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February 2023

How can IoT integration to connected vehicles improve large-scale mobility?

Learning Unit Consulting Presentation - Mobility

DO WELL DO GOOD

Executive Summary

Background

- The coalition between connected vehicles and IoT creates a two-way communication between a vehicle and its surroundings
- The connected car market is expected to grow to around 192B USD in 2028
- IoT integration has also been implemented in connected public transport
- Connectivity in vehicles has revolutionize safety systems, driving experience, traffic management, and life on the road

Impacts

- Traffic injuries in 2019, United Kingdom, decreased in three perspectives due to an increase usage of connected vehicles
- Connected vehicles are proven to be more efficient up to 6 times, rather than an average petrol car

Problems

- Several initial costs to integrate IoT to vehicles includes: hardware cost, app development cost, and cybersecurity cost

Executive Summary

Problems

- Other operational costs includes data processing and connectivity costs
- Interoperability and performance challenges over heterogeneous IoT network to achieve large-scale mobility in connecting vehicles

Solutions

- Several measures can be taken to decrease the initial and operational costs
- Unified IoT technology foundation and standardized procedures of are required to unlock 40% potential interoperability value.

Implementation

- To improve large-scale mobility, all parties can collaborate standardizing connected vehicle system
- Implementing connected vehicles on public transport would be beneficial in large-scale mobility, however it takes a long time for the whole world to be fully sustainable.
- In 2045, IoT integration in connected vehicles are predicted to produce efficient, safe, sustainable, and integrated smart cities
- To optimize opportunities, dispersing implementation based on urgency can significantly boost large-scale mobility.

The coalition between connected vehicles and IoT creates a two-way communication between a vehicle and its surroundings

Internet of Things (IoT)	The network of physical devices which enables seamless communication and data exchange.
Connected Vehicles	Wireless connectivity between vehicles that allows communication with infrastructure and external systems.

IoT in Connected Vehicles → Vehicle-to-Everything (V2X)

V2V	V2I	V2P	V2N	V2C
Vehicle-to-Vehicle - Communication between two or more vehicles. - Exchange speed, position, and road conditions data.	**Vehicle-to-Infrastructure** - Communication that exchange data on road signs, traffic lights, and smart city systems.	**Vehicle-to-Pedestrian** - Communication between vehicles and passengers with wearable devices or smartphones.	**Vehicle-to-Network** - Communication between vehicle and satellite systems, cellular networks, or wifi networks.	**Vehicle-to-Cloud** - Enable vehicles to access and exchange data stored in the cloud, such as maps & software updates.

Source: ATS (2018), Sensors (2022)

Background: Current Market

With rapid development of IoT, the private connected vehicle market is expected to grow to around 192B USD in 2028

Currently, some of the most popular connected car services are…

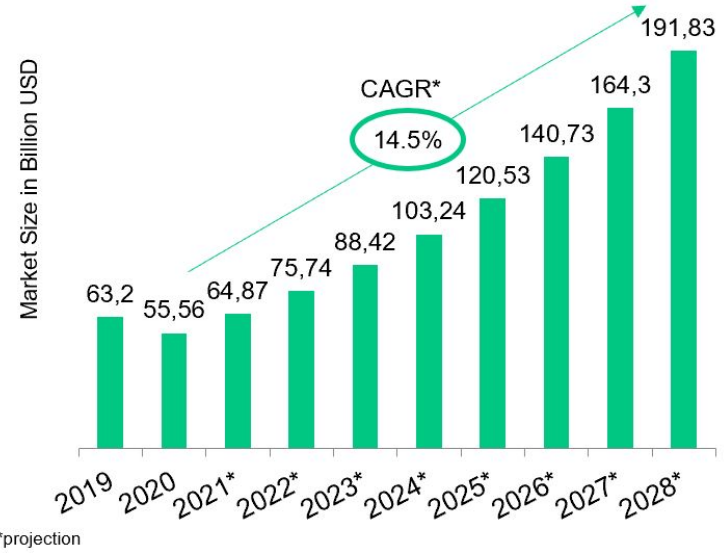
- Navigation
- Infotainment
- Emergency Call

However, driven by..

