LeMO Synthesis Report

November 2017 – October 2020

Leveraging Big Data to Manage Transport Operations

Deliverable 6.3

Contact information:

For enquiries about the project please contact the project coordinator

Rajendra Akerkar

LeMO Project Coordinator

Western Norway Research Institute

Sogndal, Norway

URL: bigdata.vestforsk.no

E-mail: rak@vestforsk.no

Horizon 2020 Research and Innovation Programme

MG-8-2-2017 - Big Data in Transport: Research opportunities, challenges and limitations

The consortium consists of:

Vestlandsforsking (Western Norway Research Institute), Norway

Confederation of Organisations in Road Transport Enforcement (CORTE), Belgium

Bird and Bird LLP, Belgium

Panteia B.V., The Netherlands

Johann Wolfgang Goethe-Universitat Frankfurt Am Main, Germany (*until March 2020*)

Disclaimer

This report is part of the LeMO project which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 770038.

More information on the project: lemo-h2020.eu

EXECUTIVE SUMMARY

Big Data at its core is precisely the collection of enormous amounts of data from hundreds of sources such as: operation systems, weather reports, customer interactions, social media, vehicle diagnostics, mobile devices, and online activity. Recent developments in the quantity, complexity and availability of data collected from and about transport, together with advances in Information and Communication Technology (ICT), present new opportunities to create more efficient and smarter transport systems for both people and freight. Furthermore, “opening up” data in transport by making it more widely available and linking it to data from other sectors, is also a fundamental part of the European strategy concerned with improving transparency and encouraging economic growth.

Big Data has opened a wide spectrum of opportunities in the field of transport research. Several challenges will constitute opportunities for researchers (as well as the industry) in the foreseeable future. In observing the recent growing interest in the application of Big Data within transport science as well as the widened scope of its applications; it is evident that most of the challenges have yet to be addressed.

Leveraging Big Data to Manage Transport Operations (LeMO) project addressed these issues by investigating the implications of the utilising Big Data to enhance the economic sustainability and competitiveness of the European transport sector. The project consortium studied and analysed Big Data in the European transport sector in particular with respect to five transport dimensions: mode, sector, technology, policy and evaluation. LeMO accomplished this by conducting a series of case studies, which were pre-cursors to providing recommendations on the prerequisites of effective Big Data implementation in the transport field.

Pertinent methodological, technological, governmental, and institutional issues were investigated in seven case studies, which in turn contributed to evidence-based decision making. These case studies were supplemented with a horizontal analysis in order to identify the barriers and limitations of the transportation system to exploit Big Data opportunities. In consultation with an Advisory and Reference Group (ARG), and expert stakeholders, LeMO devised a research and policy roadmap which sets out the necessary incremental steps towards data openness and sharing to make transport safer, more efficient and more sustainable. Notably, LeMO brought crucial issues linked to privacy, data security and legal

aspects to the forefront, paving the way for a future legal framework for the collection and exploitation of Big Data in transport.

The LeMO consortium disseminated the project findings to a large population of stakeholders, including transport authorities and industries, which has led to a better understanding of travellers' and consumers' behaviour, targeted information and the identification of policy interventions.

TABLE OF CONTENTS

INTRODUCTION

LeMO context

As the global population becomes more and more urbanised, cities grow more congested. As a consequence, the travel behaviour and transport preferences of city dwellers are changing. Transport researchers and policymakers are therefore faced with numerous challenges as they strive to create efficient, safe and sustainable transportation systems.

In order to address these issues, the EU-funded project LeMO (Leveraging Big Data to Manage Transport Operations) was launched to explore the opportunities provided by Big Data in the field of transport research. It investigated the implications of using Big Data to enhance the European transport sector's economic sustainability and competitiveness. Big Data applications in the transport sector have received a lot of interest at national and EU level, both for their potential to drive future economic growth and also because of the data privacy concerns surrounding their usage. LeMO research and policy roadmap provides incremental steps that are necessary to achieve data openness and sharing to make transport safer, more efficient and more sustainable. Notably, LeMO brings crucial issues linked to privacy, data security and other legal aspects to the forefront, paving the way for a future legal framework for the collection and exploitation of Big Data in transport.

Main objectives

1. To produce a research and policy roadmap towards data openness, collection, exploitation and data sharing to support European transport stakeholders in capturing and addressing issues, which range from technical to institutional, and include legitimacy, data privacy and security.
2. To involve European transport sector actors in order to identify and analyse concrete opportunities, barriers and limitations of the transportation systems in exploiting Big Data opportunities.
3. To disseminate the LeMO findings, recommendations and the contribution of LeMO to evidence-based decision making by improving knowledge on methodological and exploitation issues that also take into account economic, legal, social, institutional and technical aspects.

