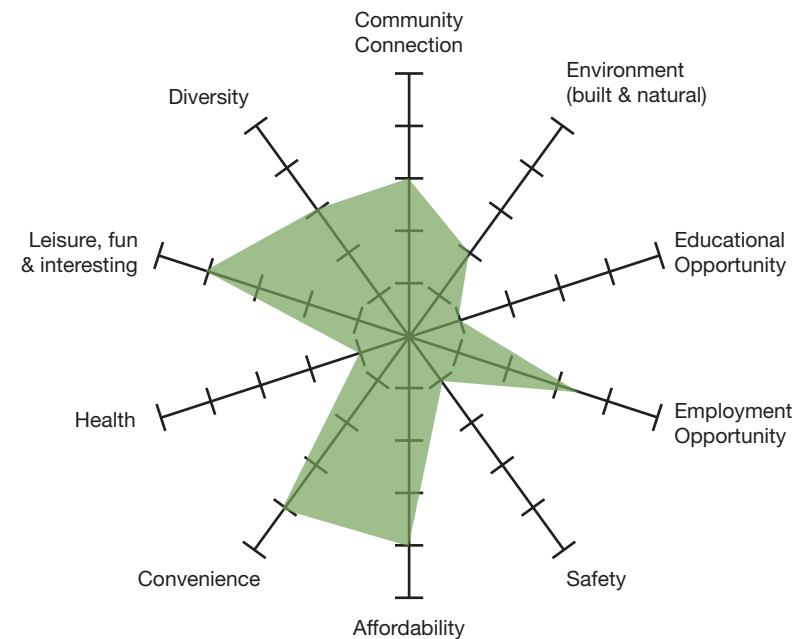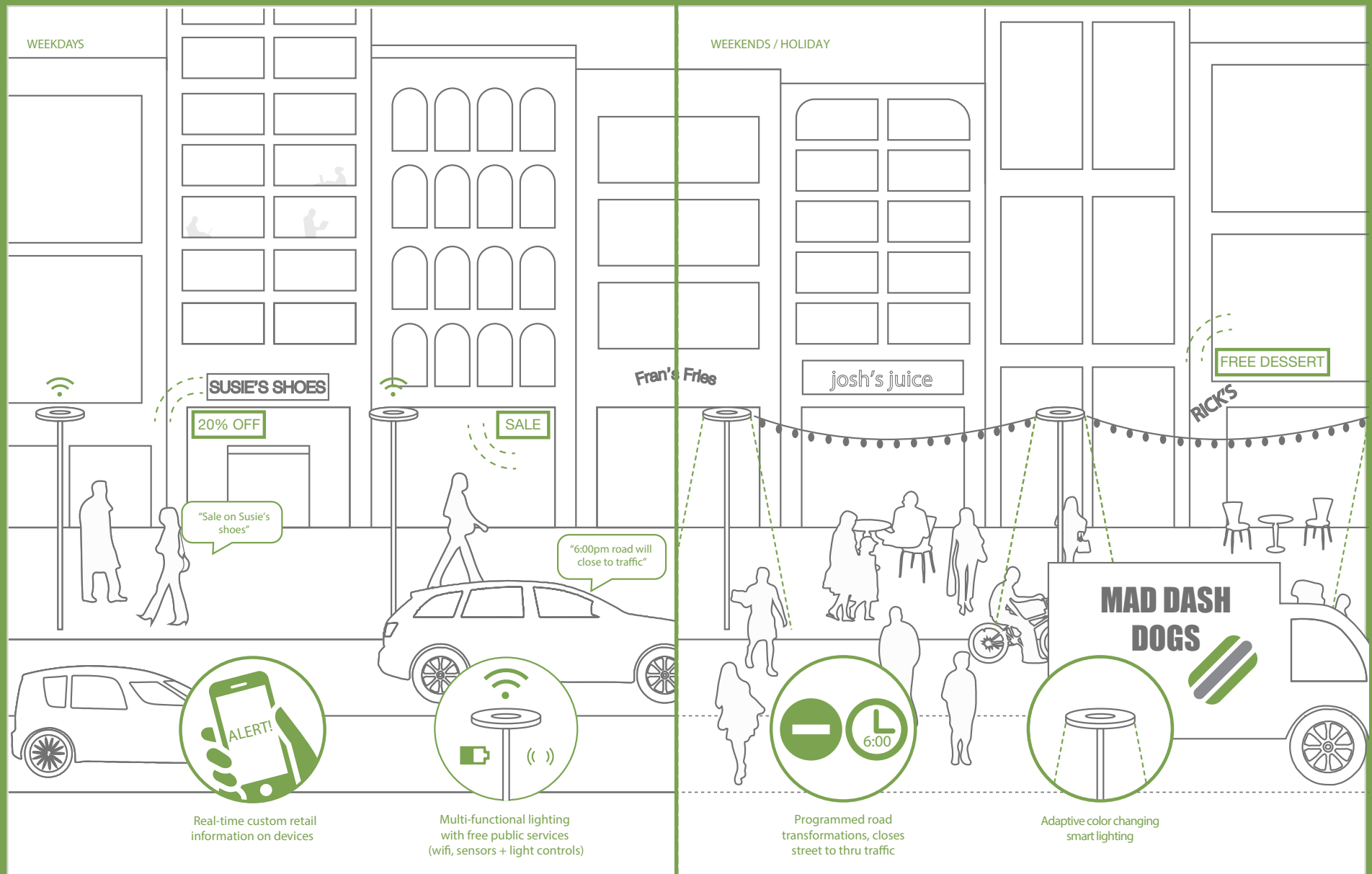
What Needs Does it Meet