- Increasing adoption of **Advanced Driver Assistance System (ADAS)**
- Emergence of technologies like **5G and AI**
- Increasing **popularity of automation** in automotive sector
- Developments in **ridesharing and mobility services**

the connected car market is expected to grow rapidly in the upcoming years

Size of the Global Connected Car Market
between 2019 and 2020, with a forecast through 2028



Key Takeaway

The connected car market will continue growing, especially with the increasing services provided by the connected vehicles.

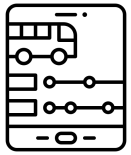
Source: Statista (2021), MarketsandMarkets (2021)

Background: Current Public Transport Market

IoT integration has also been implemented in connected public transport

Several things that utilizing IoT in connected vehicle in public transport sector are…

Fleet Management
Information such as driver behavior and route management enables management to **track what is happening on the road.**



Real-time Vehicle Tracking
Passengers get real-time information about where the vehicle is or when it will arrive at a particular stop.

Video Surveillance & Security
With IoT devices, **many can capture a series of events**, thus municipalities can track traffic violation.

Unexpected Events Management
IoT will enable district to re-route vehicles, notify passengers, and make alternate arrangements in unexpected events.

while some countries and companies are developing IoT in public transport

Denmark

Movia, public transport authority, **count number of passengers in bus** and pass out the information to bus stops and drivers.

Italy

MITT use IoT to **detect the position of buses in real time** and transmit information on journey times to passengers.

England

London's fatigue management project use IoT to present a holistic approach to driver management, especially at **reducing the risk of fatigue related accidents.**

Nomago

In Central and East Europe, IoT devices were installed on city buses, and the **data is used to improve operations performance.**

Key Takeaway

Several parties have develop IoT integration in public transport and show improvement in mobility, while some others may not aware of the issue yet.

Source: UITP (2020)

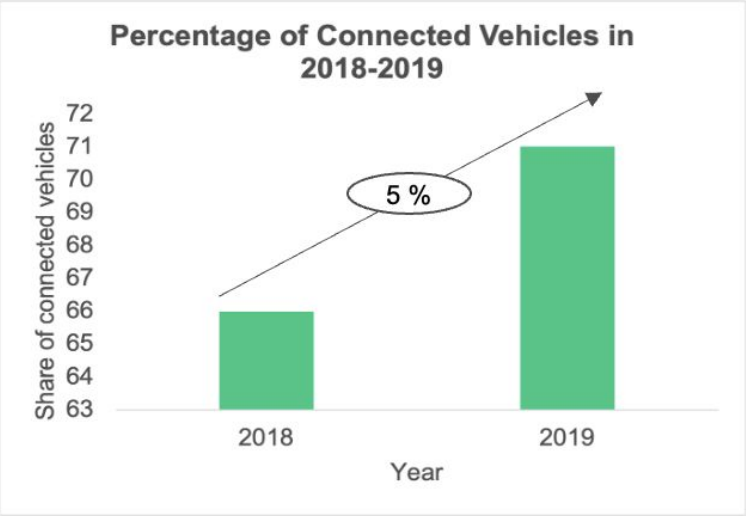
Connectivity in vehicles has revolutionize safety systems, driving experience, traffic management, and life on the road

		Before Connected Vehicles	After Connected Vehicles
Road Safety	Safety System	Limited to basic safety systems, such as **seat belts** and **airbags**.	Advanced safety features, such as **collision avoidance** and **lane departure warning.**
	Road Condition	There has been **higher road accidents** due to the limited safety features and traffic information.	With the advanced features and information, **road accidents are massively prevented**.
Efficient Mobility	Traffic Management	Inefficient, as there has been **higher traffic congestion** and **longer travel times**.	**Real-time traffic information** is available, leading to a **more efficient traffic flow.**
	Fuel Consumption	Significant amount of **fuel** and **emissions** are **wasted in traffic**	Much more efficient due to **optimized routing** and **improved driving behavior**

Source: Otonomo (2021), Sensors (2021)

