DRAFT 1

Visualising the Future: Big Data and the Built Environment

ABSTRACT

Building on four years of material generated by the Cambridge Forum for Sustainability and Environment, this report examines the future use of big data in the built environment. Experts from academia, government and private companies were invited to join monthly discussions in the Forum over four years of meetings. Big data within cities was a recurring theme and core challenges and opportunities for the advancement of the use of big data were examined. From the Forum's database key individuals were selected for semi-structured interviews to further examine the identified areas regarding big data. Further interviewees were selected via recommendations from the original selection of participants. This report amalgamates the central elements of these interviews with observations from the Forum and a review of literature.

The report considers how barriers vary for different sectors when it comes to the utilisation of big data within the built environment; these include budgetry pressure, resource allocation, technical challenges resulting from legacy systems, crossing organisational boundaries (even within connected public sector entitities), data access and privacy concerns at an individual level. The need for regulation, either formally through legal structures or by the evolution of social norms, is explored, while considering the challenge of regulating a rapidly developing area of technology. Related to all these points is the key challenge of engaging people who live and work in cities. While many of these barriers may be applicable across the globe, UK-specific applications are explored in more detail.

The opportunities on the horizon stemming from big data are also considered. Big data is not a panacea for the world's problems but will allow for the optimisation of systems and the identification of as yet unknown patterns. This is particularly valuable for understanding cities, where innovation and growth are rapidly advancing. The ability to alter policies in a dynamic and real-time environment can allow for far more efficient resource allocation and supply and demand monitoring in cities both now and in the future.

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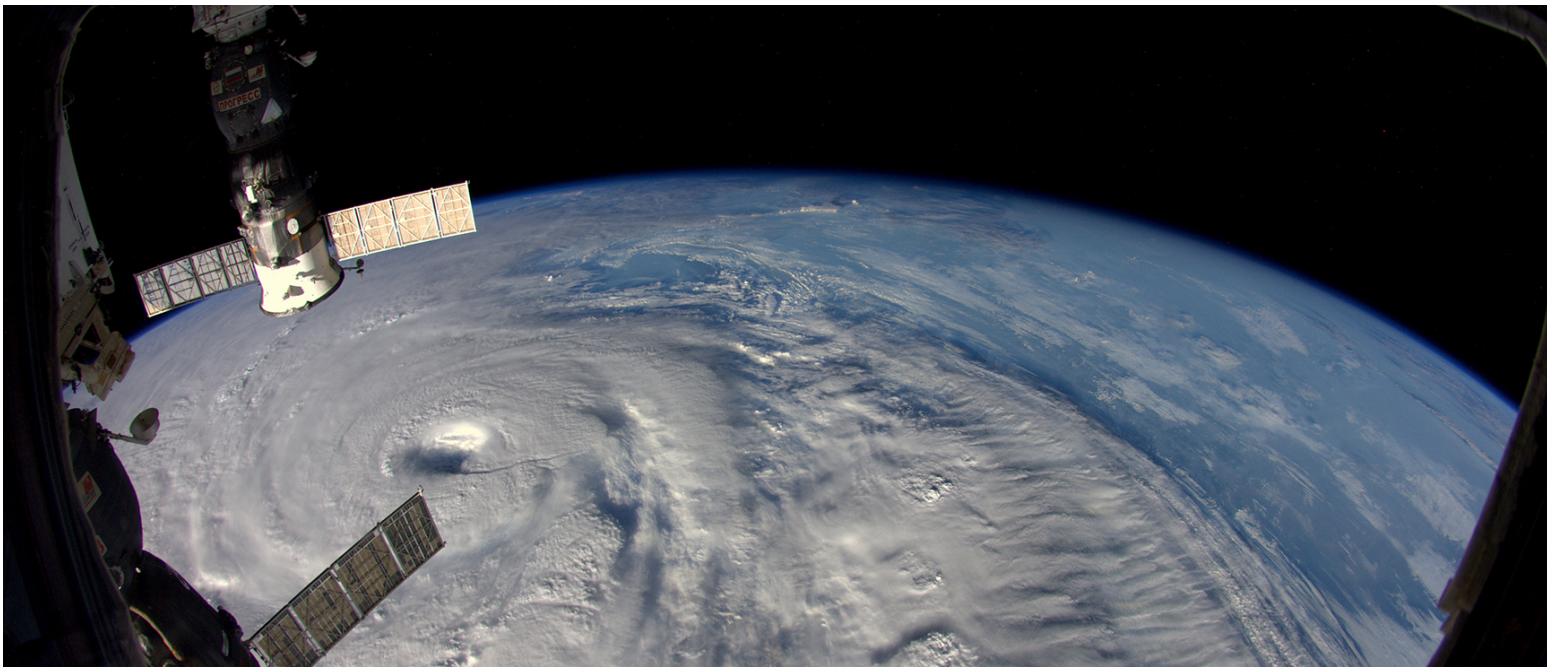


The challenges and opportunities of big data

How can we use big data to improve how we live, where we live and the world around us? How can people access and understand the information contained within these vast datasets and then use them to solve the environemtal and sustainability challenges we all face in the future?

