



Environmentally Sustainable Innovation in
Automotive Manufacturing and Urban Mobility
*Identifying the role of technology in enabling mobility
services & sustainability*



A Frost & Sullivan White Paper in Conjunction with BT
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FOREWORD

Richard Waters, Head of Sustainable Business Innovation, BT

At BT, we recognise that climate change is one of the greatest global challenges of our time and believe that Information & Communications Technology (ICT) has a key role in helping cut carbon emissions and grow economies at the same time.

BT is already playing its part, with an ambition to use 100% renewable electricity globally by 2020, where markets allow. The end-to-end carbon footprint of our business continues to be more than offset by the carbon savings our products and services bring to our customers, with an ambition to help our customers reduce carbon emissions by at least three times the end-to-end carbon impact of our business by 2020.

BT was a key contributor and sponsor for Global e-Sustainability Initiative's (GeSI) recent SMARTer2030 reportⁱ, which outlines the potential for ICT to abate 12 Gigatonnes of CO₂eⁱⁱ and generate over \$11 trillion in economic benefits per year by 2030. The mobility and manufacturing sectors are important contributors, with 'smart manufacturing', 'smart logistics', 'traffic control and optimisation' and 'connected private transportation' as key use cases. It is therefore clear that the automotive sector has a key role to play in carbon reduction—in vehicle manufacturing *and* promoting more sustainable mobility solutions—with ICT solutions as a key enabler.

Vehicle manufacturers and their suppliers depend on systems and applications to manage operations across a complex network of plants and sites worldwide. The efficiency of the ICT platform and digitalisation of the systems and processes impact how functions as diverse as engineering, manufacturing and logistics, all major contributors to the size of the industry's carbon footprint, are executed. Such an ICT backbone also allows data analytics, agile manufacturing and supply chain integration to deliver on the numerous benefits of advanced manufacturing. Of course, ICT is one of the important levers these companies have at their disposal to deliver environmental benefits.

Remanufacturing, a key opportunity within the 'circular economy', preserves the structural integrity of key automotive components and allows worn-out parts to be restored. The warranty can be maintained, or even enhanced, and each remanufactured part is produced at a much lower energy requirement than the original. ICT has an important role to play here, too, in terms of managing quality control, complex logistics and supply chains. Alongside other advances, such as use of renewable power sources, ICT can support minimising the embodied carbon of each vehicle.

However, the sector is starting to see the most disruption after a vehicle has been manufactured. Private car ownership is becoming a less-attractive proposition to a new always-online, constantly connected generation with a smartphone as its closest ally. Individuals (and goods) still need to travel from A to B within a city, but they are now seeking innovative 'Mobility-as-a-Service' (MaaS) solutions to meet their needs. BT, bolstered by the acquisition of the UK's biggest and fastest mobile network, EE, recognises the exciting potential for the following changes:

- Increasingly blurred lines between private vehicles and public transport, with innovative ticketing and navigation solutions transforming movement across a city
- On-demand services integrating with smart-city 'Internet-of-Things' (IoT) data like smart traffic lights and parking, reducing congestion
- Electric/hybrid powertrains reducing local air pollution, with cycle schemes and pedestrian movement complementing, rather than competing, with vehicles
- Electric vehicle batteries providing an important energy store for promoting a future distributed renewable energy grid
- Autonomous vehicles and new business models increasing vehicle utilisation, reducing the need for urban parking

A more efficient fleet of highly utilised connected vehicles has implications for their manufacture, too:

- Fewer vehicles will be required to meet mobility needs, leading to a reduced total embodied carbon footprint for the sector
- Connected vehicles will provide remote monitoring of a vehicle's durability—and opportunities for a more directed application of remanufactured components, thereby promoting a 'design for remanufacture' mindset
- New car features can be deployed via secure over-the-air connectivity, extending the useful life of a vehicle

BT is excited at the prospect of helping the industry use the power of ICT to take advantage of the digital disruption that stands before it and enjoy the benefits of a more sustainable future.

EXECUTIVE SUMMARY

Transportation is an essential part of social and economic development, facilitating movement and trade in particular. However, in light of a growing population and demand for mobility, much of the transport network is constrained by congestion and pollution, accentuated in urban areas. Due to a convergence of socio-demographic changes and technological innovation, ICT solutions are demonstrating ways to negate these challenges whilst improving the user experience and encouraging more sustainable travel. A combination of these solutions is changing the way vehicles and city transport networks are used.

A combination of ICT solutions are demonstrating the potential to mitigate urban mobility challenges, and enable new business models to change the way vehicles and city transport networks are used.



The mobility industry is seeing a convergence of initiatives around electric, connected and autonomous vehicles that can communicate with infrastructure to better understand the network and link public with private transport to seamlessly deliver multi-modal mobility. A key output of this convergence is the creation of new business models—leveraging communication and localisation through smartphones in particular—that can offer improved services with reduced emissions, costs, and journey times.

The considerable investment and uptake of such services demonstrates a realisation from key industry participants that ICT is set to play a far greater role in the manufacturing, delivery, and use of transportation services. BT is already playing a role in enabling this shift towards the provision of Mobility-as-a-Service (MaaS), supporting customers with connectivity, communications, data services, and cyber security in particular, with case studies from Uber, Gett, Milton Keynes Council, and other market participants.

The purpose of this paper is to demonstrate the evolving use cases of ICT in both manufacturing and mobility services, using assumption-based analysis from Frost & Sullivan and external sources to project the growth potential of new mobility business models. The logic of the analysis is based on emerging evidence that alternative mobility services such as carsharing, ridesharing, and ride-on-demand hailing services can lead to a net reduction in private car ownership and/or distance travelled by cars. After quantifying the resulting financial and emissions benefits, our analysis showed the potential for a £150 billion financial saving to users in 2025, emissions savings of 56 MtCO₂, and 1.1 trillion km less travel on roads.

- Our analysis demonstrates the global potential for a £150 billion saving to users in 2025 and 56 MtCO₂ through the growth of new mobility business models;
- With 20 million fewer cars required on the road, the global embodied carbon savings in manufacturing could be as great as 121 MtCO₂e.

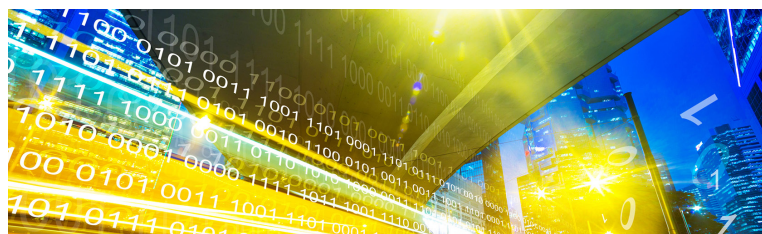
Our analysis also illustrates the resulting sustainability benefits this could yield in the manufacturing of vehicles. If new mobility business models grow as projected to 2025, our analysis shows that 20 million fewer cars would be required to be manufactured in 2025 relative to the estimated vehicles in operation, representing a saving of 121 MtCO₂e embodied carbon. Furthermore, improved ICT practices will still be applied in manufacturing to those that are still required; our scenario-based analysis quantified the potential from lightweighting and remanufacturing. This indicated that eco-innovation principles used in vehicle design can reduce the embodied carbon impact by 89 MtCO₂e in 2025 across total car production globally, and up to an estimated further 2 tonnes CO₂e could be saved per vehicle through remanufacturing alone.

These findings confirm the role of sustainability in improving the future of mobility in both the manufacturing and usage stages, with the potential sustainability benefits greater in the manufacturing stage than usage of vehicles. ICT will be the critical factor enabling the potential benefits demonstrated in this paper; the partnerships and investments being made today are aimed at delivering these to customers and society.

INTRODUCTION & CONTEXT

Transportation and mobility is the lifeblood of a city and its infrastructure, facilitating economic growth through the movement of people and goods. Any constraint on these sectors limits the freedom and viability of its society to live and function.

Spending on transportation infrastructure is set to increase by 5% CAGR from £0.6 trillion in 2014 to £1.1 trillion annually by 2025.ⁱⁱⁱ However, new infrastructure is only part of the solution to urban mobility challenges. With the global population rising and urbanisation set to increase from 54% in 2014 to 66% by 2050^{iv}, the existing transportation infrastructure needs to be better utilised—especially in emerging economies.



Furthermore, the negative impacts of congestion and pollution are already being realised in most urban areas. Congestion constrains the economy, with an estimated equivalent of 1% of global GDP foregone through lost productivity and wasted fuel. Additionally, 7 million lives are lost prematurely each year through respiratory-related issues caused by pollution^v. As the demand for mobility continues to rise, transportation is the only sector with rising emissions; road transport emissions are 21% higher than in 1990^{vi}, despite the global efforts to mitigate climate change. These issues are set to worsen if left unchecked and a new, smarter approach to mobility is required if we want to manage these significant challenges.

Despite growing investment in transportation infrastructure, the effects of pollution and congestion are accelerating, stifling an estimated 1% of global GDP and leading to 7 million premature deaths per year; a smarter approach to mobility is required if we want to manage these significant challenges.

There are several potential improvements that can be made by leveraging a combination of technology, investment, and policy-led approaches. The intent of this paper is to highlight the extent of future mobility challenges faced and consider how new approaches and business models could be used to address them. Our assumption-based analysis quantifies the extent to which this can be achieved and the resulting impacts and benefits.

The underlying logic of this analysis is that people are ready to change their mobility patterns for a better alternative—especially in urban areas—by moving away from private cars and towards an increasingly multi-modal scenario. This is already being realised in some cities where an increasing number of new, compelling alternatives to private cars are being offered, such as public transport, cycling, and on-demand shared mobility services.

While some of these services are at a very nascent stage, their rapid growth in usage, combined with high-profile investments and policy changes, lead us to believe new alternative mobility solutions can influence consumers and businesses to reduce their reliance on single-occupancy and often under-utilised private cars. There is an emerging evidence base suggesting that the level of car ownership is already being reduced as a result of these new services. Our analysis considers projections regarding the future potential of this (up to 2025), assuming the growth of new mobility business models at the current/predicted trajectory from several sources.

Our analysis is focused on quantifying the extent to which car ownership levels could be reduced and the resulting impact on distance travelled, emissions, and economic cost/savings to users. In spite of the fragmented nature of the current evidence base, the potential benefits and impacts could be considerable. Additionally, given the relatively low infrastructure requirements for most alternative services, such mobility business models offer cities and transport authorities the opportunity to better manage the existing infrastructure by leveraging technology and data. This will aid in making smarter transport investments based on a real-time understanding of the network, using data to predict events such as congestion or accidents, and the ability to react by suggesting alternatives.



