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The TransformingTransport Project – Mobility Meets Big Data

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Abstract

Big data is expected to have a profound economic and societal impact in mobility and logistics. Examples include 500 billion USD in value worldwide in the form of time and fuel savings, and savings of 380 megatons CO2. With freight transport activities projected to increase by 40% in 2030, transforming the current mobility and logistics processes to become significantly more efficient, will have a profound impact. A 10% efficiency improvement may lead to EU cost savings of 100 billion EUR. Despite these promises, interestingly only few mobility and logistics companies employ big data solutions as part of value creation and business processes.

The TransformingTransport project (http://www.transformingtransport.eu) will demonstrate, in a realistic, measurable, and replicable way the transformations that big data can bring to the mobility and logistics market. Structured into 13 different pilots, which cover areas of major importance for the mobility and logistics sector in Europe, TransformingTransport validates the technical and economic viability of big data to reshape transport processes and services. To this end, TransformingTransport exploits access to industrial data sets from over 160 data sources, totalling 410,000 GB.

Starting with the explanation the structure and aims of the 13 pilots, we provide the key main characteristics of the involved data sets in terms of variety, volume, and velocity. We explain the methodology of the project to achieve replicability and scalability of its results in particular to cope with data volume and velocity. We provide concrete examples for the innovation potential and impact of the project outcomes, including gains in operational efficiency, improved customer experience and new business models made possible when mobility meets big data. We conclude with a critical discussion on data management concerns.

Keywords: Big data; efficiency; customer satisfaction; business models; freight; passenger transport; railways; inland water and sea transport; air transport; logistics

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1 Introduction

The compound annual growth rate of the European big data market over the period 2014 – 2020 may be as high 14.1% (see IDC (2017)). This means the size of the data market is expected to more than double from 2014 to 2020, thus reaching a market size of around 111 billion EUR by 2020. Data-driven innovation has the potential to enhance resource efficiency and productivity, economic competitiveness, and social well-being as it begins to transform all sectors in the economy (e.g., see Cavanillas et al. (2016)). Available evidence shows that companies using data-driven innovation have raised productivity faster than non-users by around 5-10% (see OECD (2013)).

Big Data will have profound economic and societal impact on mobility and logistics. The improvements in operational efficiency empowered by big data are expected to lead to 500 billion USD in value worldwide in the form of time and fuel savings, as well as savings of 380 megatons CO_2 in mobility and logistics (see OECD (2013)). With freight transport activities projected to increase, with respect to 2005, by 40% in 2030 and by 80% in 2050 (see Franklin (2015)), transforming the current mobility and logistics processes to become significantly more efficient, will have a profound impact.

The mobility and logistics sector is ideally placed to benefit from big data technologies, as it already manages massive flow of goods and at the same time creates vast data sets (see DHL (2014)) – a 10% efficiency improvement will lead to EU cost savings of 100 B€ (see Franklin (2015)). Even though there are huge untapped opportunities for improving operational efficiency, delivering improved customer experience, and creating new business processes and business models, only few mobility and logistics companies currently employ big data solutions as part of value creation and business processes (see PWC (2015)). The mobility and logistics sector is ready to exploit big data solutions to significantly increase the EU market in the mobility and logistics sector.

The TransformingTransport project (http://www.transformingtransport.eu) will demonstrate, in a realistic, measurable, and replicable way the transformations that big data can bring to the mobility and logistics market. Structured into 13 different pilots, which cover areas of major importance for the mobility and logistics sector in Europe, TransformingTransport validates the technical and economic viability of Big Data to reshape transport processes and services.

Many large-scale projects[†] have acknowledged the increasingly important role that ICT plays, reflecting the major impact that the digital transformation has on the mobility and logistics sector. Nonetheless, these large-scale projects share the following limitations with respect to the use of big data technologies:

- Many projects address big data from a domain-specific, single mode angle, focusing usually on infrastructures such as rails or roads. Whilst facilitating a focused vertical innovation within particular modes, this limits the potential to develop reusable and multi-modal big data technologies. TransformingTransport is pursuing such multi-modal and modality traversing approach to have large-scale innovation and impact of big data technologies, thereby ensuring that big data best practices can transform data-intensive sectors such as mobility and logistics.
- In many projects, data technologies play – at most – a supportive role, facilitating communication among assets and stakeholders in the mobility and logistics networks. In TransformingTransport big data technologies and their value to the industrial sector take centre stage.