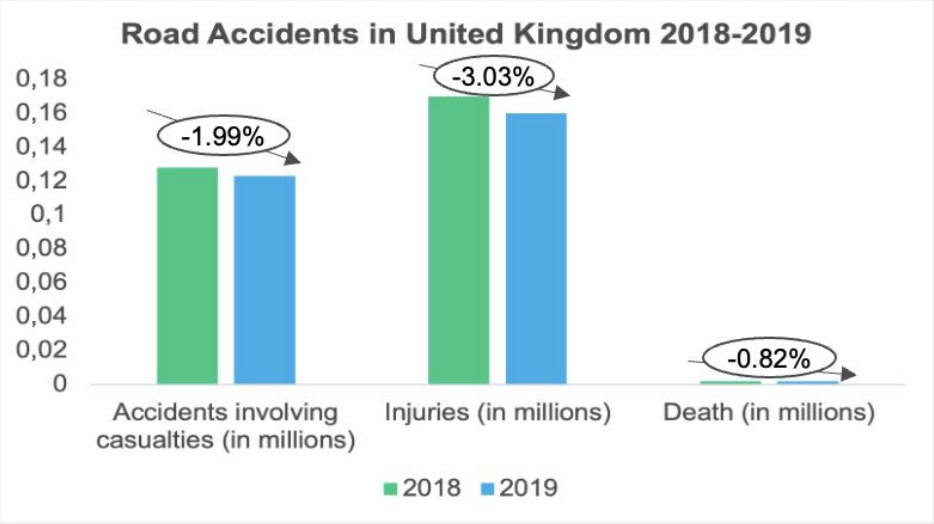
Traffic injuries in 2019, United Kingdom, decreased in three perspectives due to an increase usage of connected vehicles

The quantity of connected vehicles operating in 2018 to 2019 increased...



The number of connected vehicles in 2018 to 2019 experienced a 5% increase

…therefore, all aspects of road accidents in United Kingdom decreased



Three different aspects of road accidents, from casualties to death, all decreased in the same year in United Kingdom.

- **Exchanging safety-critical information between nearby vehicles and infrastructure** makes it possible to drive down the number of accidents and casualties.
- Through **In-vehicle warnings**, drivers would be alerted to imminent crash situations, as well as **communicating with roadside infrastructure**, drivers would be alerted when entering certain environments such as entering school zones, working site, etc.

Source: OECD (2023), Road accidents (indicator), Statista

Connected vehicles are proven to be more efficient up to 6 times, rather than an average petrol car

	Average car in United States	Toyota Prius C 2020	Hyundai Ioniq 2019	Tesla Model 3
				
Vehicle Type	Petrol car	Hybrid Vehicle	Hybrid Vehicle	Electric Vehicle
Fuel Consumption	10.3 km/litre	Around 19.3 km/litre	Around 24.4 km/litre	Around 60 km/litre
Fuel Efficient Features	-	• Eco navigation feature that gives anonymous signals in vehicles that would help **generate up-to-the-minute data on how, when, and where vehicles travel in real time.** • Automated eco driving feature **allows vehicles to avoid sharp braking or accelerating**, which helps reduce nitrogen oxide and carbon dioxide emissions due to less fuel usage		

Key Takeaways

Features enabled in connected vehicles such as eco navigation and automated eco driving allows the vehicles to obtain data in real time, as well as having access to gas and break pedals, creating a more efficient fuel usage.

Source: The Driven (2019), Alternative Fuels Data Center (2020)

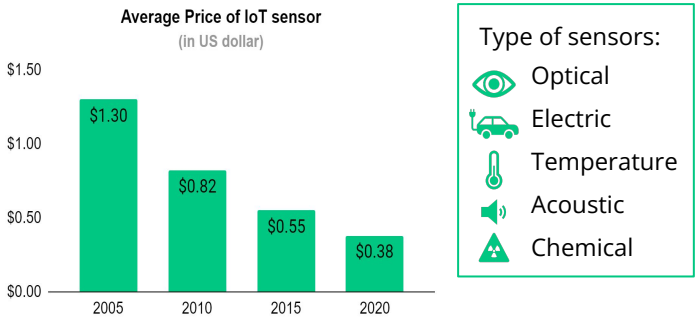
Problems: Initial Investments

Several initial costs to integrate IoT to vehicles includes: hardware cost, app development cost, and cybersecurity cost

IoT devices and sensors used in vehicles is costly, especially if specialized for automotive use.