Importantly, the analysis not only considers the impacts and benefits arising from the changing use of mobility options, but it also considers the implied emissions savings (embodied carbon) from the resulting reduction of vehicle manufacturing. New mobility business models at scale have the potential to reduce car ownership and therefore the number of cars manufactured. The fact that manufacturing a new car can release as much carbon as driving it (depending on the model) only further highlights the sustainability potential that new technology-led mobility businesses can offer.

ICT is central to the future of intelligent mobility. If transport is the lifeblood of the city, technology is quickly becoming its nervous system.

Smart manufacturing practices from vehicle manufacturers can deliver further sustainability benefits through a combination of improved supply chain processes and circular economy concepts, such as recycling and remanufacturing vehicle parts (lowering carbon emissions and the unit economics of vehicle manufacturing). Several vehicle manufacturers are investing heavily to realise future benefits, as our paper demonstrates with case studies and the estimated emissions reduction from production and remanufacturing to 2025.

ICT, the platform on which services are both provided and consumed, is central to the future of intelligent mobility. This paper will consider how ICT can improve the provision and usage of mobility services and the results that can be expected.

Advances in ICT provide a tremendous opportunity to instigate a paradigm shift from the current 'predict and provide' of transportation to a 'sense and respond', which uses real-time information and advanced analytics to deliver mobility services. These advances, however, need to be met with the sufficient investment in systems and infrastructure in order to meet demand and cope with cyber security threats that are a central part of intelligent mobility services. ***If transport is the lifeblood of the city, technology is quickly becoming its nervous system.***

MOVING TOWARDS SMART AUTOMOTIVE MANUFACTURING

In the past four decades, technological innovation and rapid globalisation have shaped the design and conception of factories worldwide. Technological advancements have helped manufacturers automate production, while globalisation has provided the necessary labour arbitrage to achieve adequate profit margins. However, recently, there has been a growing realisation among developed economies of the impending challenge of competition from the emerging world, especially Asia. This is further compounded by the intense demand for innovation and customisation from consumers. These market developments call for a fundamental need to reimagine the role of manufacturing, from product design to end of life. These new ideas are paving the way to what has become known as the 'fourth industrial revolution'. In the future, factories will be marked by cyber-physical production, and ICT will become the new norm for all industrial operation. This large-scale digital transformation of global industries will mark the beginning of Smart Manufacturing.

Automotive manufacturers are required to strike a tough balance between expanding production capacity, increasing product complexity, and intensifying market competition.

The Future of Automotive Manufacturing

The automotive industry has long been a bellwether for manufacturing globalisation. It has been a frontrunner in adopting new technologies and business models that have slowly made their way into other industries. Automotive manufacturers continue to grapple with stiff global competition, changing consumer preferences, volatile energy prices, and increasing regulation. They are required to find a balance between expanding production capacity, increasing product complexity, and intensifying market competition. In order to overcome these challenges, original equipment manufacturers (OEMs) and suppliers are required to adopt new design philosophies and business models that can help drive innovation, efficiency, and productivity throughout the product lifecycle. Over the next decade, platform standardisation and modularisation will become a common denominator in the industry, and global OEMs will reduce the count of their vehicle platforms. ICT will play a prominent role in achieving these new design objectives. The industry's focus on environmental sustainability will gather more momentum, and innovative vehicle designs, efficient material composition, and circular business models will become universal themes adopted by all major manufacturers.

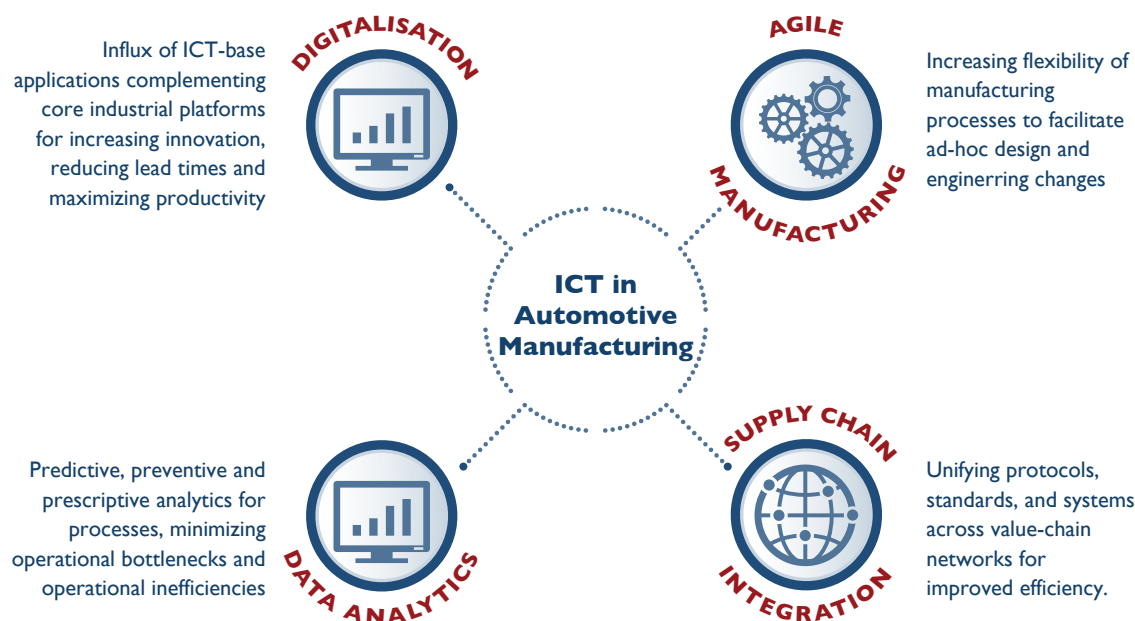
Innovative vehicle designs, efficient material composition, and circular business models will become universal themes adopted by all major manufacturers.

ICT in Automotive Manufacturing

ICT applications are transforming the very architecture of automotive design, engineering, production, and services. The benefits of ICT include the ability to enable connected factories, shortened innovation cycles, reduced lead times, and productivity improvements in manufacturing processes.

The impact of ICT in automotive manufacturing is spread across four key areas, as indicated in the chart below.

ICT in Automotive Manufacturing: Core Components



Digitalisation

Digitalisation is a Mega Trend that has implications across all segments of automotive manufacturing. Through the use of dedicated ICT applications, manufacturers can enhance design innovation, improve operational efficiency, and maximise plant productivity.

ICT in automotive manufacturing can enhance design innovation, improve operational efficiency, and maximise plant productivity.

Digital ICT tools are extensively used in maximising plant performance. For example, Magna Steyr—an Austrian-Canadian supplier—has been using digital manufacturing solutions to create, simulate, and optimise programmes for efficient robot control in its assembly lines.

Digital solutions support innovations in the supply chain ecosystem as well. StreetScooter, an innovative electric vehicle (EV) initiative by RWTH University in Aachen, Germany, uses a digital platform to integrate inputs from 30 collaborating suppliers to facilitate a crowdsourced design approach. Without the application of an open-digital platform, visualising an open-source innovation framework would have been impossible.

Agile Manufacturing

Agile manufacturing is the ability to respond to market needs for new products through a dynamic and flexible production process. ICT applications have been instrumental in helping OEMs and suppliers react to unpredictable product requirements in a timely manner.

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For example, South East (Fujian) Motors used a full-scale product lifecycle management (PLM) platform to achieve an integrated solution that covers the entire product lifecycle, starting from design ideation to production and services. Establishing a PLM platform helped the company achieve faster time to market and accrue direct economic returns of nearly 13 million Yuan.

Harley-Davidson, an American motorcycle manufacturer, has achieved agility in manufacturing its numerous vehicle designs by investing in an advanced ICT-based connectivity solution. The company is leveraging an Ethernet-based automation solution to integrate its factory under a single network. Through this Internet protocol (IP)-enabled connected factory, the company has been successful in managing the complexity of manufacturing 1,200 different configurations of motorcycles in addition to reducing downtime and shortening time to market.

Supply Chain Integration

The automotive supply chain is one of the most diverse networks in the world and achieving synergy is of utmost importance. Below are examples of how ICT enables integration of multiple supplier groups and drives overall performance.

Automotive manufacturers and their suppliers manage extremely complex supply chains. Streamlining and optimising the flow of information and material across the ecosystem is of the utmost importance.

The Swedish bearing manufacturer SKF chose BT-networked IT services to assure the integrity of its mission-critical processes and applications. Manufacturing operations in SKF depend on data flows from numerous external sources, feeding the applications that ultimately make assignments of materials, production capacity, staffing, and production planning. BT analysed these complex and interdependent requirements to design and implement a three classes-of-service (3CoS), IP-based network for SKF that met the enterprise's current and future needs. It did this while providing the ability to prioritize critical information flows and enforce corporate security standards.

Data Analytics

Data analytics is a new area of opportunity enabled by ICT in automotive production. It drives value by using product and process data to capture intelligence that can be utilised for operational improvement. It also supports the seamless integration of manufacturers with suppliers, consumers, dealers, and other ecosystem partners.

The availability of data in a unified network provides a platform for OEMs and suppliers to foster innovation and manage complexity.

Data analytics drives value by using product and process data as a capital for intelligence that can be utilised for operational improvement. The availability of data in a unified network provides a platform for OEMs and suppliers to foster innovation and manage complexity.

With the growing need for data analytics, there has been a sharp rise in new infrastructure solutions that can aid in data storage. A good example is how BT helped Fiat standardise one of its dealership networks, the Italian Motor Village (IMV). Through BT's On Demand Compute, a cloud-based virtual data centre solution, IMV was able to set up a virtual operational production platform that offered great flexibility without the need for new capital investment.