Section 2 briefly introduces the TransformingTransport project and explains the structure and aims of the 13 pilots. Section 3 provides the key main characteristics of the involved data sets in terms of variety, volume, and velocity. Section 4 explains the methodology of the project to achieve replicability and scalability of its results in particular to cope with data volume and velocity. Section 5 provides concrete examples for the innovation potential and impact of the project outcomes, including gains in operational efficiency, improved customer experience and new business models made possible when mobility meets big data. Section 6 concludes with a critical discussion on data management concerns.

[†] Such as the AUTOPILOT, CAPACITY4RAIL, EBSF_2, EfficienSea 2, E-Freight, FIspace, IN2RAIL, INFRAVATION, IT2RAIL, NEXTRUST, OPTICITIES, and SARISTU projects.

2 The Project and its Pilots

TransformingTransport is one of the first two lighthouse projects of the European Big Data Value Public Private Partnership (http://www.big-data-value.eu/), which is funded by the European Commission within the framework of the Horizon 2020 program. TransformingTransport started in January 2017 and brings together knowledge, solutions and impact potential of major European ICT and big data technology providers with the competence and experience of key European industry players and public bodies in the mobility and logistics domain. Altogether, 47 partners from industry, public bodies and academia join forces in TransformingTransport. TransformingTransport partners are from Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, United Kingdom, Spain and Portugal. The TransformingTransport project will run for 30 months in total and has a budget of 18.7 MEUR.

TransformingTransport addresses 13 pilots in seven highly relevant pilot domains within mobility and transport that will benefit from big data solutions and the increased availability of data. The seven pilot domains are shown in Table 1 together with the turnover of the related transport mode and domain. As can be seen, these pilot domains cover areas of significant market size in Europe and thus strongly support the relevance of the chosen pilot domains. The seven pilot domains cover all relevant transport sectors and stakeholders as well as data sources across the whole data value chain.

Table 1: TransformingTransport pilot domain areas and relevance in terms of market size

TransformingTransport Pilot Domain	Related Transport Sector / Market	Market Size (2011; from DG MOVE (2014))
Smart Highways	Road freight & passenger transport	419 326 MEUR
Sustainable Connected Vehicles		
Proactive Rail Infrastructures	Railways	78 354 MEUR
Ports as Intelligent Logistics Hubs	Inland water & sea transport *(+ partially railways and road)*	112 803 MEUR
Smart Airport Turnaround	Air transport	127 394 MEUR
Integrated Urban Mobility	(cross-cutting)	(included in above)
Dynamic Supply Networks	Warehousing and support & postal and courier activities	567 200 MEUR
TOTAL		1 305 BEUR

2.1 Pilot Structure

Within the seven pilot domains, TransformingTransport pursues 13 pilots (see Figure 1). For each pilot, TT will explore innovative use cases and will engage key players in the sector to demonstrate the transformative nature that big data technologies can bring about.