By **Simon Patterson** *and* **Rosamunde Almond**

At a glance

The use of real-time analysis and large scale, dynamic datasets has grown significantly over the last decade and has the potential to enhance cities and rural communities alike. The term 'smart cities' was coined to highlight the growing importance of Information and Communication Technology (ICT) in enhancing the way in which people live, work and move around cities as well as their quality of life, their environmental impact and their engagement with governance. Similar technology is being used in rural areas, for example by using mobile phones to transmit information about weather patterns to farmers to improve their crop productivity. Large-scale datasets - or 'big data' - can be used as the foundation for global, regional and even local scale models which can help anticipate pressures on transport systems, quantify the impacts of changes in land use and enable rapid responses to changing environmental conditions. In short, big data is a valuable and ever-growing tool for researchers, governments and businesses to make countries, cities and communities more resilient to large scale changes and short term shocks and to make better use of natural resources.

Using this evidence as a starting point, a mixture of technical experts, researchers and policy and decision makers from government and business were invited to be 'witnesses' at the Cambridge Forum for Sustainability and the Environment's monthly meetings. They each provided their perspective on the gaps in our knowledge about key sustainability challenges and these were used to as a springboard to identify key 'unknown unknowns' and to formulate 'burning' questions in need of more research.

Big data is large in volume and it can involve complex and heterogeneous information. This presents certain challenges: How do we manage and process such large datasets? How do we filter useful and presentable information in a way that can be used at all levels, from government to the individual?

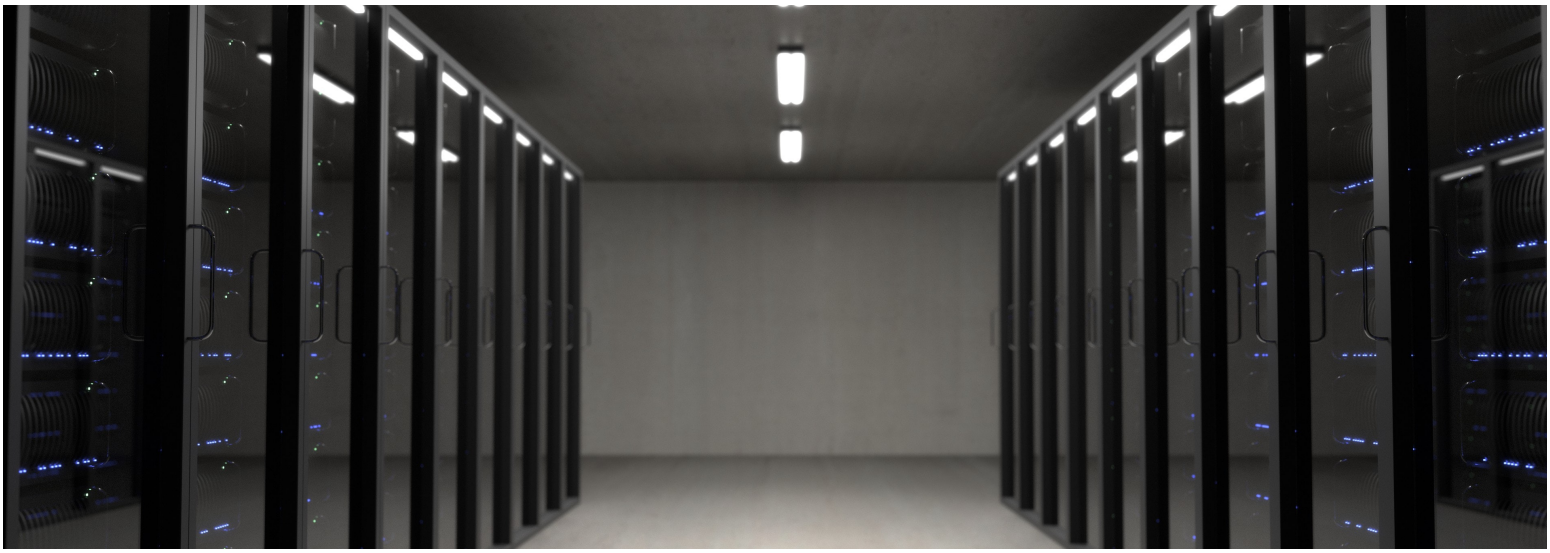
Professor Alan O'Neill, Emeritus Professor of Meteorology at the University of Reading, observed that, in some respects, big data does not lend itself to a homogenous research approach and, although we should strive to get the best value out of the implementation of this newly generated information, attempting to control the various initiatives taking place would be counterproductive. But nonetheless examining the challenges of big data can help to improve our methods through an iterative process.