Hardware Devices in IoT

Sensors	Microcontrollers	Other IoT hardwares



Type of sensors:
- Optical
- Electric
- Temperature
- Acoustic
- Chemical

The average price of IoT sensors over the years with a decreasing trend, due to increasing demands

App development consists of 4 stages, which adds up to the total initial costs:

Stage 1: Analysis
Developing app's functionality

Stage 2: Modeling
Design a model of the app for client

Stage 3: Prototyping
Collaborating on a series of prototypes

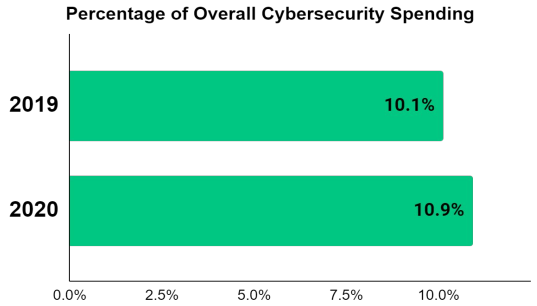
Stage 4: Testing
Testing to ensure a flawless final product

Cybersecurity preparations is costly, but it is essential due to increasing security risks:

54% Increase in IoT hacking in 2019

1.51B IoT breaches occurred from January to June

200% Increase in IoT cyberattacks yearonyear during the first half of 2021



Companies continue to spend more on cybersecurity

Key Takeaway

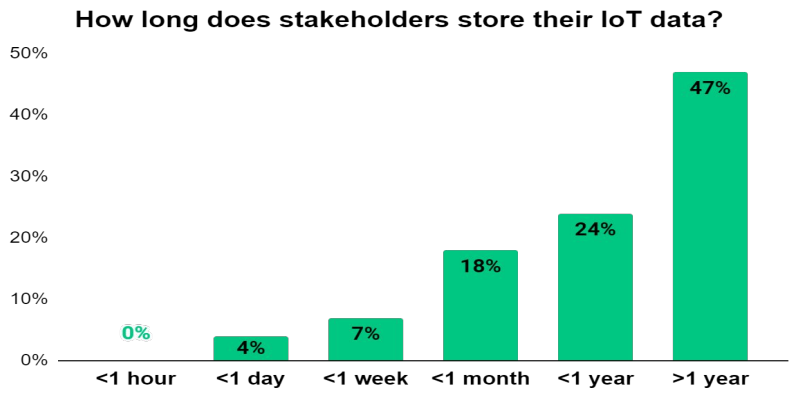
There are several initial costs to consider for IoT implementation in vehicles.

Source: Deloitte (2020), Supplychaindive (2019)

Other operational costs includes data processing and connectivity costs

Data Processing Costs

Data from sensors and devices are stored for long-term or short-term applications.



Most companies **stores** their **IoT data** for **more than a year**, which requires a **large amount of storage**

IoT cloud storage solutions

Pricing varies in different companies (e.g.: Azure starts from $10 / month per IoT hub unit)

Connectivity Costs

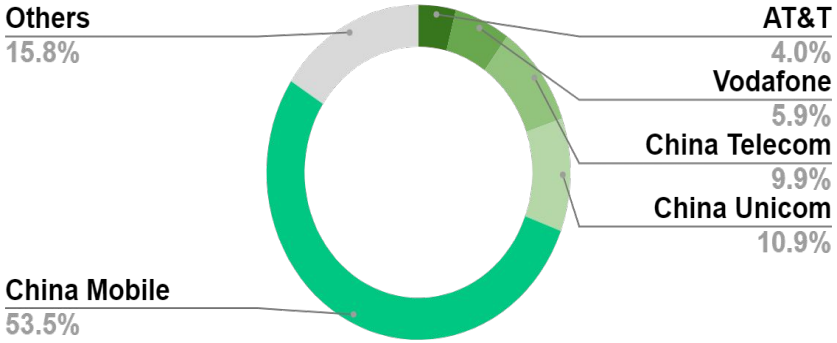
Cellular IoT

Wireless connection facilitated by cellular towers (e.g. 2G, 3G, 4G, 5G)

LPWA Network

Wireless connection designed to allow long-range communications at a low bit rate

Global cellular IoT connections by operators as of 2020



Connectivity expenses might fluctuate around **$0.04 per megabyte**. Some telecom companies offer narrowband IoT pricing plans for enterprises, charging **$6 per device annually**

Key Takeaway

Operating expenditures for IoT implementation includes data processing and connectivity costs.

