Air Quality Monitoring Using IoT and Big Data

A Value Generation Guide for Mobile Operators

February 2018

About the GSMA
The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with more than 300 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events such as Mobile World Congress, Mobile World Congress Shanghai, Mobile World Congress Americas and the Mobile 360 Series of conferences.

For more information, please visit the GSMA corporate website at **www.gsma.com**

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Digital Greenwich
The Royal Borough of Greenwich in London, is one of Europe's leaders in smart city innovation. Greenwich was one of the first to realise that the challenges cities face - traffic congestion, environmental pollution, pressure on services and infrastructure etc - cannot be solved through traditional methods alone. Greenwich instead realised that smarter approaches, making use of new technologies and digital services, are needed to cope with urban challenges. Greenwich has a comprehensive smart city strategy in place and linked to it, a range of strategic and scalable smart city initiatives; delivered by its Digital Greenwich department and wholly owned subsidiary DG Cities Ltd. Central to Greenwich's approach is a comprehensive and integrated strategy which seeks to capture the opportunities from recent advances in technology, data capture and analysis, and apply them at a city scale.

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LUCA is Telefónica's specialist data unit, which sits within the Chief Data Office, led by Chema Alonso. Its mission is to bring Telefónica's know-how in transforming into a data-driven organisation to other private and public sector organisations in a wide range of markets including Retail, Tourism, Outdoor Media, Financial Services and Transport. Its diverse product portfolio, which brings together expertise in Artificial Intelligence, Data Engineering, Data Science and Infrastructure, enables companies to accelerate their Big Data journey with a wide range of solutions and expertise to propel their digital transformation.

China Mobile IoT Co. Ltd.
China Mobile IoT Company Limited is a wholly owned subsidiary of China Mobile. Based on the overall strategy of China Mobile, China Mobile IoT Company aims to become the supporter of IoT business services, the provider of IoT chips & modules and the promoter of IoT products & applications. In practice, China Mobile IoT focuses on operating IoT private network, designing IoT chips and modules, producing IoV, smart home applications and wearable, developing IoT open platform One Net, promoting IoT solutions, which makes a comprehensive architecture name "Cloud-Pipeline-Device".China Mobile IoT Company collaborates with China Mobile provincial and professional companies to provide the community with the most advanced IoT technologies. Following the philosophy of open, cooperation and sharing, China Mobile IoT strives to become a China based, globally leading IoT Company which promotes IoT applications in various industries.

Deutsche Telekom
Deutsche Telekom is one of the world's leading integrated telecommunications companies, with some 156 million mobile customers, 29 million fixed-network lines, and more than 18 million broadband lines.

We provide fixed-network/broadband, mobile communications, Internet, and IPTV products and services for consumers, and information and communication technology (ICT) solutions for business and corporate customers.

Deutsche Telekom is present in more than 50 countries. With a staff of some 225,200 employees throughout the world, we generated revenue of 69.2 billion Euros in the 2015 financial year, about 64 percent of it outside Germany.

So that we can continue to be successful, we are already evolving from a traditional telephone company into an entirely new kind of service company. Our core business, i.e., the operation and sale of networks and connections, remains the basis. But at the same time we are proactively committing to business areas that open up new growth opportunities for us like in the area of Smart Cities.

Contents

Executive Summary

Over the next decade, the Internet of Things (IoT) is expected to offer mobile operators a massive revenue growth opportunity. Analysts predict that much of the new revenue opportunity will be obtained from services beyond connectivity, such as platforms, applications and managed services. This guide illustrates how operators are building on their existing capabilities to successfully deliver new air quality services that create new revenue streams.

MARKET GROWTH

IoT M2M Mobile Connections Forecast Growth

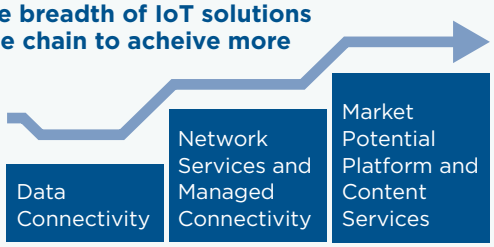
Mobile and LPWA IoT Connections
Source: GSMAi 2017

MARKET OPPORTUNITY

Enable Operators to deliver the breadth of IoT solutions required and move up the value chain to acheive more of the full market potential

$1.6 TRILLION

All income from IoT devices and related services in 2025*



*Source: Machina Research, 2017

Air quality is a global challenge for governments, regulators, city administrators and citizens. Many governments are investing multi-billion dollar sums in policies and solutions to improve air quality and they are empowering cities to tackle air pollution locally. In order to implement effective policies and interventions there is an increasing focus on understanding the levels and causes of air pollution. Today, air quality monitoring is performed by large, expensive scientific instruments permanently installed and professionally maintained, at a relatively small number of fixed locations. For example London has around 100 monitoring stations[1]. This makes it difficult for citizens to understand the levels of pollution they experience in their daily lives, as the monitoring data is not available in real time and is very sparse.

Advances in sensors, IoT platforms and mobile communications technologies have led to the emergence of smaller, portable, low cost, mobile-enabled sensors that can measure and report air quality in near real time. "Big Data" capabilities, such as analytics and machine learning, can then be applied to this data and related data sets, such as weather and traffic, to understand the causes and fluctuations in air pollution.

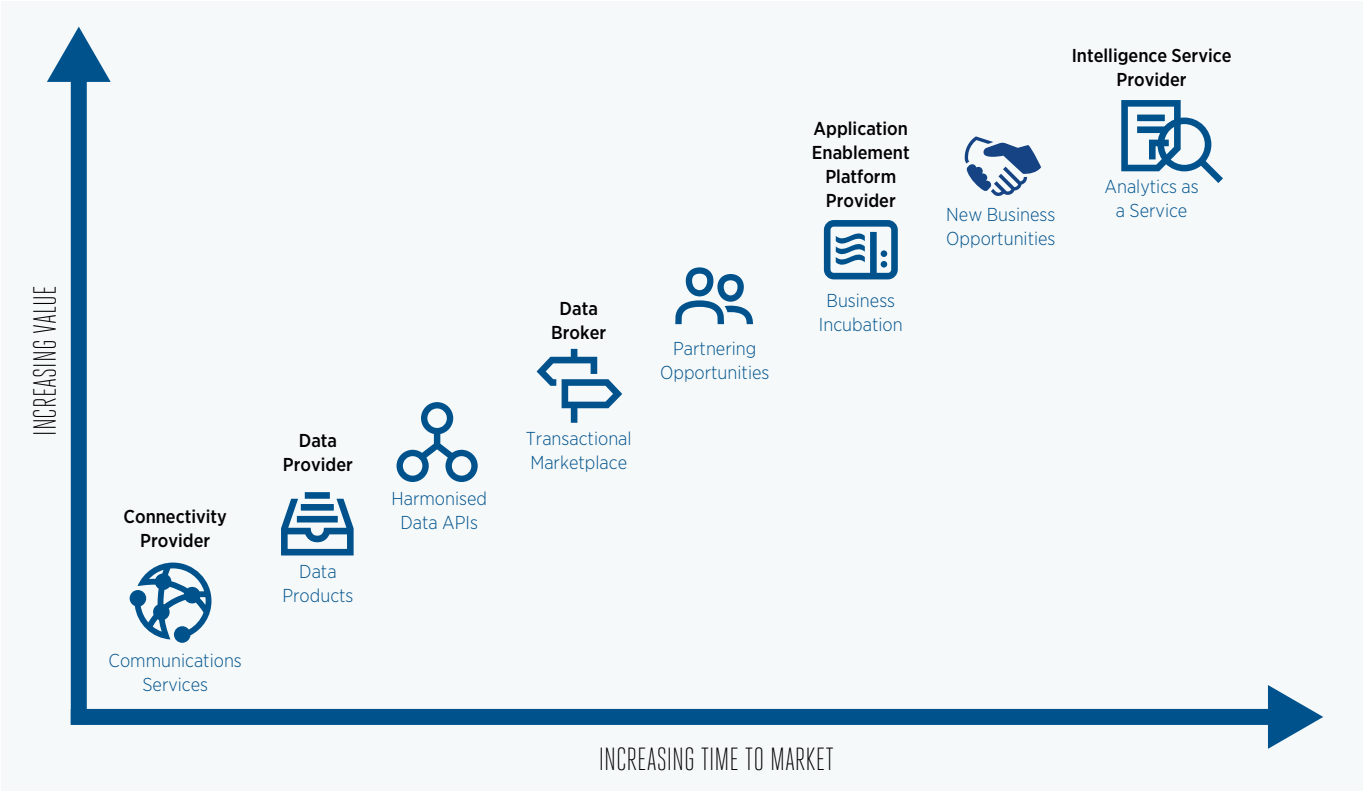
The key customer segments for air quality services are:

- **Government bodies, who benefit by avoiding fines for poor air quality, reducing health spending and obtaining higher taxation revenues due to increased economic output.**
- **Third party solution developers, who create value by offering new products and services to businesses and consumers.**
- **City administrators, who benefit from carbon trading, green bonds and from more informed urban planning that delivers an improved urban environment.**
- **Regulators, who benefit by ensuring regulatory compliance through a new independent monitoring capability and achieving reduced societal impact from poor air quality.**

Significant commercial opportunities are emerging, for example, South Korea's KT Corp announced a government funded nationwide 'Air Map Korea Project'[3]; the C40 Cities Climate Leadership Group announced its intention[4] to issue a Request for Proposals (valued at $1M) for the provision in London of a system of air quality sensors to support policy design and citizen engagement.