ECO-INNOVATION IN MANUFACTURING

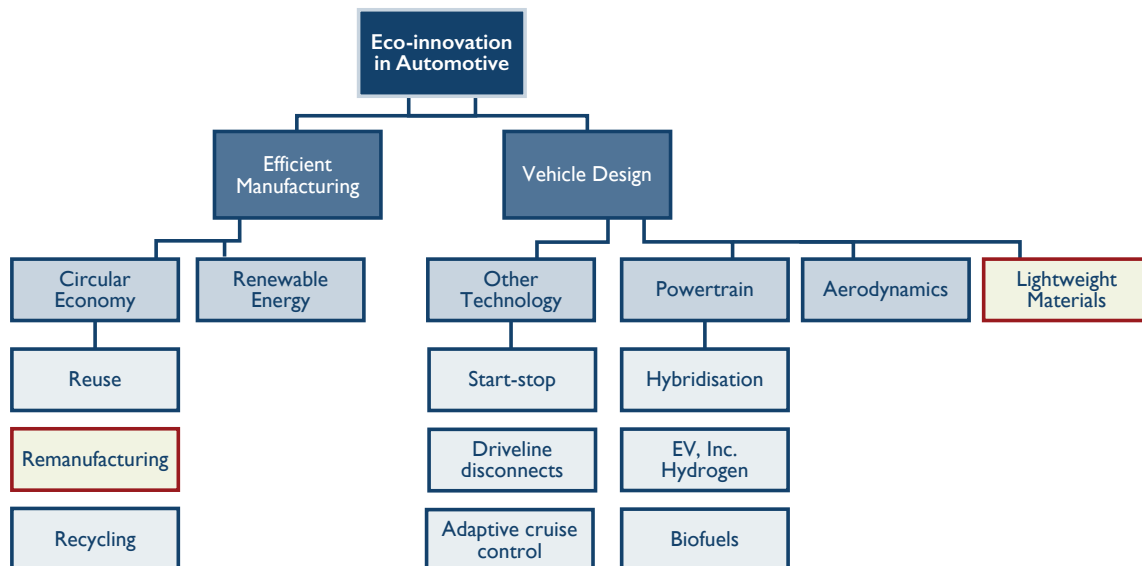
Environmental sustainability, traditionally approached as a reluctant compliance initiative by major manufacturers, has now become a business opportunity for suppliers and OEMs alike. It has transformed into an opportunity for design ingenuity and is popularly referred to as Eco-innovation—a term that indicates innovations in vehicle design that can help reduce overall lifecycle environmental impact, either within its production or its use.

PSA Peugeot Citroen has placed the idea of eco-innovation at the centre of its business ideals. The company’s Eco-innovation strategy includes a combination of enhancing fuel efficiency, reducing carbon dioxide/pollutant emissions, and expanding the use of recyclability. From a material standpoint, the company uses green materials—a combination of recycled plastics, natural materials, and bio-sourced materials (recyclable polymers)—in vehicle building. The use of recyclable polymers has helped the company save on resource usage, like oil, during production and also minimise carbon dioxide emissions. The company’s growing use of green materials within production optimises the use of natural resources, makes the final product completely recyclable, and leads to the creation of circular business models that have long-term environmental benefits.

Eco-innovation indicates innovations in vehicle design that can help reduce overall lifecycle environmental impact, either within its production or its use.

The chart below indicates a simplified view of the application of eco-innovation within manufacturing. In this section, we elaborate on two key opportunities supported by digital technologies—lightweighting in vehicle design and remanufacturing.

Application of Eco-innovation in Automotive Manufacturing



Lightweight Materials in Vehicle Design

The method of using lightweight materials in vehicle production has been identified as one of the most important eco-innovation strategies in the auto industry. Using lightweight materials in vehicle design is a trend that is pursued by many major OEMs.

Steel has been the most popular and widely accepted material for vehicle manufacturing until now. The metal has gone through several iterations of chemical compositions and treatments to match current automotive requirements. However, in order to realise the stringent efficiency and emissions targets year on year, OEMs must look at drastic methods to reduce overall average fleet weight. They have found that aluminium matches this need.

Using lightweight materials in vehicle production has been identified as one of the most important eco-innovation strategies in the auto industry.

The automotive industry accounts for the highest share of aluminium industrial consumption at 26%. More than 500 alloys have been registered for use in the automotive industry. Advanced alloys such as the 7xxx and 8xxx series are finding applications in intricate, thin-walled, leak-proof, and fatigue-resistant profiles. These and future alloys are expected to compete against the next generation of steel, even in safety-critical vehicle parts. Therefore, by 2025, it is expected that nine out of 10 OEMs will have at least one aluminium-intensive vehicle (AIV) in their fleet.

BMW is a leading OEM that has adopted eco-innovation as a core part of its design philosophy. The company pursues lightweight manufacturing through an engineering strategy titled BMW EfficientLightweight. This mechanism involves choosing the most appropriate material for every vehicle component that helps to reduce weight, improve bodyshell stiffness, and provide adequate passive safety for customers. The EfficientLightweight approach involves an extensive use of aluminium in the construction of car fronts and car chassis, and enables efficient driving by creating a balanced distribution of weight between the front and rear axles.

The automotive industry accounts for the highest share of aluminium industrial consumption at 26%.

In order to measure the effect of sustainable practices in production, we forecast how developments in different vehicle technologies impact lifecycle carbon dioxide emissions. For this analysis, we referred to the report 'Life Cycle Carbon Dioxide Assessment of Low Carbon Cars 2020-2030'^{vii} for results and drew insights on CO₂ emissions during production. The analysis involved using a small family car as a basic functional unit and included four different vehicle technologies as part of the research scope. The different vehicle technologies include the internal combustion engine vehicle, hybrid electric vehicle, plug-in hybrid electric vehicle, and battery electric vehicle.

Assuming individual development scenarios for each vehicle technology, the report identified potential CO₂ emissions during production for 2020 and 2030. The scenarios included a typical case and a best case that indicates the lower limit and upper limit of expected development. Using these conclusions as a basis, Frost & Sullivan used the growth patterns from the report to forecast the carbon dioxide emissions impact for the years of 2015, 2020, and 2025. In order to ensure that the scenarios reflect the highest possible impact, we used the best-case scenario inputs to forecast emission estimates for 2020 and 2025. The results indicated a decline of 7.8% in carbon dioxide emissions in production by 2020 and of 13.2% by 2025 (on a base year of 2015).

Embodied Carbon Impact in Production* of a Small Family Car - Scenario Forecast

Production	2015 (t CO ₂ e)	2020 (t CO ₂ e)	2025 (t CO ₂ e)
Internal Combustion Engine (ICE)	6.3	5.8	5.4
Hybrid Electric	7.7	6.9	6.5
Plug-in Hybrid Electric	7.9	7.4	6.9
Battery Electric	10.8	9.8	9.2
Weighted average based on expected sales (n.b. ICE still forecast to be dominant)	6.3	5.8	5.5

*Note: The scope of production includes raw materials extraction, fuel production, vehicle component and parts production, and vehicle assembly.

At a global level, these reductions will help to save nearly 46 MtCO₂e in 2020 and 89 MtCO₂e in 2025 across total car production. The last forecast was based on total cars expected to be sold in 2020 and 2025, and the difference in the embodied carbon impact across production between the base year of 2015 and the forecast years of 2020 and 2025.

The analysis used assumptions on vehicle technology developments and production processes as a means to measure embodied carbon impacts. The developments assumed in the scenario analysis included material composition (use of lightweight materials), improved sustainability principles in internal combustion engine (ICE) design, use of organic fuels like bioethanol, in addition to other external factors.

Achieving eco-innovation in product design is largely dependent on how sustainability goals are implemented within the supply chain, and showing the necessary leadership to ensure this happens. Learning from another industry helps demonstrate the potential for this approach.

Adopting eco-innovation strategies can help to save nearly 46 MtCO₂e in 2020 and 89 MtCO₂e in 2025 across total car production.

BT Better Future Supplier Forum (BFSF)

BT believes that a product or service can only be truly sustainable if the complete value chain is too. To do this, BT's Better Future Supplier Forum (BFSF) offers suppliers an environment in which they can collaborate with BT to identify, collect, share, and implement best practices on sustainability at every point in the lifecycle of a product. This runs from the sourcing of raw materials, through the manufacturing process, to the delivery of the finished product to the customer, and maximum recyclability when it reaches end of life.

BT and SGW: Sharing know-how to make more sustainable handsets

SGW Global designs and manufactures award-winning mobile phones and DECT cordless phones for consumers. The company has been a BT supplier for a number of years, and some of the most popular phones in the BT range have been produced by SGW Global. With the help of the structured BFSF approach to sustainability and a suite of best-practice analysis tools and techniques, SGW Global developed a plan to accelerate its transformation into a more sustainable business. As a direct result, the company is taking a fresh, more eco-friendly approach, both during the generation of new concepts and ideas, and in the review of existing products. At the end of its first 12 months as a member of the BT BFSF, SGW Global is forecasting some important sustainability savings. Comparing like-for-like against the previous year, it is on track to cut carbon emissions associated with the manufacture of BT products by 4%. Water usage will be down by 7.3%, and there will be 15.4% less solid waste to dispose of. In total, the company's annual production volume carbon footprint is set to reduce by almost 10,000 tonnes.

REMANUFACTURING AND THE SHIFT TOWARDS A CIRCULAR ECONOMY

In the globalised markets of today, companies are seeking multiple means to differentiate their value proposition. In this quest, companies are forced to find ways to minimise risks and optimise supply chain costs. This requirement is compounded further by the regulatory, reputational, and commercial need to adopt environmental sustainability.

In a move to meet these objectives, automotive OEMs are beginning to pursue the approach of reintroducing end-of-life product parts back into production. This technical approach of circling goods from the aftermarket into upstream production is called remanufacturing. According to the European Commission, remanufacturing is defined as **‘Returning a product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product’**. Remanufacturing is one opportunity within the circular economy where concepts like reuse and recycling are also used to minimise environmental degradation and maximise the efficient use of finite materials.

According to the European Commission, remanufacturing is defined as ‘Returning a product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product’.

‘Closing the loop’ for specific materials has many use-case examples from the industry today. In 2008, Jaguar Land Rover (JLR) and Novelis, along with funding from Innovate UK, launched the REALCAR (REcycled ALuminium CAR) project that aimed to create a closed-loop production model for aluminium. The project structure required JLR to segregate scrap from end-of-life vehicles and circle it back to Novelis instead of sending it to the general scrap market. The project helped JLR expand its revenue generation from scraps in addition to helping Novelis meet its recycling and sustainability targets.

Novelis, the world leader in rolled aluminium projects, while riding on the success of the REALCAR project, emulated a similar partnership with Ford in the US for the company’s aluminium-based 2015 Ford F-150 truck model. Novelis was successful in establishing an automotive circular economy by converting its customers into suppliers. JLR and Ford, on the other hand, ensured that they derived greater value from the material they sourced even after the end of product life.

