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Ingenuity for life

# The Data Opportunity

**Using data to transform mobility for passengers, authorities, and operators**

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# Siemens foreword

Getting from point A to point B is something the vast majority of people face every day. And it's the movement of people and goods that ensures that our cities and nations thrive and grow.  As the world's population continues to grow and as trends such as globalization and urbanization continue to intensify, we will have to transport an ever greater amount of people and goods across ever greater distances, in particular in, and between, cities. This is an enormous challenge.

The good news is: technologically, we are well equipped to meet this challenge. Automation and digitalization offers us opportunities to make our transport networks, both existing and new, vastly more efficient and – economically and environmentally – much more sustainable. There is no doubt that the transportation industry is equipped to provide intelligent transportation solutions fit to serve as the basis for efficient mobility for everybody.

People should be fully aware that a lack of efficient mobility is holding back economic growth and social development. This is why large capital investment in our infrastructure is both necessary and hugely beneficial. In the "Mobility Opportunity" Siemens worked with Credo to establish the potential economic benefits of investing in public transport. Our aim was to stimulate wider discussion and the report spurned workshops and discussions with transportation authorities and cities. The question of how data will transform the delivery and consumption of mobility services was frequently discussed. How could the benefits of digitalization, which is cutting across all parts of society, be quantified?

Again we partnered with Credo to investigate how the gathering of data through automated sensors, together with accompanying analytics, can transform the transportation sector's value chain, exploring questions such as "How can digitalization deliver benefits in the key areas of throughput, availability, and passenger experience?" and "What is the 'Data Opportunity'?"

At Siemens more than 300,000 devices are connected to our Sinalytics platform. The data generated from the devices is leveraged to increase the availability of assets and optimize maintenance. Digitalization has also revolutionized the way rolling stock is being serviced. Ultimately, it can lead to reduced expenditures on capital and operations while simultaneously raising service levels.

The "Data Opportunity" aims to showcase how today's digitalization is being applied across the mobility sector, while analyzing how data can drive value for society, operators and authorities.

We hope you find it interesting.

Dr. Jochen Eickholt,
Chief Executive Officer (CEO) of Division Mobility,
Siemens AG

Dr. Jochen Eickholt, Chief Executive Officer (CEO) of Division Mobility, Siemens AG

# Credo foreword

Having worked with Siemens previously to produce 'The Mobility Opportunity', in which we quantified the potential global benefit of investment in transport infrastructure, we were delighted to be asked to work again with Siemens on this paper.

Particularly so, because since we completed the report in 2014 it has become clear in conversations with our clients across the transport spectrum, from operators to authorities, that the benefits outlined in the study seem like a pipe dream to many.

Too many networks are caught in vicious cycles of underinvestment which depresses ridership growth and leads to decreased farebox revenue, which in turn further decreases investment. With governments increasingly looking to cut budget deficits the investment needed to achieve the benefits outlined in the Mobility Opportunity seems infeasible.

However at the same time we have seen tremendous technological advances, with pioneering examples showing how data can be used to optimize planned investment, run networks more efficiently and add value, even those systems built many decades ago.

In this report we combine a granular view of project benefits with a holistic view of transport systems worldwide, through the data set built for the Mobility Opportunity, to determine how best in class technology could benefit transport networks globally.

Credo's approach is data-driven and rigorously analytical; in the Data Opportunity we have applied this approach to determine how cities can use emerging technologies to mitigate the challenges of growing populations and economies, aging networks and tightening budgets to deliver transport networks fit for the 21st Century.

Matt Lovering, Credo, Global Transport Lead

Matt Lovering, Credo, Global Transport Lead

# Summary for decision makers

Since the launch of the first mass market web browser in 1993, entire industries have been comprehensively transformed. The first to be disrupted were those based on the exchange of information, such as the products sold by a retailer or a platform providing information on movie times. Amazon was founded in 1995, Google in 1998, and Wikipedia in 2001, irreparably changing the way people shopped, searched for information, and researched topics. Previously lucrative models like business and personal directories and encyclopaedia makers have become extinct, while still others, like travel agents, have had to rapidly evolve, adapting to new models to survive, models which gave consumers cheaper and more convenient ways of discovering businesses, finding general information, and researching and booking travel.

This transformation has not touched all industries equally. Sectors concerned with making or moving physical material remain relatively unchanged compared with the radical changes seen elsewhere.

Now the Internet of Things, fuelled by technological progress such as reliable and fast wireless internet and increasingly powerful mobile devices, is starting to impact "physical" business models.

Interestingly, public transport has not yet been significantly impacted by these new technologies; leaving the potential benefits virtually unrealized.

**Opportunity unfulfilled**

The lack of application doesn't reflect a lack of need; all over the developed world capacity of existing transport systems is struggling to keep up with the growth and increasing demands of the populations they look to serve, while in the developing world governments are looking to support and encourage economic growth, rendering the transport links vital to prosperity and competitiveness in an increasingly global economy. In both, there is a pressing need for effective, targeted investment that ensures that transportation, or lack thereof, doesn't become the limiting factor in economic growth.

In 'The Mobility Opportunity', 2014, Siemens and Credo explored the potential growth achievable through the right investment in transport networks around the world, establishing that global GDP could be 1% higher if all networks achieved the same efficiency as their best in class counterparts.

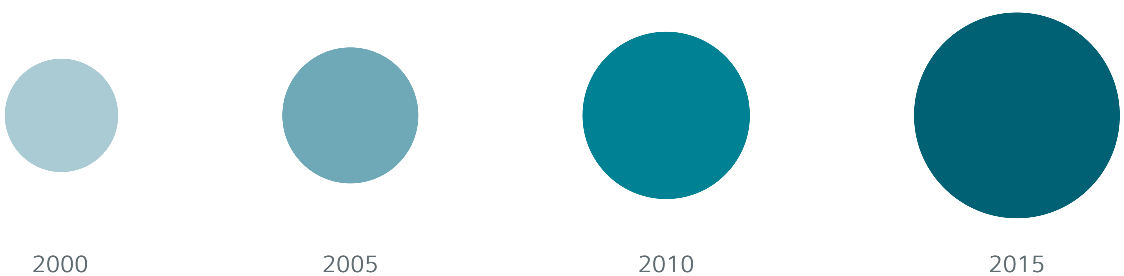



Figure 1: OECD government debt

In order to enjoy the $800bn per annum benefit in 2030 as outlined in the Mobility Opportunity, between $250–400bn would have to be invested per year.

And while innovative models facilitating the private funding of public infrastructure are becoming more common, funding requirements for transport infrastructure still largely fall on governments. These same governments are largely focusing on reducing spending and looking to pay down record levels of debt, meaning there is not the slack in government budgets to afford this investment.

While this presents a threat to global growth, it also presents an opportunity and motive to leverage new technologies to improve mobility for passengers, authorities, and operators around the world.

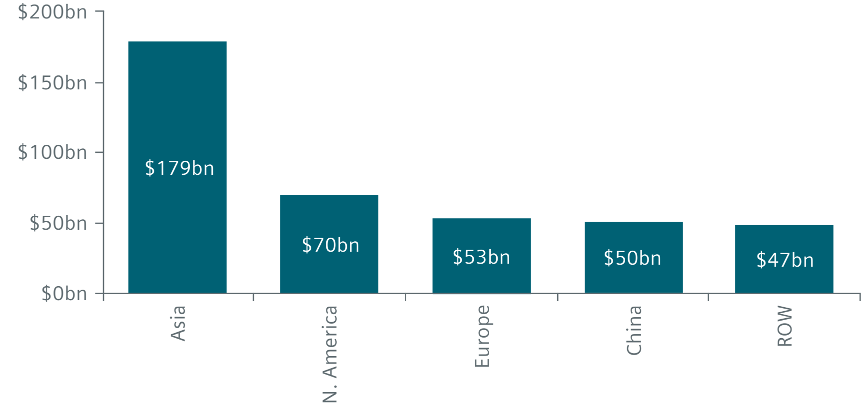



Figure 2: Conservative annual investment requirement by 2030 to achieve the Mobility Opportunity

# Data in action

Pioneering projects across the world are beginning to realize some of the potential of data to improve transport. We have classified the emerging examples into the five areas outlined in Figure 3, based both on reviewed global examples of transport innovation and the combined experience of Siemens and Credo.

These projects are principally focused on performance in three areas: throughput, availability, and passenger experience. Benefits are achieved through the network's development and lifecycle; from the earliest stages of planning, to solutions that are retrofitted onto existing systems to help optimize their operation.

In this report we have focused on five areas where the emerging use of data is transforming business as usual, such as mobility. From using innovative data sources to plan new public transport and automating existing metro networks with data to make them more effective, to helping users to optimize their journeys by opening up mobility data, we examine the concrete benefits being delivered by data to operators, authorities, and passengers in the most advanced use cases around the world.

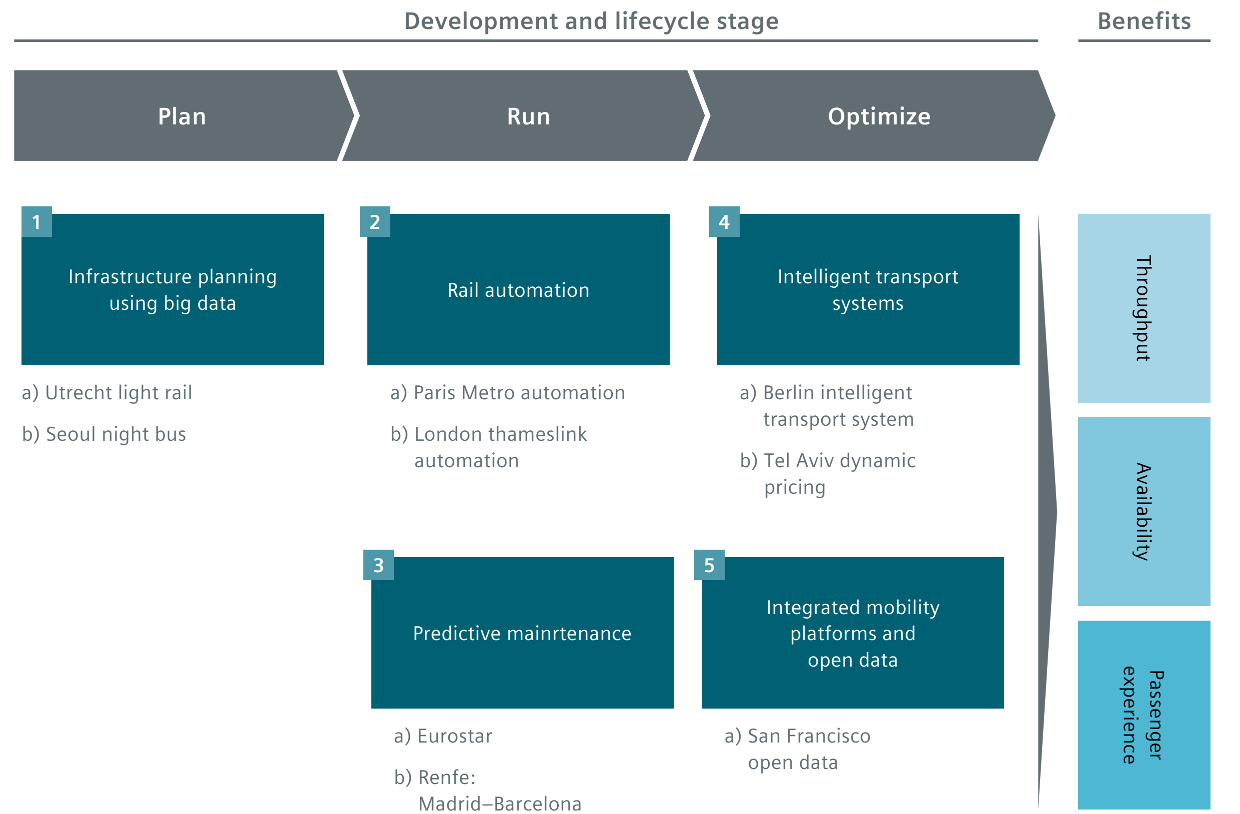



Figure 3: Use cases of data in transport

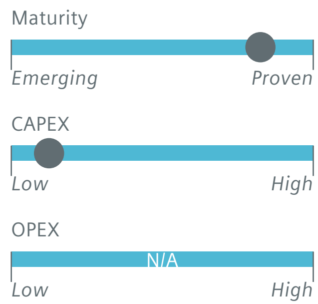
# Technologies

## Infrastructure planning using big data

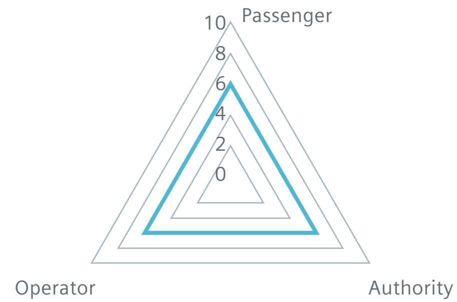
### Description

Using new and innovative sources of data to better understand demand and optimize transport investment.