Use of case studies

The LeMO project performed seven case studies in transport related areas through the course of this project. These case studies involved organisations actively using Big Data for specific purposes and enabled LeMO to understand strategies, actions and changes in behaviour associated with Big Data, and the identification of their resultant merits and demerits. These case studies produced evidence-based, clear and precise questions based on rigorous knowledge that illuminated opportunities, problems and viable solutions to be further investigated in the LeMO roadmap. The identification of these issues complemented by a horizontal analysis to identify challenges, opportunities, limitations and other consequences of cross-disciplinary nature, were thus relevant to Big Data in the transport sector.

Key outcome

Research and policy roadmap including recommendations for identifying and addressing the societal impacts of Big Data, particularly amplifying opportunities and diminishing limitations associated with transport Big Data.

SCOPE AND METHODOLOGY

The pivotal aim of the European Union's Transport policy is to strengthen the existing transport infrastructure, which is crucial to economic development. The improvement in the transport sector should provide efficient logistics of goods, better travel and commuting facilities, and accessibility of the European region.

Technological developments, particularly related to the extended and expanding use of ICT in the transport sector, allows the collection of unprecedented volumes of data across all modes and transport systems. This Big Data has generated a strong interest in the transport research community as well as in the relevant industries and among policymakers.

The landscape of Big Data is changing rapidly, and this momentum pushes the boundary of the definition of Big Data consistently. The LeMO project encompasses **four "Vs" of Big Data with a focus on the transport sector.**

- Volume – This is the most popular and obvious characteristic of Big Data, as the first word of "big" is indicative of this characteristic. There is a massive volume of data collected from millions of vehicles in Europe, social data, sensor data, etc.
- Variety – The differences within the industry standards, sampling rates, and data types such as video, JSON (JavaScript Object Notation), XML (Extensible Markup Language), pictures, text and more.
- Velocity – The high arrival of rate data, for instance, sensor data, weather data, GPS (Global Positioning System) generated data, social media messages, and data generated from vehicle onboard devices etc.
- Veracity – The potential for missing or erroneous data due to environmental conditions, unreliable data sources, equipment failures, or malicious intent etc.