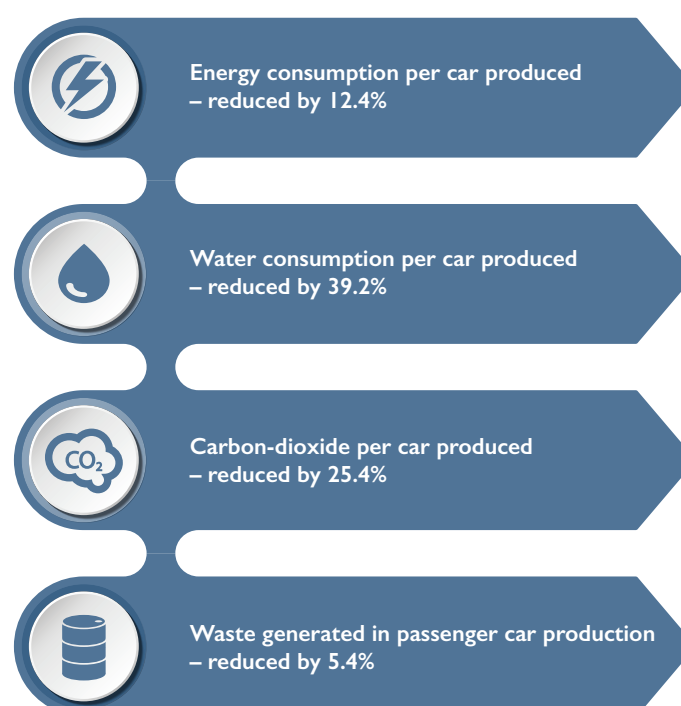
Through remanufacturing specifically, automotive OEMs can manage volatility across material price and availability by retaining control over end products and thus, all the different materials in use. Vehicle components like engines, gear boxes, and water pumps are some examples of automotive components that have been remanufactured by major OEMs today.

To give some perspective on the scope of this market, the European Association of Automotive Suppliers (CLEPA) indicates that the European aftermarket sector has nearly 27 product groups that can be remanufactured and estimates this sector to be worth nearly €8 to €10 billion in retail sales.

The trend of remanufacturing is also being adopted in emerging economies. For instance, the Lin’gang Remanufacturing Demonstration Zone in China is a national model that is conceived to promote circular business models through recycling and reuse of materials from end-of-life products. A recent development in this regard is the joint initiative of Daimler-Benz AG and Lin’gang Group in opening the world’s largest remanufacturing centre in China. The new centre is expected to cover 6.66 hectares and is estimated to cost more than 600 million yuan. Notably, Daimler-Benz AG already has six remanufacturing centres globally, with a prime focus on car engines and gear boxes.

According to ACEA, adopting the circular economy approach has already enabled European car manufacturers to accomplish a number of sustainability objectives over the past 10 years. The details of this progress are indicated in the chart below.

Circular Economy in European Automotive Manufacturing, 2005-2014



Source: ACEA

To foresee the benefits of remanufacturing in automotive production, Frost & Sullivan explored the impact of reintroduced steel and aluminium in the production of an average automotive car. This scenario-based approach assumed that 50% of steel and aluminium within a typical vehicle could be sourced from remanufactured parts.

The analysis required estimates on energy intensity for the two metals and greenhouse gas (GHG) intensity of the different energy sources that are likely to be used in the production process. The research inputs for energy intensity estimates for steel and aluminium production was acquired from a report by the Michigan Technological University titled ‘A comparison of manufacturing and remanufacturing energy intensities with application to diesel engine production.’^{viii}

For the production process, we assumed that the extraction/refining of metals will be driven by thermal energy from gas while casting, manufacturing, and remanufacturing will be accomplished via electrical energy. The greenhouse gas intensity estimates for these energy sources were inferred from the ‘Life Cycle CO₂e Assessment of Low Carbon Cars 2020-2030’ report^{ix}. The estimates for remanufacturing included a lower limit and upper limit for energy consumption and CO₂e emissions. We took the median value to arrive at the possible savings on energy and emissions during production of an average-sized car (approximate weight of 1.2 tonnes).

Remanufacturing Benefits - CO₂e Emissions in Production

For an average-sized car	New Manufacturing (kg CO ₂ e)	Remanufacturing (kg CO ₂ e)	Difference (kg CO ₂ e)
Aluminium	1291	655	635
Steel	2977	1607	1371
Total	4268	2262	2006

The results indicated savings of 2.0 tonnes of CO₂e per car by following the remanufacturing approach.

There are a number of case studies that affirm the benefits of remanufacturing in the auto industry. Renault’s factory in Choisy-le-Roi has been involved in remanufacturing spare automobile parts since 1949. The factory’s output is primarily used for repairing in-use vehicles. A remanufactured part does not consume the same amount

of energy or water, and also does not produce the same amount of waste as a new one. At Choisy-le-Roi, every remanufactured part consumes nearly 80% less energy, 88% less water, and 70% less waste. In total, the remanufacturing business at Choisy-le-Roi contributes nearly €100 million for Renault (as of 2012) and is a brilliant use case of how remanufacturing can extend automotive lifecycle and reduce the environmental impact of new manufacturing.

Remanufacturing aluminium and steel parts could help save 2.0 tonnes of CO₂e per car during production.

Smart Automotive Manufacturing – Summary of Findings

The automotive manufacturing sector is undergoing a significant transformation, impacting the entire value chain from vehicle design and engineering through to assembly and aftermarket. ICT is the key enabler, driving innovation and productivity across all manufacturing processes with digitalisation, agile manufacturing, supply chain integration, and data analytics all being important trends. Eco-innovation continues to grow in importance, too, driven by consumer demand, regulatory pressures, and cost-minimisation drivers. In particular, vehicle lightweighting and the increased use of remanufactured parts have the potential to reduce the embodied carbon of vehicles.

According to our forecast, adopting eco-innovation principles within vehicle design can reduce the embodied carbon impact by 46Mt CO₂e in 2020 and 89Mt CO₂e in 2025 across total global car production. Additionally, our research into remanufacturing outlined further potential for savings, with our scenario indicating a savings of 2.0 tonnes of CO₂e per car, a one-third reduction from a conventional manufacturing process. This highlights that, even with the growing use of recycled content in vehicles, the circular economy has more potential to be exploited.

TRAVELLING EFFICIENTLY & SUSTAINABLY IN A CONNECTED WORLD: NEW MOBILITY

Introduction: Environmental, Economic, and Social Context

The ability to transport people and goods is essential for economic growth and social inclusion. However, as this movement increases, there are also negative consequences that need to be mitigated. The increasing damage to the environment through rising emissions and climate change is at the forefront of these concerns.

Already, over 20% of EU greenhouse gas emissions are from the road transport sector. Whilst improvements are being made to lower vehicle emissions in particular, they are still 21% higher than in 1990^x. Transport is the only major sector in the EU where greenhouse gas emissions are still rising (*source: European Commission*), and although the European Commission is targeting a 60% reduction by 2050 on 1990 levels^{xi}, this will not be met at the current trend line.

Transport is the only sector in the EU where emissions are still rising. The effects are being felt locally through premature deaths resulting from poor air quality, and congestion costing global society £0.4 trillion based on our analysis, projected to rise to £0.8 billion by 2025.

A combination of policy, behaviour change, and private sector innovation is required to mitigate these significant challenges.

Whilst a global challenge, the effects of this are already being realised and felt locally. The World Health Organisation estimates that 7 million deaths per year are a direct result of poor air quality^{xii}, and King's College London^{xiii} estimates that 10,000 of these each year are in London. To put this problem into context, the research estimates that all Londoners could live a month longer (1.3 months for men, 1.2 months for women) if London's poor air quality was addressed in several measures—especially those related to transport.

Closely linked to the issue of sustainable mobility is congestion, which is estimated to be stifling the economy of productivity and wasting fuel consumption. The Inrix annual congestion scorecard^{xiv} shows that at the national level in 2015, each driver wastes between 19 to 50 hours per year in congestion—an average of 31 hours in Europe and 50 hours in the United States. At an urban level, this rises to as high as 101 hours wasted in London, the most congested city from their analysis. When considering the value of time and fuel wasted, we calculated this amounts to £0.4 trillion in 2015, assuming a global average of 50 hours wasted per car per year. This represents 0.9% of global GDP. If traffic and congestion levels rise as Inrix predicts, by 2025 this value will rise to £0.8 trillion.

To mitigate these rising challenges posed by mobility in urban areas in particular, it is critical to adapt public sector policy, encourage behaviour change from users, and, most importantly, enable innovation and investment from the private sector. A combination of solutions can be implemented to deliver this, focusing on vehicle technology, the city infrastructure technology, and new mobility business models.

The Evolution of Urban Mobility Solutions

Vehicle Technology

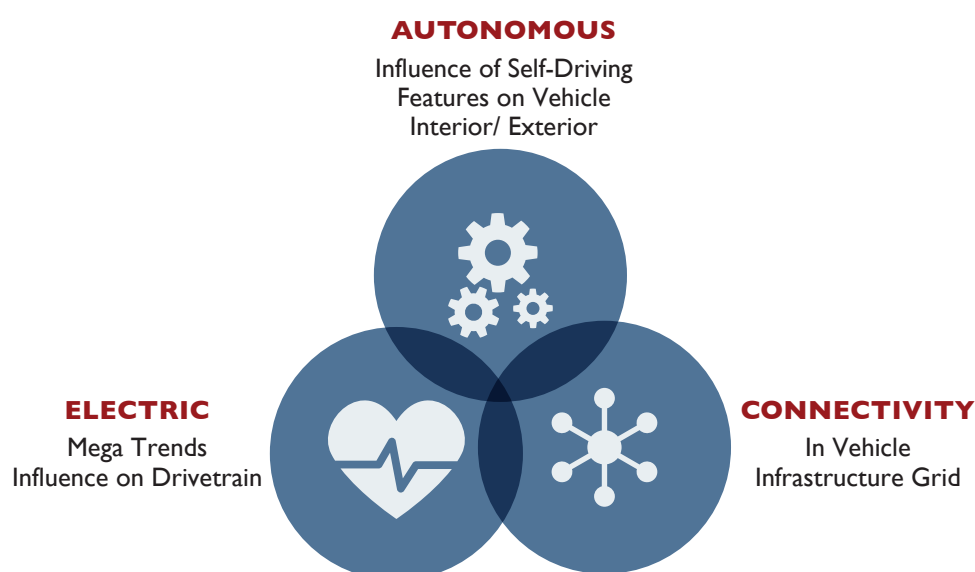
In order to negate the aforementioned mobility challenges, technology is being deployed in vehicles in multiple ways. Some of this is mandated by government policy, such as reduced tailpipe emissions or the emergency call function (eCall) in Europe, but also it's being driven by changing consumer preferences. This is particularly true regarding smaller, more sustainable vehicles equipped with supporting services that improve journeys, such as navigation or parking services.

Vehicle manufacturers are adopting a new service-driven approach to mobility, leading to a shift from cities designed around cars, to cars designed around cities.

In response to this changing customer and policy scenario, vehicle manufacturers in particular are adopting a new service-driven approach to mobility. This is particularly the case in urban areas, where congestion and pollution tend to be worse, and as a result we are seeing a shift from cities designed around cars to cars designed around cities.