### Maturity and cost overview




### Benefit

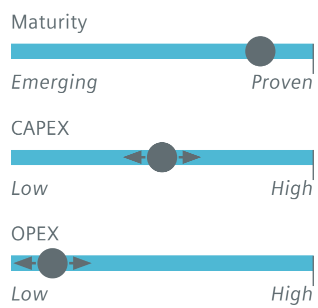



## Rail automation

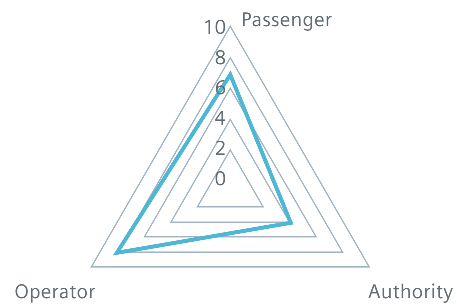
### Description

Automating rail services to increase capacity and improve safety, while improving punctuality and customer experience.

### Maturity and cost overview




### Benefit

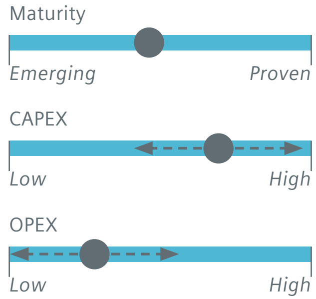


## Predictive maintenance

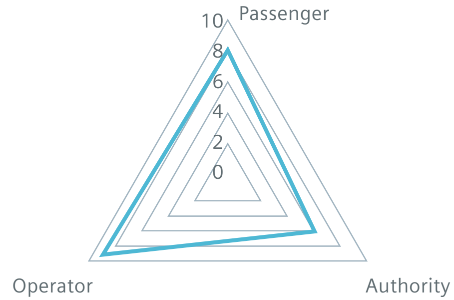
### Description

Predicting outages using smart data analytics to minimize breakdowns and insure maximum availability for customers.

### Maturity and cost overview




### Benefit

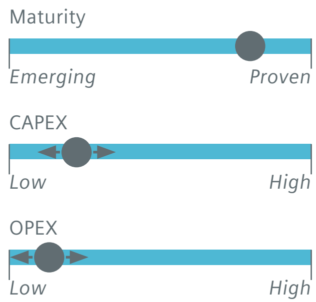



## Intelligent transport systems

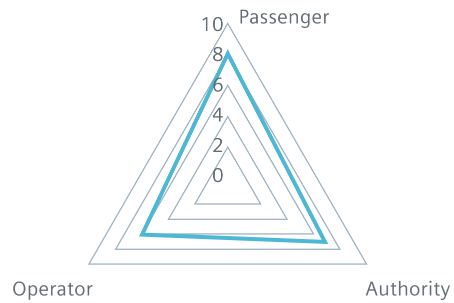
### Description

Using data to optimize, co-ordinate and control transit throughout cities.

### Maturity and cost overview




### Benefit

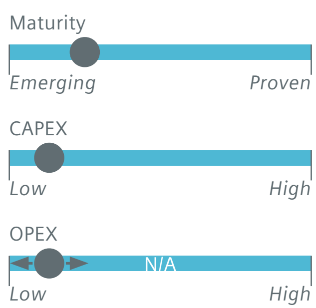



## Integrated mobility platforms and open data

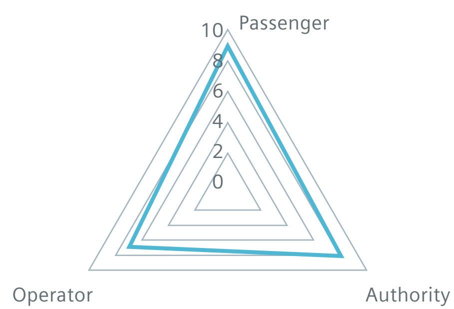
### Description

Opening up transit data, including arrival and departure times, to help users make better transport decisions.

### Maturity and cost overview




### Benefit



# The Data Opportunity

These individual cases of best practice offer a glimpse of the potential which data possesses to add value to global transport networks; empowering citizens to live more productive, prosperous, and healthier lives. And of course, the impacts can vary depending on the technology and the stage of maturity of that technology, with impacts ranging from little to no impact to a global impact on worldwide transport networks.

The use cases observed highlight the benefit of the individual and are only isolated examples of best practice, meaning it does not begin to illustrate the collective potential of the Data Opportunity. To estimate this we have used the aforementioned comprehensive 10,000 point dataset built for the Mobility Opportunity to calculate the impact of each use case across applicable transport systems globally. Using this methodology we have explored the concrete benefits delivered by the use cases in terms of reduced journey times and more efficient, productive, travel time, with increased quality.

Overall, we estimate that the use cases explored could add c. $100bn a year to the global economy through improving the throughput, availability and customer experience of transport systems worldwide. While this represents just 26% of the Mobility Opportunity, it represents c. 5% of annual infrastructure investment worldwide, and ultimately much of this could be achieved with a magnitude of investment vastly lower than that required to realise the Mobility Opportunity; mitigating the funding challenge that currently blocks so much potential prosperity.

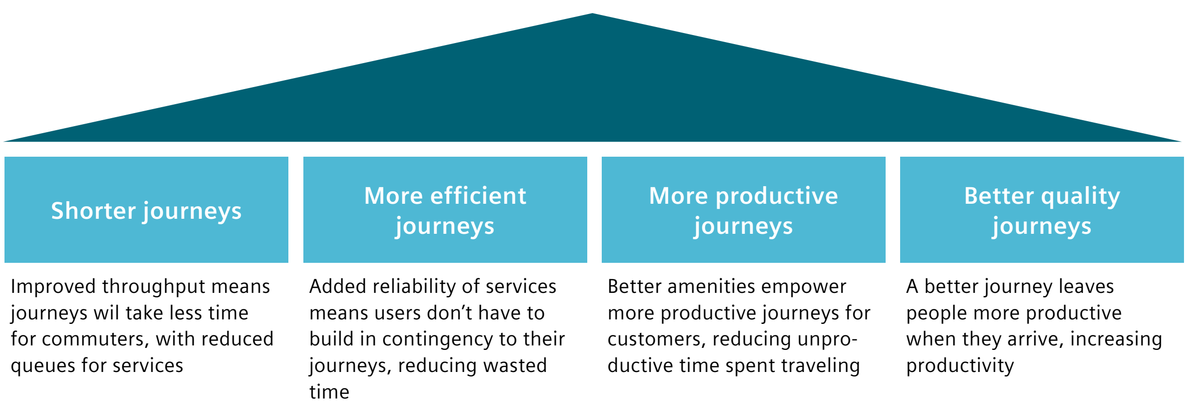



Figure 4: Economic value added by improved transport

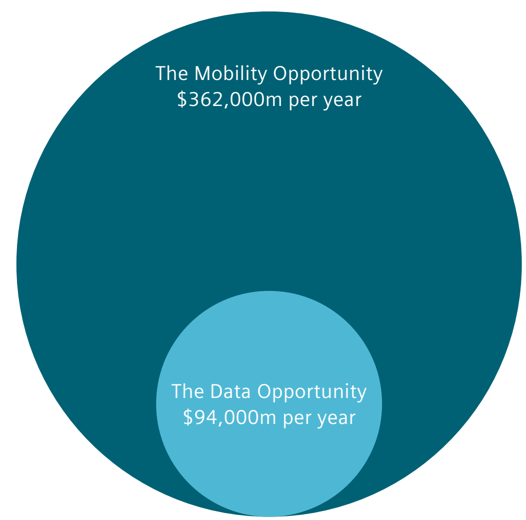
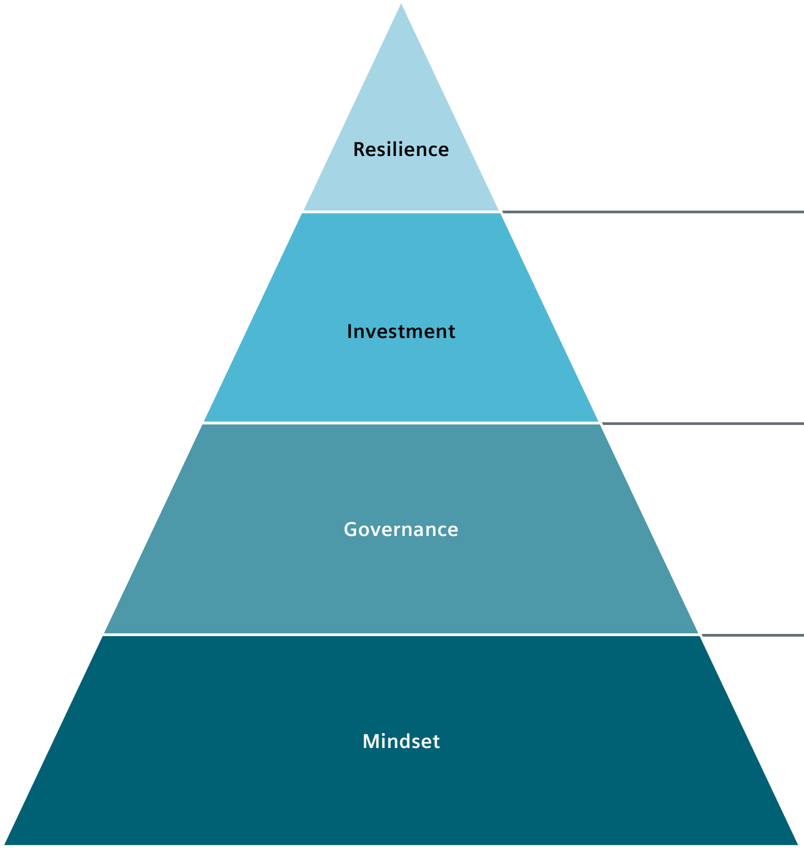



Figure 5: The annual Data Opportunity

# How to seize the Data Opportunity




As the communication of data around a transport network becomes mission critical, the resilience of the digital infrastructure that supports this becomes mission critical and must be ensured

While the investment required to realize benefits through data is less than that required for physical infrastructure investment is still needed

These changes to mindset should be reflected in new regulation and KPIs

The first step is changing mindsets and paradigms that have stood as long as the oldest transport networks. In the new normal open is better than closed and competitors are collaborators

Figure 6: Our model for achieving the Data Opportunity

The foundations of the Data Opportunity is not investment in expensive equipment, but developing the right mindset and culture. Where in the past, live train arrival and departure data would have been considered only for internal use and guarded as proprietary, the trend is for organizations to publish it freely, opening their services up to mindset in the process. Authorities should increasingly see themselves as enablers of mobility in complex ecosystems, rather than just service providers. Emerging ride-hailing platforms, such as Uber or Lyft, should be seen more as collaborators than competitors.

This shift in mindset should be formalized in new ways of governance. This should take the form of regulation that encourages experimentation and innovation, similar to 'pro-Uber' legislation enacted in Massachusetts, and KPIs that recognise the potential benefits that public-private partnerships can bring.

These changes must then be supported by the investment in the right equipment and, importantly, the right skills. Though investments required for the Data Opportunity are more subtle and less glamorous than traditional transport investment, they are vital. This is evident in examples such as the installation of sensors on existing trains, the creation of an underlying IT infrastructure to support the transmission of train or road traffic data, or the creation of a 'digital hub'.

Finally, this new infrastructure must be cared for in a way that reflects its mission critical status. It's not hard to imagine instances where a hacker could instruct a city's Intelligent Transportation System (ITS) to shut down every traffic light or deliberately cause accidents at intersections, or where an IT crash paralyzes an entire metro network. And yet, other critical systems, for instance the global financial system, have been able to run securely for decades and show that it is possible to entrust mission critical functions to online systems without experiencing significant difficulties. Authorities should look to partner with firms with established expertise in cloud and cyber security in order to ensure best in class resilience from day one and employ KPIs that recognize security as a core capability and not a luxury.

Benefitting from the smart use of data is not binary, rather it is an incremental process in which authorities should look to grab low hanging fruit. Changes to mindsets and regulations that encourage third parties to develop innovative solutions for transport users are essentially free but can have huge benefits. Partnering with third parties can cheaply build expertise and deliver new services to consumers with no investment on the part of the authority, helping to improve user experience with little or no cost to the taxpayer. In effect, enacting legislation to empower third parties that share your goals is cheap compared to the cost of infrastructure investment.

Taking these small, but meaningful, first steps will set transport networks on a course to better outcomes and futures for operators, authorities and passengers.

# 2. State of play

### A new world of possibility

Since the launch of the first mass market web browser in 1993, entire industries have been comprehensively transformed. The first to be disrupted were those based on the exchange of information, such as the products sold by a retailer or the information on movie times. Amazon was founded in 1995, Google in 1998 and Wikipedia in 2001; irreparably changing the way people shopped, searched for information and researched topics. Previously lucrative models like business and personal directories and encyclopedia makers have become extinct, and others like travel agents have had to rapidly evolve to survive as new models gave consumers cheaper and more convenient ways of finding businesses, finding general information, and researching and booking travel.

This transformation has not touched all industries equally; those sectors concerned with making or moving physical material remain relatively unchanged when compared with the radical changes seen elsewhere.

However, with technological progress such as reliable and fast wireless internet and increasingly powerful mobile devices driving the emergence of the Internet of Things these same changes are starting to impact 'physical' business models. Emerging technology is beginning to empower the optimization of physical assets, and is changing the way customers use these goods and services. In 2016, the largest accommodation provider in the world has no rooms and the largest taxi company owns no cars; the advent of 3D printing is threatening to distribute production, eliminating the need for long established supply chains and traditional factories in some industries. New business models are emerging, telematics data from General Motors' OnStar navigation system is used to offer "pay as you go" car insurance; low risk customers have seen discounts of up to 15%.