> One of the challenges the Royal Borough of Greenwich is concerned about is air pollution; and it has clear commitments to tackling poor air quality. The Royal Borough has an existing network of large static monitoring stations; but exploring ways we can supplement this with data from different situations and locations; and understanding the data behind the air quality in our Borough is important to help us introduce measures to lower the impact of air pollution for the citizens of Greenwich. This is why we're working with the GSMA and the mobile industry – to make this happen. Collaboration with industry partners such as the GSMA is allowing us to understand how we can use new technology to gain detailed information about the factors which influence air quality in the Royal Borough of Greenwich[2].
>
> **Cllr Danny Thorpe,** Royal Borough of Greenwich

1. http://www.londonair.org.uk/london/reports/2016_LAQN_Summary_Report.pdf
2. Cllr Danny Thorpe, Royal Borough of Greenwich 's Deputy Leader and Cabinet Member for Regeneration and Sustainability
3. http://www.businesskorea.co.kr/english/news/ict/19374-ict-based-air-quality-measurement-kt-develops-new-technology-measuring-air-quality
4. https://c40-production-images.s3.amazonaws.com/other_uploads/images/1519_EOI_C40_Hyperlocal_pilot_%281%29.original.pdf?1512464347



This guide shows through case studies that operators are actively delivering new services for air quality in a number of different roles including:

- **Connectivity Service Provider**
- **Data Provider**
- **Application Enablement Platform Provider**
- **Intelligence Service Provider**

For example, China Mobile is working with the city of Chongqing and other cities in China, while T-Mobile, Telefonica and Orange are working with cities in Germany, France, Spain, Portugal and Brazil. Korea Telecom has won the government funded "Air Map Korea"[5] project to collect air quality data from monitors installed within its nationwide infrastructure. During the first phase of the project, Korea Telecom will install air quality monitors across seven major South Korean cities including Seoul.

This guide also notes that there will be opportunities to offer air quality data and services that may not generate direct revenue but could enhance the value of the operator's brand. As an example, sharing air quality data with health professionals may result in insights that influence the delivery of health services, patient treatments and beneficial patient outcomes. Associating with these societal benefits is likely to improve perception of the operator's brand and ultimately deliver value for the company.

Mobile operators have an opportunity today to leverage their existing capabilities in IoT, Big Data, analytics and cloud solutions,

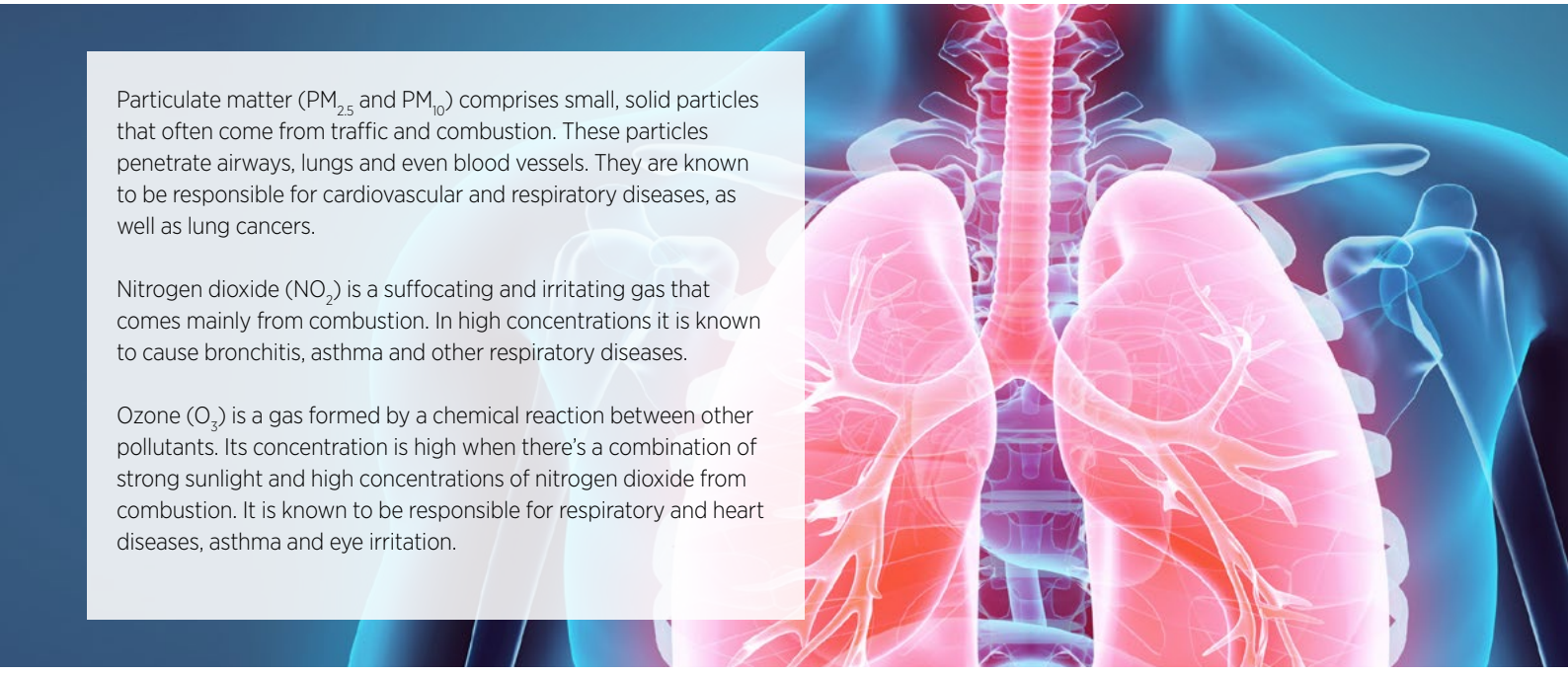
- **to address the global air quality monitoring and control market which is forecast to be worth around $20BN[6] in 2021**
- **to build an ecosystem of carefully selected partner and supplier companies**
- **to offer a portfolio of complimentary air quality solutions and services to governments, cities and third party solution providers**

We encourage mobile operators to explore this opportunity to create new revenue streams from air quality services.

5. https://www.telegeography.com/products/commsupdate/articles/2017/09/20/iot-time-m2minternet-of-things-weekly-digest/
6. https://www.bccresearch.com/market-research/environment/air-pollution-control-equipment-markets-report-env021b.html

Background

Air quality is in the news globally, whether the context is regulatory breaches[7], poor visibility[8], traffic congestion[9] or health impacts[10]. Air pollution levels in many cities exceed legal and World Health Organization (WHO) limits for particulate matter and gaseous pollutants which can be found in concentrations that are hazardous to health. Poor air quality is causing a public health problem, since breathing polluted air increases the risk of debilitating and deadly diseases such as lung cancer, stroke, heart disease and chronic bronchitis. Air pollution is now the world's fourth-leading fatal health risk, reported as causing one in ten deaths in 2013[11].



Particulate matter ($PM_{2.5}$ and PM_{10}) comprises small, solid particles that often come from traffic and combustion. These particles penetrate airways, lungs and even blood vessels. They are known to be responsible for cardiovascular and respiratory diseases, as well as lung cancers.

Nitrogen dioxide (NO_2) is a suffocating and irritating gas that comes mainly from combustion. In high concentrations it is known to cause bronchitis, asthma and other respiratory diseases.

Ozone (O_3) is a gas formed by a chemical reaction between other pollutants. Its concentration is high when there's a combination of strong sunlight and high concentrations of nitrogen dioxide from combustion. It is known to be responsible for respiratory and heart diseases, asthma and eye irritation.

Elevated levels and/or long term exposure to air pollution can lead to serious symptoms and conditions affecting human health. This mainly affects the pulmonary/respiratory systems, but can also lead to more serious conditions such as heart disease and cancer. People with existing lung or heart disease are generally more susceptible to the effects of air pollution and are likely to experience effects at lower concentrations than the general population[12].

Conventionally, air quality monitoring is performed by large, expensive scientific instruments permanently installed and professionally maintained, at a relatively small number of fixed locations typically in cities and along major transportation routes. Government agencies manage and often publish the data collected from country, regional or citywide environmental monitoring networks[13]. Normally this data is verified and aggregated, often resulting in at least a 24-hour lag before publication, offering no opportunity to use this data in "real-time" to avoid or reduce the often unseen risks from poor air quality conditions.