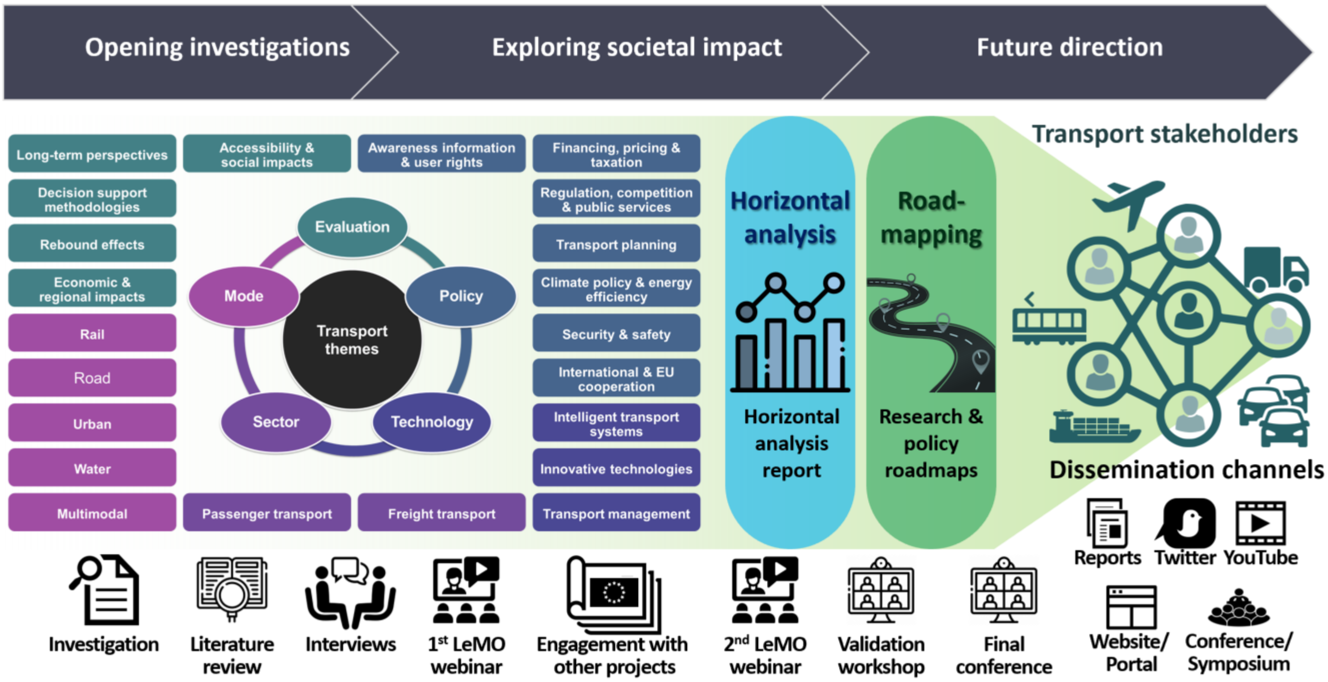

Figure 1 The LeMO overall methodology

To meet the current needs, the LeMO project aimed at providing a comprehensive view to amplify opportunities, while diminishing limitations. The LeMO project consists of three phases. Phase 1 investigates the role of Big Data in the transport sector and identifies institutional and governmental issues. Phase 2 explores the societal impact of comprehensive case studies based on the findings of Phase 1. The findings of Phase 1 and 2 will feed into exploring the future direction in Phase 3. The created value from all three phases was disseminated via various channels in parallel.

OVERVIEW OF WORK CARRIED OUT

Opening investigations

The Big Data in the transport sector that can be used to create additional value is identified and categorised in deliverable D1.1. It started by identifying the different data types (the *variety* characteristic) used by various use cases in the transport sector. Following on from this, the data types and use cases were mapped to relevant Big Data technologies that can be successfully employed in the data transformation (the *velocity* characteristic) and storage (the *volume* characteristic) process. We also mapped data as a resource on a European and international scale, examining where data originates, where it flows and where it is being processed. It examined which countries, industries, actors and companies are deriving economic and other benefits from Big Data internationally, as well as which regions, companies and actors are losing out. The goal was to produce a graphical representation of Big Data flows that can be used to examine Member State and third-country policies so as to readily determine which policy contexts warrant further examination.

In the different transport areas, policies and initiatives have been developed in the EU to support the access, (re-) use, linking and sharing of data. Preceding and in light of these developments, the private sector has also moved ahead to incorporate the use of Big Data techniques into their own business models as process or product innovations.

The development of a policy roadmap to foster the growth of Big Data in transport requires an understanding of how existing policies affect the economic, political, social and legal environment for government and private agencies in the transport sector. The work presented in deliverable D1.2 highlighted the status of the policies which are undertaken and promoted in the public and private sector to further their agendas in relation to Big Data in the transport sector.

Several Big Data platforms have been proposed recently: open source and proprietary. In order to tackle the demands and challenges in the transportation domain, an optimal stack of Big Data technologies needs to be selected and designed based on the application requirements. The deliverable D1.3 offered an in-depth introduction to relevant technologies for Big Data Analytics and Big Data Management. It also looked at how these technologies are applied to build a Big Data Platform suitable for the transport sector. We presented in detail how application-specific benchmarking can be used in order to evaluate which Big Data technologies are most suited for the domain. We concluded the investigation with an applied example of using data analytics for urban mobility.

Next we embarked on a broad brush examination of the different institutional and governmental issues that are relevant to Big Data currently, and which may be relevant to Big Data as opportunities for the production of, access to, linking of and re-use of Big Data further develops. Primarily, deliverable D2.1 is aimed at revealing the wider economic and political issues involved with utilising Big Data by elaborating on the interaction between transport actors (demand-, supply-, external- and governance actors) and their role in the data economy (as data users, suppliers or facilitators). Subsequently, the interaction between these actors on various levels is described below.

- On the **firm level**, private parties use Big Data for improved situational awareness of the transport system, improving the capacity of transport networks, improving transportation services and facilitating the shift to sustainable transport.
- On the **industry level**, the data economy is expected to grow rapidly in the coming years. While the EU data economy remains to be in a deficit compared to the US regarding structural factors (fewer data SMEs), cultural/educational factors (ability to create and keep data-related skills), and the presence of IT giants, there is a healthy presence of digital start-ups and innovation capacity.
- On the **national level**, governments utilise Big Data in improving organisational performance and in-service provision and policy making. Subsequently, Big Data is applied in transport related government tasks, including transport planning, traffic monitoring and public transport provision.
- On an **international level**, governments want to control data flows to limit the negative consequences of data, e.g. preventing the misuse of personal or classified data. Another reason is to facilitate the fulfilment of their tasks as supervisor, e.g. demanding local storage of tax or gambling data to simplify control routines.