Over the course of four years a series of meetings centred on the overarching themes of sustainable cities, land-use change, resilience and health and wellbeing. Forum members, witnesses and guests were drawn from 65 University of Cambridge departments, centres and initiatives and 101 other universities, NGOs, companies and local and national government departments. A box at the end of the article contains the names of all Forum witnesses and their affiliations. These discussions triggered questions about some fundamental and yet still unanswered questions pertaining to big data. This article explores these questions in more detail and highlights some of the most promising research questions stemming from the discussions.

Key questions

Through our discussions, we identified three questions which require further examination

- **What drives research? The questions that need to be answered or the available data that we have?**
- **Who is responsible for deciding what data are collected and how it is utilised?**
- **How and when can big data successfully influence decision-making processes?**
- **How can big data be filtered and visualised in a way that becomes useful at an individual level and to respond in real time?**



Access and ownership of data

Who should have access to data? Important data are often collected but then inaccessible to researchers because they are either shrouded in layers of governmental bureaucracy or hoarded by private companies. Fair, open access to data on a global scale can unlock enormous opportunities, and steps have been taken in this direction. For example, in 2008, a policy decision was made to make US satellite archives free and open, and both changes have given researchers access to data that can be used to create new maps and models that were previously unthinkable. Then in June 2014 the US government relaxed its licencing restriction on the resolution of commercial images, allowing them to include features smaller than 50cm. Publically funding programmes, such as the European Union's Earth Observation Programme, Copernicus, have the remit of making their remote-sensing data available to the public. However, a number of witnesses highlighted that there are still plenty of problems when it comes to sharing data, whether it is at an international scale or within a single organisation.

It is possible that the transformative nature of remote-sensing data will lead to research to improve ground-level data, but nonetheless it is often difficult to ground-truth the data. This can be because the release of datasets might force a company or government department to admit it has not reached a certain target. For instance, transport regulation forcing UK companies to release GPS information regarding their buses as part of their contract has quickly led to applications created by entrepreneurs that distil that information to the public. This results in people knowing how long they will have to wait for public transport, making it a more attractive proposition, as well as making service providers more accountable. Conversely, there is also a danger that overconfidence in the improvements in remote – sensing data collection will discourage the funding of data collection systems on the ground or that in attempting to understand the big picture important factors at smaller scales will be missed. Consequently, it is important that remote-sensing data complement, rather than replace, ground sensors and information. One of the great potentials of enabling open access data and creating platforms that will allow people to innovatively use that data is that people with different frames of reference and approaches will be able to do things that perhaps academic researchers would overlook.

The proliferation of data available to the public and technological advances also increase the scope for crowdsourcing projects. People will be able to understand and even participate in data gathering and analysis, creating a bottom-up environment for decision-making to occur. It has the potential to share the ownership of planning decisions that affect local areas. Jon Alexander, Founder and Director of the New Citizenship Project, asserted that the evidence suggests that when people see themselves as participants of something they become more willing to engage with wider concerns beyond their own individual viewpoint.

Laurie Palmer of the Policy Research Group in the Department of Psychology described her work to take advantage of crowdsourcing for gaining a better understanding of wellbeing and its connection to the environment. She created Naturebuzz, an app which gathers basic demographic information before surveying its users to help understand the moment-by-moment relationship between wellbeing and the environment before mapping its results geographically against biodiversity. By seeing or handling data, or contributing to its collection, people can feel part of the solution. The social aspect of such a participatory environment may provide an additional benefit by creating a feeling of collaborative engagement. Nonetheless, individuals may have a short-term view and not fully appreciate the long-term impact of certain decisions, so the way in which information is presented at different levels needs careful thought so that individual or community-level thinking does not affect wider systems negatively.