7. https://www.theguardian.com/environment/2017/jan/06/london-breaches-toxic-air-pollution-limit-for-2017-in-just-five-days
8. http://timesofindia.indiatimes.com/city/delhi/Air-quality-very-poor-but-visibility-may-improve/articleshow/55760195.cms
9. http://www.bbc.co.uk/news/world-europe-26599010
10. http://www.scmp.com/news/china/society/article/2056553/smog-linked-third-deaths-china-more-deadly-smoking-study-finds
11. https://openknowledge.worldbank.org/handle/10986/25013
12. https://openknowledge.worldbank.org/handle/10986/25013
13. UK's Automatic Urban & Rural Network (AURN) monitoring stations : https://uk-air.defra.gov.uk/networks/network-info?view=aurn

The Challenge

In 2013 the World Bank reported[14] that premature deaths due to air pollution cost the global economy about $225 billion in lost labour income and about $5.11 trillion in welfare losses, a cost that is roughly equivalent to the gross domestic product of Japan[15]. That study showed that air pollution is not just a health risk; it is also an economic burden. By causing illness and premature death, pollution reduces the quality of life, by causing a loss of productivity, pollution reduces global output and incomes.

Air pollution can have a lasting effect on productivity in other ways, such as by stunting plant growth which reduces agricultural productivity. It can also make cities less attractive to talented workers, thereby reducing a cities' competitiveness. For example, some Indian cities are reporting a reverse migration trend[16] from the city back to the country as citizens take steps to avoid high pollution. Governments also face fines for non-compliance to regional air pollution legislation. Many countries across Europe including the UK, Germany, France, Italy and Spain face the prospect of huge fines arising from persistent failures to comply with European air pollution laws[17]. The UK has been threatened with a $400M fine and cities including London, Berlin, Lyon and Barcelona have all been highlighted by regulators for their unacceptably high air pollution levels.

Many governments, knowing the financial and societal impacts of air pollution, are investing huge sums in policies and solutions to improve air quality. The Chinese government[18] has committed $277 billion to improving air quality and the Mayor of London has a budget of over $1 billion[19] to tackle air pollution. The United States has legislated to control air pollution, with California demonstrating how effective regulatory approaches can be, with every dollar invested in air pollution control since 1970 reported to yield $30 in benefits[20], giving an impressive $1.5 trillion return for a $65 billion investment.

Governments are encouraging citizens to be more aware of air pollution and are promoting changes to behaviours and purchasing choices. For example, the November 2017 UK budget, announced that higher vehicle tax charges will be levied from April 2018 for diesel fueled vehicles that don't meet a specified emission standard[21]. The revenue raised from this new vehicle tax being allocated to a $300M clean air fund. Reinforcing this "polluter pays approach" the Mayor of London has introduced measures to levy an additional $13 per day charge[22] on users of older, more polluting vehicles within central London.

In most cities today, there is no opportunity for citizens to understand the levels of pollution they are experiencing in their daily lives or for them to avoid or reduce their risks from poor air quality conditions. The information available from Government funded environmental monitoring networks[23] is not published in real time and is geographically very sparse due to the high costs of the fixed monitoring stations.

14. http://www.worldbank.org/en/news/press-release/2016/09/08/air-pollution-deaths-cost-global-economy-225-billion
15. https://en.wikipedia.org/wiki/List_of_countries_by_GDP_(PPP)
16. https://economictimes.indiatimes.com/news/environment/pollution/pollution-in-indias-cities-draws-residents-back-to-rural-life/articleshow/61722534.cms
17. http://www.independent.co.uk/life-style/health-and-families/health-news/air-pollution-final-warning-european-commission-uk-breaches-failure-latest-environment-16-areas-a7581191.html
18. https://thediplomat.com/2013/07/chinese-government-will-spend-277-billion-to-combat-air-pollution/
19. https://www.theguardian.com/public-leaders-network/2017/jan/25/uk-deadly-air-pollution-cost-solving
20. http://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(17)32345-0.pdf
22. http://www.energylivenews.com/2017/11/22/budget-2017-tax-hike-for-diesel-cars-and-new-220m-clean-air-fund/
23. https://tfl.gov.uk/modes/driving/emissions-surcharge
24. UK's Automatic Urban & Rural Network (AURN) monitoring stations : https://uk-air.defra.gov.uk/networks/network-info?view=aurn

The Opportunity

A new generation of lower-cost sensor devices, benefiting from advances in communications and sensor technologies have recently appeared[24, 25, 26, 27] in the market. These IoT connected devices sense the environment several times a minute and typically deliver a one minute average value to a connected analytics solution, creating an opportunity for mobile operators to offer air pollution monitoring and control services that deliver dynamic, local information to stakeholders.

Whilst not intended to fully replace established monitoring networks, these low cost, easy-to-deploy IoT solutions provide additional benefits. These include enhanced visibility and situational awareness and early indications of pollution hotspots, giving citizens the opportunity to avoid those areas. These new products and services help cities connect their infrastructure, regulatory stakeholders and citizens, to address the current air quality challenge.

There are strong forecasts for the air quality monitoring and control market, which lies at the intersection of several technologies including Air Pollution Monitoring and Control equipment, IoT sensors and IoT solutions, each of which have considerable independent growth potential.

- **Analyst BCG[28] forecast that "Business to Business" spending on IoT technologies and solutions will reach $267 billion by 2020.**
- **The global market for air pollution control equipment is expected to increase from over $14 billion in 2016 to over $20 billion in 2021, a compound annual growth rate (CAGR) of 7.8%[29].**
- **Sales of sensing devices for air quality monitoring were worth $3.4b globally in 2015, and are forecast to continue growing at a rapid rate, expected to reach $5.64bn by 2021[30].**

24. https://bettaircities.com/specifications
25. http://www.smart-sense.hr/smart-city#first_page
26. https://urbanclouds.city/outdoor-air-quality/
27. https://draysontechnologies.com/cleanspace.html
28. https://www.bcgperspectives.com/content/articles/hardware-software-energy-environment-winning-in-iot-all-about-winning-processes/
29. https://www.bccresearch.com/market-research/environment/air-pollution-control-equipment-markets-report-env021b.html
30. https://www.eventbrite.co.uk/e/46th-intelligent-sensing-program-sensing-the-air-quality-and-emissions-registration-35540770401?utm_campaign=933489_Intelligent%20Sensing%20Program%20Event%20registration%20reminder&utm_medium=email&utm_source=dotmailer&dm_i=2VFU,K0A9,1T53W6,238GL,1#

Air quality monitoring presents an opportunity for operators to create new value propositions, products and services targeted towards a number of different customer segments including:

Customer Segment ranked in order of opportunity size	Value Proposition
Government Bodies	Avoid fines for poor air quality Reduced health spending Higher tax revenues
City Administrators	Access carbon trading and green bond markets Improved urban planning
Third Party Solution Developers	Access to new data sources Access to application enablement platforms Access to analytics capabilities and services
Regulators	Ensure regulatory compliance via independent monitoring capability Reduce societal impact of poor air quality

Other organisations who have an interest in air quality services and who are likely beneficiaries of services commissioned by others, include;

Customer Segment	Value Proposition
Hospitals and Health Professionals	Reduce hospital admissions Improved health outcomes Reduced service delivery cost
Schools and Education Providers	Improved educational outcomes Healthier pupils Higher pupil attendance
Environmental Scientists and Researchers	Improved environmental data New analytics, insights and understanding Access to new data sources Access to application enablement platforms Access to analytics capabilities and services

As an example of the new opportunities for air quality services, the C40 Cities Climate Leadership Group announced its intention[31] to issue a Request for Proposals (valued at $1M) for the provision in London of a system of air quality sensors, presentation of hyperlocal data derived from these sensors, and data analysis to support policy design and citizen engagement. The project will be carried out in partnership with the Greater London Authority and the lessons learnt shared throughout the C40 Cities Group.

31. https://c40-production-images.s3.amazonaws.com/other_uploads/images/1519_EOI_C40_Hyperlocal_pilot_%281%29.original.pdf?1512464347

Business Models and Operator Roles

There are a number of different business models and roles that mobile operators can adopt to position themselves in the market and to enable them to deliver new air quality data and analytics services including:

- **Data product business model – creating and selling air quality data products[32, 33] via a marketplace where the buyer has the opportunity to add further value, for example by creating and selling their own applications. Typically an operator would monetise this through subscriptions or transaction charging for the data service;**
- **Partnering business model – see for example case study 4, where the operator partners with selected third parties who provide the domain expertise. Typically this would include an outcome based payment model where revenue/profit is shared with the operator.**
- **Platform business model – see for example case study 2, providing, an IoT application enablement[34], data storage and analytics platform for third parties to use across market sectors. The operator would charge for usage of the platform. The payment model may include; Pay-as-you-go, Freemium or Subscription charging for access to, or use of the platform;**
- **'New Product' business model – see for example case study 3, where the operators creates and invests in a new product, business and/or brand and develops domain expertise to develop these new opportunities. The payment model may include transactional, Pay-as-you-go, Freemium or Subscription charging**.