To deliver this, the most important developments in the short to mid-term will revolve around electric, connected, and autonomous vehicles. The resulting convergence provides the potential for several new business models, as is demonstrated in this paper. All of this requires a new ecosystem of partnerships that are heavily reliant on ICT.

Convergence towards Electric, Connected, Autonomous Vehicles



Electrification

One of the most important methods of reducing emissions from road transport has been the hybridisation and electrification of vehicles. There are several powertrain derivatives now available, including hybrid, plug-in hybrid, range-extended electric vehicles (eREVs), and full-battery electric vehicles (BEVs). Globally, there are 82 such passenger car models available today (~5% of all car models), which is expected to rise to more than 250 by 2025 due to increasing customer demand and improved economies of scale. For example, battery costs are projected to reduce by 60% over this period.

Despite this, consumer adoption has been relatively modest. In 2015, just 0.6% (0.5 million) of vehicle sales were alternative powertrain (electric, plug-in-hybrid, or fuel cell), and Frost & Sullivan forecasts this to grow to 2.4% (2.5 million) annually by 2020 considering the current trajectory and policy initiatives proposed. Clearly, more needs to be done to make these vehicles more appealing to the mass market through improved technology, especially regarding the vehicle range, cost, and supportive government policies.

With these relatively low volumes, hybridisation and electrification of the powertrain alone will not be enough to achieve stringent fleet average emission reductions. For example, Europe will be the strictest, mandating 95gCO₂/km by 2021^{xv}. Thus, advanced powertrain technologies, in combination with the innovative lightweighting techniques outlined in the previous section of this paper, will have an important role to play. Examples of this include cylinder deactivation or driveline disconnects (e.g., altering from an all-wheel drive to two-wheel drive configuration dependent on driving environment) in the drive technology and amending fleet segmentation to include lower-emission vehicles, such as micro-mobility models delivering <50g CO₂/km sub-A segment vehicles.

The number of electric vehicle models available is expected to rise from 82 (2015) to >250 by 2025, but customer adoption has been modest; thus in addition to electrification, advanced powertrain and innovative lightweighting techniques will be essential to lower emissions from vehicles.

Beyond the drivetrain technology, advanced driver-assisted safety systems can exponentially improve the fuel efficiency of vehicles by combining several individual technologies. Adaptive cruise control automatically adjusts vehicle speed to maintain a safe distance from cars ahead, but it also automatically regulates fuel flow. This technology alone is already present in 21% of vehicles sold today and is projected to rise to 55% of new vehicles by 2020. To build on this adoption rate and to cater to increasing customer demands, OEMs are deploying further features in addition to adaptive cruise control, such as start-stop systems and intelligent path planning. Intelligent path planning ensures efficient routing and speeds between signals and junctions, which further contribute to fuel reduction.

Importantly, this rapidly increasing deployment of technology in vehicles will require upgraded electrical architecture to facilitate and power the systems. To do so, the majority of cars will need to shift from 12 volts to a 48-volt or a similar high-power net system in the short to mid-term, deploying a full electrical architecture in the long term.

Connectivity

In order to deliver many of these services effectively, vehicles need to be connected to communicate between one another and the infrastructure. OEMs are investing heavily in connecting their vehicles due to customer demands for improved infotainment and services in particular, such as live traffic and routing updates, streaming content, and replicating smartphone functionality (e.g., accessing social media platforms). Going forward, this will enable further commercial purposes, such as allowing cars to pay for parking automatically. In 2015, 19 million vehicles sold (20% of global sales) were connected through embedded or tethered solutions. This is projected to increase to 52 million by 2020 (55%) and to >90% of new cars sold by 2025.

Frost & Sullivan forecast >90% of new cars sold to be connected by 2025, enabling several new revenue streams and safety through communicating with other vehicles and infrastructure.

From a manufacturer's perspective, this will open up several new potential revenue streams and prolong the relationship with customers through automotive app stores and over-the-air vehicle updates, offering real-time connected services. This policy-led desire to improve safety is being met with increasing demand from customers wishing to be constantly connected, and the manufacturers have an increasing opportunity to monetise this potential and build brand awareness through the connected services they provide to customers. The Mercedes Digital Drive Style or Audi Connect are early examples of this. Public transport providers are also doing the same in order to leverage connectivity and improve customer experience and operational efficiencies.

Autonomous

Once connected car and driver assistance systems reach significant penetration, there will be a tipping point towards commercialised, highly automated vehicles. All OEMs are investigating the implications and opportunities of highly and fully autonomous vehicles, which are expected to become a commercial reality by 2025 and create a new industry value chain, with technology providers growing in importance. There are several enabling layers that have already started materialising in vehicles today. Autonomous emergency braking (AEB), which has the potential to reduce accidents by 10% itself, is moving from a premium option to a standard fitment. Other enabling technologies like high-definition mapping and artificial intelligence (AI) will be improved by connected services and electric architectures in vehicles. These are expected to become mainstream by 2025, alongside improved sensor functionalities and cameras to interpret the driving environment.

Once connected car and driver assistance systems reach significant penetration, there will be a tipping point towards commercialised, highly automated vehicles, expected to be a commercial reality by 2025; autonomous, connected and electric vehicles will enable the industry to become leaner, cleaner, and safer.

This is part of a wider convergence in the automotive industry—the investigation of these technologies in one parallel domain rather than three individual silos is set to provide exponential benefits. Autonomous, connected, and electric vehicles will enable the industry to innovate to zero emissions and ownership, becoming leaner, cleaner, and safer.

The Role of ICT in Vehicle Technology

To deliver this opportunity, software, connectivity, and communications will have a far more significant role in the ecosystem. This will be made possible with increased bandwidth and speed, which have already significantly improved with 4G and will continue with the rollout of 5G after 2017.

Software, connectivity, and communications will have a greater role to play in the future mobility ecosystem, enabled by increased bandwidth speeds and a greater need for cyber security solutions in particular.

However, as this connected mobility network comes together, the potential threat to the network is continually increasing. Automotive cyber threats have become a major concern for the auto industry, with significant investments required to increase encryption and the level of security in connected vehicles. The risk of not doing this can pose financial, safety, and personal security risks. Of over 83 million vehicle recalls in the United States in 2015, 6.4% were related to software^{xvi} (source: Harman), costing the industry £310 million in rectifications. While it is not clear how many were cybersecurity related, several OEMs will look to over-the-air updates and increased network-level security measures due to an increasing number of recent hacks.

BT and connected vehicles, including security

BT is working with several companies to help realise the potential that ICT can bring to vehicles, supporting leading technology providers to deliver their service. For example, in the UK, EE, part of the BT Group, is supporting Traffilog in accelerating connected vehicle and safety apps. Traffilog prides itself on constant remote fleet monitoring, improving the utilisation of auto vehicles and reducing operational expenditure on vehicle fleets of all types. This includes a robust monitoring of driver performance and safety, and includes analysing braking and driving styles. Using telemetry and remote sensing they assess the health of a vehicle before warning lights appear by remotely pulling diagnostics data from a vehicle's computer.

Delivering this requires significant levels of connectivity, and EE's 4GEE product supports technicians and sales teams with the necessary bandwidth. This has made operations slicker and improved customer service.

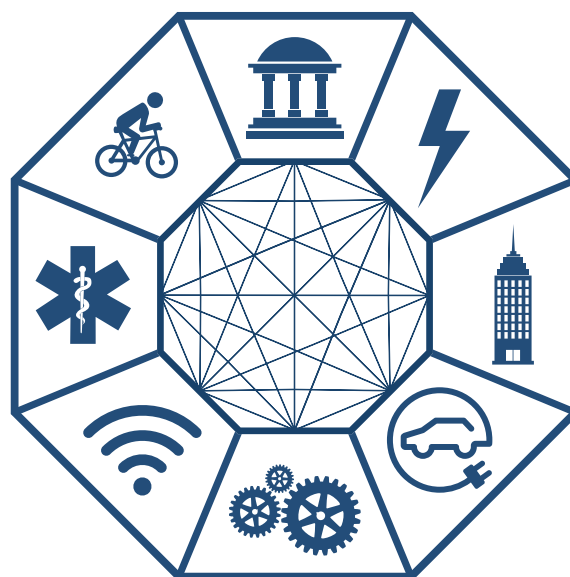
Furthermore, BT's security expertise—which was gained by working with clients with advanced digital security, such as government, banking, and healthcare—is being deployed to help automotive companies to:

- Benefit from expertise and know-how acquired in industries that have been on the bleeding edge of cyber security for more than a decade
- See who is on a vehicle's network and understand any threats they are likely to pose
- Identify vulnerabilities in the network and applications
- Satisfy auditors and regulators that providers are performing adequate due-diligence
- Identify the source of cyber threats

City Infrastructure Technology

As the proliferation of technology continues, cities can improve efficiency and liveability by enabling solutions across multiple sectors. Cities are becoming smarter through enabling sensing mechanisms and the two-way flow of data communication to improve our services. This Smart City concept is being implemented by several global cities and is a market that will be worth an estimated £1 trillion by 2020, according to Frost & Sullivan analysis, adopting solutions from the following parameters.

Smart City Parameters



Source: Frost & Sullivan

Smart Mobility is one of the core opportunity areas. This can be delivered through data collection and analysis, and by enabling communication between vehicles and infrastructure, in order to gain a better understanding of the road transport network, integrated with information from public transport services.

This holistic visibility and understanding of the transport network is increasingly referred to as Intelligent Mobility, which is reliant on open access to data and deploying new technology in transportation. This increases the scalability of Intelligent Transport Systems (ITS) to deliver a more integrated mobility network.

There are several solutions that can be deployed to achieve this, enabling operational efficiencies and improved customer experience. The UK Transport Systems Catapult projects that the global market for Intelligent Mobility will rise from £140 billion to £900 billion per annum from 2015 to 2025^{xvii}, with significant contributions from commerce (£301 billion), communications (£162 billion), and network management (£94 billion) in particular. This can be leveraged to manage travel demand through pricing mechanisms, such as tolling and congestion charging, and through voluntary measures, such as improved information, to encourage rerouting.

Smart Mobility can be delivered through data collection and analysis to gain a better understanding of the transport network, increasingly referred to as Intelligent Mobility, a market worth an estimated £900 billion by 2025.

However, public money for such systems is scarce following the global recession and uncertainty over the benefits/revenue streams of some Intelligent Mobility solutions. Therefore, solutions need to be more innovative to potentially migrate or leapfrog from expensive infrastructure systems to cloud-based scalable services, which can be enabled if the right data is crowdsourced from the network. This will ensure sustainable business models that encourage the further deployment of connected infrastructure and effective partnerships with the private sector. Aggregating an existing communications infrastructure, such as HERE's digital transportation infrastructure, is one way to enable and deliver crowdsourced connectivity.