Open data does not preclude privatisation of data and a competitive market in other aspects, such as the packaging of open data into a useable product or report. Usually stakeholders will not have the resources to do their own research and will require a synthesis of the information when a new commercial question requires an answer. A huge amount of data is still owned by private companies, which in certain instances gives them more power than government authorities. At the moment researchers must negotiate with commercial companies for access to data on a case-by-case basis. A number of witnesses highlighted that an additional risk of privately controlled data is that access to it may be withdrawn at a later date, creating uncertainty for research projects and monitoring systems.

The **Cambridge Forum for Sustainability and the Environment** was established in 2013 in the University of Cambridge. Chaired by Lord Martin Rees. It met once a month until March 2018, bringing together thought leaders from the worlds of research, policy and industry to talk about some of the great sustainability challenges the world faces in the future and the research pathways which will help to prepare for and address those challenges.

Similarly, data that is not freely available for reasons of sensitivity may be made available for researchers by anonymising the analytical process. Dr Matthew Smith, a scientist in the Computational Science Lab at Microsoft Research, described how recent developments in cloud computation mean that algorithms on data could be run without the data itself ever being seen, meaning that information could be extracted without compromising specific privacy issues. Professor Andy Hopper of the Computer Laboratory described a different research area that might alleviate privacy concerns: differential privacy. By this method, instead of collecting accurate data, deliberately inaccurate data is reported and this can be processed to establish an accurate measure. For example, if everyone is required to report what speed they are not doing, the true average speed can be ascertained without any data about particular individuals.

Finally, providing free access to big data may not always be viable, even for agencies which may wish to take such an approach. Craig Mills, CEO of Vizzuality, called attention to the price of gathering, maintaining and releasing large datasets, which can be prohibitively expensive without a commercial model. This is particularly true in the conservation area where valuable data may be collected without an explicit marketable purpose or for governmental use, but may have important information for long-term research goals. How can support for such data collection and maintenance which falls outside the private or governmental sphere be maintained while also making such data freely available?

Ownership and responsibility for data

Professor Peter Guthrie, Director of the Centre for Sustainable Development in the Department of Engineering also pointed out that we should not assume that those actors collect or have access to big data are benign or that their goals align with more global considerations such as the UN's Sustainable Development goals. Sérgio Freire, a Scientific/Technical Project Manager at Global Security and Crisis Management Unit of the Joint Research Council, highlighted that because of such concerns, and the need for sources of data with consistency, reliability and continuity, the role of governments in big data collection remains vital. Who is responsible for critical decisions such as when and how information is used needs more research and possibly more consideration at a policy level. This is a problem where big data is not openly accessible for reasons of privacy or commercial sensitivity. How such data and the information it contains can be extrapolated and presented to decision-makers in policy in a non-partisan manner for the wider global benefit is not currently clear. Susan Owens, Professor of Environment and Policy in the Department of Geography, observed that there is also a lack of trust in systems that keep data anonymously aggregated. As a result, it is unsurprising that it is harder to use big data in areas where information is more likely to be sensitive, such as health, educational outcomes or social issues. Even where trusted users of data, such as universities, can be afforded more flexibility there are still risks from rogue individuals disseminating data or accidental data breaches, as well as the increasing prevalence of security threats from hacking.

> ***"It is very important maintain critical datasets and to identify who will have this responsibility. This is very rarely addressed."***
>
> Dr Grégoire Dubois,
> Institute for Environment and Sustainability, Joint Research Centre, EC

Another concern is that there is a danger in giving away personal data for purposes that are not in the best interests of the individual or society as a whole. The ownership of individual data needs to be valued and understood so that people maintain their own autonomy and not simply become consumer datasets. Professor Jaideep Prabhu, the Jawaharlal Nehru Professor of Indian Business and Enterprise at the Judge Business School, suggested that there is an increasing expectation on the part of the younger generation that when data are shared with a private company there is a direct benefit, making the process of data collection transactional. Researchers need a better understanding of what shared data can empower or disempower the individual, and how much data collection is necessary to make a community work better. Governments and supranational bodies need to take responsibility for legislation and decide who can own what data, and for how long.

Visualisation and users of data

Data and technology also have the potential to 'make the invisible, visible' because visualising and effectively communicating information about a city and the environment makes it easier for people to see patterns and better understand the consequences of their own actions on environmental and social conditions. However, turning big datasets such as remote sensing data into a useful tool at a local, accessible level is a key challenge. For example, the

Greater London Authority is currently building a 'triple jeopardy map' of London that looks at how the urban heat island creates hot spots within the city. This includes which buildings might be prone to overheating and where the most vulnerable people might be so that they can deploy extra resources where needed. Bringing together different datasets can therefore be a powerful way to make previously unknown connections visible and then to direct resources to where they have the greatest impact on reducing problems.