Having discussed this, the most critical challenges for the future identified in the D2.1 are:

- Lack of data professionals, in particular within governments

- Government compartmentalisation, limiting optimal data usage by governments
- An insufficient framework that satisfies both the user demand for privacy and the usage of personal information for business innovation. This is particularly relevant for public-private data sharing schemes
- Too little awareness on the capacity of Big Data, as "bad" Big Data analysis happens quickly, i.e. too little knowledge on what transport-related questions it can and cannot address, and how Big Data should address these questions.

Deliverable D2.2 identified and examined various legal issues that are relevant to the production of, access to, linking of and re-use of Big Data in the transport sector. The comprehensive report came up with notable findings summerised as follows:

- **Privacy and data protection**: Some concepts, principles and obligations under data protection law appear to be problematic for the uptake of Big Data. In particular, the broad definition of "personal data" and "processing", the qualification of the various actors involved as (joint-)controllers or processors, the core data protection principles, the need to identify a ground for processing, the requirement to conduct data protection impact assessments, the implementation of privacy by design and by default measures, the rights of data subjects, and the requirement to put in place adequate data transfer mechanisms seem difficult to reconcile with the concept of Big Data.
- **(Cyber-)Security**: The requirement to put in place security measures is imposed in various legislations at EU and national level, including key instruments like the GDPR and the NIS Directive. However, such legislative framework remains rather general and vague as to which specific measures are deemed appropriate. In order to comply with this requirement, organisations involved in Big Data analytics generally need to rely on security experts and take into account the evolving guiding documents published by authorities such as ENISA. Relying on certification mechanisms, seals, marks, and codes of conduct will enable companies complying with their legal obligations and demonstrate their compliance.
- **Breach-related obligations**: The various actors of the (Big) Data value chain need to implement measures, procedures and policies to abide by the strict notification requirements and be prepared to provide the necessary information to the authorities, within the imposed deadlines. Such requirements will also need to be adequately

reflected in the various contracts between the stakeholders involved in the chain in order to adequately address any incident that may occur.

- **Anonymisation/pseudonymisation**: Anonymisation and pseudonymisation techniques generally provide fertile ground for opportunities with respect to Big Data applications, including in the transport sector. Nevertheless, a balance will need to be struck between, on the one hand, the aspired level of anonymisation (and its legal consequences) and, on the other hand, the desired level of predictability and utility of the Big Data analytics.
- **Supply of digital content and services (personal data as counter-performance)**: Personal data as a form of payment for the supply of digital content is an emerging reality. In this respect, the proposed EU legal framework on the supply of digital content and services will ensure an adequate level of protection for the consumer. Nevertheless, the obligations concerning data may make some current digital services inoperable. Some companies may also start to charge for digital content services that are currently free. On a wider scale the ecosystem of innovative services in the field of transport could be jeopardised.
- **Free flow of data**: The free flow of data presents a scenario in which no legal barriers hinder the cross-border flow of data. Such cross-border data flows may be restricted by data localisation requirements, which come in many shapes and forms. The new EU Free Flow Regulation should ensure the free flow of data across EU Member States, ensure data availability for regulatory control by EU authorities, and encourage the creation of codes of conduct for cloud services. The elimination of data localisation requirements is expected to create more innovation, which will positively impact Big Data analytics in the transport sector.
- **Intellectual property in Big Data environment**: All intellectual property rights examined may have, to some extent, an impact on the use of Big Data, including in the transport sector. Depending on the manner in which and the extent with which a right holder may exercise its exclusive rights attached to the intellectual property right concerned, intellectual property rights may pose a barrier to data access, interoperability, and exploitation.
- **Open data**: The EU institutions have taken both legislative and non-legislative measures to encourage the uptake of open data, most notably through the PSI Directive which attempts to remove barriers to the re-use of public sector information throughout the EU. Open data is a key component of most Big Data applications. A proposal for a revision of the Public Sector Information Directive (PSI) intends to extend the scope of application

to public undertakings, including actors in the transport sector such as ports and airports, public passenger transport services by rail and by road, and air carriers and EU ship owners fulfilling public service obligations.