These technologies don't just have consumer facing applications, the ability to monitor and control assets wirelessly enables businesses to gather and analyze data previously unmeasurable in industrial processes, helping to achieve previously untapped levels of efficiency.

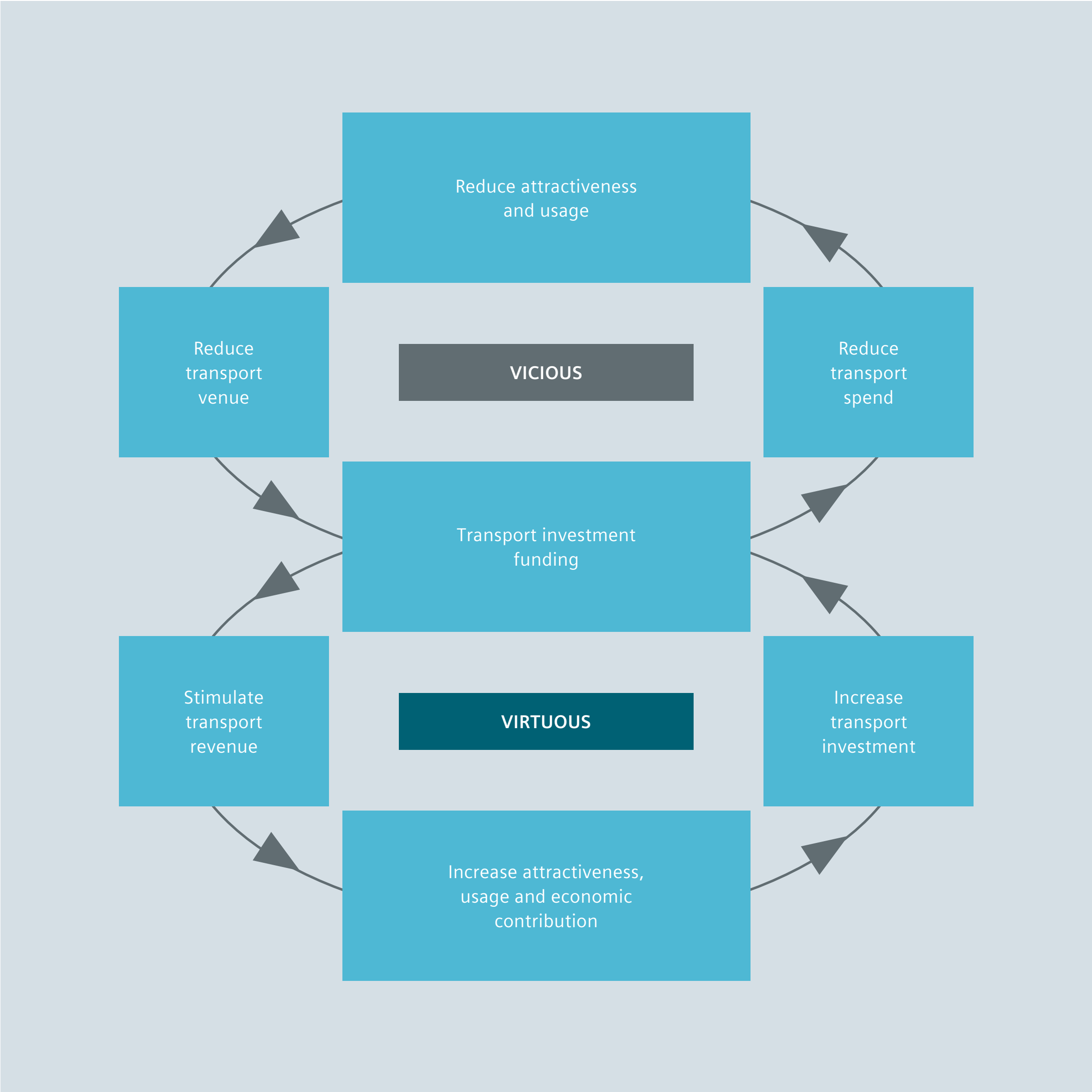
- Using advanced analytics, a Biomed manufacturer was able to determine the nine parameters that most impacted yield. Based on this insight they were able to improve yield by 50%, saving between $5–10m a year
- Traditional quality assurance procedures at Intel meant running each chip through 19,000 tests during production. Applying predictive analytics to data collected throughout the manufacturing process, Intel was able to determine those chips most likely to experience issues and reduce the number of tests. This has delivered a proven saving of $3m, with the company expecting to save $30m more as they expand the pilot
- Struggling to meet global demand without investing in further capacity, Siemens automated production at its Programmable Logic Controls factory. Aside from the absolute gains in number of units produced, the minimization of defects (with an improvement in production quality to 99.99885%) further increased effective capacity

In short, the use of previously untapped data is enabling new value to be extracted from existing assets, maximizing the effectiveness of new assets and helping multiply the value of new investment.

However, public transport is yet to be widely impacted by these new technologies, with the potential benefits remaining unrealized.

### Opportunity unfulfilled

The lack of application doesn't reflect a lack of need; all over the developed world capacity on existing transport systems is struggling to keep up with the growth and the increasing demands of the populations they look to serve, while in the developing world governments are looking to support and encourage nascent economic growth with the transport links vital for prosperity and competitiveness in an increasingly global economy. In both there is a pressing need for effective, targeted investment that ensures transportation, or lack thereof, doesn't become the limiting factor in economic growth. Those systems that don't make the investments needed run the risk of falling prey to vicious cycles by which underinvestment leads to lower ridership of public transport, which in turn leads to reduced revenues and reduced reinvestment. Making the right investment in transport networks, right now, has therefore become critical.



In ‘The Mobility Opportunity’, 2014, Siemens and Credo explored the potential growth achievable through the right investment in transport networks around the world, establishing global GDP could be 1% higher if best in class technologies and practices were transplanted onto suboptimal existing networks.

However, and as may be expected, best in class transport infrastructure requires significant investment. Transport investment typically enjoys a benefit cost ratio of between 2 and 4 times1, $270–400bn would need to be spent globally by 2030 (see figure 1).

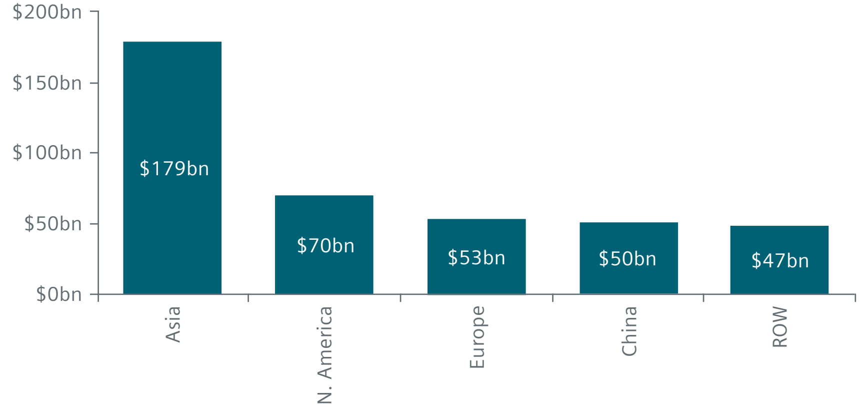



Figure 1: Conservative annual investment requirement by 2030 to achieve the Mobility Opportunity

And while innovative models facilitating the private funding of public infrastructure are becoming more common, funding requirements for transport infrastructure still largely fall on governments. However these same governments are largely focusing on reducing spending and looking to pay down record levels of debt as a percent of GDP, meaning there is not the slack in government budgets to afford this investment

### The Data Opportunity

These challenges to funding the Mobility Opportunity present a threat to global growth; they also present an opportunity and motive to leverage the new technologies disrupting other 'physical' industries. Breakthroughs are starting to be seen from the automation of century old metros to increase capacity, to the emergence of innovative ride sharing apps in developing countries.

This combination of the need to deliver the mobility required to fuel economic growth and the inability to fund all of the capital intensive infrastructure to facilitate it has begun to drive new and innovative solutions which are beginning to deliver value to transport systems around the world.

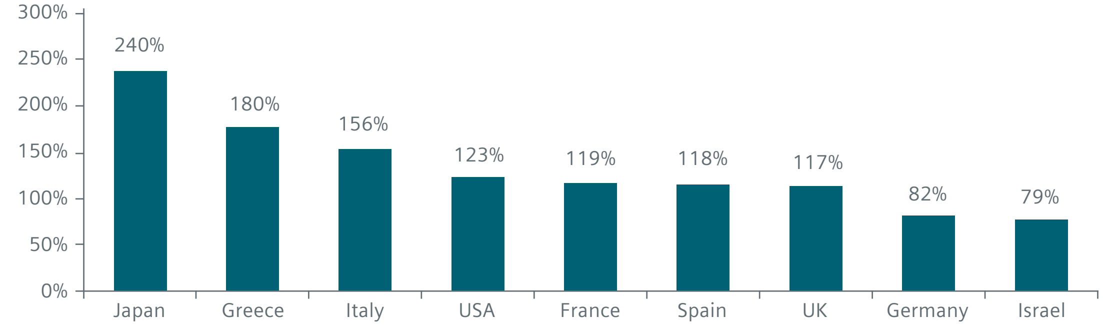



Figure 2: Government debt to GDP ratio (OECD data, 2014)

# 3. Data in action

Pioneering projects across the world are beginning to realize some of the potential of data to improve transport. Having reviewed global examples of transport innovation as well as Siemens and Credo experience, we have classified the emerging examples into the five areas outlined in Figure 3.

These projects are principally focused on performance in three areas: throughput, availability, and passenger experience. These benefits are achieved through the network's development and lifecycle from the earliest stages of planning, to solutions that are retrofitted onto existing systems to help optimize their operation.

In this report we have focused on five areas where the emerging use of data is transforming business as usual mobility. From using innovative data sources to plan new public transport or increase the effectiveness of existing metro networks through automation, to opening up mobility data to help users optimize their journeys.

Through this section we examine the concrete benefits being delivered by data to operators, authorities, and passengers.

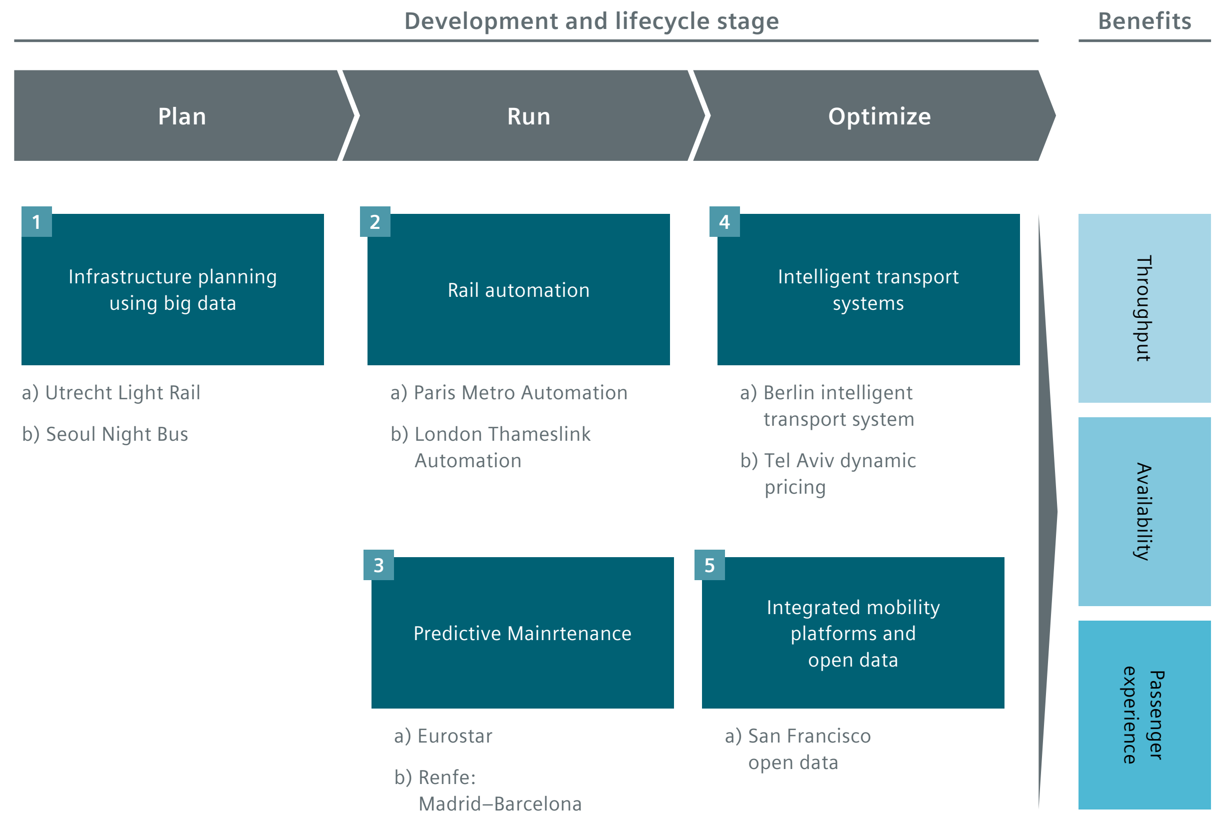



Figure 3: Use cases of data in transport

# Optimized infrastructure planning

# Infrastructure planning using big data

### Big data analytics can play a critical role in planning infrastructure and services

Operators collect data from existing transport services, such as metro cards and contactless cards, but can also harvest data from alternative sources such as mobile phone data, social media, footfall sensors, and traffic flows. Using this information, operators can model passenger movements to a high degree of accuracy, and tailor the most appropriate infrastructure when it is still in the planning stage in order to best suit their citizens' needs.