Each business model has inherently different (risk/reward/ investment/ time to market/channels to market) characteristics and operators may elect to follow one or more business model simultaneously to match their strategy, capabilities and market opportunities. Within each business model, there are different roles that mobile operators can take, each different role includes a core set of capabilities and services as outlined in the diagram below.

Connectivity and Device Management Provider	Data Provider	Application Enablement Platform Provider	Intelligence service provider
■ Connectivity services utilising 2G/3G/4G including LPWA Mobile IoT technologies ■ Device management services ■ Identity and Security services	■ Providing air quality, network, customer and IoT data sets ■ Cleansing, harmonisation and aggregation anonymising of different data sources, including context data ■ Participation in data marketplaces	■ Providing a platform enabling developers and partners to access rapid application development tools ■ Providing an incubation programme supporting new business and partners to develop new products and services	■ Providing analytics and machine learning as a service, across multiple data sources ■ Providing a platform enabling developers and partners to access intelligence services

32. https://www.earthsense.co.uk/
33. https://breezometer.com/plans/
34. http://open.iot.10086.cn

Mobile operators are well placed to take on these new roles and to deliver new air quality solutions and services to different customer segments. Operators are a natural, low risk partner, who is already delivering a wide range of IoT services over extensive territories. Many air quality solution providers are keen to partner with mobile operators as their solutions require efficient, reliable and secure mobile communications. Mobile operators have an opportunity today, to leverage their capabilities in IoT, big data, analytics and cloud solutions, to address this market and offer a portfolio of solutions and services to governments, cities and other customer segments.

Mobile Operator Case Studies

Within this section we present a selection of case studies, illustrating the roles that mobile operators around the world are taking as they deliver particular IoT and analytics/big data services to address the local air quality challenges.

SMART LONDON - AIR QUALITY PROOF OF CONCEPT (GSMA)

Introduction

To illustrate the value of deploying IoT air quality sensors within cities, the GSMA is working with the Royal Borough of Greenwich (Greenwich) in London on a proof of concept project to trial a range of sensors and advanced analytics to measure air quality and gain further insights into the levels and causes of pollution. Partners, Everimpact, are making air quality and environmental data available from a combination of satellites and sensors. Ordnance Survey, are providing OS map zone data for Greenwich.

To illustrate the value of these types of environmental monitoring opportunities, the GSMA, acting in the role of an operator and systems integrator, is deploying a range of low-cost static and mobile IoT sensors in different ways (e.g. carried by people, on bikes, on vehicles, on buildings) to measure local air quality. All the IoT sensors include mobile communications capabilities and report data throughout the day.

> One of the challenges the Royal Borough of Greenwich is concerned about is air pollution; and it has clear commitments to tackling poor air quality. The Royal Borough has an existing network of large static monitoring stations; but exploring ways we can supplement this with data from different situations and locations; and understanding the data behind the air quality in our Borough is important to help us introduce measures to lower the impact of air pollution for the citizens of Greenwich. This is why we're working with the GSMA and the mobile industry – to make this happen. Collaboration with industry partners such as the GSMA is allowing us to understand how we can use new technology to gain detailed information about the factors which influence air quality in the Royal Borough of Greenwich[35].
>
> **Cllr Danny Thorpe,** Royal Borough of Greenwich

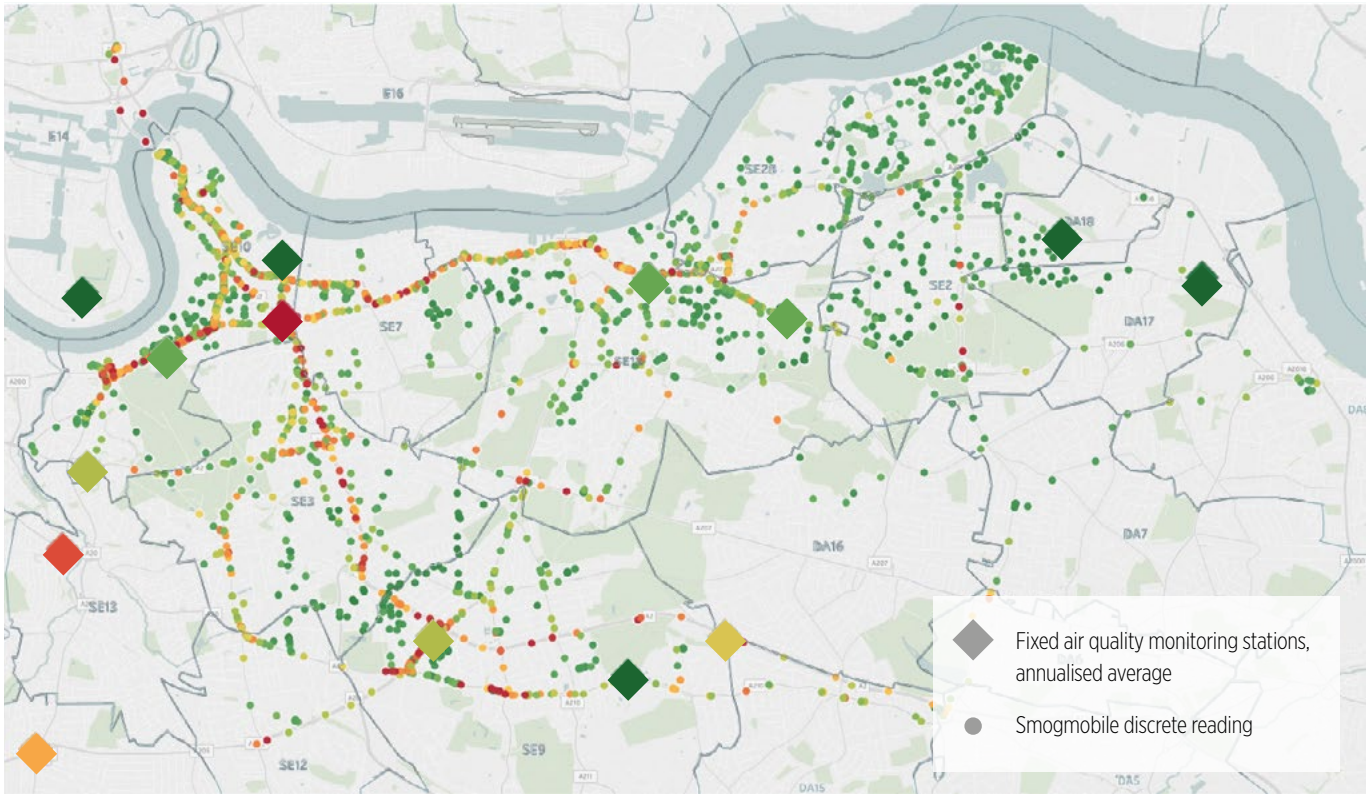
35. Cllr Danny Thorpe, Royal Borough of Greenwich 's Deputy Leader and Cabinet Member for Regeneration and Sustainability

> These portable IoT sensors can travel freely anywhere within Greenwich including across parks, along footpaths, pedestrian routes, major roads and side roads. As they assess air quality in 'real-time' we expect they will provide much more granular data on the air quality in different locations throughout the day."
>
> **Aruna Srinivasan,** GSMA

The initiative also undertook roadside data collection using a high quality mobile air quality laboratory called "The Smogmobile ", which sampled and measured the air quality every minute as it was driven around Greenwich over eight days during two consecutive weeks in July 2017. The routes included driving by a number of stationary air quality monitoring locations, passing by local schools and driving along particular roadways of interest.

The following figure shows the increased granularity of air quality measurements taken within Greenwich during the period 19th to 29th July 2017 compared with the current fixed monitoring site locations:

MOBILE AIR QUALITY MEASUREMENT LOCATIONS IN GREENWICH DURING THE PERIOD 19TH TO 29TH JULY 2017



Source: Enviro Technology Services Ltd on behalf of GSMA – http://www.et.co.uk/the-smogmobile

35. Cllr Danny Thorpe, Royal Borough of Greenwich 's Deputy Leader and Cabinet Member for Regeneration and Sustainability

Roadside measurements of air quality reveal how nitrogen dioxide, particulate matter and ozone levels varied significantly along traffic routes. Higher levels of nitrogen dioxide and particulate matter were recorded where vehicles accelerate and where slow or stationary vehicles with idling engines occurred in large numbers at more congested locations.

The initiative also utilised open air quality data from the London Air Quality Network (LAQN) (hourly data, reported daily) which monitors air pollution in and around the Greater London area. Within Greenwich, an area of 47.35 km^2 (18.28 sq miles) in which there is a residential population of over a quarter of a million people, there are just eleven permanent air quality monitoring stations which form part of the LAQN, and data is only available from nine of these via the 'londonair' website. Context data including METAR weather observation data[37] from static monitoring sites (hourly data, reported hourly) was also accessed.