- **Sharing obligations**: While private companies often generate huge amounts of data, they are not always prepared to voluntarily share this data outside the company. This is due to the large number of legal, commercial and technical challenges associated with private sector data sharing. In certain circumstances, private companies are therefore legally required to share their data. This Deliverable succinctly examines the body of legislation specific to the transport sector that could impact a company's control of, the access to, or the rights in data. The analysis has shown that data sharing obligations are increasingly adopted in the context of Intelligent Transport Systems.
- **Data ownership**: In a Big Data context, different third-party entities may try to claim ownership in (parts of) a dataset, which may hinder the production of, access to, linking and re-use of Big Data, including in the transport sector. This deliverable demonstrates however that the current legal framework relating to data ownership is not satisfactory. No specific ownership right subsists in data and the existing data-related rights do not respond sufficiently or adequately to the needs of the actors in the data value cycle. Up until now, the only possible solution is capturing the possible relationships between the various actors in contractual arrangements, i.e. data sharing agreements.
- **Data sharing agreements**: It is unclear whether the common practice to use data sharing agreements to govern the access to and/or exchange of data between stakeholders in a Big Data analytics lifecycle enables covering all possible situations with the necessary and satisfactory legal certainty. Data sharing agreements entail numerous limitations in the absence of a comprehensive legal framework regulating numerous rights (e.g. ownership, access or exploitation rights) attached to data, the way in which such rights can be exercised, and by whom.
- **Liability**: The EU institutions have looked into and continue to examine issues related to extra-contractual liability, statutory liability, and safety requirements in the context of disruptive technologies, including in the transport sector. Based on their continued efforts, it will be possible to determine whether any regulatory intervention is required. The contractual liability legal framework, which differs across the EU, may however limit the uptake of new technologies, including Big Data in the transport sector. The present deliverable further looks into the relevance for Big Data in the transport sector of the exemption of liability for intermediaries (the so-called safe harbour regime), and the

proposed liability regime for suppliers of digital content and services under the Draft Directive on the Supply of Digital Content.

- **Competition**: Assessing the market conduct of companies with access to large volumes of data raises complex issues under competition law. The difficulty of the exercise is compounded by the fact that the analysis also needs to take into account data privacy and consumer protection issues that are intimately linked to the questions under competition law. The present deliverable considers three main areas in which competition law may have an impact on the use of Big Data. In view of the important role of Big Data in the transport sector, the deliverable discusses the competition law issues that could arise with respect to organisations belonging to the broadly-defined “transport sector”.

The several improvements suggested by the D2.2 vary between the different legal issues and range from avoiding restrictive interpretations by the relevant authorities or courts, over soft law measures (such as guidelines and codes of conduct), to regulatory intervention at EU level.

The subsequent deliverable D2.3 explored various societal and ethical issues that are relevant to the production of, access to, linking of and re-use of Big Data in the transport sector. The detailed report offered the following notable findings:

- **Trust**: Although the research in trust has already become relatively mature, the huge amount and diversity of data and data sources provides lots of new opportunities but simultaneously poses many challenges for online trust, notably in the context of transportation.
- **Surveillance**: Considering the role of government agencies and their increasing requests of information to the private sector for public security purposes, it appears necessary to adopt specific rules to regulate the information flow, to define the rights over data and to ensure adequate enforcement.
- **Privacy** (including **transparency**, **consent** and **control**): The advent of the GDPR has had a considerable impact in the domains of privacy, transparency, consent and control. This strengthened legal framework is likely to respond to several ethical issues and thus improve end-users' trust in the use of personal data in a Big Data context.
- **Free will**: Although Big Data-driven profiling practices can limit free will; a huge part of what we know about the world comes from data analysis. Careful and appropriate

information analysis can open up plenty of chances and might reduce the limitations and problems for free will.

- **Personal data ownership**: This deliverable concludes that a claim of ownership by a data subject in its personal data would be hard to sustain. Nevertheless, in a Big Data context, different third-party entities may try to claim ownership in (parts of) a dataset, which may hinder the use of Big Data, including in the transport sector.
- **Discrimination**: Using Big Data analytics to improve business processes or provide personalised services may lead to discrimination of certain groups of people. Also, the "Digital Divide", i.e. the social differences in access to technology and education or skills to use it, may lead to data-driven discrimination.
- **Environmental**: There are trade-off or rebound effects from the use of Big Data in transport, which limits the effect of Big Data exploitation or creates unintended consequences. Such trade-off or rebound effects further assessed in deliverable D2.4.

In the context of ethical and social issues, we broadly distinguish two types of remedial actions: (i) regulatory intervention, i.e. by means of legislation, standards or soft law; and (ii) design, i.e. by ensuring that systems or applications are designed in such a way that the decisions they take are ethical.

The deliverable D2.4 provided an introduction to the concept of rebound effects. In LeMO, the rebound effect is defined as *the difference between the expected and observed environmental impacts from new technologies aiming at efficiency improvements.*

Different types of rebound effects are addressed. This encompasses direct and indirect rebound effects, as well as society-wide, or overall rebound effects. Different application areas of rebound effects are presented. They cover rebound effects in connection with energy efficiency measures and climate gas reduction measures, as well as in connection with measures aimed to reduce other environmental pollutants. A critique of the rebound effects is also described. We then turned to strategies to mitigate the rebound effect and suggested approaches for assessment of rebound effects from the use of Big Data in transport.