Source: IoT Analytics (2020)

LPWA: Low-power wide-area
PaaS: Product as a Service

Solutions: Cost

Several measures can be taken to decrease the initial and operational costs

Reducing Initial Costs

Standardizing

Allows **economies of scale** in production and development

Where

- Sensors
- Networks
- Intelligent analysis

Open-source technology

Allows **sharing and reuse** of software and hardware components

Examples

ARDUINO

openremote

ThingsBoard

Cybersecurity measures

Reduce the risk of breaches and need for expensive remediation

How

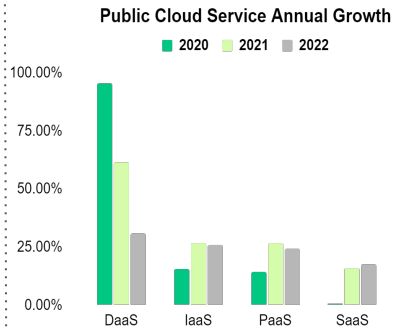
- Introduction in design phase
- Public Key Infrastructures and digital certificates
- Network security
- Application Programming Interface security

Reducing Operational Costs

Cloud computing

Reduce data storage and processing **costs**

How



Increasing growth trend of cloud service providers

Subscription to service

Cost-effective for the **long run**

Benefits

- Business and citizen transformation
- Scalability and cost-effectiveness
- Transparency and open source

Key Takeaway

Both costs can be reduced by standardizing, improving open-source technology, cybersecurity, cloud computing, and subscription.

Source: plainconcepts

Problems: Interoperability

Interoperability and performance challenges over heterogeneous IoT network to achieve large-scale mobility in connecting vehicles

V2V IoT Communication Systems

Wave	DSCR	HONDA, Ford, gm, TOYOTA
Celular	4G/LTE	PORSCHE, Audi, VW
	C-V2X	BMW, TESLA, Mercedes-Benz

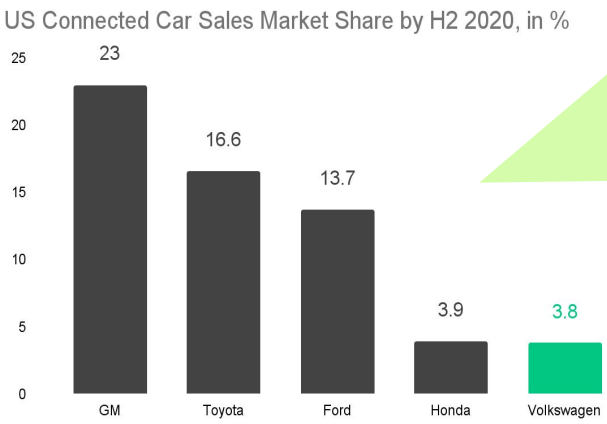
Comparison of connected vehicle network capability

	Wave	Cellular
Communication	Indirect	Direct
Latency	150 ms	<50 ms
Range	<1 Km	<10 Km

Substantial Gap

Large-scale mobility demands a direct, low-latency, and long-distance connection, however Wave **cannot provide**

Comparative market share of DSCR and Cellular



Connected vehicles employing **DSCR** represent 57.2% of the market. They are frequently more appealing to clients due to their **lower prices.**

Independent Communication Protocols

Each manufacturer has its own protocols for receiving and delivering info, which, if met, would make it tough for most of connected vehicles to quickly interpret the accurate info.

Market dominated with Wave-based network

As they rely on WiFi infrastructure for inter-vehicle communication, a shortage of WiFi infrastructure in the surroundings will reduce the number of functional services.

Ununified and Unstandardized = **Interoperability** ↓

Source: Kimley (2020), Counterpoint (2021), Universiti Teknologi Malaysia Journal

DSCR: Dedicated short-range communications

Solutions: Interoperability

Unified IoT technology foundation and standardized procedures of are required to unlock 40% potential interoperability value.