The proof of concept has applied big data analytics and machine learning techniques to analyse long range historical air quality and weather information resulting in new understanding of the fluctuations and trends and most likely factors influencing air pollution in Greenwich and methods to generate near term predictions for air quality that may in future be used for interventions. In addition the IoT based air quality sensors allow improved monitoring of air quality, at a more granular level, and in near real time (typically reported every minute).

Working on this project, the GSMA has taken a big step towards measuring, at a granular level, the local air quality within Greenwich, providing city administrators the data, analysis and insights that will help them assess pollution levels and consider how to improve conditions for citizens.

> With so much data being generated, conventional analytical techniques become difficult to apply to the data and this is where the 'Big Data' approach including 'Machine Learning' becomes vitally important.
>
> **Aruna Srinivasan,** GSMA

CASE STUDY CANVAS

GSMA Air Quality Service – Greenwich Proof of Concept		
Value Proposition	**Key Partners**	**Customer Relationship**
Demonstration of the value and insights available through the analysis of data obtained from an array of mobile enable IoT air quality sensors	Royal Borough of Greenwich Everimpact Ordnance Survey	Analysis and insights presented via GSMA reporting tools
Operator Role	**Key Resources**	**Customer Segment**
Data Provider Intelligence Service Provider Provider	IoT sensor Data Open Data Weather data Air quality data Satellite data	Local Government
Revenue Stream This is a non-commercial proof of concept		

Future Plans

This proof of concept will continue gathering data from mobile enabled IoT sensors installed on service vehicles operated within Greenwich for several months during 2018. Greenwich plan to include the insights obtained from this study within their annual 2017/2018/2019 Air Quality plans. It is also hoped that in time the service could be enhanced by mobile network data and offered as a commercial service by a UK based mobile operator.

FarEastTone is using the same IoT and analytics and machine learning techniques, supplemented with mobile network data to implement an air quality monitoring solution within Taiwan. FarEastTone plan to offer these services to the Taiwanese government on a commercial basis, demonstrating how new revenues can be realised from air quality services.

37. National Oceanic and Atmospheric Administration: National Weather Service http://www.aviationweather.gov/metar

ONLINE AIR POLLUTION MONITORING PLATFORM (CHINA MOBILE)

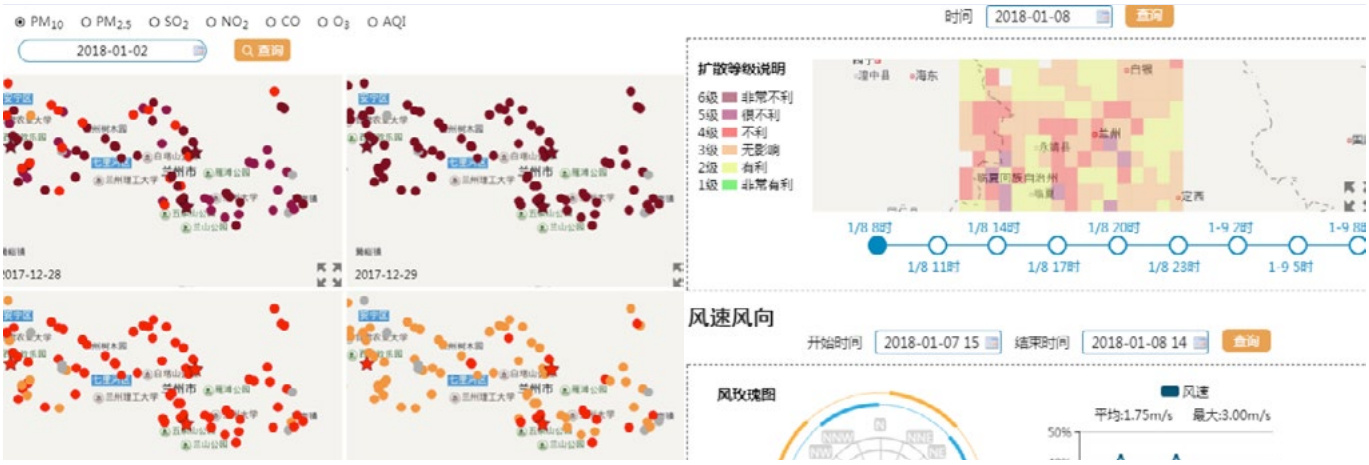
Introduction

With a rapidly growing economy, a related increase in energy use and substantial growth in the number of motor vehicles now in use, there is a growing concern about urban air quality in China. Across China over a billion Chinese citizens are thought to experience poor air quality for more than six months of the year. Chongqing, a large industrial city in central China with a population of over 28 million, has undergone substantial expansion and as a result has many large construction sites across the city throwing dust and other pollutants into the air that mix and react with traffic pollution resulting in very poor air quality[38].

ONLINE AIR POLLUTION MONITORING PLATFORM (OAPMP) – CHONGQING

To improve the monitoring of air pollution created by construction sites, China Mobile, along with its partner Guangruida Information Technology Company, have developed and deployed at a number of construction sites, IoT sensors and cameras together with an Online Air Pollution Monitoring Platform (OAPMP). The IoT devices gather information about atmospheric pollution such as particle sizes and concentrations, local weather conditions and the cameras record images of the site activity. All the data is automatically uploaded to the China Mobile OneNET platform via WIFI or cellular connectivity. The data is then processed following the specification of the local Ministry of Environmental Protection (MEP). Construction sites, which fail the emission standards, trigger alarms in the platform, which are then automatically reported to the MEP who respond appropriately.

DATA UPLOADED VIA WIFI OR CELLULAR CONNECTIVITY



38. https://air.plumelabs.com/en/month/chongqing

The core functions of OAPMP are:

- **Online monitoring: monitoring of air pollutants, recording images of pollution sources, recording alarms, and proposed rectification options;**
- **Online visualisation: visualise and present real-time information from all surveillance sites, including local weather conditions;**
- **Online reporting: present statistical indicators of monitoring data and present images of sites with pollution violations;**
- **Regional analysis: analyse and present the aggregated picture of conditions within a region; calculating the pollution severity level.**

The OAPMP solution is currently operational in the cities of Chongqing and Lanzhou[39].

CASE STUDY CANVAS

China Mobile Air Quality Service – OAPMP		
Value Proposition	**Key Partners**	**Customer Relationship**
OAPMP provides a platform for regulators to collect pollution evidence, achieve real time monitoring and perform law enforcement Those sites which fail the emission standards trigger alarms within the platform	Guangruida information technology company Local government agencies	Self Service Automated Service User Community Information dashboards delivered via the OneNET platform
Operator Role	**Key Resources**	**Customer Segment**
Connectivity Service Provider Data Provider Application Enablement Platform Provider Intelligence Service Provider	OneNET Platform Location data Weather data Air Pollution data Camera data	Local environmental protection agencies in Chongqing and Lanzhou in China Building managers for indoor Air Quality
Revenue Stream This is a commercial sustainable service with a CAGR forecast of 10%-15%		

Future Plans

In collaboration with the Ministry of Environmental Protection, China Mobile plan to roll these revenues generating services out nationwide. In addition they are beginning to offer building managers a similar, in-building air monitoring solution.

39. https://open.iot.10086.cn/en/case/detail24.html

NO_2 MONITORING AND PREDICTION (TELEFONICA - LUCA)