Exploring societal impact

In the second phase of LeMO, seven case studies were conducted. Besides developing a deep understanding of the Big Data technology and its business applications, the case studies also presented an analysis of the issues that serve as "opportunities" and "barriers" to the implementation of Big Data, as well as the resulting outcomes of the implementation. These issues were analysed using the knowledge developed in Phase 1 of the LeMO project, from economic, political, social and ethical, legal, and environmental perspectives.

- **Case study 1** focused on the application of Big Data technologies in predictive maintenance in rail transport. The digitalization of train and rail infrastructure operations produces valuable data, which when analysed with the right Big Data technologies, can improve the prediction of potential train-related failures and the precision of maintenance schedules, thus improving overall safety and fleet availability. As rail transport forms the backbone of the transport strategy of many Member States in the EU, any promising improvement in railway operations will have a considerable positive impact on the EU as a whole.
- **Case study 2** explored the opportunities and challenges of successfully making Big Data available as open data. Open data is an important policy objective and strategy of the European Commission to support research and innovation in the field of transport. While it may seem simple to implement, making Big Data open entails many technological and organisational challenges, especially when economic incentives are lacking. Initiatives on open data are currently championed by transport authorities and organisations that rely on data, especially to keep up with customer demands and to provide innovative transport services through real-time and precise transport information.
- **Case study 3** delved into the real-time traffic management which is one of important components in Intelligent Transport Systems (ITS) that rely on Big Data analytics. ITS and the emerging field of C-ITS (Cooperative Intelligent Transport Systems) is effective in dealing with many challenges of managing road traffic, as well as in dealing with the emergence of connected and automated vehicles. While many transport management systems in Europe produce a wide variety and volume of data, there is still an untapped potential for the widespread use of Big Data techniques to improve traffic flows.
- **Case study 4** provided an in-depth description and analysis of the use of Big Data to support logistics processes in an era where customer and supply chain requirements are stricter and more varied. The study was based on the very advanced and successful company Kepler51, which is based in the USA. The case study presented their Big Data solution that monitors, assesses, and forecasts transport risks and delays along the transport chain. However, their application, which focused on non-vehicle data as a

primary source, does serve to illustrate some of the potential benefits and risks facing transport carriers in Europe when considering the use of Big Data technology.

- **Case study 5** introduced a unique application of Big Data to coordinate the traffic of both the road and inland waterway network in the Netherlands. Coordination of inland waterways is an important topic in the Netherlands, especially since the network intersects with the road network at bridges. The major challenge faced was the political challenge to organise the collaboration between powerful governmental bodies and port authorities. But, once the initial challenge was met, the benefits of the programme were acknowledged, spurring replication in other parts of the Netherlands. While other countries in the EU may not have a similar application (i.e. the integration of the road and inland waterway network), the lessons learned in this case provide important clues as to the organisational challenges of multi-stakeholder large-scale project implementation.
- **Case study 6** presented the application of Big Data technology and analysis methods to provide a multimodal public transport information and route planning service to passengers. The challenge has been to develop a service that provides real-time information to passengers, while preserving the brand and identity of the individual public transport operators. This also offers an important opportunity for identifying an alternative to current non-European service providers that reduce the digital autonomy in Europe, thus leading to an imbalanced market. The service discussed in the case-study supports improved mobility and customer experience by providing effective route planning by combining open data from various sources. It also intends to further improve its product in the future by combining data collected from end-users (e.g. through data from fare cards), but this seems difficult on account of privacy concerns expressed by end-users. The case serves as an important source of knowledge about the issues that many cities are facing in terms of both improving the multimodal transport information services as well as route planning, especially in the context of disruptive and innovative transport services (e.g. scooter sharing).
- **Case study 7** presented the challenging and disruptive on-demand urban mobility services sector. A disruptive technology company working in the heavily regulated urban transport sector needs to be innovative in order to tackle the challenges of policy, a small customer base, and the competition with established firms. Furthermore, the technologies supporting the activity have to be very reliable and attractive so that new customers easily become regular customers. The case described a spin-off from an

established company aiming to cover the gaps in their existing services. Big Data, especially open data, empowers the start-up to provide niche services that fill the gaps in the existing public transport system.

These case studies, as described in the deliverable D3.2, supplied a realistic view of the opportunities and benefits provided by Big Data in the specific domains. However, they also brought to light many challenges that must be overcome for a successful and sustainable improvement of the transport sector using Big Data. The issues highlighted must therefore be carefully addressed via policy at the right governmental levels and via further research to improve the technical application of the technology. The LeMO consortium used the results of these case studies in the next phase of the project to perform a horizontal analysis and road-mapping.