Leveraging Data to Enable Smart Cities

Several initiatives are already being deployed by cities to improve their technology by upgrading their infrastructure or opening their data sources, allowing third parties to access and improve the services. This is the key objective of the Milton Keynes data hub—an alliance of partners including BT, Milton Keynes council, and academics such as Cambridge and the Open University.

BT and the Smart Cities Ecosystem

BT is the lead technology partner in the MK:Smart programme, a £16 million collaborative venture to turn Milton Keynes into a Smart City. In particular, this will be done by delivering a platform that integrates large amounts of data from over 440 sources from key infrastructure networks (e.g., transport, energy, water), sensor networks (e.g., weather), and crowdsourced data (e.g., social media).

This innovative initiative launched in 2013 and combines freely accessible, private and/or chargeable datasets with the unique aspect being the commercial model underpinning the data hub. This revolves around free services to developers and users of certain datasets, with pricing then calculated on the type of data accessed and bandwidth requested.

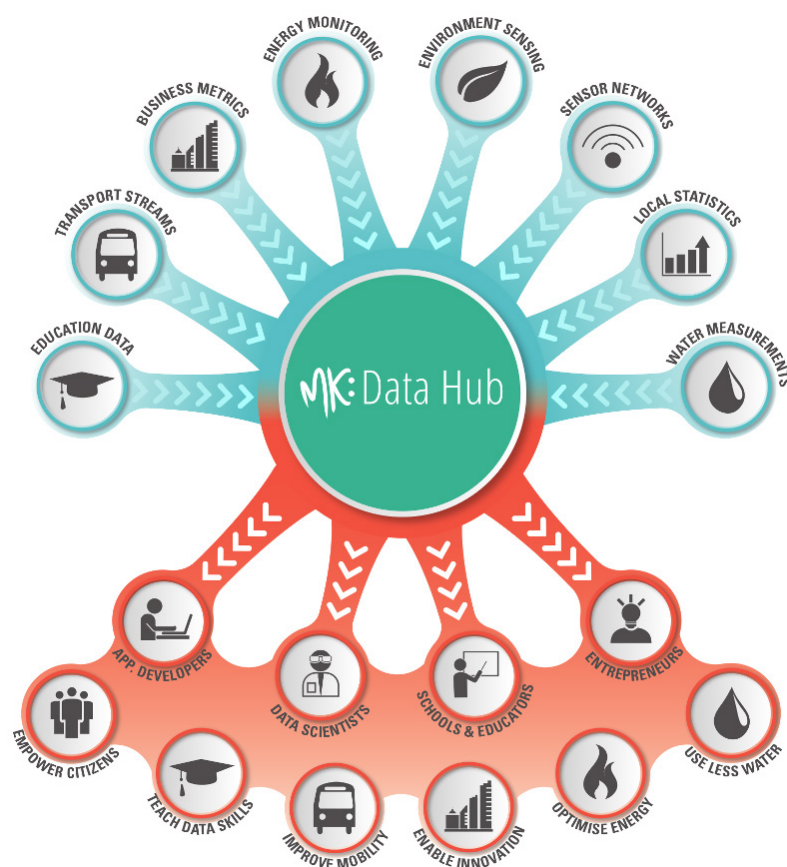
“Overall the MK:Smart initiative is forecast to make savings of 20% in water use and almost 3% in energy use, halving the projected rise in congestion, and reduced fuel use and vehicle emissions. Smart parking will contribute significantly to that latter area,” said Geoff Snelson, director of strategy, Milton Keynes Council.

“To achieve this target of halving the projected rise in congestion, two main approaches are being taken in transport. Firstly, to use information to encourage voluntary demand management, with the objective to provide customers with the right data to change their travel behaviour. The second objective is to minimise the vehicles on the road by enabling new mobility services such as on-demand transportation, and providing the systems and algorithms to these services through the data hub. For example, having a fusion of sensors across the city from multiple sources gives 100% reliable data to these services in routing, parking, patronage and other areas to better manage and optimise their service,” said John Miles, chairman of the UK Automotive Council Working Group on Intelligent Mobility.

This innovative project showcases the thought leadership from the city in leveraging technology-led and data-driven services to improve transportation, and is already being explored by several cities to replicate the approach.

Data can be used to encourage people to voluntarily change their travel behaviour and to enable new mobility business models; BT is powering this vision in Milton Keynes, as lead technology partner in the MK:Smart Programme.

Milton Keynes MK: Data Hub Illustration



New Mobility Business Models & Behaviour Change

New Mobility Business Models

The transportation market is witnessing a transformation that is underpinned by new technology-led services, giving customers the opportunity to access services on demand through platform-based systems. In many cases this is challenging the need to own or lease private vehicles, which is being replaced by a new wave of products and services, improving the efficiency of the transportation network and facilitating the seamless integration of several services, making it easier for people to get from A to B.

This trend is commonly referred to as mobility—a mixture of products, concepts, services, partnerships, and digitally enabled platforms that improve a city’s transportation offering. This is a trend that is disrupting the automotive and transportation sectors; every organisation is looking to capitalise on this opportunity and analyse any potential threats to their business, disrupting themselves before others can disrupt their business model.

The transportation market is witnessing a transformation underpinned by on-demand, platform-based systems; commonly referred to as mobility, this disruptive trend is forcing automotive & transportation providers to evaluate the benefits and threats this brings.

This has led to the rise in popularity of new business models enabled through ICT, and accessed predominantly through smartphones.

There are several well-established alternative mobility business models, some with already significant scale and most with a relatively untapped potential ready to exploit. These are convincing service providers and investors to develop and fund these services, which can be segmented into five main business models:

- **Smart Parking:** With parking creating up to 30% of city congestion, there is a large potential to use technology to improve parking efficiency by managing demand and pricing, and using data to facilitate the information, booking, payment, and directions to empty spaces. Frost & Sullivan's 2015 review of the market identified a current €2.7 billion in revenue in the technology and platforms alone.
- **Bikesharing:** There are already more than 139,000 bikes across 430 cities in Europe, and this is growing largely from city tenders, advertising companies, and tech-based start-ups looking to encourage sustainable mobility as a viable and flexible option.
- **Ride-On-Demand:** Taxi and private-hire applications—This market, relatively, had the highest growth and media exposure in 2015 and is facing a backlash from taxi drivers and regulators alike. There are 2 million vehicles already connected to such platforms and have attracted significant recent investment from OEMs such as GM in Lyft (£353 million), Toyota (undisclosed) and Tata in Uber (£71 million), and VW in Gett (£212 million). Interestingly, the value of all these are surpassed by Apple's investment in the Chinese firm Didi (£0.7 billion), demonstrating how potentially consumer electronics and mobility are set to become further integrated.
- **Carpooling/Ridesharing:** With European car occupancy at just 1.6 people, there is a tremendous opportunity to reduce private vehicle trips, cost, and emissions through sharing journeys with others. Europe is the hub of technology-enabled carpooling, with 23 million registered members of the global 30 million. BlaBlaCar leads the way, combining a trusted network of members to offer/book long-distance trips. Commuting is also moving in this direction, with start-ups such as Faxi using route-matching software and integration with parking and crowdsourcing/geofencing to allow this trend to become reality, saving companies money in the process.
- **Carsharing:** There are three main business models of carsharing: traditional, peer to peer, and corporate. All providers and platforms make vehicles available temporarily, whether for minutes, hours, or longer periods, but the ownership structure differs. Traditional carsharing companies own and operate the fleet themselves, whereas peer-to-peer providers take privately owned vehicles and make them available through similar platforms. Lastly, corporate carsharing companies offer the chance to access vehicles dedicated to their company using keyless access and operation. Combined, these services have over 9 million members globally, with Germany being the largest market for traditional carsharing (1.3 million members) and France being the world's peer-to-peer capital (with over 1.5 million members).

The importance of these new business models will vary by market depending on scale and adoption, but the main rationale for their success thus far has been maximising the efficiency of existing assets and infrastructure, thereby increasing utilisation. In turn, this reduces costs to providers and users of mobility services.

This growing opportunity has proven to be quite disruptive in certain cases, especially when well-established unionised transport industries are impacted. The evolution of such on-demand platforms and their ability to aggregate a fragmented marketplace has huge potential to increase utilisation further. This can be done through pooling a large user base and leveraging data to predict and respond to surges in demand with reallocations of drivers through real-time notifications, dynamic pricing to balance the demand, and a convergence of several of the operating models.

The evolution of on-demand mobility platforms and their ability to aggregate a fragmented marketplace has huge potential to increase utilisation for operators and change user behaviour from a single-mode to multi-modal transport journeys, blurring the lines between public and private transport in the process.

The business models of today are likely to evolve and become more closely integrated with public transport services, promoting a shift away from private car usage and towards mass and shared transport.

All of this is predicated on technology and connected services, and on the assumption that operations, users, and drivers understand and rely on new mobility services. These services have the potential to move behaviour away from a single-mode, familiarity-driven choice to a seamless multi-modal journey, blurring the lines between public and private transport in the process.

BT Supporting New Mobility Business Models

BT is already supporting new mobility service providers to deliver the most important aspect of the service—connectivity. For example, London's two leading ride-hailing services—Uber and Gett—are both supported by EE, part of the BT Group.

Ride-hailing application Uber has redefined the transportation market through innovative thinking and a unique approach built on advances in mobile technology. Present in more than 70 countries around the world, Uber is valued at over £47 billion (June 2015)—the most funded startup in the world—having raised nearly £8 billion thus far. Upgrading its mobile applications service for drivers to 4G was key to accelerating business growth—all drivers get online with an Uber phone and a pre-activated 4GEE SIM card.

This also facilitated additional connected services to be delivered. UberMUSIC was launched in London to allow riders to connect their Spotify account and play their own music through the car's speakers, using the driver app again facilitated by EE. "Switching to 4GEE has helped us deliver the speed of service that people want. The extra network capacity has also helped bring new products to market," said Sarah Slater, marketing manager, Uber. The speed of the EE network means the Uber system matches the customer and their closest driver faster, helping bring down average car arrival times in central London to <4 minutes. Operationally, this faster platform dispatches bookings quicker, ensuring fast pick up for customers to reduce downtime and increase vehicle utilisation, and reduce fuel spend, as customers are allocated the nearest vehicle.