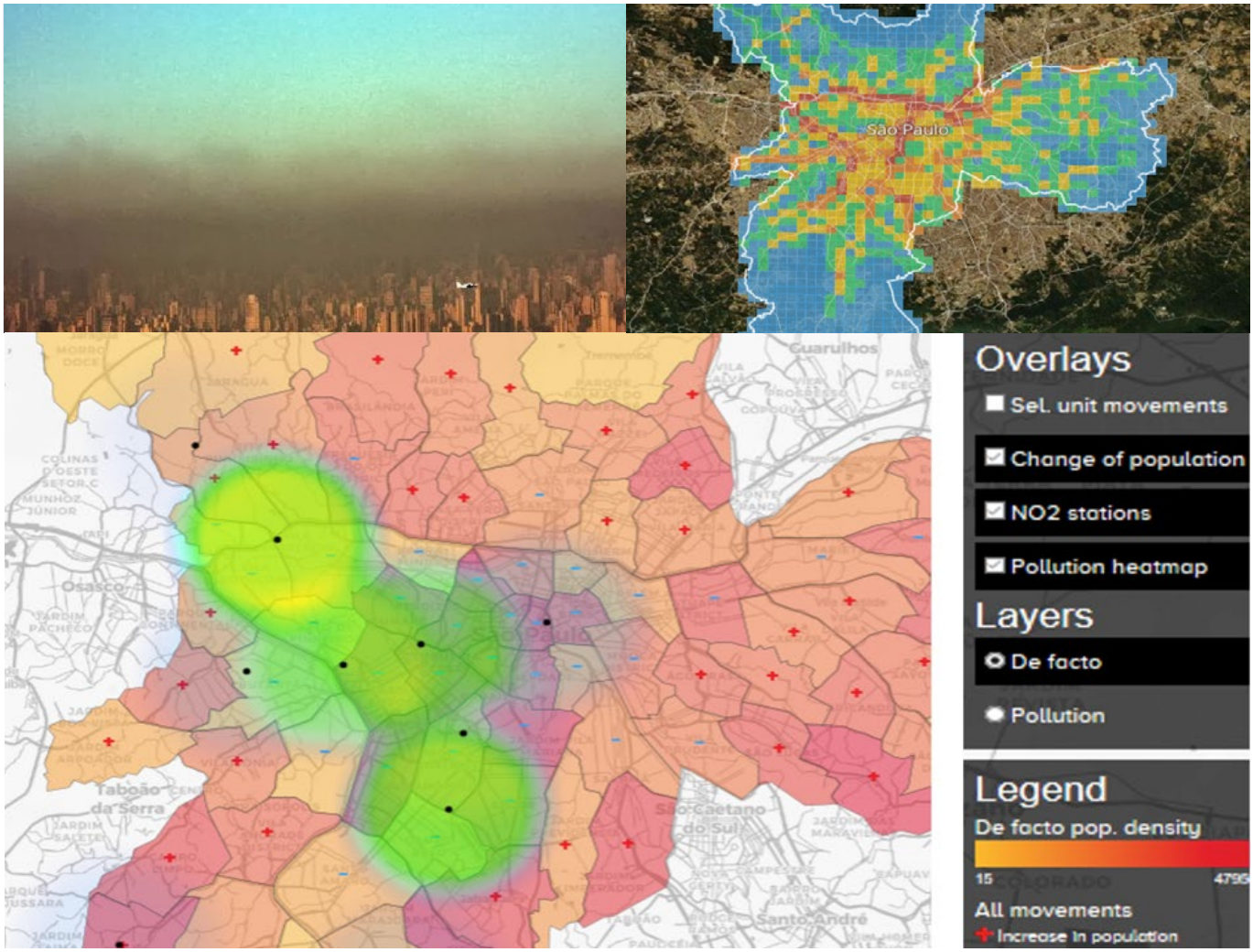
Introduction

Mobile data analysis can provide actionable insights about vehicular traffic and pedestrian mobility patterns to help measure and predict air pollution in a more cost-effective way. At the same time, this analysis helps provide valuable information on journeys across cities and countries which helps to make public transport systems more efficient, with improved journeys that reduce commuter stress.

Telefónica Brazil have commissioned a trial in São Paulo, the largest city in Brazil, with a population of around 12 million, to demonstrate that operator network data can create social value. This trial analysed the city air quality using open data from existing air quality sensors and mobility data to estimate vehicle numbers and locations. Correlating mobile device location data with other datasets reveals insights and valuable information for local administrators about how to improve traffic distribution and traffic management. The project proposed interventions that could help improve the lives of citizens and give new information to decision makers to improve transportation systems.

The project trial was delivered by the Telefónica -LUCA Big Data for Social Good Unit in collaboration with Telefónica Brazil (VIVO), São Paulo Municipality and the GSMA. It focused on how traffic and human mobility impacts on city air quality and consequently, on the health and wellbeing of the citizens. Telefónica are validating the approach they have developed within this trial by initiating a similar project within Madrid, Spain.

TELEFÓNICA BRAZIL PROJECT TRIAL



> In Telefónica, we know that it is possible to invest in an innovation model that serves the most relevant demands within the social and environmental spheres and, at the same time, to generate long term value offering quality services to our clients. In this particular case, with Big Data and IoT solutions we can contribute to allow the public administrations to optimize the urban development and the management of the traffic, besides evaluating the quality of the air in places that do not have any type of monitoring, therefore saving resources and enhancing decision-making processes to public authorities.
>
> **Eduardo Navarro,** CEO of Telefónica Vivo Brazil

CASE STUDY CANVAS

Telefonica Air Quality Service – Pollutant monitoring and prediction		
Value Proposition	**Key Partners**	**Customer Relationship**
Mobile network data delivers valuable insights into the factors affecting urban air pollution and is a valuable aid pollution	Telefonica Brazil (VIVO) Sao Paulo Municipality GSMA	Self Service Information dashboard delivered via the LUCA platform
Operator Role	**Key Resources**	**Customer Segment**
Data Provider Intelligence Service Provider	LUCA Platform Mobility Data Location data Behaviour data Traffic data Open Data – Air Quality, Weather	Cities of Madrid, Spain and Sao Paulo, Brazil Government Agencies: Health Transport Environment
Revenue Stream This is non-commercial proof of concept, based around a core product with customisations delivered as a service		

Future Plans

Telefónica plan to develop this trial into a customisable product and service that can be marketed and deployed globally in cities to help with transportation planning and with the understanding and reduction of urban pollution.

AIR QUALITY MONITORING (DEUTSCHE TELEKOM)

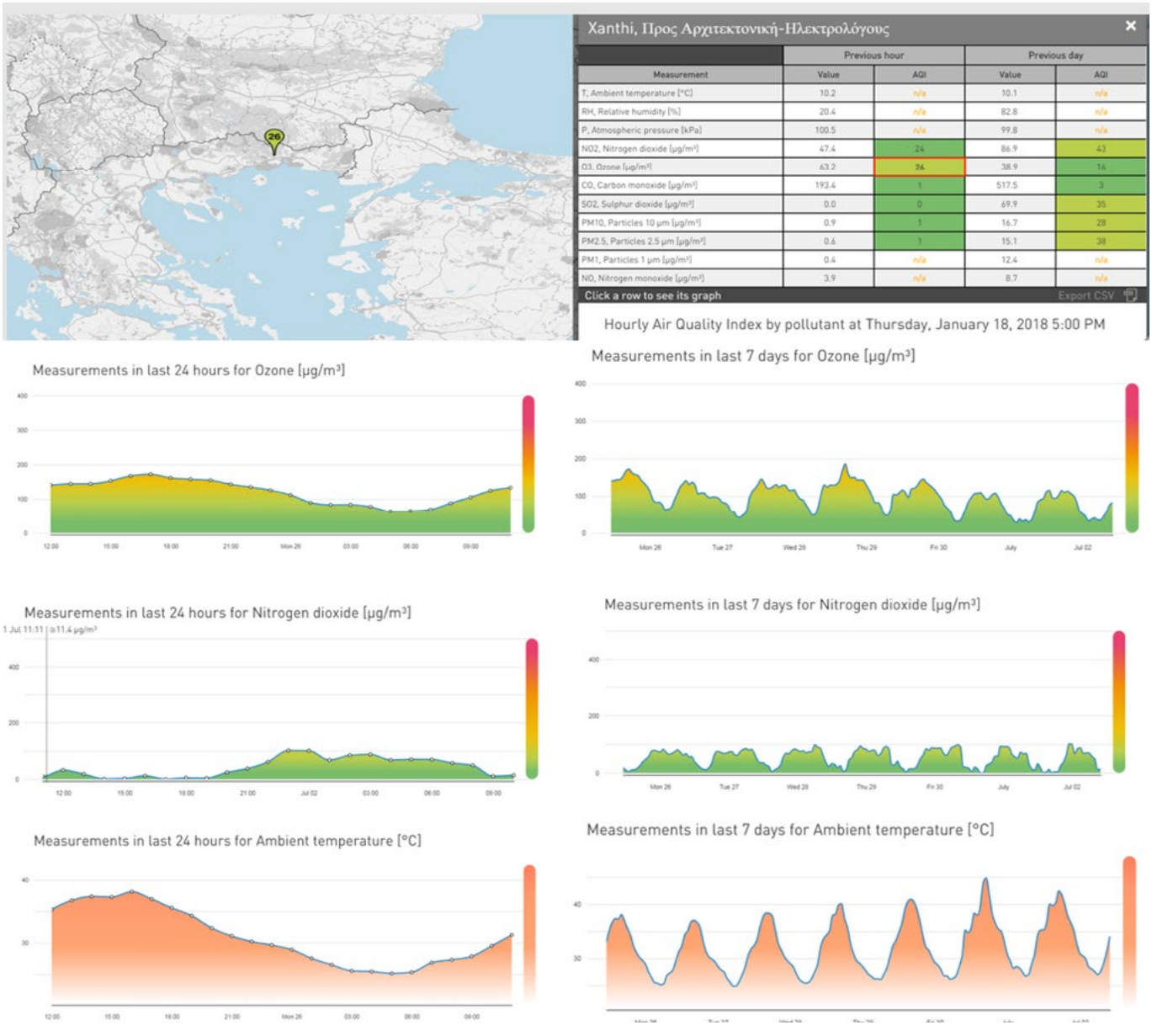
Introduction

Deutsche Telekom working with the sensor provider Smart Sense[40] have developed and deployed Smart AirQ monitoring system; a smart sensor platform for monitoring air quality. The solution, which was initially deployed within city of Dubrovnik, Croatia and has now been deployed in four different countries on two different continents: in Croatia, Germany, Greece and Saudi Arabia.

The Smart AirQ system supports the indoor and outdoor monitoring of multiple air quality parameters at a room, street and city level including relative humidity, temperature, atmospheric pressure, CO_2, NO_2, NOX, CO, SO_2, O_3 and airborne particles.