Future direction

In the third phase of LeMO, at first, we uncovered different barriers to the utilisation of Big Data in the transport sector and their characterisation. We also explored whether these barriers currently occur in the real-world or not. We extracted a total of 129 barriers (and limitations) from the various aspects and identified 54 from the LeMO project case studies, the NOESIS project use-cases and the TransformingTransport project pilot systems. These observations are reported in the deliverable D4.1 and further used to perform a horizontal analysis in deliverable D4.2 and to produce constructive findings and recommendations for successful Big Data implementation in the transport sector in deliverable D4.3. The horizontal analysis exemplified that Big Data does not stand for the same practice in every case study domain but covers a wide variety of datasets and data practices and the technical challenges these present. Mapped across the Big Data value chain the technological/policy and legal/social and ethical/economic and political challenges raised in the case studies are mostly observed in the data collection and data curation, and to a lesser extent in the data usage phase.

Finally, the LeMO roadmap is devised in two sections: namely a research roadmap focused on identifying the research priorities at stake, and a policy roadmap providing a set of recommendations to build a policy framework which will ensure that the European transport sector can make the most out of the data transition.

Overall, the LeMO roadmap offered in deliverable D4.4 contains eleven research actions and thirteen policy actions, which are spread over eleven themes. These actions are designed to improve the data economy in the transport sector and provide a source of inspiration for further research in this area. This roadmap culminates with a suggestion for the implementation of the actions.

RECOMMENDATIONS

An overview of the policy and research actions identified in LeMO and which are part of the roadmap are shown in Figure 2 (LeMO infographic). These actions are intended to serve as a guide to improve the data economy in the transport sector and as a source of inspiration for further research in this area.