Gett offers a different service in London, allowing ride-hailing exclusively for licensed taxi services in 60 cities globally. In London, for example, the app connects only black cab drivers. The app allows a cab to be hailed with two taps, providing information on the vehicle and driver, their location, cashless payment, and corporate accounts that have been very successful. The foundation for the business model is an innovative machine-to-machine (M2M) platform provided by EE. From the moment a customer uses the app or calls the 24-hour contact centre, continuous automated communication between mobile devices begins. Every stage of the journey is logged and tracked—pinging data back and forth between servers, a tablet located in the driver's cab, and the customer's mobile device.

Gett's former CEO Remo Gerber stated, "We wanted to bring a revolution to a 300-year-old industry, for which we needed the right provider with substantial network coverage and value for money pricing. It's about bringing the offline and the online experience together using new tools in a familiar context to achieve a better outcome. In helping us achieve that, EE is the perfect partner."

Integrated Mobility-as-a-Service (MaaS)

This network of mobility services is more than just public-versus-private transport. A combination of the attractive urbanised environments, changing user social preferences (away from car ownership to usage), and the opportunities posed by new platforms (especially via smartphones) are converging to facilitate a shift from single-mode transportation and limited alternatives to a flexible, multi-modal integrated set of mobility options.

This new era of mobility business models has a user-centric, service-led approach to delivery and is leading to a potential shift away from ownership to the use of mobility services in several cases. Through smartphone-based, on-demand solutions, connected parking solutions, and integrated mobility services, technology is playing a critical

role in carving out new urban mobility solutions that are rapidly moving from niche to mainstream transportation options. Thus, Integrated MaaS has the potential to bring convenience, time, and cost savings to future mobility users.

A combination of the attractive urbanised environments, changing user social preferences, and new platforms are converging to facilitate a shift to a flexible, multi-modal integrated set of mobility options; this service-led approach is leading to a shift from ownership to the use of mobility services, and provides an opportunity to integrate several modes of transport through one digital ticket, referred to as Integrated Mobility-as-a-Service (MaaS).

The Evolving User-centric Approach to MaaS

Integrated Mobility: A User-Centric Approach to Mobility-as-a-Service

Technology enabled, any device delivery of real-time, door-to-door, multi-modal travel encompassing pre-trip, in-trip and post-trip services bringing Convenience, Time & Cost Savings to the Mobility User



Delivering this will require a technical functionality from the MaaS operator, the willingness and understanding of the customer to choose the best-informed route, and the potential involvement of and agreements between several public- and private-sector bodies. This can deliver convenience to the users and efficiencies to operators with the capability to monitor requests and the ability to alert users in times of disruption.

This is attracting several industry stakeholders to provide integrated mobility platforms, ranging from transport providers like Deutsche Bahn in Germany (with Qixxit), NS in the Netherlands (OV Chipkaart and NS Business card), through to vehicle manufacturers such as Daimler (with Moovel), and technology providers such as Citymapper and Moovit. Whilst the method of delivery varies, the objective is the same: to seamlessly piece together a door-to-door journey that highlights the most effective way to get from A to B, with some platforms going further to enable booking and payment of transport services.

The business model of each of these providers varies. This can be a fare-based model, a commission-based model that takes a slice of the revenue or referral fees, or a freemium model that can be free to customers by offering incentives for in-app purchases or selling the user's data to transit authorities/third parties. As these services become more commonplace and widely adopted, the intelligence and usefulness of such services in predicting and modelling future transport demand will continue to develop. A more complete historical understanding of people's travel habits will be valuable to multiple sectors beyond transport planning and delivery, such as to retailers that can monetise their customers' behaviour patterns through targeted offers.

This new paradigm of integrated MaaS can become the safety net for on-demand mobility as opposed to private vehicles. This is all underpinned by the need for sophisticated communications and networked infrastructure.

QUANTIFICATION OF SMART MOBILITY AT SCALE

In light of the increasing trend towards multi-modal mobility solutions and the reliance on technology for its delivery, there is a significant potential to deliver improved efficiencies and sustainability in the transportation network. Technology and new mobility business models in particular have the opportunity to facilitate a shift away from vehicle ownership.

In order to quantify the potential benefits at stake, Frost & Sullivan analyses have considered the trajectory of new mobility business models to 2025 in the UK, Europe, and globally in order to demonstrate the reduced number of required vehicles, kilometres travelled, carbon emissions, and financial cost to users. This information was derived from a combination of Frost & Sullivan and external sources.

New mobility services can improve efficiency and sustainability of the transport network, leading to a reduction in privately owned vehicles on the road; this saves money, time, and reduces emissions throughout the manufacturing and use phases of vehicles and transport services.

Given the reduction in private car-based travel resulting from the scaling scenario of new mobility business models, the implied reduction in cars sold annually to 2025 was used to demonstrate the potential reduction in carbon emissions. This takes into account the manufacture of fewer vehicles and the significant levels of carbon required to manufacture the average vehicle (6.3 tCO₂e, and 0.5 tCO₂e in the end-of-life process).

Inputs

The first step of our analysis was to gather several important data points in order to forecast the growth potential and relative impact of new mobility business models in the future. Specifically, this included the projected car sales and total volumes on the road to 2025, the average distance travelled, the average CO₂ emitted, and the cost to users per kilometres travelled. To provide a benchmark for this data, the current and future projected scenarios, valuations of congestion levels, GDP, and greenhouse gas emission volumes were collated from external forecasts from 2015 to 2025.

The full list of inputs collated were as follows, with a 2015 baseline value and forecast to 2020 and 2025 to compare the UK, Europe, and global mobility markets.

- **Cars:** Total cars on the road (parc) and total cars sold per year
- **Distance Travelled:** Average distance travelled per car per year
- **Cost:** Total cost of ownership per mile/km for cars
- **Emissions:** CO₂ per km (car fleet averages) for new cars and parc
- **GDP forecasts for each market**

The growth scenario of new mobility services was compared to the baseline trajectory of car sales and usage in particular; each mobility business model was analysed to evaluate potential savings, leveraging multiple Frost & Sullivan and external sources.

Having obtained the data to benchmark any future scenario, each of the new mobility business models was analysed to give the estimated potential societal benefits that could accrue by 2025, specifically reviewing eHailing/ride-on-demand, carsharing, parking, bikesharing, and ridesharing. Furthermore, the potential for integrated MaaS was considered separately and included the potential mode shift away from private mobility services to public transport.

Ride-on-demand/Ride Hailing

The market for ride-on-demand services continues to rise exponentially, led by significant investments from private equity firms and, more recently, vehicle manufacturers. Recent analysis by UBS shows that there are already over 66 million users of such platforms in 2015. This is set to rise to 1.1 billion by a 20% CAGR by 2025, requiring the vehicle supply to rise from 2 million to 17.5 million vehicles.

UBS Evidence Lab surveys indicate a reduction in private car ownership as a consequence of ride-on-demand services.^{xviii} Specifically, there is projected to be a reduction of 8.7 million vehicles by 2020 (0.6% of the parc) resulting from the deployment of such platforms, based on customer research scaled at projected future levels of demand. This is expected to remain consistent in our analysis to 2025. This implies an annual reduction of 10 million private vehicles by 2025. Even when considering that vehicles used in these services are utilised higher than private cars, and that 27% of trips in such services reportedly would not have been made if these platforms were not available^{xix}, there are significant sustainability benefits.

Ride-on-demand services could save users £46 billion compared to private car ownership, removing 10 million cars from the road and reducing emissions by 15 MtCO₂.

Specifically, over 120 billion km could be reduced from the roads by 2025, saving drivers £46 billion based on the current cost of motoring. Furthermore, with 10 million vehicles removed from the road in 2025, 15 MtCO₂ emissions could be eliminated due to lower fuel being consumed and 63 MtCO_{2e} could be eliminated due to the lower manufacturing requirement of vehicles.

Carsharing/Car Clubs

In addition to private operators, several cities around the world are looking to attract and implement carsharing services to provide flexible sustainable mobility options for their residents. One of the leading sustainability arguments for these services is that one carsharing vehicle takes 10 to 15 privately owned vehicles off the road through direct sales of cars from members. On average, Frost & Sullivan analysis concluded 12.5 cars would be removed from the road per carshare vehicle.

Using Frost & Sullivan forecasts for the carsharing market (46 million members utilising 570,000 vehicles), over 7 million vehicles per year could be eliminated from the roads by 2025. This would result in 107 billion km not travelled on the road and £40 billion in savings to users. There would also be large emission reductions, amounting to 13 MtCO₂ from reduced vehicle use and 43 MtCO_{2e} from manufacturing fewer vehicles.

Carsharing has the potential to remove 7 million cars from the road per year in 2025, saving £40 billion and 13 MtCO₂.

Parking

With an estimated 30% of urban congestion caused by drivers searching for parking spaces, a more effective solution is required. A recent German study by VDA^{xx} shows that on average, 12 hours is wasted per driver per year searching for a parking space. This will contribute more than £156 billion in wasted productivity and £20 billion in wasted fuel by 2025 if left unchecked.

However, the study predicts that this loss can be reduced by an average of 28% by leveraging new technologies for parking with the use of infrastructure sensors that show efficient routes to vacant parking spaces. By 2025, this could deliver £43 billion in productivity savings, £6 billion in fuel savings, and 23 MtCO₂ less emitted.

Smart parking services could deliver £49 billion and 23 MtCO₂ savings as a result of reduced time and fuel wasted searching for a space.

Bikesharing

Bikesharing provides a more sustainable solution to private car trips and can influence a reduction in private car ownership^{xxi}. With a projected rise from 1.2 million to 3 million bikeshare vehicles by 2025, recent surveys and academic papers document a reduction of up to 200km travelled per year for each car that is substituted for a bike.

By 2025, this all implies that globally, cars will travel 588 million km less and save users £221 million while removing 37,000 cars from the road. This also removes 72 ktCO₂ due to reduced usage and 220 ktCO₂e due to reduced car manufacturing.

Bikesharing could save users >£220 million and remove 37,000 cars from the road in 2025.

Ridesharing/Carpooling

As congestion and the prices of competing travel modes increase, new technology-led platforms that facilitate ridesharing are also increasing. Whether through long-distance platforms like BlaBlaCar, dynamic short-distance platforms like Fliinc, or commuting services such as Faxis, drivers are beginning to share the spare capacity in their vehicles to recoup costs and, in many cases, respond to incentives put in place by their employers.