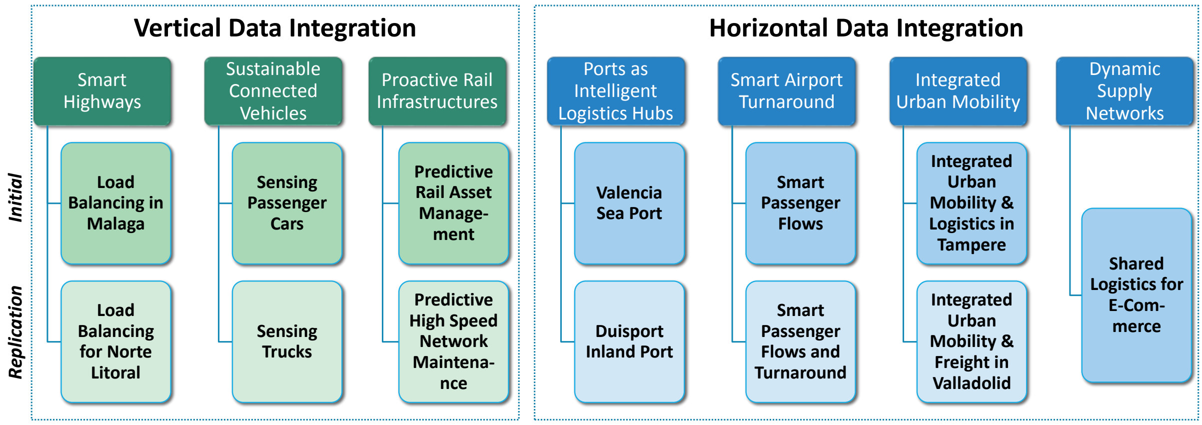

Figure 1: 13 pilots in seven pilot domains

The chosen pilots demonstrate two basic patterns for delivering value from big data:

- *Vertical data integration* means that data assets from different participants involved in a collaborative business process within a transport mode are integrated and made accessible to all participants. As an example, combining data from highway sensors with in-vehicles data (such as GPS position, efficiency, and speed) may enhance the precision of detecting mobility patterns, which in turn is essential for enhanced road traffic management.

- *Horizontal data integration* means that data will be shared and reused across transport modes. There is a visible trend in mobility and logistics towards multi-modal processes, which integrate several transport modes and thus require effective sharing of data across modes. As an example, combining live road and rail traffic information and predictions with information about ship positions and arrival times will allow improving terminal scheduling and operations.

The pilots do not work in isolation but will strongly collaborate and cross-fertilize each other. Starting from common requirements of the pilot domains (such as data quality, data protection and scalability of data processing), experience in applying big data technologies and data assets will be shared among pilots. In particular, outcomes of the vertical pilot domains (focussing on individual transport modes) will contribute to the horizontal pilot domains (focussing on the integration of transport modes).

Each of the pilots will employ dedicated data analytics solutions best suited for the specific pilot needs and datasets. The underlying rationale for not prescribing a single data analytics solutions for all pilots, but allowing the pilots to define their specialized data analytics solutions is the "no free lunch" theorem that emerged in the field of machine learning and analytics (see Wolpert and Macready (1997)). As each data set, domain, and use case may be different, using a single data analytics solution will most probably not work (optimally) in all cases. In addition, each pilot will exploit big data infrastructures, which are best suited and closely linked with the data sources of the pilot.

2.2 Pilot Aims

To provide a better understanding of the ambitions and expected outcomes of the TransformingTransport pilots, Table 2 summarizes the key main aims along the pilot domains.

Table 2: Aims of pilots

Pilot Domain	Aims
Smart Highways	Understand better the road traffic and mobility patterns.
	Optimize highway operations by prescriptive actions and maintenance.
	Guarantee safer roads and make a better use of these roads by analysing accident causes.
Sustainable Connected Vehicles	Proactively notify drivers / fleet managers about needed maintenance tasks of their vehicles.
	Inform drivers / fleet managers about tasks needed for reducing emissions and fuel consumption.
	Notify drivers to avoid traffic congestions.
	Enable truck drivers / fleet managers to reduce buffer times and delay times at ramps/ ports.
	Enable planners to adapt plans according to realistic travel times / ETA-values.
	Provide more reliable routing results and traffic predictions.
Proactive Rail Infrastructures	Improve safety of rail workers by minimising the time spent trackside.
	Improve safety of rail passengers by identifying trends toward asset failure.
	Improve reliability of services by minimising downtime and service interruptions.
	Improve cost efficiency by prioritising maintenance on assets based on a number of factors.
	Improve service capacity by minimising disruption.
	Ensure at all times the level of security for which the infrastructure was designed.
Ports as Intelligent Logistics Hubs	Improve crane scheduling by calculating the optimum sequence of crane movements.
	Prevent unexpected failures of crane spreaders.
	Increase terminal efficiency by proactive management of terminal and port operations.
	Increase robustness of terminal processes by timely response and mitigation of problems.
	Combination of planned and predicted maintenance to reduce outage times of equipment.
	Strategic optimization of equipment usage, configuration.
Smart Airport Turnaround	Reduce delays in departure flights caused by late passengers.
	Reduce the number of passenger missing connections and lost baggage.
	Improve efficiency of passenger processing stations.