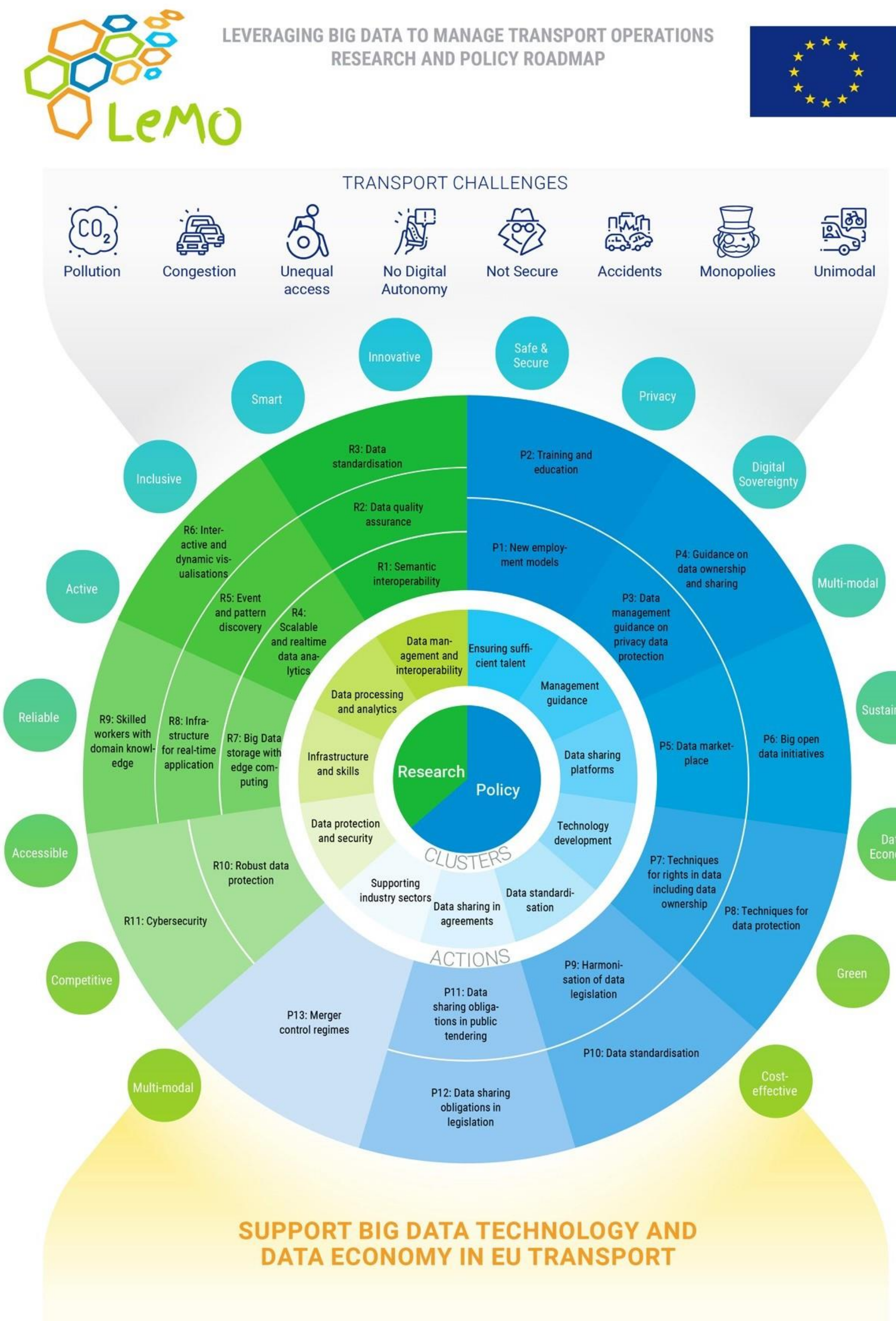

Figure 2 Overview of the 11 research actions and 13 policy actions

EXPECTED IMPACT OF LeMO

The anticipated impact of the LeMO project will be on transport stakeholders and broader society, through the development of the research and policy roadmap which will assist stakeholders diminish barriers and limitations, and amplify the opportunities associated with Big Data in the European transport sector. The LeMO project gathered evidence of barriers, limitations and opportunities across a number of vital transport modes to support these key impacts.

Strategic impacts – Provide research and policy recommendations to assist stakeholders.

Economic impacts – Assist European stakeholders in gaining a greater share of the Big Data market by 2025.

Social impacts – Provide recommendations that will assist stakeholders to diminish the negative social impacts associated with Big Data in the transport sector.

CONCLUSION

The use of Big Data in the transport sector is relevant for governments (e.g. traffic control, planning and modelling, route planning and congestion management), for the private sector (e.g. travel industry, route planning and logistics, and competitive advantages) and for individuals (e.g. route and travel planning). Big Data has opened a wide spectrum of opportunities in the field of transport research. Several challenges constitute opportunities for the industry and scientists in the foreseeable future. The LeMO roadmap for Big Data in transport in Europe focuses on ensuring the crucial conditions for the development of a European Big Data in the transport ecosystem based on the research outcomes of the project.

The LeMO roadmap is divided in two sections. The research roadmap focuses on identifying the research priorities at stake, and the policy roadmap provides a set of recommendations to build a policy framework which will ensure that European transport sector can make the most out of the data transition. The policy roadmap is more concerned with policies that will resolve economic and political challenges together with legal, social and ethical issues. This highlights technology innovations which are usually neutral until they become embedded in larger social systems. Consequently, the policy roadmap focuses on the digital single market, cross-border data arrangements, government services, public investment and resource management. The research roadmap focuses more on technological resources and capabilities. The LeMO research and policy roadmap is oriented towards a range of different stakeholders which will be prepared to consider their contributions to these policy and research actions, including policymakers, civil society organisations, institutions, business and industry bodies and academics.

The LeMO roadmap culminates with a suggestion for the implementation of the actions. The results of one of the surveys provides a basis for this. Some of the actions identified in the roadmap have a higher priority than others for certain reasons. LeMO's goals can be achieved more quickly if research and policy focus on actions that are more of a priority than others, have a higher impact or are easier to implement.

ANNEX 1 – List of LeMO Deliverables

Deliverable D1.1 Understanding and mapping Big Data in transport sector

Deliverable D1.2 Big Data policies

Deliverable D1.3 Big Data methodologies, tools and infrastructures

Deliverable D2.1 Report on economic and political issues

Deliverable D2.2 Report on legal issues

Deliverable D2.3 Report on ethical and social issues

Deliverable D2.4 Report on trade-off from the use of Big Data in transport

Deliverable D3.2 Case study reports on constructive findings on the prerequisites of successful Big Data implementation in the transport sector

Deliverable D4.1 Report on the characterization of the barriers and limitations

Deliverable D4.2 Horizontal analysis and socio-economic impacts

Deliverable D4.3 Roadmap - research and policy recommendations for the efficient utilisation of Big Data in the transport field (version 1)

Deliverable D4.4 Roadmap - research and policy recommendations for the efficient utilisation of Big Data in the transport field (version 2) Final

Deliverable D5.1 LeMO website

Deliverable D5.3 Creating Shared Value for the European Transport Sector (version 1)

Deliverable D5.4 Creating Shared Value for the European Transport Sector (version 2)

Deliverable D5.5 Strategy for communication plan beyond project lifetime

Deliverable D5.6 Dissemination Annual Report I

Deliverable D5.7 Dissemination Annual Report II

Deliverable D5.8 Dissemination Annual Report III

Deliverable D6.1 LeMO Project fact sheet

Deliverable D6.2 Progress and status report to the Commission