With the goal of helping students with chronic respiratory diseases and improving cognitive functions and attention span of both students and professors, Smart Sense has delivered AirQ Indoor systems to multiple schools in Croatia. AirQ Indoor uses both hardware and software developed by Smart Sense. AirQ Outdoor sensors wirelessly communicate using Mobile or Mobile IoT (NB-IoT) technology with a custom-built cloud platform, where the data is analysed and presented to users. The first NB-IoT enabled solution was deployed in Xanthi, Greece with data being collected and presented as summarized in the screenshots below.

SMART AIRQ MONITORING SYSTEM



40. http://www.smart-sense.hr

CASE STUDY CANVAS

Deutche Telecom Air Quality Service – AirQ and AirQ Indoor		
Value Proposition	**Key Partners**	**Customer Relationship**
Demonstration of the insights obtained through analysis of data from mobile-IoT enabled air quality sensors	Smart Sense T-systems HubRaum Hrvatski Telekom COMOTE	Automated Service Data and Analysis presented via the AirQ IoT platform
Operator Role	**Key Resources**	**Customer Segment**
Connectivity Provider Data Provider	Air quality data	City Administrators Government Environment Agency Educational Establishments
Revenue Stream This is a commercial proof of concept, based on core products (indoor and outdoor) with customisations delivered as a service		

Future Plans

Deutsche Telekom, T-Systems and SmartSense believe that a number of new use cases and business opportunities will arise with the data obtained from Air Quality Monitoring. The data will not only be used to generate direct revenue but also indirectly when automatic decisions and actions can be triggered depending on the data received. For example, traffic management systems can be controlled to ease pollution for a better citizen experience and congestion or pollution charges could be invoked using various Smart City solutions. Deutsche Telekom, T-Systems and SmartSense plan to offer the Smart AirQ monitoring solution as a customisable product and service that will be marketed and deployed globally in cities where Deutsche Telekom offer Mobile IoT (NB-IoT) services.

Operator Roles

In the following section we provide further details about each of the different operator roles and detail some of the opportunities to create new revenue streams.

CONNECTIVITY & DEVICE MANAGEMENT SERVICE PROVIDER

The core business of mobile operators is supplying efficient, reliable and secure communications, connectivity and device management services underpinned by licensed spectrum. Mobile operators deliver a wide range of communication services such as 2G/3G/4G over extensive territories that encompass all the major cities across the globe. In addition, many operators now offer Mobile IoT connectivity services, utilising new cellular Low Power Wide Area network technology (LPWA), to support the growing deployments of IoT devices across cities.

Operators have sophisticated device management platforms and often offer these as part of a service package. Operators also have the opportunity to provide consultancy services around communication, connectivity, security and device management. The customers for these type of services are typically sensor device manufacturers, device resellers, solution providers or end customers who need their devices and solutions to work "out of the box", with zero configuration, as soon as they are powered and switched on; a ubiquitous mobile communications network forming a core component of their solutions.

Security is rising to the top of the IoT agenda and is a core focus for governments, regulators, enterprises, vendors and mobile operators alike. In some cases, organisations may choose to only deploy an IoT solution if they are confident that it can be properly secured. Licensed spectrum using 3GPP-standardised technologies are routinely integrated with proven existing security and authentication systems enabling operators to offer a compelling proposition of a portfolio of secure, reliable, resilient and enduring connectivity solutions that may be matched to requirements of the IoT solution.

Mobile IoT networks from mobile operators support low cost, long battery life, low bandwidth connections in high volumes within licensed spectrum. These technologies are well suited for environmental and air quality monitoring. Features of Mobile IoT include:

- **Very low power consumption, with up to ten years battery life;**
- **Low module costs;**
- **Better indoor coverage and extended outdoor coverage;**
- **Secure and scalable connectivity;**
- **Optimised data transfer, supporting small intermittent messages;**
- **Low risk of network congestion (due to licensed spectrum);**
- **Simple integration to IoT platforms.**

DATA PROVIDER

In the role of the data provider, operators offer the air quality data they have gathered from their network of connected IoT sensors, typically as a paid-for service with access provided through an API. The value add that is provided by the operator as a data provider is that they deal with differences in obtaining and cleansing raw data received from a variety of device types and then provide that data as a higher quality harmonised data set, as a service to third parties.

Operators may also receive and, if required, cleanse data from third parties and make these data sets available via suitable APIs. These may then be offered in paid-for, subscription or other transactional arrangements via a digital marketplace. Operators may also work with selected partners to trade access to their data in return for a share of the revenues or profits from data harmonisation, data cleansing and marketing services. The cleansed, harmonised data sets produced by operators generally have a higher value to data consumers than the raw data as they enable developers to use the data more easily and reduce the complexity and cost of scaling applications across multiple geographic markets. For example, in the context of air quality, combining, cleansing and aggregating air quality data from a specific geographic location and time with the associated weather data into a single data set, accessed via a single API, provides more value to many customers than the raw data sets from different data sources.

The GSMA API Directory[41] lists examples of harmonised data products available from operators and additional examples of how those data sets may be used to create useful applications. The GSMA API Directory provides:

- **Access to a library of harmonised data sets through common APIs;**
- **A channel through which other data providers can make their data APIs available;**
- **Mechanisms that allow for developers to register interest in particular data sets and establish contact the data owner;**
- **Mechanisms that allow developers to showcase applications that use the harmonised data sets.**

Marketplaces for data sets and data products are beginning to emerge; for example Dawex[42] is a global data marketplace where organizations (including a small number of GSMA members) meet, buy and sell data, directly and securely.

CONSENSUS ABOUT THE RISE OF DATA MARKETPLACES

FORRESTER®	"All companies are in the data business now..." "... In 2014 only 10% of enterprises took their data to market, but **32% reported in 2016 data commercialization efforts**" *
Gartner	"By 2020, 25% of large organizations will be either sellers or buyers of data via formal online data marketplaces" "... **We expect to see a sharp rise** in increasingly sophisticated and function-rich **data marketplaces**..." **
McKinsey&Company	"The overall revenue pool might add up to $450 billion to $750 billion by 2030" (for the sole car data monetization) ***
451 Research®	"The ability to monetize the vast amounts of data that ordinary businesses generate is an ambition held by many companies. **Dawex offers a mechanism to enable this to happen**..." "Across industry businesses, both sellers and buyers of data must have confidence in the transactional process. The security and legality of that process is critical to building the reputation of a data marketplace, so it makes sense that **this is the focus for Dawex, and, interestingly, this creates a point of differentiation from its competitors** ..." ****

* Forrester Data: Global Business Technographics® Data And Analytics Survey, 2016

** Gartner: Predicts 2017: Licensing, Legal and Language Lessons for Data and Analytics, 2016

*** McKinsey: Monetizing car data: New service business opportunities to create new customer benefits.

**** 451 Research - Dawex introduces a B2B data marketplace, focusing on security and legal aspects, 2017

41. https://apidirectory.iot.gsma.com/
42. https://www.dawex.com/en/

Another example of a data marketplace is the IoTA Foundation[43] which has recently launched[44] a new micropayment-based data marketplace, powered by distributed ledger technology. This new initiative has gathered participation from more than 20 global organisations, including two mobile operators, Deutsche Telekom and Orange. This public marketplace aims to give the owners of connected devices the ability to securely transfer, buy and sell fine-granular and diverse datasets in a simple transactional way using their own digital "IOTA cryptocurrency".

Offering a portfolio of standardised data products is a relatively low-risk, low-cost way of generating revenue. Operators could create pricing strategies for data products that account for the age of the data, with near real-time products potentially commanding premium prices compared with historical data, thus differentiating their product offering and increasing their revenue opportunities.

APPLICATION ENABLEMENT PLATFORM PROVIDER

Many operators have developed sophisticated platforms that support their IoT opportunities. Some have chosen to offer these cloud based platforms along with software development kits, developer training programs, developer support and flexible commercial arrangements as a complete IoT Application Enablement Platform (AEP). These application enablement platforms often include connectivity and device management services and deliver horizontal enablers that can be used across many different vertical sectors. Developers benefit from device management, authentication and security capabilities, the reuse of existing code, toolkits, tested and approved hardware/firmware/software and a reliable platform infrastructure all of which help to accelerate their product development timeline, improve their product capability and reduce their time to market.

IoT Application Enablement Platforms such as the China Mobile OneNET AEP or the IoT platform ThingWorx, which has been adopted by several leading mobile operators (including Vodafone, Telefonica, NTT DoCoMo and others), enable third parties with deep domain knowledge to deliver tailored services to a large number of different sectors. Operators providing an AEPs for third parties to use typically charge for the features/functions/capabilities of the platform using a payment model which may include Pay-as-you-go, Freemium or Subscription charging.