Using the newly unveiled IoT technical base (C-V2X and Qualcomm Chip) will elevate the interoperability possibility amongst vehicles …

C-V2X

- Cover **30 - 40%** area more than DSRC
- Improved **Non-Line-of-Sight** performance
- New and **costly feasible**
- **Direct communication** over longer distances

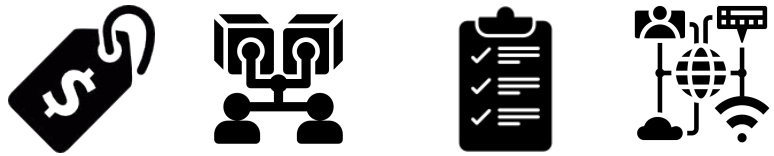
Automotive Connectivity Chipset Shipment Share by Vendor, H1 2022

- Newly released that proven to communicate across vehicles from different car manufacturers and resonates in 5.9 Global Hertz.
- Costly-effective for a long run as they don't require additional infrastructure cost

... and having clear regulations on connected vehicle operations will aid in increasing the viability of interoperability.

SAE	IEEE	ETSI
Defining the automation level standards for connected vehicles	Pass interoperability test for universal V2X for connected vehicles	Fulfill ETSI specification standards for connected vehicles

International and National Standards



These will reduce the risk of private investment and hasten the delivery of C-V2X-based innovations for connected vehicles in the public interest.

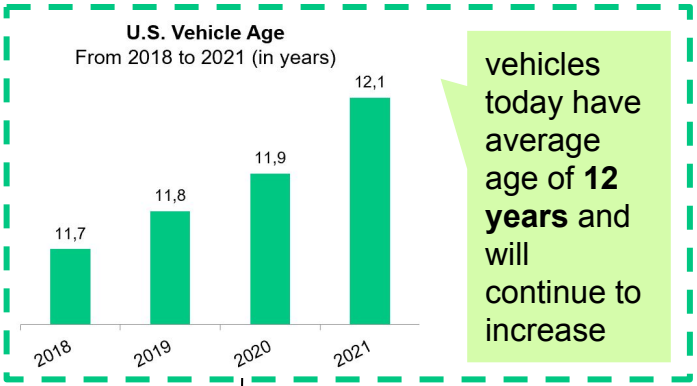
Source: EnoTrans (2018), IET (2020), Counterpoint (2022), Parliament of Australia, European Commission

SAE::Society of Automotive Engineers, ETSI: European Telecommunications Standards Institute, IEEE: : Institute of Electrical and Electronics Engineers

To improve large-scale mobility, all parties can collaborate standardizing connected vehicle system

Developed-nation **government** start cooperating with **OICA** to develop a clear **regulation to standardize connected vehicle system**

2023



vehicles today have average age of **12 years** and will continue to increase

in 13 years

Almost **100% vehicles** in developed-nation **are equipped with IoT** integration to connect with each other

2040

Transition Phase → **Implementation Phase** → **Evaluation Phase**

Recommendation

C-V2X	Qualcomm
increase usage of CV2X for all vehicles to unify communication	develop and standardize Qualcomm-modeled chipset in all vehicles

2027

All vehicles produced by automotive companies **must follow connected vehicle unified standard**

2033

With predicted good impact on large-scale mobility, it is expected for **developing countries** to start **implementing** standardized **connected vehicle regulation**

2045

Other **countries all over the world implement IoT in connected vehicle**

Source: Statista (2022)

OICA: Organisation Internationale des Constructeurs d'Automobiles (International Organization of Motor Vehicle Manufacturers)

Implementing connected vehicles on public transport would be beneficial in large-scale mobility, however it takes a long time for the whole world to be fully sustainable.

Advantages

Improving Accessibility for All

- **Current paratransit services are costly and challenging to use.** Incorporating the disabled would enable an equal chance for them.
- **Inhabitants that lack of access towards private vehicles are given a new experience of riding public transports**, whilst creating another positive impact towards the world.
- **Right-sizing vehicles for occupancy, while including routes through low-density areas** allows a greater range of passengers, and a greater capital investment from agencies.

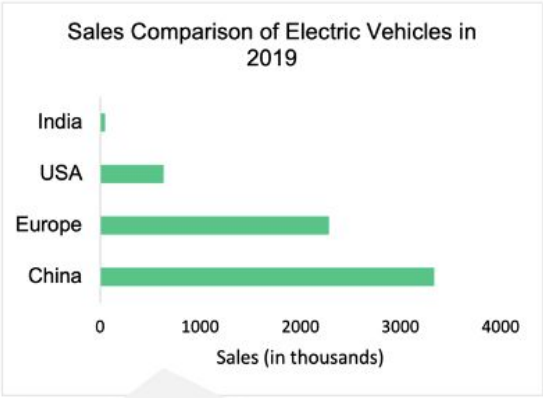
Reduced Road Congestion

- **Inhabitants would take leverage of public transport** due to higher convenience, hence the reduce of private vehicles would decrease road congestion.
- Through reduced road congestions, cities could **reduce carbon dioxide emissions and air pollutions**, hence they could be **able to live a safer and more enjoyable environments**, with less time spent in traffic.