Local Businesses / Retailers. Able to create more attractive shopping experience and thus increase foot traffic and potential revenue. More direct connection to local customers. Better data for marketing analysis and activities.

Property Owners / Landlords. Increase demand for their properties on the street and, thus, higher property values / rents.

People / Shoppers. More personalized and efficient shopping. More engaging and immersive street-level experiences.

Municipal / City Agencies. Successful businesses create more jobs and increase tax revenues to fund city operations and priorities.

Radar chart with axes: Community Connection, Environment (built & natural), Educational Opportunity, Employment Opportunity, Safety, Affordability, Convenience, Health, Leisure, fun & interesting, Diversity.

SUSIE'S SHOES

20% OFF

SALE

Fran's Fries

josh's juice

FREE DESSERT

RICK'S

"Sale on Susie's shoes"

"6:00pm road will close to traffic"

MAD DASH DOGS

ALERT!

6:00

Real-time custom retail information on devices

Multi-functional lighting with free public services (wifi, sensors + light controls)

Programmed road transformations, closes street to thru traffic

Adaptive color changing smart lighting

A flexible commercial street that transforms into a flexible, immersive, urban mall environment

WHAT KIND OF STREET WOULD **YOU** LIKE TO SEE?
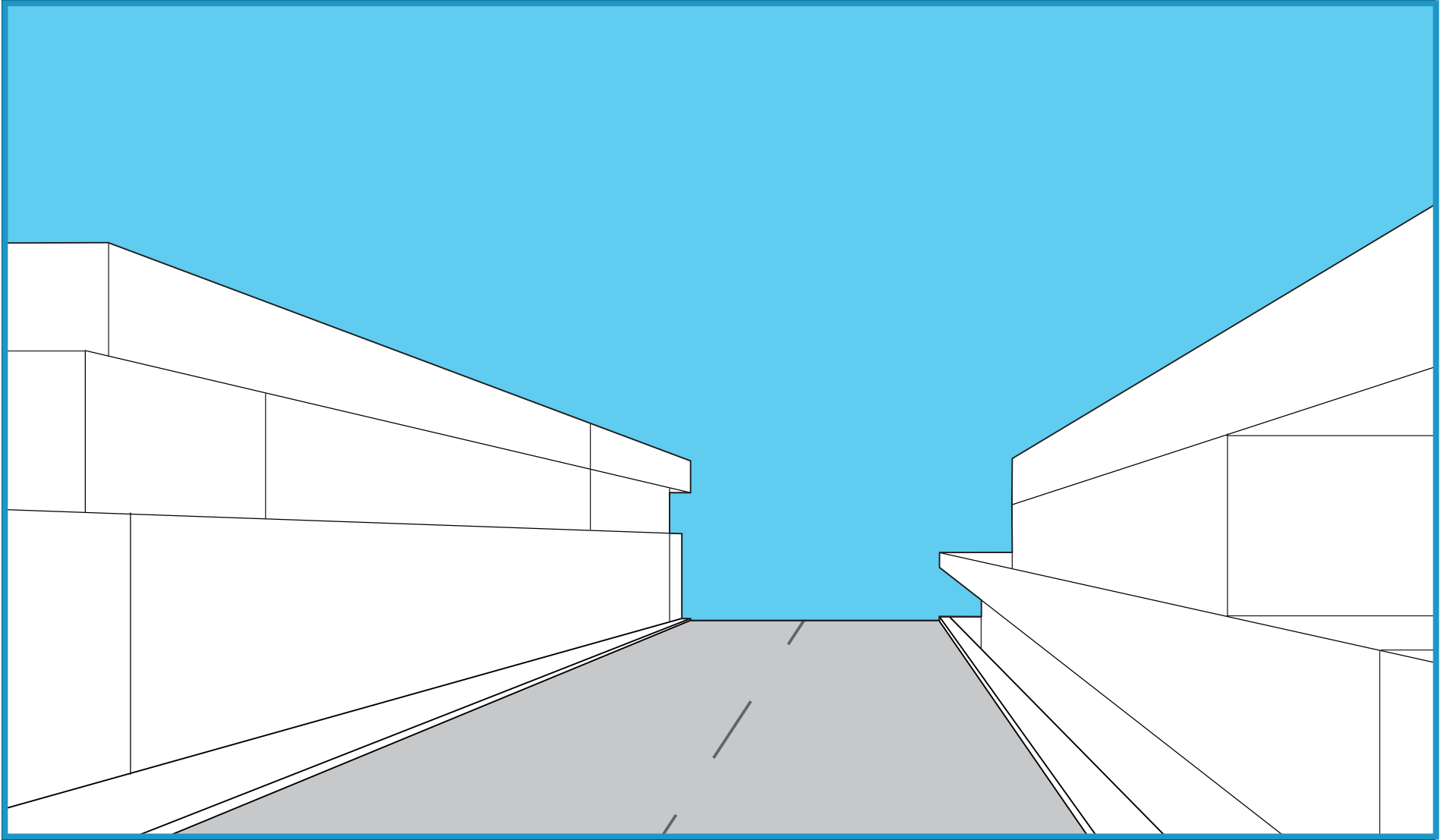
"The future is already here. It's just not very evenly distributed yet."

William Gibson - *Science Fiction Writer*

IV. The Current Reality: Learning from the Smart Cities of Today

In the case of new cities, such as those being developed in emerging markets like Pacific Asia and MENA, the connected streets of tomorrow will be built from the ground up, master-planned from the earliest stages. They will be the key connective tissue for visionary cities and towns around the globe – those that don't yet exist but may house substantial segments of our future population. With no existing legacy infrastructure these young cities will have an opportunity to create a unique model of urban intelligence.