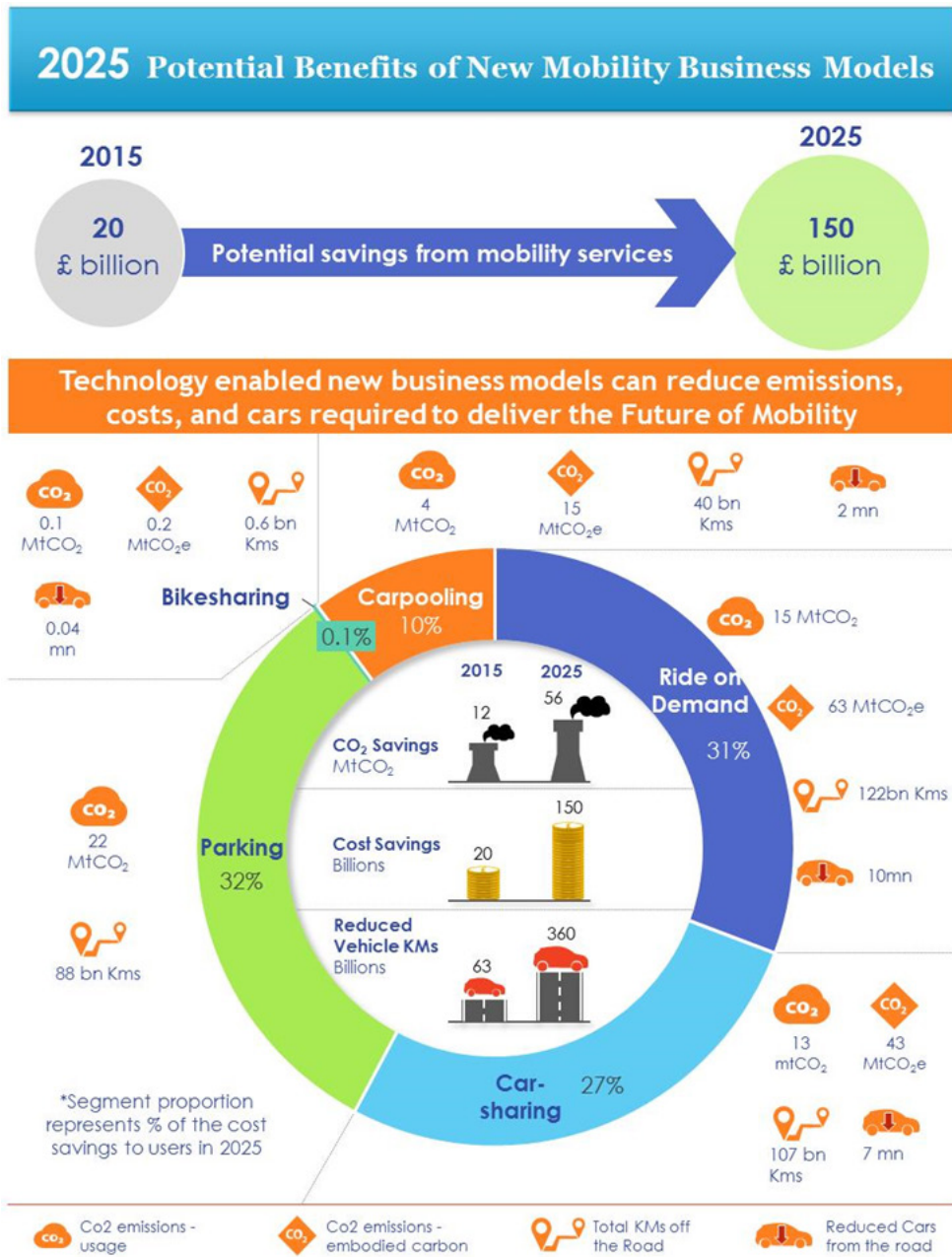
The logic is that ridesharing services increase car occupancy and therefore reduce the required amount of private car trips to fulfil the total journeys. Specifically, the 1.6 average car occupancy is increased to 2.8 when drivers utilise ridesharing platforms.

Increasing car occupancy with ridesharing platforms can enable £15 billion cost savings and remove 2.5 million cars from the road, reducing emissions by 5 MtCO₂ in 2025.

What this means is that when increasing from the current 37 million members using technology-enabled ridesharing to a projected 98 million by 2025, a reduction of 40 billion km travelled could be achieved. This would save approximately £15 billion in costs for drivers and remove 2.5 million cars from the road annually. Furthermore, 5 MtCO₂ would be saved due to reduced car usage and 15 MtCO₂e would be saved due to reduced vehicle manufacturing.

Combining Mobility Business Models

When combining these new mobility business models, a huge potential benefit could be realised. By 2025, the cost savings to users alone could amount to more than £150 billion globally, removing 20 million cars from the road per year. This would represent an overall saving of 0.2% of the global GDP from new mobility business models. Furthermore, in 2025, a total of 56 MtCO₂ could be saved by reducing vehicle use and a further 121 MtCO₂e from vehicle manufacturing. Clearly, reducing the amount of vehicles manufactured has an important role to play in decarbonising our transport network.



Frost & Sullivan analysis showed the cumulative benefits of new mobility business models could exceed £150 billion in savings to users, and over 56 MtCO₂ emissions reduction in 2025 compared to the baseline forecast; when considering the lower volume of vehicles manufactured, a further 121 MtCO₂e could be saved in the manufacturing process.

CONCLUSIONS

Our paper demonstrates that the traditional methods of providing transportation are shifting in light of new technology-led services. Set against the context of rising congestion, pollution, and safety concerns, these challenges can be mitigated by deploying a number of new smarter choices to mobility networks across both the manufacturing and usage segments. This is essential not only to reach new stringent emissions targets implemented by governments, but also to ensure that climate change is managed and to prevent further unnecessary loss of lives through toxic air quality (in urban areas in particular).

In the manufacturing phase, digitalisation is leading to increasingly smart factories and manufacturing processes. This is developing a new paradigm of Industry 4.0, leveraging ICT, remanufacturing, and other aspects of the circular economy. Because as much or more (depending on model) carbon dioxide is created in the manufacturing phase as in the usage phase, the potential to reduce the total number of vehicles required can significantly improve sustainability.

When it comes to using the transport network, customer preferences are rapidly evolving from ownership models to usage- and access-based solutions. New mobility services are beginning to thrive in specific urban locations, offering customers lower costs, flexible and multi-modal alternatives to private car ownership, and offering cities more sustainable, informed, and managed travel networks. These networks have the ability to sense and respond to travel disruption before it occurs based on current and historical data analysis. A combination of vehicle technology, city technology infrastructure, and new mobility business models will deliver this shift.

Our analysis focused on the quantifiable benefits arising from the usage of new mobility business models and their reduced manufacturing carbon requirements, based on the current growth trajectory of these services and their implied impacts to car ownership. In 2025, new mobility business models alone can globally generate savings relative to 0.2% of the global GDP, remove 20 million cars from the road, and save £150 billion in road-use costs. Carbon emissions could be reduced by 56 MtCO₂ in the usage of transportation, but a further 121 MtCO₂e from the manufacturing stage of vehicles. This indicates far greater upfront savings from the manufacturing of vehicles than the annual usage savings.

This analysis outlined how ICT can positively impact sustainability in both the manufacturing and use phase of vehicles, with digitalisation improving processes and enabling new business models that require fewer vehicles.

This type of network can also deliver tangible sustainable benefits by encouraging people to use private cars less, instead using a combination of more efficient, environmentally friendly multi-modal solutions. ICT has a tremendous opportunity to deliver this paradigm shift from automotive and transportation providers to mobility service providers.

All of the solutions and services highlighted in this paper demonstrate the importance of connectivity and communications technology in improving the future of mobility. By collaborating and developing a coherent approach to delivering these solutions, mobility providers and users will benefit from an understandable, visible, safe, and affordable network.

ENDNOTES

- i. Global e-Sustainability Initiative's (GeSI) SMARTer2030 report, by Global e-Sustainability Initiative and Accenture Strategy, 2015. <http://smarter2030.gesi.org/>
- ii. Throughout this report, carbon emissions are indicated in one of two different units: CO₂ refers to the emissions associated with carbon dioxide; CO₂e (equivalent) figures include the carbon dioxide emissions, and also the impact of other greenhouse gases, in terms of the amount of CO₂ which would have the same impact. Please see http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html for more information.
- iii. Assessing the global transport infrastructure market: Outlook to 2025, PWC & Oxford Economics (Page 2) <http://www.pwc.com/gx/en/transportation-logistics/pdf/assessing-global-transport-infrastructure-market.pdf>
- iv. World Urbanization Prospects The 2014 Revision Highlights, United Nations (Page 1) <https://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf>
- v. World Health Organisation News Release <http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/>
- vi. Reducing CO₂ emissions from vehicles, European Commission 2015 http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm
- vii. The results on embodied carbon for production were referred from 'Section 8.5 Results - Tables 8-8, 8-9, 8-10, 8-11 and 8-12'. This is referred from the report commissioned by the Low Carbon Vehicle Partnership (LowCVP) titled "Life-Cycle Assessment of Low Carbon Cars 2020-30".
- viii. The inputs were gathered from 'Table I: Comparison of energy intensity estimates for manufacturing and remanufacturing' in the report. This is sourced from a report by the Michigan Technological University titled "A comparison of manufacturing and remanufacturing energy intensities with application to diesel engine production".
- ix. This was referred from 'Section 8.3 – Data for LCI, Table 8.3.1 - Vehicle Component Manufacture Data'. 'Table 8.1 – Root Vehicle Characteristics' was used as reference for estimating steel and aluminium composition in production. This is sourced from the report commissioned by the Low Carbon Vehicle Partnership (LowCVP) titled "Life-Cycle Assessment of Low Carbon Cars 2020-30".
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- xi. Climate Action: Reducing Emissions from Transport, European Commission http://ec.europa.eu/clima/policies/transport/index_en.htm
- xii. World Health Organisation News Release <http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/>
- xiii. 'Understanding the Health Impacts of Air Pollution in London – King's College London', July 2015 <https://www.kcl.ac.uk/lsm/research/divisions/aes/research/ERG/research-projects/HIAinLondonKingsReport14072015final.pdf>
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- xvii. Transport Systems catapult: IM market breakdown <https://ts.catapult.org.uk/intelligent-mobility/market-breakdown/>
- xviii. UBS – Could Ride-on-demand end car ownership? November 2015. Interactive models available here (central estimate values quoted) <https://neo.ubs.com/shared/d13ZDjfXXO94A>
- xix. Impacts of Private Hire Study, 6T, 2015 http://cvip.sphinxonline.net/SurveyServer/s/6tbureau/LecteursUber_150923/questionnaire.ht
- xx. Parking costs drivers 560 million wasted hours per year in Germany, VDA, 2015 <http://www.welt.de/motor/article154871449/Parkplatzsuche-frisst-im-Jahr-560-Millionen-Stunden.html>
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