Disadvantage

World Sustainability

- **Each country is rolling out technology in a different phase**, the world would be unprepared if changes are made in a short period of time.



Each country's sales each year varies, defining their availability towards implementing connected vehicles.

Source: Intelligent Transport website, WSP website, Tridens Technology website

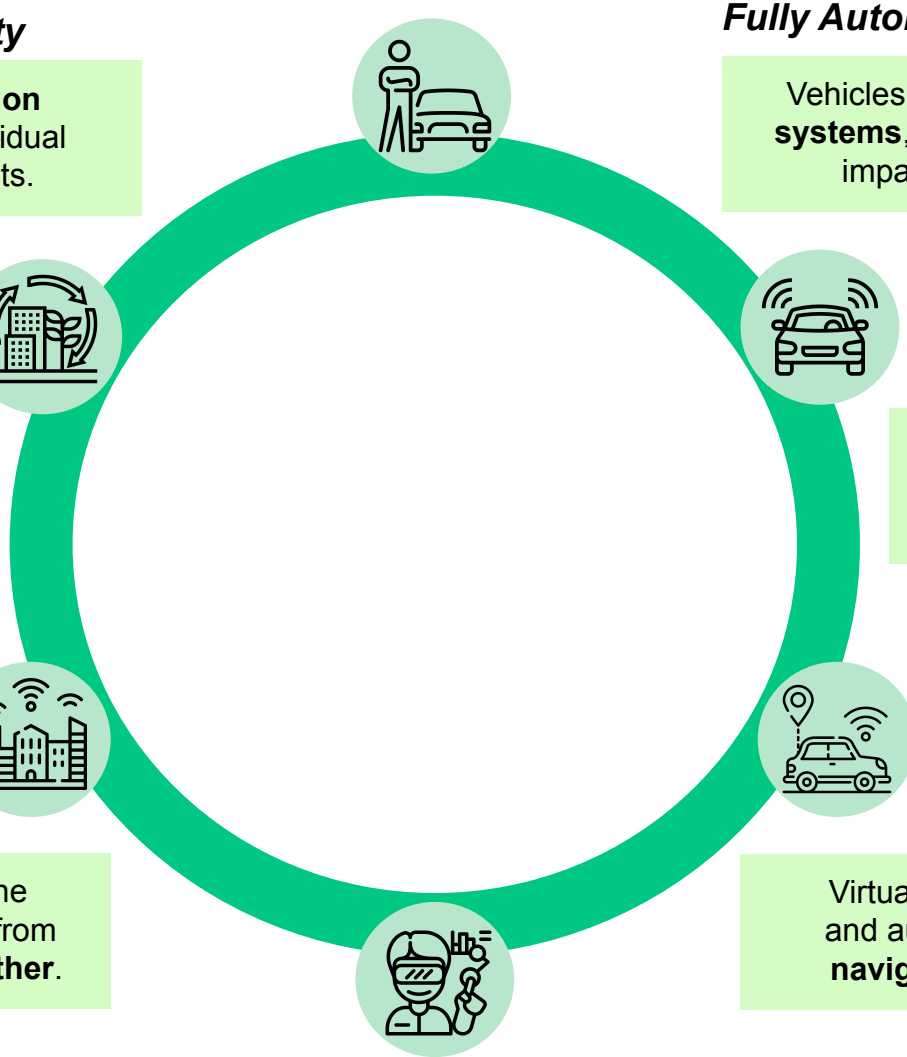
In 2045, IoT integration in connected vehicles are predicted to produce efficient, safe, sustainable, and integrated smart cities

Personalized Mobility

Tailored transportation options based on individual preferences and habits.

Fully Autonomous Transportation

Vehicles driven by **advanced AI systems**, reducing environmental impact of transportation.



Sustainable Cities

Mobility advancement that **reduce waste** and **conserve energy**.

Total Connectivity

Highly connected infrastructure, with seamless & efficient urban environment.