An AEP often forms the core service offering, but a mobile operator may offer additional business support services. For example it may offer a range of business incubation[45, 46] facilities such as business consultancy, along with developer resources, relevant datasets and analytics tools/services, to enable innovative third parties to develop new applications. In the realm of air quality, this may mean offering a developer programme and datasets on air quality, climate, transport, health and other relevant areas. In addition, intelligence services based on these datasets could be offered as an optional "upsell".

Offering business incubation along with an AEP development platform to third parties means that the third parties do not need to invest in the vast computing storage and processing power that is often required to develop IoT big data applications. By offering these kinds of services, an operator is able to tap in to a wider range of innovation and also promote business opportunities and economic growth in the community. There are many examples of operators adopting this role for example; the AT&T Foundry[47], Verizon's Technology Innovation Center[48] and Telefonica's WAYRA[49] startup accelerator programme. To help companies accelerate their Mobile IoT product development, operators have invested in (around 30) "Open IoT Labs"[50], providing access to Mobile IoT networks and developer resources across the globe.

In a recent development[51] mobile operators have established Go Ignite, an alliance of several of the world's leading operators including Deutsche Telekom, Orange, Singtel and Telefonica, that combines and connects their start up ecosystems and AEP provider offerings. This initiative offers start-ups the ability to deliver services to a market of over a billion mobile consumers across Asia, Africa, Europe, Latin America and the Middle East.

> This marks the continuation of our strong support in working with startups and other telcos to find and grow the next disruptive idea.
>
> **Ana Segurado,** Global General Director, Telefonica Open Future

43. https://iota.org/
44. https://www.forbes.com/sites/jonathanponciano/2017/11/28/iota-foundation-launches-data-marketplace-for-internet-of-things-research/#d706868f52b6
45. http://cdn.news.o2.co.uk.s3.amazonaws.com/wp-content/uploads/2014/12/O2_WAYRA_Report_121214.pdf
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48. http://www.verizon.com/about/news/collaborate-us-verizon-innovation-center
49. https://wayra.co.uk/about-us/
50. https://www.gsma.com/iot/deployment-map/#labs
51. https://www.orange.com/en/Press-Room/press-releases/press-releases-2017/Deutsche-Telekom-Orange-Singtel-Telefonica-pick-innovative-tech-start-ups

INTELLIGENCE SERVICE PROVIDER

Computing power, big data storage and analysis platforms, analytical tools and feature rich visualisation platforms have all evolved rapidly. Many operators have invested in these technologies and now offer intelligence and insight services ("intelligence as a service"). These services are sometimes offered as an "value add" to an existing AEP service. This approach enables operators to develop a market and over time to grow their share of the value chain as their domain knowledge and capabilities grow.

A key opportunity for mobile operators is to offer intelligence based on their network data. Mobile network data can be analysed to understand population movements across a particular geography, giving operators a unique insight into aggregated population movement patterns, which are useful in a wide variety of applications. In the context of air quality, aggregated population movement insights may be correlated with aggregated air pollution data to better understand both the causes and impact of air pollution on citizens.

Some mobile operators, such as Telefónica, Vodafone and Verizon, already offer these types of data analytics services, for example:

- **Telefónica has a "Big Data" business unit, "LUCA", offering services to enterprise customers;**
- **Vodafone Analytics collects data from the Vodafone network to produce customized reports for third parties;**
- **Verizon's Precision Market Insights service provides customers with "actionable insights" derived from the operator's network.**

The delivery of 'Intelligence as a Service' allows end customers or partners to incorporate or consume analytics into their own results or purchase the final insights they require to enhance their capabilities (e.g. reporting). These analytics products and services are typically delivered as a custom, one-off service today[52], with individual contract values ranging from tens of thousands to low millions of dollars depending on the scope and duration of the work involved. It is expected that many of the currently bespoke analytical services will form the basis of reusable products that can become 'standardised' products offered to multiple customers on a transactional basis as the market matures. Many analysts[53, 54] predict high year-on-year growth in this sector for the near future, with IDC[55] predicting worldwide revenues for big data and Business Analytics will grow from about $130 billion in 2016 to more than $203 billion in 2020.

52. http://abstracts.aetransport.org/paper/index/id/4881/confid/21
53. IoT Platforms and Software 2016, Berg Insights, www.berginsight.com
54. http://www.marketsandmarkets.com/PressReleases/advanced-analytics.asp
55. https://www.idc.com/getdoc.jsp?containerId=prUS41826116

Conclusion

There is increasing interest from the public, city administrators and regulators in the air quality within cities, there is also much greater awareness of the costs and impact of poor air quality. There are strong market forecasts for continued growth in this sector, in part driven by the needs of governments to reduce air pollution. Governments, cities and entrepreneurs will continue to invest in this sector, as without safe, clean air, cities and communities cannot flourish.

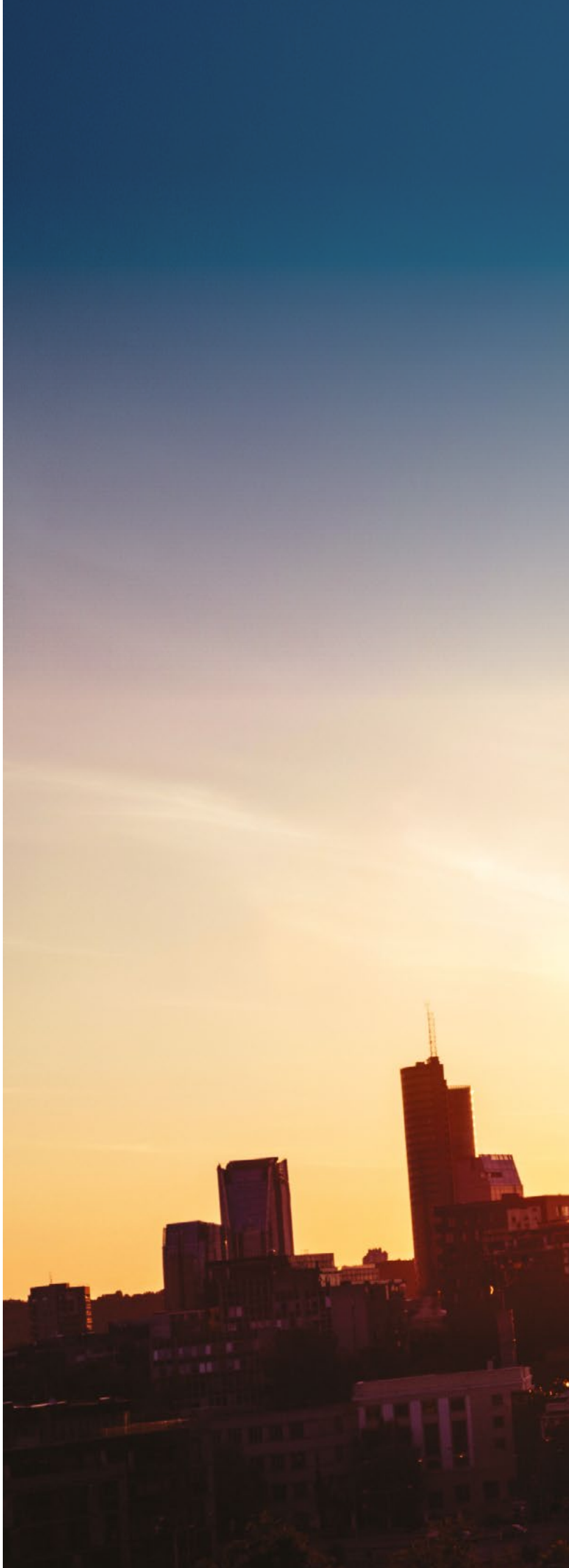
Advances in computing power, big data and the IoT, coupled with emerging Mobile IoT communications technologies, create opportunities for mobile operators to develop new revenue streams from air quality data products, services and solutions. This guide has identified multiple roles that operators can fulfill, a range of different customers and many different air quality services. The case studies show that operators are actively delivering air quality services and adopting the roles identified; some operators have commercial service offerings. In general, roles higher up the value chain require more change and investment to deliver but in turn deliver higher value revenues.

Mobile operators have an opportunity today to address this market, and offer a portfolio of air quality data products, services and solutions to governments, cities and other customers within the territories that they serve. Mobile operators also have unique access to an important source of data, the mobility information derived from network data. Analysing mobile network derived mobility data along with other data such as air quality delivers marketable services, as illustrated by the case study "NO_2 Monitoring and Prediction".

We anticipate that new air quality monitoring solutions will emerge, their development stimulated by the continued improvements to the capabilities of IoT sensors/devices, the wide availability of Mobile IoT technologies and the increased focus by governments on air quality. We encourage mobile operators to explore these new revenue opportunities and to consider the additional value of including network derived mobility data (which is a unique network operator capability) as part of their offering.

The GSMA's IoT Big Data project provides a forum through which enabling technologies and best practices for these types of services can be developed and shared, and we welcome new project members to collaborate with us on this promising opportunity. The GSMA welcomes discussions with operators who are considering delivering new air quality services.

For further information please visit our website **www.gsma.com/iot**
or email us at: **iot@gsma.com**



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