Having data or even extrapolated information available does not ensure it will be utilised. Dr Tinashe Chiurugwi, a Research Associate with the National Institute of Agricultural Botany, observed that, although information regarding improved seed varieties existed, farmers in Africa were not accessing this information. As a result, experimentation with different methods of communicating through digital platforms is needed so that the information reaches the user in a readily digestible fashion. This problem was echoed by Stephen Peedell, the Senior Scientific Officer in the Land Resource Management Unit of the Joint Research Centre of the EC. Looking at nature conservation, a lot of resources have been invested into producing data and indicators regarding risk but this does not always seem to effect decision-making processes.

> ***"With the visualisation capabilities that we now have, you can actually begin to engage a wider citzenry in the process of planning cities."***
>
> Professor Sir Alan Wilson,
> Professor of Urban Regional Systems, University College London

Turning vast, complex and dynamic data into a useful information system is a serious research problem, but we are starting to find creative ways to feed data into different modelling systems. The scale of the data can mean that not every facet of a system will be monitored, but instead indicators can be created that flag up warnings where there are problems. This would empower all sorts of people to investigate the detail, be it policymakers, researchers, journalists and so on. In this respect, new visualisation capabilities can begin to engage citizens and inspire community involvement in both research directions and decision-making, such as in the urban planning process. Craig Mills also emphasised the necessity of visualisation in creating an emotional connection to data. The Global Forest Watch allows internet users to see where deforestation occurs on an easily accessible map which is more effective in raising awareness than a series of statistics. In some respects the visualisation process removes some of the methodological and scientific process in order to tell a story, but this can be combated by creating a pathway whereby if users are particularly engaged with a visualisation they can later access the data. Effective visualisation has the potential to influence people's behaviour, but the exact mechanisms by which this happens needs further research. The way data are presented to people needs to be adapted to specific contexts, such as the educational level and requirements of the users. Professor Ash Amin, the 1931 Chair in Geography, pointed out that we should not limit our attempts to display information to visualisation alone, but other senses, such as sound or smell could equally be a compelling way of distilling data.

The response to visualisation is also something that needs to be carefully navigated, as this may have unintended consequences. For example Larry Sherman, Wolfson Professor of Criminology at the University of Cambridge argued that his research used big data gathered by the police to determine crime 'hotspots' in the London Underground network reduced the incidence of crime, both because of more targeted policing by making people more vigilant about their personal property. However, such maps could also potentially affect local rents and commerce in the highlighted areas.

Modelling and forecasting

Lawrie Robertson, Director and Partner at Happold Consulting, ascertained that cities have always depended to some degree on luck and a particular governance model being adopted at an expedient time, rather than through informed policy decisions based on complete sets of evidence. Subsequently, successful cities will be heralded as resilient and sustainable, but this often will not have arisen as a result of a complete understanding of the data.

We do not always have the requisite data to make forecasts concerning the future impact of decisions so that we can maintain or improve our environment and living standards. Many cities worldwide are lacking data about quite basic aspects of their makeup, such as their size, population or the age and condition of their infrastructure, and how fast these metrics are changing. In such situations the expectation of minute-by-minute information may not be appropriate and instead a base level of knowledge is needed so that strategic decisions can be made. However, Dr Elisabete Silva, a Senior Lecturer in the department of Land Economy, advocated the need, where possible, for dynamic data, dynamic metrics and dynamic models to help city planners produce adaptive policies that will enhance a city's resilience. Overall, it is vital to improve the quality of data at both a global and local level to construct models that can help us decide which large-scale and resource-intensive projects and research areas to pursue so as to hit global sustainability targets.

In an African context Thierry Nègre, Head of the Food Security Group within the Monitoring Agricultural Resources Unit at the Joint Research Centre of the EC, also highlighted the scarcity of the conventional data needed to support modelling on account of the lack of funding for labour-intensive data collection efforts. This can compromise calibration efforts for models based on remote sensing data, such as those regarding crop yields, waste or food scarcity. Improving coherence between the variety of different bodies that collect data will help to identify and mitigate gaps in our knowledge. Another solution is to utilise development projects as a means of gathering data from traditional sources, e.g. providing smartphones to villagers in remote areas with a targeted purpose such as photographing the measurement on an air quality meter.