Integrated City Systems

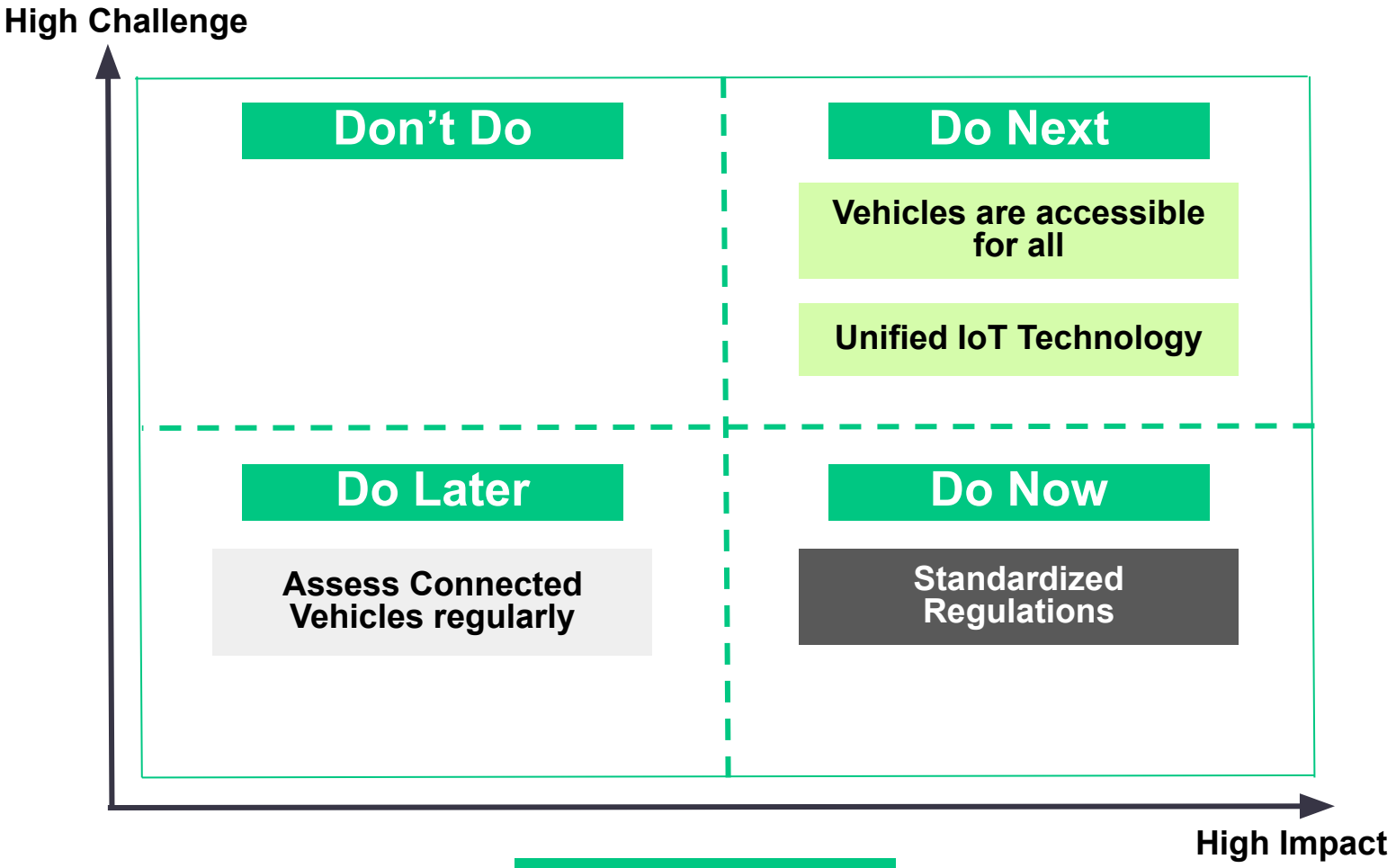
Full integration of the transportation system from **one smart city to another**.

Virtual and Augmented Reality

Virtual **tours of cities** and augmented reality **navigation systems**.

Source: Thomas Pohl, SAP (2021)

To optimize opportunities, dispersing implementation based on urgency can significantly boost large-scale mobility.



Key Takeaways

Prioritization is needed for more effective implementation based on world's current capabilities.