### Journeys are optimized from start to finish

By collating data from several sources, authorities can track travellers on every leg of their trip, enabling far deeper insights than could be gained form analyzing any one mode in isolation. Studying multiple passenger trips can highlight gaps in transport provision – for example, if a large number of people are regularly making a three-leg journey using several modes of transport, authorities can deduce that there is demand for a direct route.

### Data enables precise bus planning

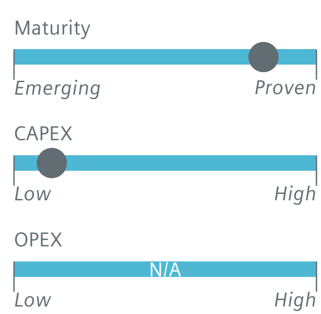
Bus operators use mobile phone data to model passenger movements to a high degree of accuracy. Looking at end-to-end routes enables operators to identify unmet demand and, therefore, the areas where new bus routes can add the most value. By identifying popular flows, operators can adjust the number of buses scheduled for any given route dependent on day or time. This shortens wait time for passengers, and (with minimal upfront cost) optimizes revenue for the operator.

### Better visibility gives authorities the confidence to invest in new services

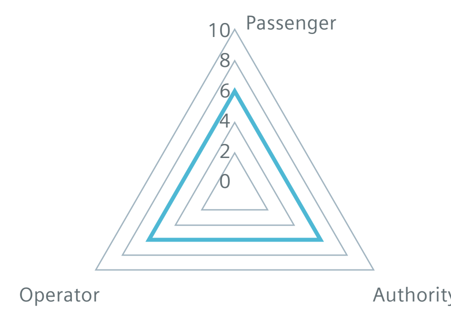
New infrastructure requires significant upfront investment, often with many years to payoff. Well-informed models reassure authorities that they have chosen the infrastructure solution that best matches their populations' mobility needs, which will be the most beneficial option in the long term.

| City | Example |
|---|---|
| London | Uses big data from smart tickets to plan alternative bus routes during planned service disruptions. |
| Seattle | Smart analysis of big data was used to support a cost benefit analysis for developing a new monorail. |
| Seoul | New bus routes were planned using Big Data from mobile phones and taxi journeys providing optimal routing for the buses, improving customer experience and operator revenue. |
| Utrecht | Big data analysis supported the cost benefit analysis of a new light rail connection, showing that a proposed bus route would not have been able to provide the needed capacity. |

**Implementation**




**Benefit**[1]




[1] Benefits scored on a scale of 0–10

# Use case: Utrecht light rail

### Context

The Uithof is a district of Utrecht in the Netherlands that is rapidly expanding as businesses, university and government institutions grow in the area. The city's metropolitan area currently has approximately 650,000 inhabitants, which is expected to reach 800,000 by 2040. The number of daily commuters to the Uithof is expected to increase from 20,000 in 2011 to 45,000 by 2020. Utrecht has the busiest bus network in the Netherlands, which negatively impacts the air quality in the city. The only current public transport link between Utrecht's Central Station and the Uithof is bus line 12, which is severely overcrowded.

### Solution

Local Authorities considered two main options to relieve overcapacity; a new bus lane and a light rail system. A cost benefit analysis was carried out with a particular focus on quantifying likely usage levels, and the operator decided to implement a light rail system. The tram will be bidirectional, featuring five modules: a driver's cabin at each end, two motorized modules and a trailer module in the center. Couplers will allow for multiple operations.

The €440 million new line will significantly improve capacity and reduce journey times, with an estimated total annual travel time saving of 641,000 hours by 2020.

### The role of data

Data was collected from smart tickets and public transport departure and arrival time records. Combining these datasets allowed the operator to undertake a detailed demand forecast, which showed the bus was not feasible – even running at full capacity, there would still be overcrowding at peak times. The tram, carrying five time as many passengers as a bus, was the clear choice. Information from the demand forecast allowed accurate predictions of how reliable the service will be, giving authorities the confidence to fund the light rail in the knowledge that it would be well used.

### Customer experience

- Crowding and waiting times are reduced, improving customer experience

### Throughput

- Effective throughput is increased compared to the potential bus route

## Benefits

- Authorities benefit from confidence in forecasts
- Customers benefit from better services
- Capacity is managed with an accurate forecast

# Use case: Seoul night bus

### Context
Seoul built an extensive metro network since the opening of its first line. However, this system shuts overnight, meaning taxis have been the only option for people travelling home between these times. This affected lower income groups disproportionately, as taxi fares increase in the middle of the night and many workers live far from the city center. Furthermore, high demand for taxis often meant extortionate fares and an uncertain and unsafe journey home.

### Solution
Seoul planned to introduce night buses, but their budget was limited and late-night public transport services had typically been unprofitable owing to low ridership. Bus routes are typically planned and designed with travel demand predicted using sample survey data. However, this method can be costly, timely, and subject to many interpretations. Instead, data was collected to analyze customer demand, with the intention being the design a new route. The Owl Bus was brought into service in September 2013, allowing commuters to travel home cheaply late at night.

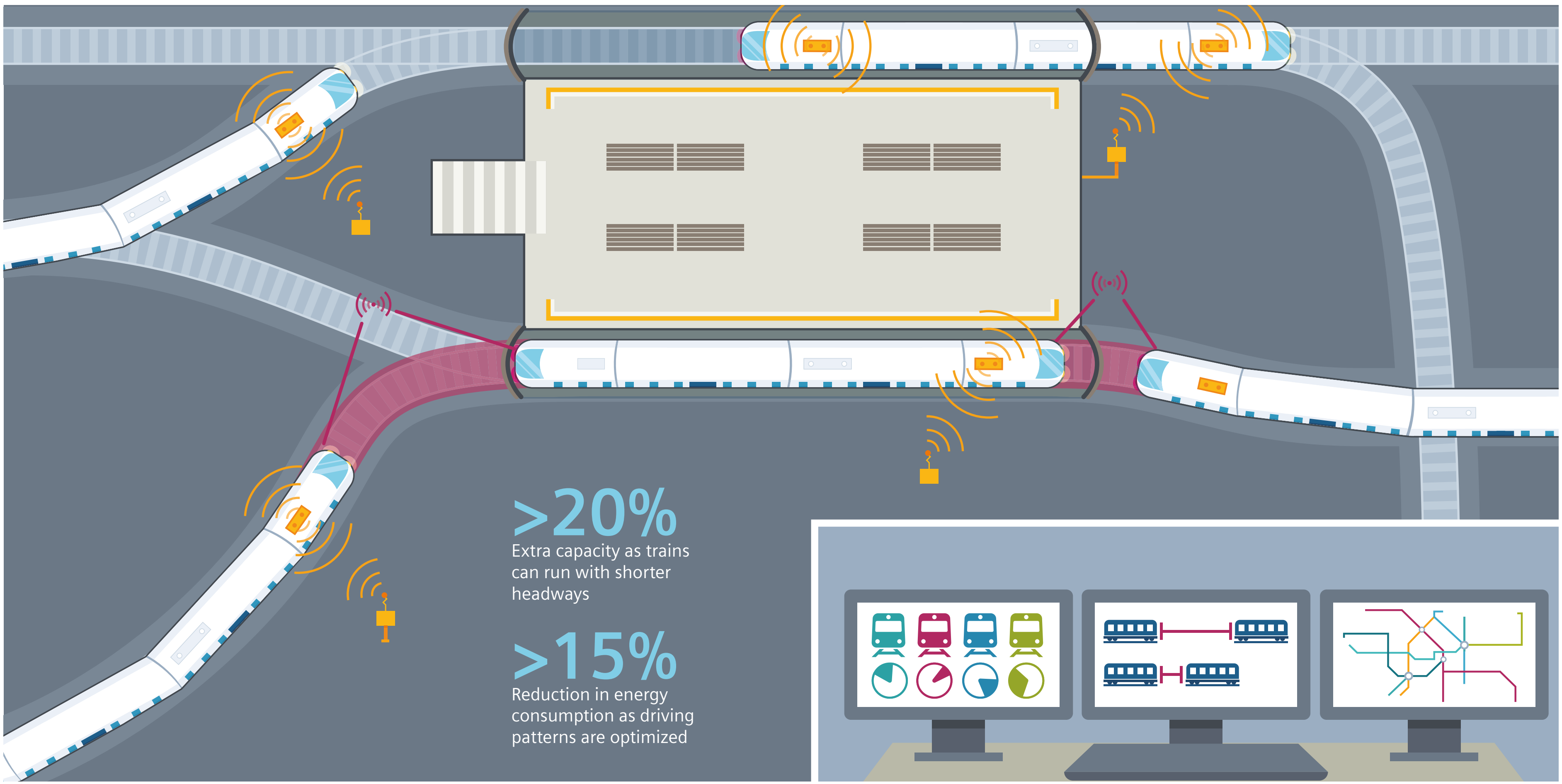
### The role of data
The Seoul metropolitan government worked together with Korea Telecom to gather data from mobile phone and taxi usage to determine common late night routes. In total, over 3 billion data points were gathered to map out the most common travel routes, and create routes to optimally suit the relevant citizens. The Owl Bus routes were planned to maximise the utility for Seoul's citizens, who collectively saved the equivalent of 2% of GDP, and time spent waiting for cabs (previously estimated at a collective 197,266 minutes a day) was much reduced.

### Customer experience
- Seoul's citizens experience significant savings and safety benefits

### Throughput
- Increase in throughput as more people are served by the bus, leading to increased revenue

| Benefits |
|---|
| Optimizing the route for the most passengers generated a 300% ROI for the operator |
| The average passenger saves about $1,500 a year (c. 2% of avg, South Korean per capita) |
| 2.3 million car journeys a year replaced |

# Rail automation



# Rail automation overview

### Today’s metro networks were not built for the cities they now serve

In some of the world’s largest cities, decades-old infrastructure was built for populations with very different movement habits. In other cities, recent wealth has created high density compact centers with fast-evolving transport requirements. In both there is the need to improve existing metro services but not necessarily the space to add extra lines.

### Rail automation offers increased capacity through improved headway

As cities expand, commuter networks become strained, and the challenge of maximizing capacity and reducing crowding becomes ever more pressing.

Reducing crowding requires that services run at ever lower headways, doing so with human drivers runs the risks of expensive and disruptive accidents; rail automation can deliver low headways while maintaining safety.

### Rail automation optimizes network efficiency and flexibility

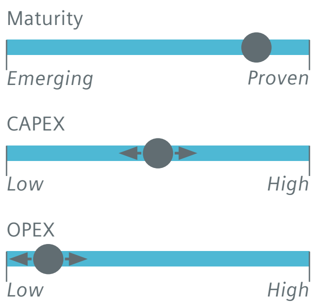
Within automated networks, on-board sensors transmit precise speed and location data to trackside computers to create a live network status map. This allows individual train speeds to be optimized, enabling higher throughput and availability. It also gives more flexibility to respond to spikes in demand, helping to ease the worst conditions for passengers.

### Rail automation delivers benefits to both operators and passengers

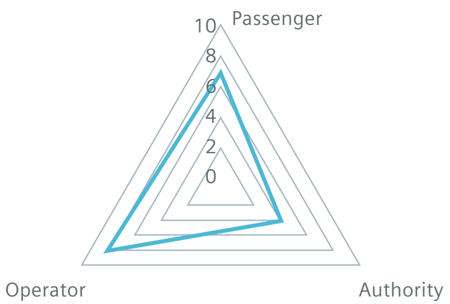
Automating metro networks increases their capacity, especially at peak times. This reduces wait times at stations and crowding which improves passenger experiences. Driving staff can be reassigned to provide customer facing services throughout the network, improving the customer experience. The higher throughput also boosts revenue for operators, helping to shift to a virtuous cycle where increased farebox revenue helps fund future improvements.

| City | Example |
|---|---|
| Kuala Lumpur | The automated Kelana Jaya line is the third longest automated metro in the world |
| New York | Fully automated light rail link between New York and JFK airport |
| Paris | Metro lines 1 and 14 have been fully automated, with work currently in progress on Line 4 |
| São Paulo | Metro lines 4, 6, 15, and 17 are fully automated |

**Implementation**




**Benefit**[1]




[1] Benefits scored on a scale of 0–10

# Use case: Paris Metro automation

### Context

The Paris Metro is one of the busiest and oldest in the world, opening in 1900 and carrying over 1.5 billion passengers per year. The 116 year old Line 1 is the busiest in the city, carrying up to 750,000 passengers per day. Much of its equipment was outdated and it faced recurring problems in terms of regularity. The line was often overcrowded, which had knock-on effects as many of its stations are important exchange hubs with other lines.

### Solution

Upgrading Line 1 required a radical solution that would completely change the way in which the line was organized, minimizing interruption to existing services and gradually rolling out the renewed infrastructure. Authorities therefore decided to automate line 1. The project involved automating rolling stock, upgrading outdated signaling systems, fitting automatic doors on platforms and constructing a centralized control room. Tests were carried out at night and automated trains were rolled out gradually.