Older cities face the challenge of an inherited set of physical and policy-related constraints, born from their particular context and having evolved over time: from infrastructure to socio-economic conditions to their political climate and beyond.

Regardless of where one might fall on this spectrum, there is an ever-growing body of relevant and compelling lessons to be learned from the pioneering individuals, institutions, companies, and governments shaping the smart cities ecosystem: the people who are in the trenches day in and day out, constantly looking for new ways to solve problems and create value for their communities.

Over the last 6 months, inspiring and innovative practitioners and stakeholders have shared their views on the future of connected streets and the lessons the world should learn from past successes and challenges. Some common themes emerged across all locations, discussed in greater detail on the following pages.

- **Successes to Learn From:** Predictive Analytics, Real-time Responses, Citizen and Community Focus, Free and Open Data, Innovative Enterprise

- **Challenges to Overcome:** Social Comprehensibility, System Security, Overcoming Obsolescence, Budget Challenges, Technical Delivery

Overview of Successes

Predictive Analytics

Developing models of probable future behaviors or occurrences in a system (often using multiple data sources) which can dramatically improve understanding, decision making, and operations.

Real-time Responses

Pervasive sensor networks, high-speed connectivity, and powerful insight-generation tools create almost instantaneous system-level awareness and enable immediate action to be taken (or automated).

Citizen and Community Focus

New technologies are making it easier to engage citizens in the process of shaping their community (policy, planning, etc.) while more efficient data collection is speeding up feedback loops to improve service delivery.

Free and Open Data

Cities, towns, and communities are becoming increasingly more "knowable" as more and more data becomes available. Keeping that data free and open encourages a range of new uses and possible sources of societal value.