In many cases, however, big data is enabling us to train models against past datasets and thus improve their predictive accuracy. Such models can be used to help companies understand uncertainty and make better-informed decisions. For example, Dr Matthew Smith has helped develop a model that improves the agricultural sectors understanding supply and demand uncertainty and hence minimises waste.

In the environmental sphere, the timescale required for analysis is limited. Although projects can now extrapolate statistics from the past decades, the current pace of change can be so extreme in vulnerable areas that research is not always able to keep up. To ensure that critical areas are monitored by modelling and addressed by policy, more multidisciplinary institutes and researchers are needed so that experts in the correct fields are deciding which data are collected and how models are shaped.

Taking an experimental approach

Cities can produce a vast amount of data that could be used to drive experimental policy approaches. Interventions can be applied to different sectors and monitored to test their effectiveness in real time. In Singapore, for example, the Travel Smart Rewards scheme was launched in 2012 for their metro system. Using data generated from travel cards, akin to London's Oyster cards, the transport authority incentivises commuters with small cash rewards for altering their travel patterns to alleviate rush hour pressures on the transport system. As part of an experiment, these cash rewards can be used to play games for larger prizes which further incentivises public engagement with the programme. Randomised controlled trials also test how people respond to disruptions and changes in their normal route. These tests are improving the Transport Authority's sense of what people can do and what they might do under different circumstances. Such systems can be used to 're-learn' what people need from their transport infrastructure week-by-week and day-by-day.

There can be ethical concerns about using real-life systems for experimentation. To mitigate such concerns slack and redundancy must be built into a system so that if an experiment is unsuccessful negative consequences can be avoided. Experimentation can come up against ideological and political resistance, often in the form of a fear of failure. There is often a preference to follow a directive based on a vision rather than to use experimental data to find the best approach. Accepting that there are weaknesses that need to be examined in crucial services such as policing or education can also be politically damaging, particularly if there is a perception that access to services is unequal.

> ***"The city is an ideal lab for trying out experiments with big data."***
>
> Mark Kleinman
> Greater London Authority

Limitations

Although it can be tempting to see big data as some sort of panacea, the analytical and scientific base is still needed to inform how and when big data is used. Large datasets are an increasingly powerful tool, but will not tell us everything we need to know to confront the variety of challenges facing humanity. For example, Hildegarde Diemberger, Senior Associate in Research at the Mongolia and Inner Asia Studies Unit, pointed out that cultural or historical factors are very difficult to model but can be crucial in assessing people's behavioural patterns or how they may be impacted by change.

The time and cost requirement for combining different datasets, such as static data from surveys and dynamic data from real-time sensors, needs to be justified and not become simply a means for private companies to generate revenue by implementing data-collecting services that are not cost efficient. Emily Shuckburgh, Deputy Head of the Polar Oceans Team at the British Antarctic Survey, also highlighted the challenge generated by the mushrooming complexity and uncertainty of large datasets and the difficulty in simplifying that information into useable responses at a local level.

Big data will only be as reliable as the various sources and sensors that contribute to its collection. If cities are filled with different instruments for gathering information, this can pose problems with regards to maintaining and renewing these networks. Dr Miles Parker, Associate Fellow at the

Cambridge Centre for Science and Policy, warned that, in some cases, the large volume of subcomponents gathering

Testing transport network resilience

Professor Michael Batty of the Faculty of the Built Environment, University College, London, provided the example of a large, unstructured dataset in the form of three months of Oyster card readings from Transport for London (TfL), the equivalent of about a billion records. Although not large in the context of big data, such a dataset required special techniques, and TfL themselves did not have the resources to devote time to analysing this data, so it was passed on to academics.

The three-month period covered the 2012 Olympics, and TfL were interested in the resilience of their system and how it would cope with the increased strain from extra visitors to London. Michael's team constructed a synthetic week as a baseline to discern how disruptions, such as major line closures, affected commuters and how they adapted to these disruptions.

Although the data provided good coverage (about 85% of travel in London), it is heavily unstructured. Owners of multiple Oyster cards or instances where tapping a card is not required, for example, would distort the data. TfL are very conscious of confidentiality so the dataset could not be used to understand the demographics of travellers. Also, the dataset did not provide information about what people did once inside the station, meaning there is an incomplete picture regarding travel.

data will lead to different rates of renewal which, in turn, can lead to different levels of accuracy and may constrain system-wide planning. There is also a risk that there might be a lack of precision in the data. For example, climate measurements consist of very small changes so precision will be important to build up an accurate picture. Similarly, data collection and accuracy is subject to global pressures such as government finance being reduced, infrastructure not being maintained or a lack of political will. This can lead to techniques being forgotten and gaps in the quality of data emerging. The long-term benefit of data collection needs to be assessed so that strategies for maintaining standards are devised.