### The role of data

Data transmission plays a key role in keeping track of the exact speed and location of every train on the line. The data is collected by on-board sensors and transmitted to trackside receivers by radio link. This enables trackside computers to constantly monitor and assign a movement authority for each train operating on the line. This allows for shorter headway and optimized speed, with customers enjoying a smoother ride and less energy used. When demand increases, schedules can be adapted dynamically, further boosting capacity.

### Customer experience

- Low crowding, lower waiting times and greater reliability

### Availability

- Service availability no longer dependent on driver reliability

### Throughput

- Reduced headway leading to greater throughput

| Benefits |
|---|
| 20% reduction in headway between trains |
| 15% reduction in energy requirements/bill |
| 20% increase in effective capacity |

# Use case: London Thameslink automation

### Context
London has a population of 8.6 million, and it is increasing at a rate of 3% per annum. More and more people are commuting to London from neighbouring cities such as Watford, Sevenoaks and Brentwood – in 2015 there were 1.58 billion rail journeys on transport for London's network. Overcrowding is an increasing problem. To boost capacity, several new projects are under way, including a major overhaul of the Thameslink route, a heavily used route which currently has a customer satisfaction score of just 46% due to overutilization.

### Solution
The £6 billion Thameslink program will extend service to 100 extra stations with 115 new Desiro class 700 trains. The trains can carry almost 2000 people, and feature wide doors and live information systems which direct passengers waiting on the platform to emptier carriages. Fleet availability is maximized through the use of predictive maintenance. Siemens has also invested in a state-of-the-art depot for the fleet at 'Three Bridges', fully equipped with signal technology and personnel safety features.

### The role of data
As well as increased rolling stock capacity, the use of data on the trains will further increase capacity. The trains can switch from the European train control system on mainline to automatic train operation in the metro area to enable low headway, high capacity service. On-board systems will monitor passenger volume to control the air conditioning, and a state of the art vehicle loading system will measure crowding in each carriage and help direct commuters to the least busy carriages, helping to reduce crowding even at the busiest times of day.

### Customer experience
- Better customer information, less crowding and more regular trains

### Availability
- Greater availability through predictive maintenance

### Throughput
- Advanced passenger loading system allows more passengers to ride the train with added comfort

| Benefits |
| --- |
| Reduction in total rolling stock life cycle cost |
| Decreased headway through seamless switchover between ETCS and ATO control systems |
| Improved passenger information and comfort |

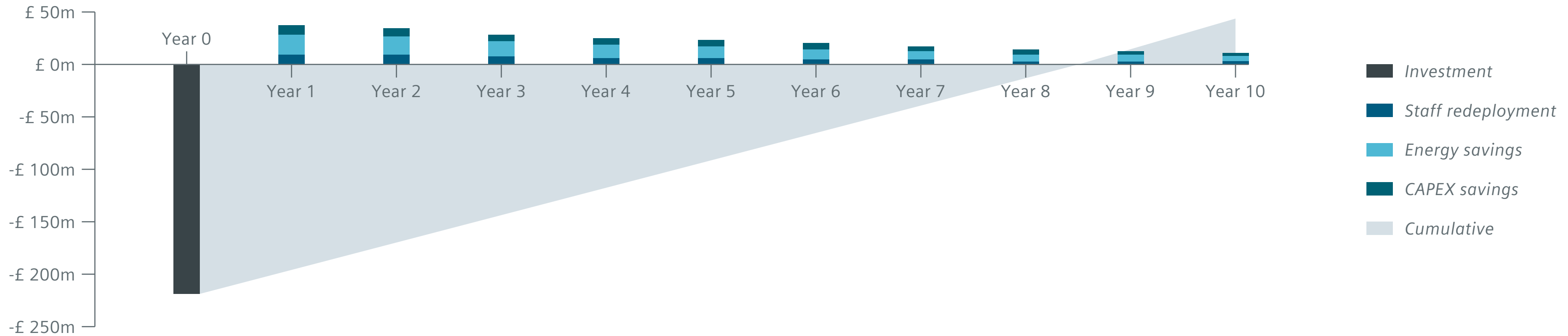
# The business case for rail automation

**A western European city is home to one of the oldest metro networks in the world.**
The first line was opened over a century ago, and the network now provides over 1.5 billion journeys per year. Passengers are transported across 14 inner-city lines which stretch across 300 kilometres of track.

The Blue Line is the busiest line in the network. When it was first opened, 116 years ago, services on line A ran once an hour. Today's trains are scheduled to run every 2 minutes, carrying 750,000 passengers every day.

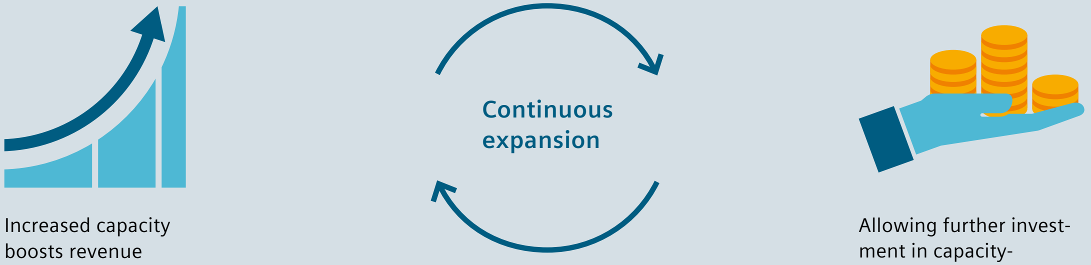
As the city's population continues to grow, so has the strain on the metro network – particularly on the blue line. In 2011, over-crowding on the line regularly lead to severe delays, which in turn caused problems elsewhere on the network. Authorities decided to combat the vicious cycle of severe delays and overcrowding by fully automating the blue line.

**Key facts**
300 km of track
1.5 bn customers per year
109 years of operation
500 dedicated staff



# Rail automation in action

## Continuous improvement




Increased capacity boosts revenue

Allowing further investment in capacity-generating solutions

### c. €20m
**saving in rolling stock**

The new infrastructure can be retrofit to existing rolling stock, and the ROI is small when compared with history of the network

### 9 years
**to payback**

Less rolling stock is needed, since time is saved at terminals and from driver changeovers. This significantly reduces CAPEX

### Increased
**passenger experience**

The significant increase in capacity, in particular the ability to be flexible at peak times, creates an uplift in revenue

**12%**
**less energy**

Used through better management of train speeds – a saving of 4,600tn of carbon p.a.

**>98%**
**punctuality**

Among the best on the network

**Passenger experience**

Improved following reallocation of drivers to customer facing roles

**Increased safety**

Due to better surveillance, faster incident-response and reduced human error

**18%**
**Capacity increase**

**55.000**

Extra capacity per day following conversion of driver's carriage

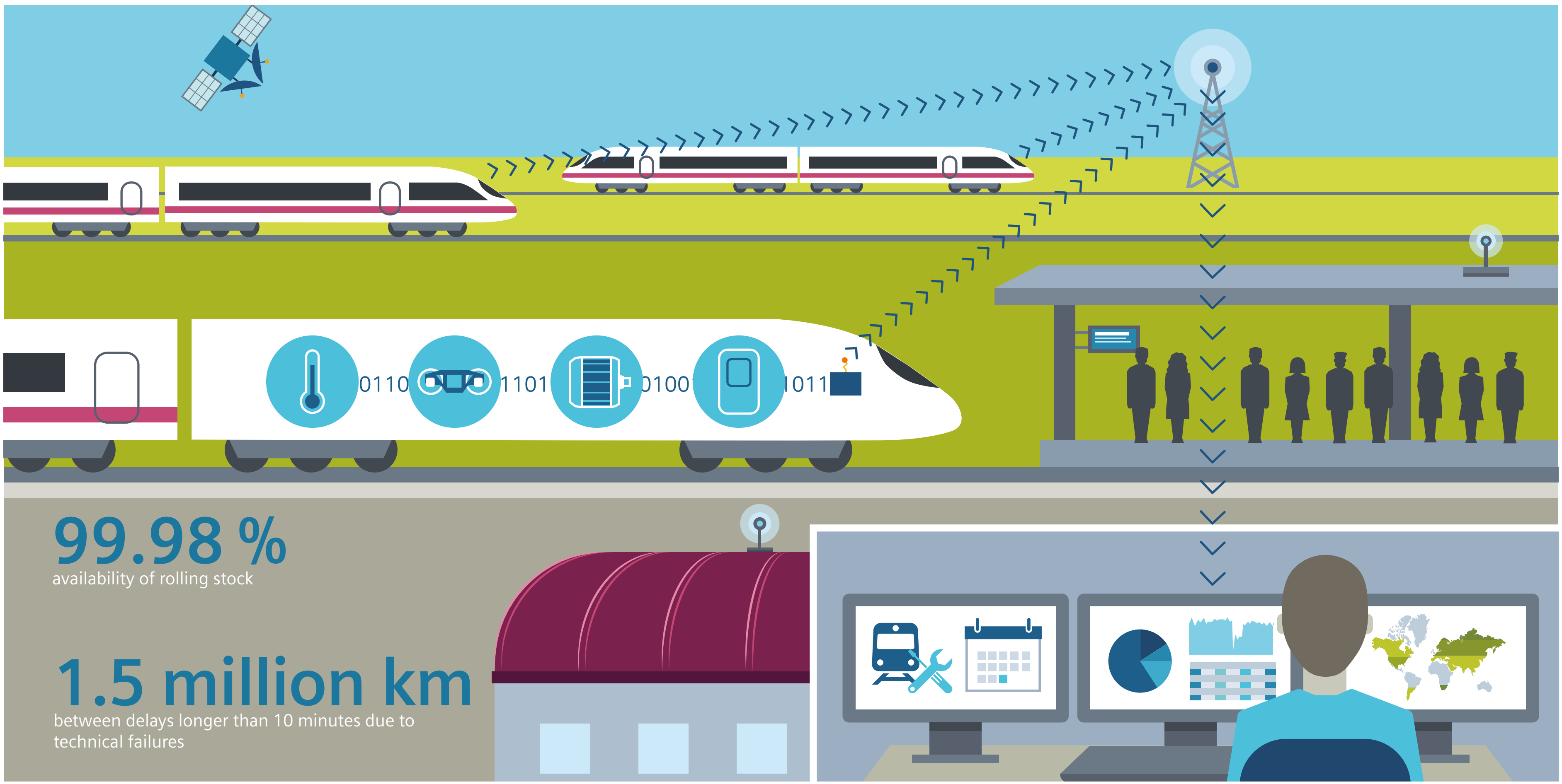
**23%**

Extra capacity available at peak times due to more flexible scheduling

**22s**

Headway reduction to boost rate at which crowds can be moved

# Predictive maintenance



# Predictive maintenance overview

**The use of data is revolutionizing maintenance in the 21st century**
Based on millions of data points captured from sensors on critical train components, analytics can detect impending part failures, ensuring maintenance is only done when required (but before a failure occurs). In-depth knowledge of which parts are likely to fail in the near future enables close to 100% availability as faults are fixed when units are out of service, avoiding breakdowns.

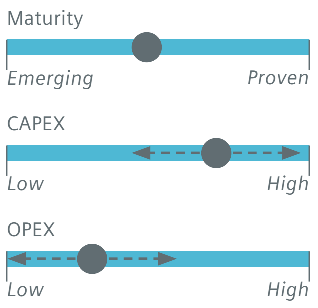
**Reducing the need for operational reserves, increasing effective capacity**
Train fleets typically keep an operational reserve of 5–15% as back up in case of operational failure. In predictive maintenance, connected train components enable optimization of rolling stock maintenance by predicting when a component will fail. Unplanned outages of rolling stock are minimized, so fewer trains need to be kept on standby. This results in substantial CAPEX savings or increased capacity.

**Maximal component usage –minimal maintenance costs**
Predictive maintenance means that components are replaced when they are actually close to failure and not when the manual suggests. This means expensive components are used optimally, lowering total spend on parts and minimizing labour costs associated with maintenance.

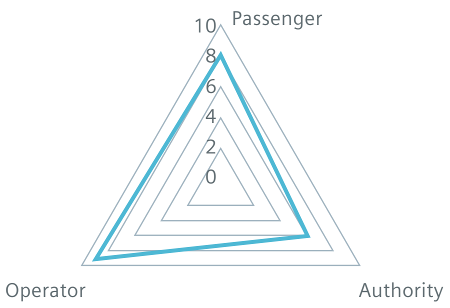
**Underwrites system reliability**
Today's transport networks are extremely complex, with interdependencies growing exponentially with the size of the network. An outage on a line in the morning can mean disruption on the whole network for the much of the day, with millions of commuters days disrupted and thousands of productive hours lost. Minimizing unplanned rolling stock outages through predictive maintenance is key to ensuring stability and reliability throughout transport networks.

| City | Example |
|---|---|
| Barcelona – Madrid Rail | Renfe use predictive maintenance to underwrite a guaranteed punctuality on their Barcelona-Madrid service; helping to gain market share against the competing air route |
| Eurostar | Monitoring of critical components minimises train failures which can cause serious delays under the channel, helping to protect the stability of the system and Eurostar's brand |
| Russia Velaro | Predictive maintenance has been implemented on Russia's Velaro trains to maximise availability and minimise outages on a flagship project |
| Thameslink | Predictive maintenance will result in availability of over 99.9%, helping to ensure connectivity across London and protecting a key intersection with the new cross rail service |

## Implementation




## Benefit[1]




[1] Benefits scored on a scale of 0–10

# Use case: Eurostar

### Context

Eurostar is a high speed train service connecting London, Paris, Brussels and several other major French cities. The service faces increased competition as other operators consider starting new services through the Channel Tunnel, which currently operates at only 50% of its capacity. Eurostar wants to defend it's position as the leading rail operator between the UK and the continent and remain the obvious choice for short haul travel; it is seeking to achieve this by looking to strengthen the quality of services offered to customers in terms of punctuality, reliability and comfort.