Innovative Enterprise

New technology tools and digital and physical infrastructures are enabling and encouraging a seemingly infinite number of new businesses to develop, while also improving operations and impact for existing institutions.

Privacy and Comprehensibility

Ensuring the privacy of individuals using the system and proactively supporting the widespread and legitimate understanding of new technologies, services, and experiences through effective communication, transparency, feedback, and affordances.

System Security

As more systems communicate digitally and more data (whether personal, organizational or societal) is generated and transferred across nodes in an interconnected system, security becomes increasingly complex and challenging to create and protect.

Overcoming Obsolescence

Due to the relentless pace of technological change, things designed for today may not be functional tomorrow. This poses challenges given the long lifespans expected for infrastructure, and requires long-range planning, open protocols, and clear standards.

Budget Challenges

Municipal budget silos, rigid procurement processes, high up-front costs, and uncertain payback periods make it difficult to finance and operate multi-departmental, long-term, connected technology infrastructure.

Technical Delivery

Unlike traditional infrastructure, there are generally fewer precedents to follow and less experience to draw from in delivering smart infrastructure globally. Effective project and process management is essential.

Case Studies: <u>Successes</u> to Learn From

Chicago + Allstate Predict Restaurant Violations

What It Is: The City of Chicago departments of health and innovation partnered with Allstate's quantitative research team to improve the restaurant inspection process. The team used a combination of datasets (mostly city data) to predict which restaurants would be most likely to produce a violation during inspection, thus identifying critical risks sooner and more effectively.[6]

Why It Matters: In general terms, as more objects become instrumented, connected, and capable of generating data and insight, predictive modelling will become an increasingly powerful tool for improving the operations and experiences of our streets, public spaces, and communities. In Chicago, this work enables the City to save time and money, and, more importantly, to improve public health and safety by catching potential problems much earlier.

BigBelly: Real-time, Sensing Waste System

What It Is: BigBelly is a solar-powered, smart waste system. The container compresses the deposited trash in the bin itself to increase the container capacity and reduce the frequency of collection on the part of the city (or waste manager). Every bin in the system can be outfitted with sensors to provide measurements of container capacity and other aspects to inform system managers in real-time.[7]

Why It Matters: Sensor-based, system-level awareness allows managers to make more effective operational decisions that have tangible impact. They can reduce the number of maintenance and collection trucks required to operate the system, address problems at the bin-level in real-time as they come up, and improve collection efficiency, saving time and money and reducing emissions.

## LinkNYC: Digital Inclusion at the City Scale

What It Is: LinkNYC is an innovative new communication network for New Yorkers, developed by a New York-based consoritum called CityBridge* in partnership with the City. In time, the system will replace over 7,500 pay phones in all five boroughs with new digital totems, each of which will provide high-speed, free public Wi-Fi, phone calls, charging for mobile devices, and a touchscreen for browsing the web, finding city services, and public wayfinding.[8]

Why It Matters: The development of LinkNYC was in response to a call from the Mayors office which required free public Wi-Fi in an effort to develop a more inclusive city for all New Yorkers. While the entire system will generate revenue via advertising, the features and functions are decidedly focused on public benefit.

* Note: Qualcomm Intelligent Solution's affiliate Qualcomm Incorporated is a member of the CityBridge joint venture