There is a danger of wasting effort collecting data for its own sake, rather than for a clear strategic research purpose. Although computational resources are becoming more efficient, a preoccupation with accruing terabytes of data for relatively little reward in terms of information creates its own inefficiencies. Collecting and analysing new data can be expensive, so there needs to be a structure and a strategy behind the decisions made by researchers. Dr Drew Purves, a research scientist at Google's DeepMind, also warned of losing the benefit of data by not making it easily accessible to those who could use it best. In most cases, particularly in a Western context, this is down to institutional rather than technological barriers.

By the same token, there will be times where we do not yet know the use of data, or perhaps collection of big data will serendipitously fuel new research questions or solutions. When data are collected, it needs to be done in a sensible fashion, with metadata that will document the provenance and methodology behind the dataset. This will ensure that even if we are currently unable to find a use for the data, future generations can.

One of the remaining issues with regards to the analysis of big data is that there are certain research avenues that carry more resonance culturally. Jon Hutton, Director of the United Nations Environment Programme World Conservation Monitoring Centre in Cambridge, attributed the problem to the human and the institutional end of the equation. Repeating tasks or working with old data may be necessary but does not suit the current competitive funding environment that operates in short cycles and understandably valorises novel projects. The short timescales of research projects are not always conducive to long-term products and this can lead to more challenging ideas that may have a greater long-term use falling by the wayside. We sometimes need to use traditional sources of data and there is a need to incentivise different ways of researching by changing the priorities of funding bodies so that the attraction of new big data sources does not lead to research gaps in other corresponding areas. Stephen Peedell, observed that often data are already available but fragmented. There will be a diversity of data, a lack of standardisation and a lack of cooperation as to how the data should be shared. There are not enough resources currently to quickly overcome these issues and turn data gathered from non-coordinated approaches into a useable tool. In particularly, more data analysts need training to process big data, especially those with additional knowledge of the subject area in question. Techniques such as machine learning could prove vital to combat this problem.

Finally, the potential of big data as a tool will not be fully realised without planning systems that can incorporate dynamic data and dynamically changing models. If real-time data are presented in a manner that can be easily visualised, political frameworks need to be able to keep pace with the change. While there is a need for caution regarding largescale projects, if decision-making is based on a static point in time then by the time of implementation the reality may well have changed, rendering the original decision incorrect or irrelevant.

Research challenges on the horizon

The proliferation of data collection and rapid technological advances makes it difficult to predict what will happen next in the realm of big data, even over a short time period. There are manifest opportunities for improved, dynamic monitoring, testing policy approaches through enhanced modelling and providing better evidence for informed decisions on short and long-term timescales. However, the challenges surrounding big data are likely to be institutional and 'human', reflective of wider societal issues such as legal frameworks and economic models. Promoting free access to and responsible use of big data in a way that promotes sustainable global development and individual equality is a societal barrier that is likely to overshadow any technological difficulties. Finding models that collaboratively combine governmental, academic and commercial resources and encourage the effective and efficient use of big data for globally sustainable purposes is the key research challenge.

The Cambridge Forum for Sustainability and the Environment.

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We would like to thank everyone who took part in Forum meetings to discuss our four key topics, especially the expert witnesses and guests who joined us from across and outside Cambridge:

Sustainable Cities
Prof. Alan Short (Dept. of Architecture); **Prof. Sir Alan Wilson** (University College, London); **Alex Nickson** (Greater London Authority); **Prof. Ash Amin** (Dept. of Geography); **Dr Britt Baillie** (Centre for Urban Conflicts Research); **Carmel McQuaid** (Marks and Spencer); **Prof. Catharine Ward Thompson** (University of Edinburgh); **Dr Craig Davies** (European Bank for Reconstruction and Development); **Dr David Ogilvie** (MRC Epidemiology Unit); **Dr David Pencheon** (NHS Sustainable Development Unit); **Diane Haigh** (Allies and Morrison, Architects); **Dr Felipe Hernandez** (Dept. of Architecture); **Dame Fiona Reynolds** (National Trust); **Prof. Frank Kelly** (Dept. of Pure Mathematics and Mathematical Statistics); **Jo da Silva** (Arup International Development); **Jon Alexander** (The New Citizenship Project); **Kirsten Henson** (KLH Sustainability); **Lawrie Robertson** (Happold Consulting); **Prof. Marcial Echenique** (Dept. of Architecture); **Mark Kleinman** (Greater London Authority); **Prof. Michael Batty** (University College, London); **Simon Marsh** (The Royal Society for the Protection of Birds); **Prof. Steve Evans** (Institute for Manufacturing); and **Prof. Richard Sennett** (New York University).