### Solution

Eurostar sought to compete on journey quality and reliability and decided to upgrade its existing fleet and ordered 17 new trains equipped with predictive maintenance technology.

### The role of data

Sensors mounted on critical train components gather over 1 billion data points per year, helping Eurostar to understand the condition of the components. Leveraging deep engineering knowledge and data analytics capabilities, analysis of this data can be used to predict component failures and carry out root cause analysis when failures do occur, supporting continuous improvement components and processes. This allows tailored maintenance planning, improved availability and reduced overall maintenance costs. This improves punctuality and reliability, improving customer experience and helping Eurostar to defend their position in the market.

### Customer experience

- Delays almost eliminated and more services to choose from

### Availability

- Significantly greater availability

### Throughput

- More services with the same fleet

## Benefits

- Improved reliability and availability for a better passenger experience
- Increased rolling stock availability leads to effective capacity increase and more services
- Reduced costs can be passed on to passengers in reduced fares, further improving ridership

# Use case: Renfe Madrid-Barcelona

**Context**

Renfe is the main rail operator in Spain, providing passenger and freight services and has long operated a route between Madrid and Barcelona. Originally, this route took 5.5 hours and serviced only 800,000 passengers per year. This service was struggled to compete with a high frequency plane route provided by Iberia offering a much faster (1.5 hours) alternative, servicing 80% of the market between the two cities despite being the more expensive option.

**Solution**

Renfe opened a new high speed train route between Barcelona and Madrid in 2008, with speeds of up to 310 km/h. This reduced the journey time to under 3 hours, making the plane and train journeys comparable and giving passengers a real choice. Renfe sought to directly target the air routes' passengers by offering full refunds for any journey that was delayed by more than 15 minutes. This was popular with passengers but exposed Renfe to considerable financial risk in the case of delayed trains.

**The role of data**

Renfe's 15 minute guarantee is underwritten by the reliability delivered by predictive maintenance. With unplanned outages minimized, there is little chance of a mechanical failure on route or rolling stock availability delaying a train more than 15 minutes. This has meant that Renfe have broken their guarantee on only one journey in 2,300, protecting Renfe's bottom line while helping them to grow their share of the Madrid-Barcelona market to 60% from 20%. Passengers benefit from significantly increased reliability and punctuality and the reduced use of the air route reduces carbon emissions.

**Customer experience**

- Guaranteed punctuality

**Availability**

- 99.98% availability

**Throughput**

- Increased throughput with a larger effective fleet size

## Benefits

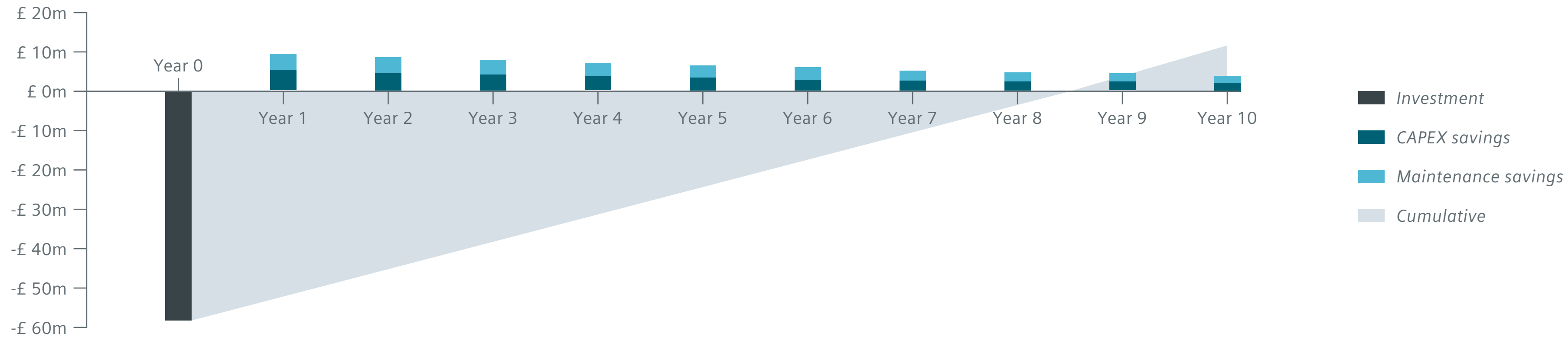
| Benefits |
|---|
| Guaranteed punctuality for customers, increased market share for operator |
| Reduced operational and capital costs for operators |
| Reduced environmental impact of travel |

# The business case for predictive maintenance

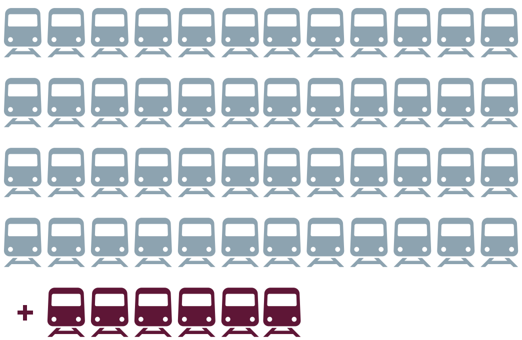
**A train operating company provides a long-distance service between two cities which are 1000 km apart.** The total journey time by train is 3 hours, and the service runs twice an hour between 8am and 6pm daily. Each service can carry up to 1,000 passengers, but at peak times the trains can become crowded.

The rail route is in direct, and intense, competition with one of the busiest air routes in the world which previously dominated the market for travel between the two cities before the introduction of the new high speed line. The flight takes 90 minutes which, when including the required check in time, makes the journey times highly comparable.

**Key facts**
700 km journey
3 hr journey time, 90 mins by plane
Top five busiest air route globally
300+kmph top speed
500 dedicated staff



# Predictive maintenance in action

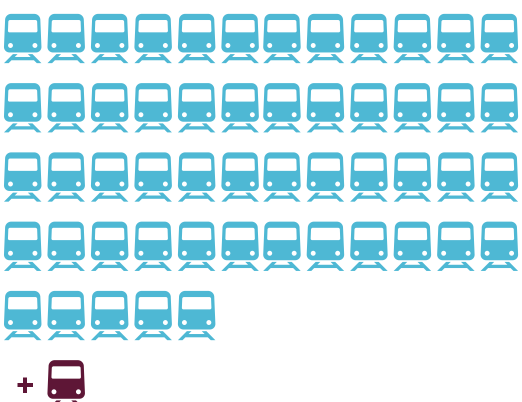


The train operating company currently keeps

## 6 trains

permanently on reserve as backup for its

## 40 active trains



Using predictive maintenance, the company can run

## 5 more

of its trains, increasing capacity by c.

## 13%

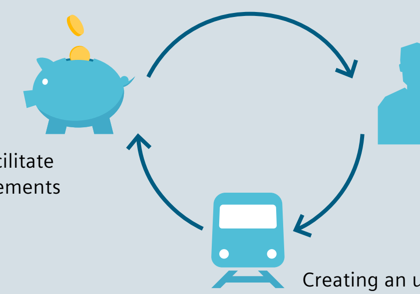
### Predictive maintenance in action:

Saving of c. £40m in upfront investment

The company's services become more reliable, and customer satisfaction improves

With fewer unnecessary component upgrades, maintenance costs fall

### Continuous improvement



Greater customer satisfaction causes market share to grow

Creating an uplift in revenue

Cost savings facilitate further enhancements for passengers

**c. 130%**
**10 years ROI**
Cost savings alone produce a significant ROI after 10 years

**<3 years**
**to profitability**
Upfront development and infrastructure costs are made back within 3 years

**<99,9%**
**service reliability**
Consistently high service wins market from alternative industries such as air travel

# Intelligent transport systems

# Intelligent transport systems overview

### Solving problems before they arise to minimize congestion and improve transport

By collecting data from a range of sources such as road-side sensors, car location data, smart tickets and video feeds, intelligent transport systems (ITS) can model traffic flows and spot problems before they occur. The data collected can be used to implement a range of solutions to ease traffic flow like traffic signal management and dynamically priced access.

### Prioritizing public transport flows to encourage modal shift

ITS can also prejudice the flow of high priority vehicles, such as emergency services or public transport, through cities. This helps to increase the effectiveness of emergency services and also incentivises use public transport use as journeys become faster. Carpooling can be encouraged through high occupancy toll (HOT) lanes open to carpools or those willing to pay a toll. All of the above contribute to taking cars off the road.

### Supporting better decisions with better information

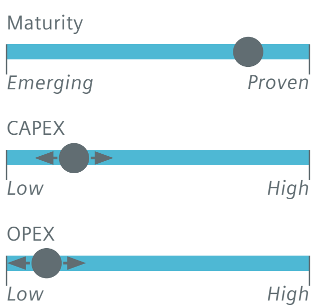
The superior levels of data collected by ITS can then be used to help users make better decisions. For instance, passengers may realize that the bus that stops outside their house can reliably get them to the city center quicker than their car, helping to take vehicles off the road and improving traffic for all.

### Using dynamic pricing to price and optimize road usage

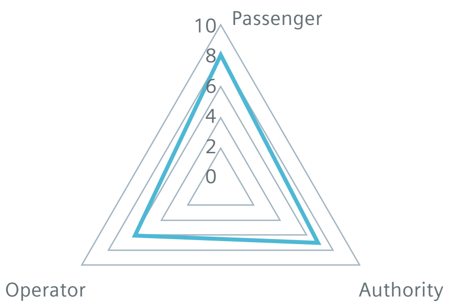
HOT lanes, where single occupancy cars can pay to use carpool lanes, face a dilemma. At what level do you price the toll? Too high, and too few people will use the road; too low, and too many people will use the road. Using Data and smart algorithms the toll can be dynamically priced, encouraging use when needed and discouraging when there is too much usage. These same principles can be applied to congestion charges to optimize their application and achieve civic goals.

| City | Example |
|---|---|
| Berlin | Berlin manages its transport through a traffic control center and an integrated mobility platform helping to proactively solve problems and improve user information. |
| London | Leading smart ticketing system implemented, now accepting contactless cards, improving user experience and encouraging intermodal integration |
| Singapore | The world's first electronic road pricing system manages traffic congestion during peak times, allocating an economic cost to usage of road capacity when it is most scarce. |
| Tel Aviv | A high occupancy toll lane featuring dynamic pricing guarantees fast throughput for users, greatly reducing the journey time along a crucial commuter corridor. |

### Implementation




### Benefit[1]




[1] Benefits scored on a scale of 0–10

# Use case: Berlin ITS

### Context
The volume of road trips in Berlin increased from 55.8 to 57.0 billion between 2007 and 2012, with the average citizen making 3.5 journeys a day and spending 81 minutes on the road. This increasing road usage put the city's road network under growing pressure. Concerned that congestion was becoming a threat to economic growth and their 3.4m citizens' quality of life, the Berlin senate set out the Berlin traffic management plan with the aim of achieving a free flow of traffic at all times.

### Solution
A key part of this strategy was the establishment of the traffic control center (VKRZ), which was designed to leverage data from roadside sensors to supervise and control traffic. In 2011, a traffic information center (VIZ) was also implemented to provide drivers with near real-time updates on traffic conditions in the city. These were followed by an integrated mobility platform (IMP) that supports integration between different transport modes, encouraging commuters to take alternative transport options reducing reliance on cars which made up 40% of the modal split at the beginning of the program.

### The role of data
Data sits at the heart of the Berlin traffic management plan. Data collected from roadside sensors, video cameras, and floating car data is combined with information on special events and road closures to build a common data pool. This data is then used to control traffic signals and variable message signs as well as being shared with the public to inform journey decisions. Aggregating data from other transport operators has also allowed an IMP which promotes multimodal travel and supports the objectives of reducing congestion and allowing a free flow of traffic.

### Customer experience
- Better information for passengers, allowing them to make better decisions

### Availability
- Prevents problems before they arise, improving availability

### Throughput
- Reduction in incidents improves throughput, better information means better use of capacity

## Benefits

- Better traffic flow, saving citizens time and reducing pollution
- Better data to improve journey planning and improve user experience
- Faster flow for priority vehicles, supporting more effective public transport and emergency services

# Use case: Tel Aviv dynamic pricing

### Context

Tel Aviv is the second largest city in Israel and attracts more than 600,000 commuters from the surrounding Gush-Dan metropolitan area daily. A significant number of these commuters enter the city from the south east, which often suffered from severe congestion, with commuters losing 40 minutes a day to the traffic. This wasted time threatened the continued economic growth of the economic capital of Israel.

### Solution

To help manage this traffic flow a high-occupancy toll (HOT) lane was introduced in conjunction with a park and ride facility along a 13km stretch of the highway leading to Tel Aviv from Ben Gurion Airport. HOT lanes are for use of cars which either have multiple passengers, or those willing to pay a toll. Setting a toll price is often difficult; too low and everyone will use the road reducing the incentive to carpool and too high and no one will use the road reducing throughput and increasing congestion on other lanes.