Transparent Chennai: Open Data Initiative
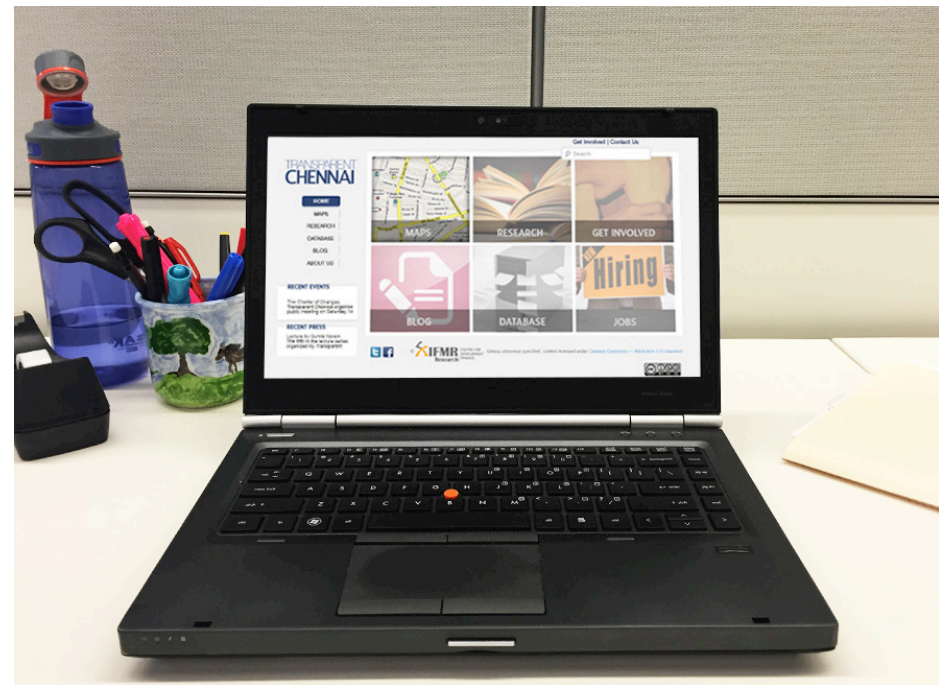
What It Is: Transparent Chennai seeks to empower residents by providing information about civic systems, projects, and processes in a useful, accessible form. The project aggregates and disseminates data from a broad swath of planning, operations, and governance platforms. A particular focus is the creation of interactive maps to help contextualize development policy decisions for citizens.[9]

Why It Matters: Informed and engaged citizens are a key component to thriving and resilient communities. This project conducts regular open meetings where researchers, residents, and officials can discuss ongoing issues and exchange ideas actively with more informed perspectives. Connected streets can and will provide opportunities to both collect and effectively disseminate locally relevant information.

Case Studies: <u>Challenges</u> to Overcome

Socializing Tech: Nordstrom Movement Tracking

What It Is: In 2012 and early 2013, Nordstrom department stores tested a series of in-store Wi-Fi sensors at 17 of their locations in an effort to uncover actionable insights by aggregating and analyzing customer foot traffic. In order to be transparent, they posted signs in the stores to inform customers that they weren't collecting personal data, and that shoppers could easily opt out simply by turning off their Wi-Fi (or their phones). Despite their openness, the stores received negative feedback from shoppers.[10]

Why It Matters: Attitudes and behaviors are constantly in flux regarding new technologies. Ensuring users adequately understand the functions and the implications of the tech they are actively or passively engaging with is essential. This will be increasingly important as more devices come online and connect to each other. Privacy and security are core elements of the technology comprehensibility narrative, but theyre not alone. Affordances and transparency are key.

The Case for Secure Systems: Hacking an SUV

What It Is: In 2015, a pair of hackers demonstrated a subset of the many problems that can arise when connected systems aren't entirely secure. Charlie Miller and Chris Valasek exploited a system vulnerability in a commercially available SUV's on-board entertainment system granting them remote control not only to the radio, A/C, lights, and wipers but also the engine, brakes, and steering. Making the hack visceral, they turned off the vehicle's engine while a reporter was driving on a highway in St. Louis, MO.[11]

Why It Matters: As more of the objects in our lives connect to the web, managing security and establishing how systems communicate and authenticate will become increasingly complex and challenging. In this example, the hackers exploited a less secure system in the vehicle (entertainment) which gave them access to much more secure systems (steering, braking, transmission). At the street or city level, how will we protect our interconnected systems from vulnerabilities?