Pilot Domain	Aims
	Reduce overall turnaround times.
	Obtain insight on how passenger behave along their journey.
	Enable fleet-wide turnaround optimization.
	Integrate passenger flow as well as ETA prediction models in overall smart turnaround process.
Integrated Urban Mobility	Improvement performance of the urban traffic management to better manage the traffic in the city.
	Improve quality of the information regarding traffic status provided to end-users.
	Improve last-mile logistics by providing possibility to reserve parking areas for goods delivery.
	Improve situational awareness of traffic flow in the city.
	Reduce traffic congestion in the city centre.
	Optimize routes and delivery times taking into account ongoing deliveries.
Dynamic Supply Networks	Explore how collaboration in e-commerce logistics improves overall distribution process performance.
	Identify synergies among e-commerce stakeholders for reverse logistics.
	Analyse current distributions to depict the distribution patterns and forecast future problems.
	Provide alternative shipping methods to consumers.
	Enable dynamically changed supply chains taking into consideration various routing and customer preference characteristics.

3 Data Assets

Table 3 provides the characteristics of the data sets identified for each of the TransformingTransport pilot domains, along the four key big data dimensions: volume, velocity and variety; e.g., see Zillner et al. (2016). An inventory and meta-information about the TransformingTransport data sets is available from the project's Transport Data Portal at http://data.transformingtransport.eu/. At the time of writing, a total of 135 data sets is available (i.e., ca. 85% of the data sets identified in Table 3).

These data characteristics are in line with a recent study (see Bean (2016)), where 69% of corporate executives named greater data variety as the most important factor, followed by volume (25%), with velocity (6%) trailing – indicating that the big opportunity lies in integrating more sources of data, not bigger amounts.

Table 3: Data assets per pilot domain (as anticipated for the year 2020)

Pilot Domain	Volume [GB]	Velocity [GB/day]	Data Variety (Data Sources)
Smart Highways	~1.000	~1	> 20, live traffic information, historical traffic data, meteorology information, OCR data, spatial infrastructure, car sensor data, social network streams, …
Sustainable Connected Vehicles	~2.500	~7	> 20, vehicle, position, speed, brake, black ice sensor, ABS, ESP, fuel level, emergency button, engine status, engine revolutions, tyre pressure, temperature, …
Proactive Rail Infrastructures	~1.500	~2	> 40, environmental, geospatial, Network Model, track circuits, axle counters, points heaters, rail temperature monitoring, overhead line tension, rail signalling power, scheduled planning and control data, track usage, …
Ports as Intelligent Logistics Hubs	~400.000	~110	> 25, information about import and export of containerised, general and bulk cargo, tracking and tracing through the whole logistics chain, machines equipped with, AIS (vessel tracking), video streams of trucks and trains (from video gates), traffic management data, …
Smart Airport Turnaround	~3.000	~30	> 35, flights scheduling, flights updates, passenger tracking information across the airport, queuing times for check-in/security/lifts, hand luggage scanning information, shops level of occupation, aircraft sensor data, …
Integrated Urban Mobility	~500	~10.5	> 10, real time probe data from personal, freight and public transport vehicles; traffic light data and sensors, roadside camera images, usage data from public transport, …
Dynamic Supply Networks	~1.500	~11	> 10, inventories, orders acquired of online retailers, deliveries, distribution information collected by 3PL/courier companies, customer delivery preferences, geographical position of customers, cost of deliveries, vehicle fill rates, …

Pilot Domain	Volume [GB]	Velocity [GB/day]	Data Variety (Data Sources)
TOTAL	*~410.000*	*~172*	*> 160 data sources*

4 Methodology

Overall, TransformingTransport follows an incremental, iterative approach to design, develop and validate the big data solutions with the pilots. Such incremental, iterative approach has the benefit of incorporating learning effects, reacting to recent insights and technology trends, as well as exploit new outcomes and insights from relevant from the state of the art (e.g., see Larman & Basili (2003)).