### The role of data

To solve this utilization issue on the new lane, dynamic pricing is used to guarantee average speeds of at least 70km/h and minimum throughput of 1,600 vehicles per hour. Speed and volume measurements of traffic travelling on and around the HOT lane are taken along 500m to 1km long cross-sections. Based on this real-time data, a Siemens dynamic pricing algorithm (Dynafee) sets the toll to encourage either more or less traffic on the toll lane, to achieve throughput volume and speed objectives set by the city. This ensures a travel time of between 10 and 15 minutes for paying customers while optimizing revenue for the operator.

### Customer experience

- Reduced journey time for all, guaranteed journey time for toll road users

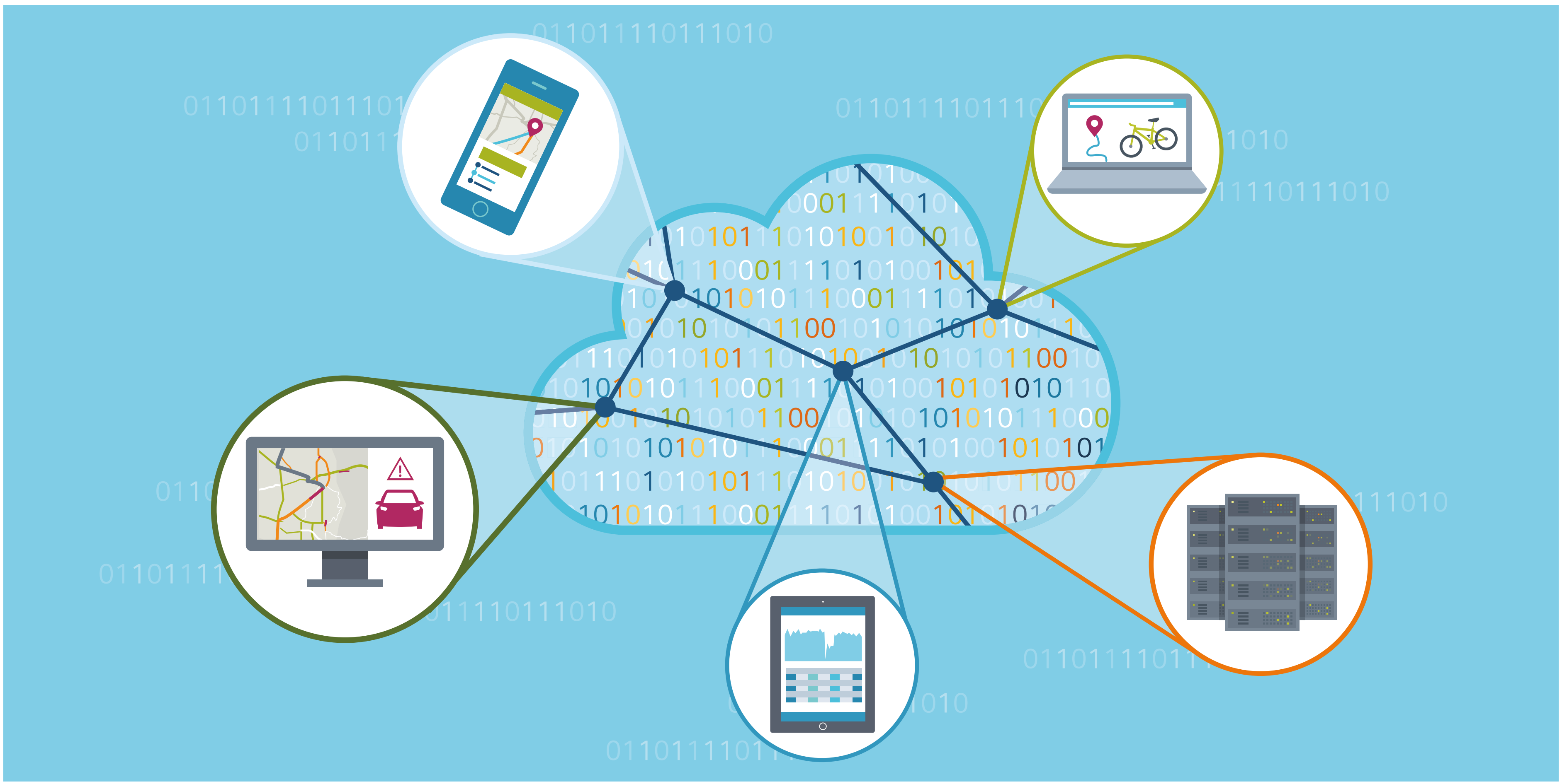
### Throughput

- Increased throughput through active management of the toll fee

## Benefits

| |
|---|
| Reliable journey times for customers |
| Incremental revenue for operators |
| Reduced congestion for all through the optimization of toll lane traffic |

# Open data



# Open data overview

**Combining data from several sources creates a powerful information source**
Transport operators often hold a vast amount of data, not only on their services and the services, but also on the services of other, from transport scheduled and live transit feeds to data about passengers' travel habits. A large variety of data sources are collated in a common data pool, to allow users to use a range of services to fulfill their travel needs.

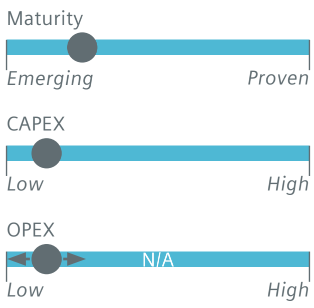
**Opening up this data enables the development of new transit solutions**
Opening this data up to third party developers encourages experimentation and innovation. Third party apps have been created to help users optimize their travel in a range of ways, helping passengers to make optimal decisions and improving the passenger experience.

**Informed travellers facilitate smart schedule and infrastructure planning**
Operators use customers' travel data to plan new infrastructure routes and optimize bus routes (see optimized infrastructure). Much of this assumes that passengers choose the optimal route for each journey – so the availability of travel apps to guide users' choices is central to the planning analysis.

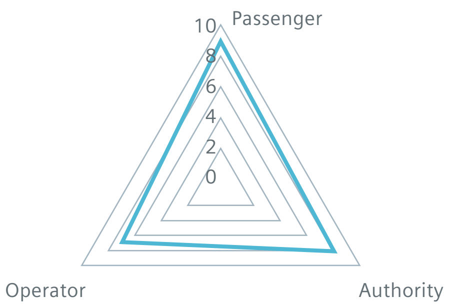
**Open data lets companies manage their supply chains more effectively**
Real-time data allows optimization along the entire supply chain by sharing loads and vehicles and minimizing empty running. Distribution companies can run more effectively using rail and traffic data provided authorities.

| City | Example |
|---|---|
| Amsterdam | Publishing open data in Amsterdam led to the development of 48 new apps in a single year |
| Berlin | An integrated mobility platform aggregating journey planning data from 15 transport modes was created to help the citizens of Berlin plan the best route for them |
| London | Open data published by London's transport authority spurred the development of Citymapper which is now used by millions of people to plan their journeys |
| San Francisco | Open data published on the data.sfgov.org website prompted the development of third party apps that help users make better transport choices |

**Implementation**




**Benefit**[1]




[1] Benefits scored on a scale of 0–10

# Social ride sharing in developing countries

Lagos is the smallest state in Africa, but it is home to the most populous city – Lagos City has a population of 21m, and is growing at 6% p.a. As Africa's economic hub, Lagos also houses the nation's principal commercial air and seaports, and a staggering 45% of the state's residents live within the city center. In total, there are 7 million passenger journeys every day.

As is typical for fast-developing cities, movement within Lagos is predominantly via private cars and transit buses. (The rail system can cope with just 1% of trips). Lagos' road network has significant shortcomings – most importantly, the lack of a proper mass-transit public transportation system. Combined with poor road capacity, a lack of traffic management, and poor integration with urban planning, the city's congestion levels are chronic.

# Data is revolutionizing automobile transit in Lagos

Ride sharing in Lagos is not new. Given the lack of public transport, private minicabs operate shuttle services on popular journeys for those without cars. The cabs typically operate independently, with no organized network or optimized flows to maximise mobility. Rather, each car will wait until it is full before starting its journey, meaning passengers have to wait indeterminate amounts of time.

Data is streamlining the ride sharing effort. Emerging and developing economies were quick to embrace mobile technologies, 'leapfrogging' legacy wired telephony in favor of wireless cellular and broadband technology. This has enabled the fast growth of ride-sharing apps in cities such as Lagos, designed as a stand-in for absent public transport.

**Independent organizations have created mobile applications to facilitate and optimize ride shares**

**Ridebliss** is a social enterprise created to address congestion problems within Lagos. Rides are therefore free unless otherwise agreed upon via the app between driver and passenger.

For the passenger **Jekalo** feels like Uber, but anyone can be a driver as soon as they have been vetted. Jekalo costs 'about the same as a commercial bus'.

**Pair** runs on a subscription model, to allow users to travel to work in a private car and drivers to earn some extra money. The app matches suitable riders together.

# Implications for the future

### Benefits for citizens

The influx of ridesharing apps has many benefits for citizens, both in the short and the long term:

- Fewer cars on the road – riders will ultimately enjoy faster journeys as ridesharing increases
- Convenience – with more drivers to choose from, passengers needn't rely on a single agreement which may fall through
- Safer travel – as drivers are vetted and details stored, 'one-chance' muggings are less likely
- Greater participation – travellers who own cars can participate as driver or rider, allowing more flexible schedules

### Recommendations for governments

LAMATA, Lagos' transport authority, is currently addressing the congestion issue with a range of solutions including rail, cable cars, and segregated bus lanes. It should also look to work with ride sharing, which has the common aim of helping to reduce the chronic traffic issues suffered by citizen by reducing the amount of cars on the road.

Developing cities should see mobility providers as collaborators, not competitors. A collaborative, data-driven approach can help tackle chronic congestion in developing cities

# Use case: San Francisco open data

### Context
San Francisco expects a 15% increase in population and growth of 25% in employment by 2035. As the population and the economy grows, there will be an increasing strain on its transport network. Already, commuter numbers increased from 403,000 to 447,000 per day between 2011 and 2014. Leveraging different transport modes efficiently is the key to supporting this growth. This can be done by increasing transparency of the options available to the general public through publishing open data.

### Solution
San Francisco's authorities have published open data across a range of sectors to make it available for the general public. This aligns with the broader aim set out by the US government to share data sets, promoting better information and encouraging innovation. The authorities now provide a cloud-based open data site in an effort to provide a more robust data infrastructure. As a result of this, third parties have developed applications that improve journey information for travellers.

### The role of data
The key idea behind sharing open data is that it enables innovative solutions that improve the customer experience without large capital expenditure from operators. Data can include timetables, smart ticket demand data, and live arrival and departure information across transport modes. These data sets have been published in Google General Transit Feed Specification (GTFS) format, a format which is used around the world and enables developers to apply the same algorithms to analyze data and implement solutions across different transport modes and geographies.

### Customer experience
- Aggregated data for users, helping them to make the best decisions for them

### Throughput
- Better transparency leads to better use of the full spectrum of transport options

## Benefits

- Collaboration with third party providers helps authorities remain at the center of the transport ecosystem
- Better transport information encourages multimodal travel, reducing congestion
- Passengers have more control over their transport

# 4. The Data Opportunity

**From best practice to standard practice**
These individual cases of best practice offer a glimpse of the potential data possesses to add value to global transport networks; empowering citizens to live more productive, prosperous and healthier lives. However, these impacts are not all imminent, or equal- with different technologies at different stages of maturity and different potential to impact global transport networks.

While the use cases observed highlight the benefit of individual, isolated examples of best practice, it does not begin to illustrate the collective potential of the Data Opportunity. To estimate this we have used the bespoke and comprehensive 10,000-point dataset built for the Mobility Opportunity to calculate the impact of each use case across applicable transport systems globally. Using this methodology we have explored the concrete benefits delivered by the use cases in terms of reduced journey times and more efficient, more productive, and better quality journeys.

By quantifying the benefit delivered by the use cases in each of the areas in Figure 4 we model the potential global benefit that could be realized by the wide application of the leading use cases we have explored.

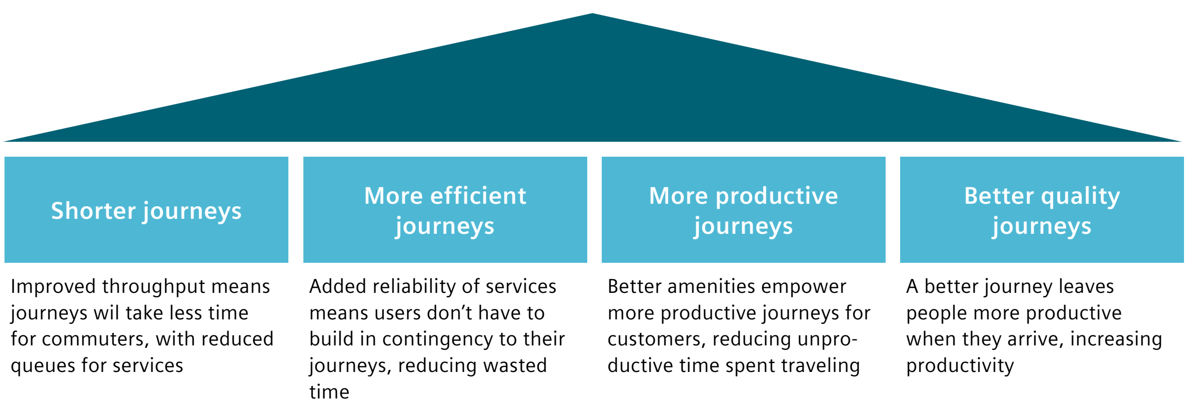



Figure 4: Value added by transport investment

## Seizing the Data Opportunity

Overall, we estimate that the use cases explored could add c. $100bn a year to the global economy through improving the throughput, availability and customer experience of transport systems worldwide. While this represents just 26% of the Mobility Opportunity, it represents c. 5% of annual infrastructure investment worldwide, and further, much of this could be achieved with a magnitude of investment vastly lower than that required to realize the Mobility Opportunity, thereby mitigating the funding challenge that currently blocks so much potential prosperity.