Anti-Obsolescence: NEMA Interoperability Standards

Budget Challenges: Financing India's Smart Cities
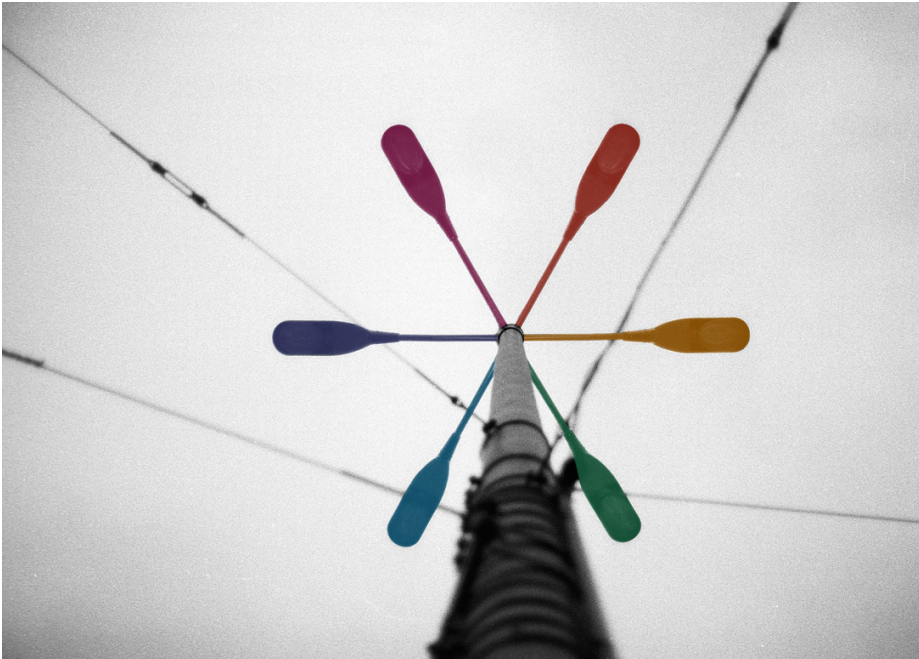
What It Is: The National Electrical Manufacturers Association (NEMA) has published the ANSI C136.41 standard for roadway and area lighting. This standard ultimately sets systems requirements that enable interoperability between the diverse array of lighting control systems made by different manufacturers and the lights themselves (also made by a broad range of different companies).[12]

Why It Matters: The break-neck pace of technological change and the endless cycle of new technologies and companies implies a level of future uncertainty that does not align well with the traditional lifecycle of large scale infrastructure projects (like those required for smart cities). Lighting control interoperability is one small but concrete standard which should create more flexible systems that can adapt to future needs and don't lock whole cities into one proprietary technology. Designing adaptive and interoperable systems will be critical to cope with this ongoing change.

What It Is: Indian Prime Minister Narendra Modi announced a bold goal for India to develop 100 smart cities by 2022. It is estimated that doing so could cost close to $1 trillion, more than the government can afford. In response, a series of global Public Private Partnerships have been announced to close the budget gap and encourage diverse industry insights in the planning and implementation process.[13]

Why It Matters: As governments across the globe weigh the citizen benefits of smart city implementations against the budget constraints they face, financing will be a key concern. This is compounded by the fact that most smart city approaches require intra-governmental collaboration, raising questions about how each department's budget is impacted and who controls what. Innovative financing and new business models will be critical to unleash the true potential of smart cities and connected environments at scale.

"Practitioners use knowledge in ways quite distinct from academics – to make things, recommend policy, take part in the world of action. The professional gets the fun of both learning and doing and, if lucky, the reward of seeing the results."

———

Denise Scott Brown - Architect

V. The Road Ahead: Actionable Steps for a Connected Future

We began this collaborative research with the intent of identifying new visions for the connected streets of tomorrow. The technological possibilities that continue to become available provide a robust platform for experimentation in our cities, but the challenge will always be to ground these new urban technologies in the real needs and aspirations of people in a range of communities.

We recognize, though, that while the process of envisaging the future of our streets, communities, and society as a whole is an important step, it is not the endpoint. Visions help to create a North Star to guide our collective efforts and actions and to set us on a meaningful and compelling course forward. They help bring nascent ideas to life and encourage dialogue – to make the invisible visible, and, if done well, to inspire real change. For us, that is the aspiration: to truly shape a better world by taking real action and empowering others to do so as well.

Throughout the process of developing this piece, we've had the pleasure of working with and learning from some truly inspiring and highly accomplished thinkers, makers, researchers, technicians, engineers, and city officials, all of whom are helping in their own ways to shape the connected future. These are some of the people who will be tasked with making visions into reality in their local contexts and, for them, an inspiring starting point is not enough.

On the following pages, we've outlined some of the key system characteristics that they feel need to be considered while undertaking the hard work (the 99% perspiration) of creating connected streets that are realistic from a technological, social, environmental, and economic perspective. These are the attributes that the system and the technologies within the system should include. Furthermore, with the hope of moving the focus beyond technical specifications, we've also included a set of development processes (i.e., actions and approaches) that we think are worth considering as you help shape the future of your connected streets.