Land-Use Chang
Alison Mollon (Fauna and Flora International); **Ariel Brunner** (BirdLife International); **Dr Alan Belward** (Joint Research Centre, European Commission (EC)); **Dame Barbara Stocking** (President of Murray Edwards College); **Prof. Charles Godfray** (Oxford University); **Dr Chris Brown** (ASDA); **Dr David Nally** (Dept. of Geography); **Prof. Georgina Mace** (University College, London); **Dr Helen Crowley** (Kering); **Prof. Ian Bateman** (University of East Anglia); **Dr Jon Hutton** United Nations Environment Programme World Conservation Monitoring Centre); **Dr Jon Kirkpatrick** (Lend Lease); **Dr Liz Watson** (Dept. of Geography); **Dr Lucas Joppa** (Microsoft Research); **Michael Ramage** (Dept. of Architecture); **Prof. Paul Dupree** (Dept. of Biochemistry); **Prof. Peter Freer-Smith** (Forest Research and Forestry Commission); **Prof. Tim Wheeler** (University of Reading); **Dr Toby Gardner** (Stockholm Environment Institute); **Prof. Theresa Marteau** (Dept. of Public Health and Primary Care); and **Dr Tinashe Chiurugwi** (National Institute of Agricultural Botany).

Risk and Resilience and Response
Prof. Alan O'Neill (Cavendish Laboratory); **Edgar Blanco** (AnDigestion Ltd); **Prof. Sir Brian Heap** (Smart Villages Initiative); **Prof. Chris Howe** (Dept. of Biochemistry); **Craig Mills** (Vizzuality); **Prof. Danny Ralph** (Centre for Risk Studies); **Dr Drew Purves** (Google DeepMind); **Dr Elisabete A Silva** (Dept. of Land Economy); **Dr Francois Kayitakire** (Joint Research Council, EC); **Dr Heinz Ossenbring**, (Joint Research Council, EC); **Prof. Jaideep Prabhu** (Judge Business School); **Prof. James Jackson** (Dept. of Earth Sciences); **Dr John Mullett** (SOWTech (Sustainable OneWorld Technologies), CIC); **Prof. Michael Batty** (University College, London); **Dr Muhammad Tayyab Safdar** (Centre of Development Studies); **Dr Mukesh Kumar** (Institute for Manufacturing; **Paul Newell** (Met Office); **Dr PB Anand** (University of Bradford); **Dr Rana Pant** (Joint Research Centre, EC); **Rob Mills** (Ofgem); **Rowan Douglas** (Willis Research Network, Willis Group); **Sérgio Freire** (Joint Research Centre, EU); **Stephen Peedell** (Joint Research Centre, EU); and **Thierry Negre** (Joint Research Centre, EU)

Health, Wellbeing and Sustainability
Bee Wilson (Food writer, journalist and historian); **Dr Brent Loken** (EAT Foundation, Oslo); **Prof. Catharine Ward Thompson** (University of Edinburgh); **Prof. Charles Godfray** (Oxford University); **Craig Bennett** (Friends of the Earth (England, Wales and Northern Ireland)); **Dr David Cope** (Royal Botanical Gardens Kew and CSaP); **Dr Dimitris Ballas** (University of Sheffield); **Ellie Robinson** (National Trust); **Dr Gillian Petrokovsky** (University of Oxford); **Laurie Parma** (Dept. of Psychology); **Dr Marco Springmann** (Oxford University); **Prof. Martin White** (Centre for Diet and Activity Research); **Prof. Matthew Gandy** (Dept. of Geography); **Dr Michael Obersteiner** (International Institute for Applied Systems Analysis); **Dr Peeter Pärt** (Joint Research Council, EU); **Ron Bakker** (PLP Architects); **Dr Scott Hosking** (British Antarctic Survey); **Prof. Sumantra Ray** (MRC Elsie Widdowson Laboratory); **Prof. Tim Lang** (City, University of London); and **Prof. Theresa Marteau** (Dept. of Public Health and Primary Care).

For more information about Forum meetings or these themes and events, please contact Dr Rosamunde Almond (r.almond@damtp.cam.ac.uk)