## Case by case

Naturally, the technologies studied deliver differing levels of economic benefit and these benefits will be achieved over differing time frames. Different transport systems face different challenges and are offered different opportunities based on their historical, financial, and operational context; what might be effective for one network may not be equally effective in another. Using the extensive dataset from the Mobility Opportunity and the impacts of the different technologies, we are able to determine the potential of the different technologies to improve transport networks around the world and deliver economic value to the societies that they serve.

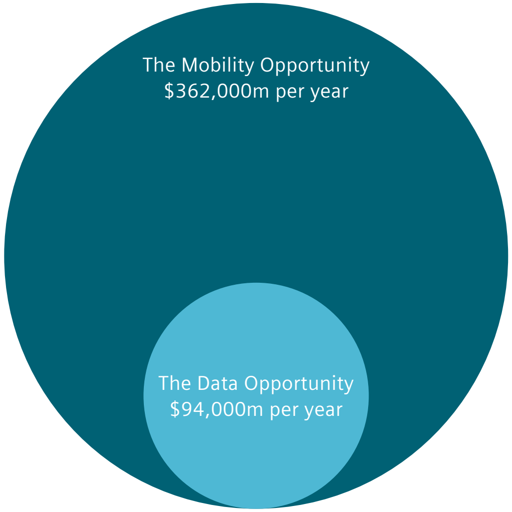



Figure 5: The Data Opportunity annual benefit

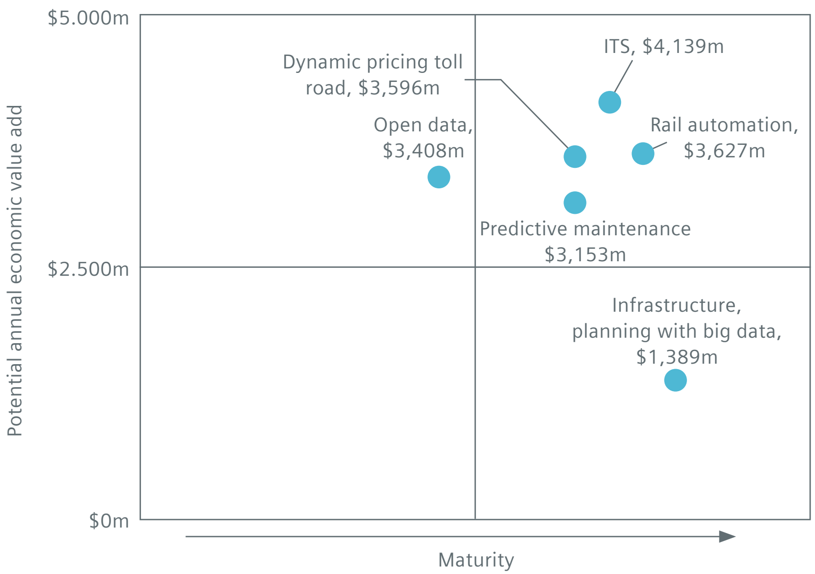



Figure 6: Maturity vs. annual potential global impact for use cases

Intelligent transport systems (ITS), which provide the digital infrastructure connecting different modes of transport that can be found in modern cities, delivers an annual benefit of c. $4bn when applied to the key population areas studied. This in part owes to the sheer number of transport modes, and therefore volume of journeys, that can be incrementally improved by the increased efficiency of ITS. The city of the future will be founded on ITS that optimize both individual journeys through improved journey information but also systems themselves by pro-actively managing traffic and demand.

Dynamic toll pricing – easily applied to congestion charges, which through continuously re-evaluating the correct fee for road usage helps to manage demand – optimizes throughput and improves reliability and customer experience on busy roads, with a projected economic benefit of $3.5bn every year, globally.

Rail automation drives c. $3.5bn a year of value across the transport networks modeled through its potential to increase throughput while improving reliability, safety and energy efficiency. While the global impact is limited by the relative scarcity of metro systems globally, with further advances the technology also has the potential to revolutionize mainline rail systems, relieving some of the chronic pressure on rail networks all over the world.

Predictive maintenance has the potential to deliver significant value to communities around the world through making rail networks more robust and increasing their effective capacity, ensuring passengers enjoy more efficient and productive journeys. As highlighted in the Renfe case, the improved competitiveness with air travel, enabled by a combination of predictive maintenance and high speed rail, could potentially significantly save energy and reduce $CO_2$ emissions by encouraging a modal shift to a more efficient form of transport.

Finally, open data and Infrastructure Planning are well positioned to take advantage of the wealth of data produced by these new technologies. Whether by providing users with better transport information produced by an ITS or by leveraging crowding information on increasingly connected trains to plan new services or infrastructure, these initiatives are examples of low hanging fruit, and a crucial first step that can form the foundations of other data led initiatives.

The analysis shows the Data Opportunity promises significant and tangible benefits to passengers and users of transport networks through allowing better planning, operation, and optimization of transport assets. The city of the future will optimize traffic flows in real time, spotting accidents as they happen and re-routing traffic, train networks will run automatically and almost never break down, and all of this information will be all available to users on all their devices, wherever they are. These benefits in turn lead to real economic gains across society as people are able to spend less time and money travelling and more time learning, working and living.

However, realizing these benefits and seizing the Data Opportunity is not a given. In some of the countries where we forecast a significant Data Opportunity, challenges and obstacles also exist, including, but not limited to: prohibitive regulation, lack of openness to foreign expertise, absence of digital infrastructure to facilitate new technology, and restrictive data privacy and ownership issues. For that reason, realizing the Data Opportunity is as much about changing mindsets, regulations, and ways of working as it is about making the right investment.

# 5. How to seize the Data Opportunity

We have developed a four-stage framework for achieving the benefits of the Data Opportunity.

The foundation of the Data Opportunity is not simply the procurement of the relevant equipment or skills, but developing the right mindset and culture. Where in the past live train arrival and departure data would have been considered only for internal use and jealously guarded, increasingly organizations are publishing it freely, opening up their services to scrutiny in the process. This is a brave move that has the potential to expose operators and authorities to criticism, but it is a key step in empowering users to optimize their journeys, allowing third parties to offer innovative new services and providing a passenger centric experience that is expected by users in the 21st century. Increasingly authorities will be asked to share data and sign up to third party standards for data, and doing so should be encouraged in order to facilitate third parties in providing services using the data. Authorities should begin to see themselves as enablers of mobility rather than just service providers. Rather than seeing emerging ride hailing platforms such as Uber and Lyft as competitors to their services they should investigate how to integrate them into the mobility offering in order to provide a better mobility experience for their citizens. This change of mindsets can create new opportunities as well as benefits to users; for instance by recognizing and exploiting their leading position in contactless payment technology, Transport for

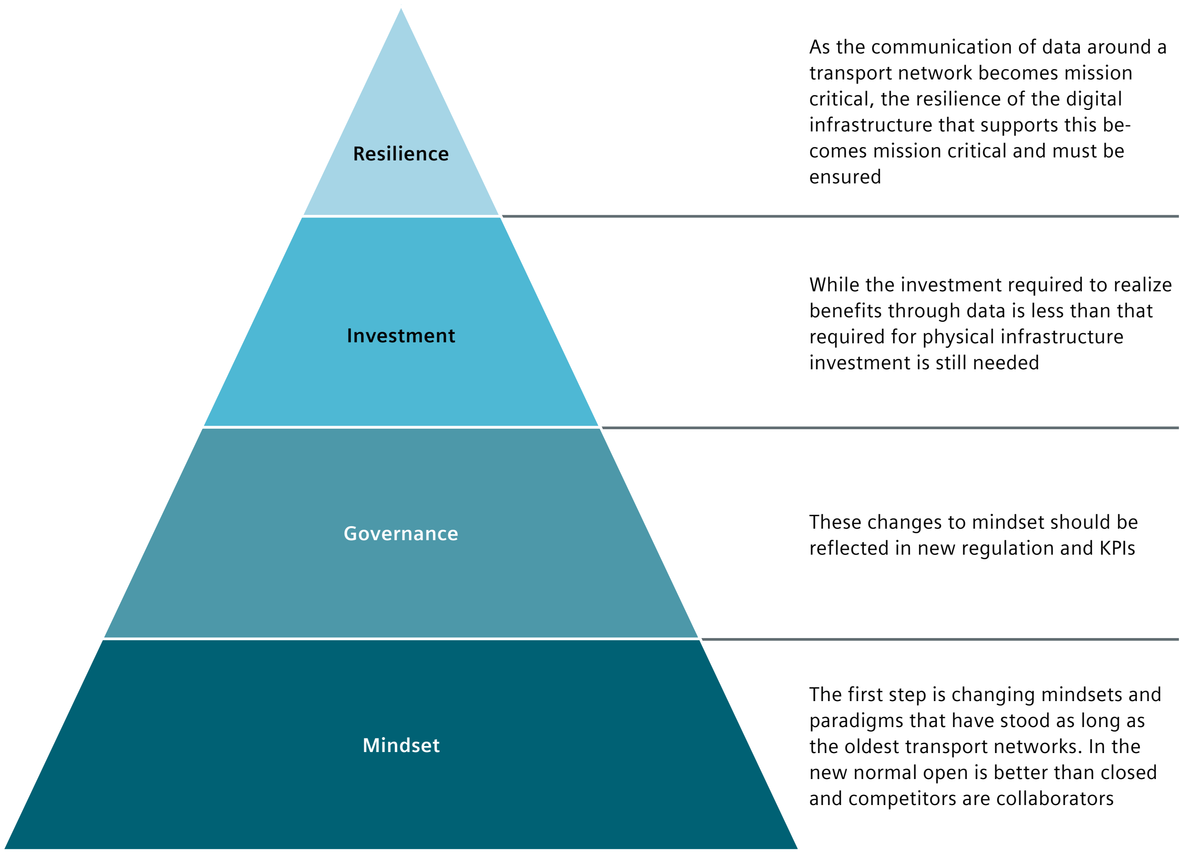



Figure 7: How to seize the Data Opportunity

London (TFL) recently signed a £15m licensing deal to apply their ground-breaking contactless payment system in other cities around the world.

This shift in mindset should be formalized in new ways of governance. This should take the form of regulation that encourages experimentation and innovation, similar to 'pro-Uber' legislation enacted in Massachusetts, and KPIs that recognize the potential benefits that public-private partnerships can bring. Where governments are reluctant to change regulations to allow for open transit data, or to enable competition from ride sharing apps, those systems will struggle to attract the third parties expertise that can help to improve passenger experience with minimal investment.

These changes must then be supported by the investment in the right equipment and, importantly, the right skills. These investments are dissimilar to infrastructure investment of the past, which leant themselves well to glamorous photo opportunities for politicians. The investments required for the Data Opportunity are lower key, i.e. the installation of sensors on existing trains or the creation of an underlying IT infrastructure to support the transmission of train or road traffic data. In order to take action on the data gathered and use it to improve processes, platforms that can handle big data and perform analytics are necessary. These platforms should have open, standard interfaces so they are able to exchange data with various systems. Today's cloud based solutions offer cost-effective and low maintenance solutions. Finding employees with the right skills to process and act on the data will present its own challenges. Building this capability should start with an expert at the top of the organization with the expertise and experience to identify the required key capabilities needed. Partnerships and secondments could be used to acquire skills and expertise quickly from a standing start and inject new ideas and ways of working into the business.

Finally, this new infrastructure must be cared for in a way that reflects its mission critical status. It's not hard to imagine instances where a hacker could instruct a city's ITS to shut down every traffic light or deliberately cause accidents at intersections, or where an entire metro network is rendered unable to function owing to an IT crash; yet other critical systems, for instance the global financial system, have been able to run securely for decades, showing that it is possible to entrust mission critical functions to online systems without experiencing significant difficulties. Authorities should look to partner with firms with established expertise in cloud and cyber security in order to ensure best in class resilience from day one and employ KPIs that recognize security as a core capability and not a 'nice to have'. They should then aim to support the functionality of the system as rigorously as they support the physical infrastructure that they control.

Benefitting from the smart use of data is not a binary question, rather it is an incremental process in which authorities should look to grab low hanging fruit. Changes to mindsets and regulation that encourages third parties to develop innovative solutions for transport users are essentially free but can have huge benefits. Partnering with third parties can cheaply build expertise and deliver new services to consumers with no investment on the part of the authority, helping to improve user experience with little or no cost to the taxpayer. And enacting legislation to empower third parties that share your goals is cheap compared to the cost of infrastructure investment.

Taking these small, but meaningful, first steps will set transport networks on a course to better outcomes and futures for operators, authorities, and passengers.

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