- **System Characteristics:** Open Data Infrastructure; Modular & Interoperable; Scalable; Transparent; Edge Processing; Secure; Multi-functional; Ethical

- **Development Processes:** Digital Master-planning; Stakeholder Engagement; Prototyping & Piloting; Ecosystem Development; Current Conditions Analysis; Innovative Financing

System Characteristics

Open Data Infrastructure

By digitally connecting more elements of our streets and communities, we encourage a vast array of data sources that, if properly planned and managed, can create considerable value for society. We also create the possibility of highly exclusive approaches owned and operated by private technology providers with closed systems.

To maximize the positive potential we must ensure that the data generated by the system is discoverable, accessible, intelligible, assessable, and re-usable, thus encouraging a plurality of innovation opportunities by a range of stakeholders.
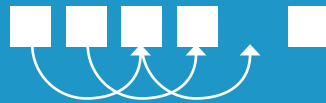
Modular & Interoperable

Connected Streets – and, by extension, smart cities and towns – will achieve their maximum potential by serving as a platform of possibility for a wide range of applications and services, most of which will be developed by a diverse array of different stakeholders.

True value for citizens, civil servants, and society will result from interoperability that enables data to flow freely across a wide range of technologies (and providers) in an array of functions like lighting, waste, transportation, and infrastructure.
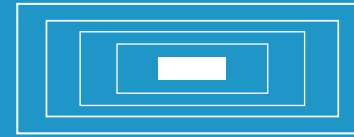
Scalable

The places we inhabit are in a constant state of flux. Businesses come and go. Populations shrink and swell. New challenges and opportunities emerge and resolve.

Amidst this ever-changing landscape, starting small and nimble can be a real asset, allowing prototypes and pilots to adapt to their context and thrive without too much cost. But thinking about scale from the outset is essential, especially in the context of connected cities, which will most likely experience population growth as the world continues to urbanize.

Transparent

Smart and connected streets create value for people – residents, governments, businesses, and beyond – partially by being predictive and automated and partially by learning and adapting continuously. Imagine a traffic system that knows where all cars, bikes, buses, and pedestrians are and adjusts in real-time to optimize flow.

The assumptions and values that are embedded in these intelligent, automated systems need to be communicated clearly and transparently to the people who will be impacted by their deployment and use. We must move beyond lengthy and opaque terms-of-service agreements.
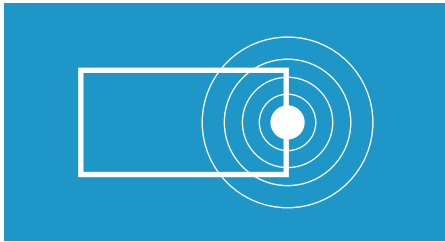
Edge Processing

As more and more sensors are deployed in a given city or municipality, the amount of bandwidth needed to send all the data they collect on an ongoing basis to the cloud will become far too expensive to reasonably maintain.

More processing and intelligence will need to be done at the edge of the local network to dramatically reduce bandwidth requirements without sacrificing performance.
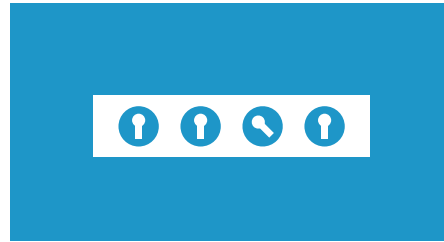
Secure

As more elements in our streets and communities become digitally addressable and connected, the possibility of system vulnerabilities will expand. This will require detailed analysis and planning to protect the network and all its users from a range of digital threats.

Furthermore, as systems integrate with greater frequency and complexity – which will in many cases be governed by automated processes and communication protocols – it will become increasingly important to ensure that the 'trust' relationships between systems are carefully considered.
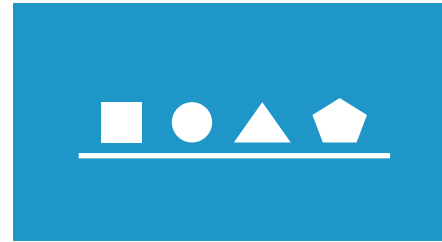
Multi-functional

Globally, many existing systems and features in the built environment were designed and implemented under certain constraints and with highly-specialized uses or functions in mind.

Connected and interoperable technologies, however, can and will enable the conversion of single use infrastructure into multi-functional infrastructure, now and into the future. Existing electricity poles or street lights, for example, can be equipped with additional environment sensors, Wi-Fi access points (to bridge the digital divide), cellular infrastructure, or any one of an infinite number of possible value-add features that will imminently emerge.
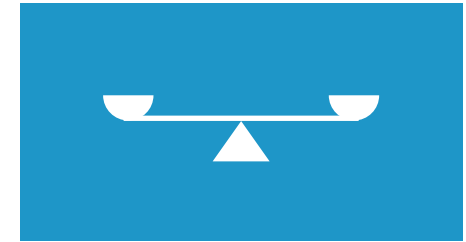
Ethical

Connected streets are man-made and thus express the biases, assumptions, and values of those who have designed and made them. This is true of both the physical experiences they enable as well as the digital ones.

As society continues to grapple with the shifting social order resulting from rapid technological change as well as other factors, it is essential that the systems and structures we create are human-centered and ethically considered, demonstrating respect for key moral principles like fairness, equality, diversity, honesty, dignity, and human rights.

Development Processes
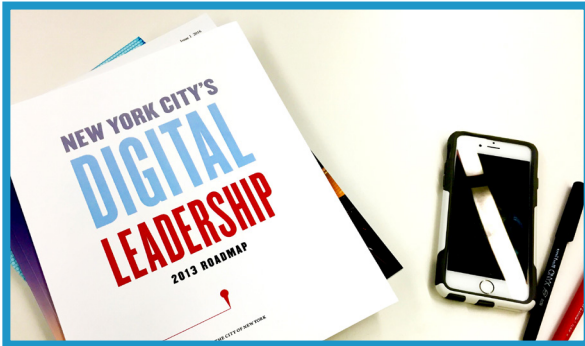
Digital Master-planning

An expanding roster of companies, agencies, and institutions are deploying new technologies in the built environment at an accelerating pace, creating a complex and ever-changing fabric to address.

One key strategy that cities and municipalities are using to manage this change is the development of "digital master plans." These plans can be powerful tools for engaging and aligning local stakeholders (from citizens to public employees and beyond) around compelling visions, targets, and road maps for adaptation to the emergent economic and technological pressures, in ways that respect the political, social, and economic realities.

Stakeholder Engagement

Streets are resources shared by many, whether they're urban, suburban, or rural, commercial, residential, or commuter. In considering their future (whether digitally connected or otherwise), early and ongoing stakeholder engagement is an incredibly valuable tool to uncover a broad range of viewpoints, issues, and opportunities, specifically at stages when projects are still perceived to be in development and open to inputs. Considerations include vision workshops, community charrettes, listening-labs with BID members, and beyond.

For connected streets, this process takes on a whole new meaning, as concerns around privacy, access, and ownership come center stage.

Prototyping & Piloting

It's difficult to predict how individuals and communities will react to the introduction of new technologies, products, and services, or what impact a new policy or program will have out in the real world. This is especially true for breakthrough innovation with little precedent from which to learn prior to launch.

Prototyping and piloting are essential processes for trying new things out in the real world early on, before they're set in stone, so rapid and low-cost learning can be incorporated. Creating effective feedback mechanisms and streamlined workflows to encourage prototypes and pilots in local contexts is critical.

Ecosystem Development

Innovation is a team sport. The approaches that will enable us to realize the true potential of connected streets in the future will require the collaboration and expertise of a wide network of stakeholders.

Supporting the right people, processes, and partnerships and creating conditions that are conducive to equitable and sustainable innovation at the street level will be critical. How do we nurture fledgling companies (or technologies) and connect them to the resources they need? What type of infrastructure must be created to encourage the development and implementation of new ideas at the street level?

Current Conditions Analysis

The current assets in any given context can serve as a rich source of inspiration for envisioning future uses and possibilities. Much can be learned by taking detailed stock and thinking both honestly and creatively about what can be reused and what can't.

When possible, strive to reuse existing systems and infrastructure. For example, consider using mobile broadband networks and smart phones to reduce capital expenditures and ongoing operating expenditures versus overlaying expensive fiber for the last mile in remote areas.

Business Model Innovation

New systems can be costly to develop and deliver. Regardless of the benefits, one of the most common challenges is financing.

Novel financing mechanisms can be key enablers of project success. Public Private Partnership (P3), for example, is an increasingly common approach to delivering the often costly public infrastructure, programs, or services without relying solely on government funding by engaging private sector partners to finance and operate public services. Crowdfunding, while smaller in scale than P3, is another novel source of funding for projects in the public realm. It has the additional benefit of clearly signaling grassroots support by showing the number of local backers for any given proposal.

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