Specifically, TransformingTransport follows a 3-phase replication approach within each pilot domain, which is combined with a 3-stage methodology for validation and scale-out within the phases as described below. One key aspect of the TransformingTransport methodology is its structured approach for assessing the improvements in transport performance (more details on this assessment approach may be found in Velazquez et al. (2018)).

4.1 3-Phase Pilot Replication and Sustainability Approach

As shown in Figure 2, the pilot domains will start with an *initial pilot* at the beginning of the project, and then replicate the solutions by reusing the results as part of a *replication pilot*‡. The replication pilot considers insights, findings and lessons learned from the initial pilot. This replication approach is one key means to demonstrate the reusability and generic nature of the TransformingTransport solutions. A replication pilot addresses similar and related objectives as the initial pilot, but typically adds a further level of complexity; e.g., in terms of processes or data assets. In addition, as indicated in Figure 2, TransformingTransport will prepare a post-project replication phase to ensure sustainability of project results.

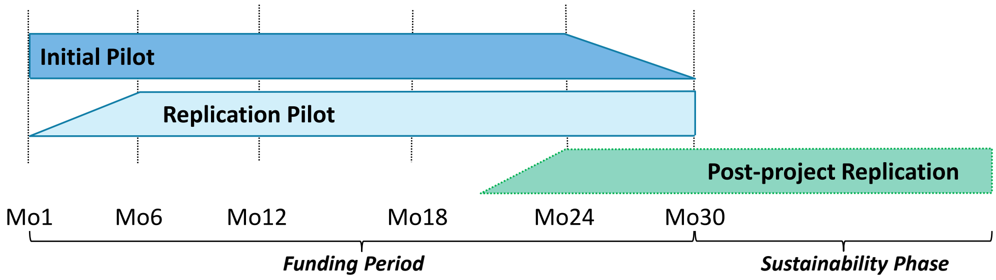

Figure 2: Pilot replication and sustainability approach

4.2 3-Stage Validation and Scale-up Methodology

Within each pilot, TransformingTransport follows a 3-stage methodology for validation and demonstrating the scalability of Big Data solutions. The three stages differ with respect to the embedding of the technology into the operational environment, the form of the big data infrastructure being used, as well as the scale of data that is exploited. Starting with a focussed technology validation, the 3-stage methodology will ultimately deliver insights from actual in-situ trials, i.e., a prototypical implementation of the solutions in the field, involving real end-user and actual production data. The three stages of the methodology along its three main aspects are explained in Table 4. This ensures that the TransformingTransport pilots will work at the scale of data volume, velocity and variety expected by the end of the project (see Section 3).

Table 4: Validation and scale-out methodology

Stage	Embedding	Infrastructure	Scale of Data
S1: Technology Validation	Problem understanding and validation of key solution ideas.	Local, existing small-scale infrastructure used for exploratory experiments.	Selected (historic) data pinpointing problems and opportunities.

‡ Due to the more complex horizontal data integration to be performed for the "Shared Logistics for E-Commerce" pilot, we deviate from this pattern for the "Dynamic Supply Networks" pilot domain.

Stage	Embedding	Infrastructure	Scale of Data
S2: Large-scale Experiments	Controlled environments, decoupled from productive environment.	Dedicated large-scale data processing infrastructure for experimental purposes.	Large historic and live data, possibly anonymized or simulated.
S3: In-situ trials	Trials in the field, involving actual end-users.	Actual data processing infrastructure of pilot partners.	Real, live production data complemented by large scale historic data.

5 Impact of Big Data in Transport

The unique constellation and complementarity of TransformingTransport partners allows driving innovation of mobility and logistics processes and services along the whole data value chain. In particular, this will lead to innovation along three key value dimensions for Big Data shown in Figure 3 and elaborated in DHL (2014).

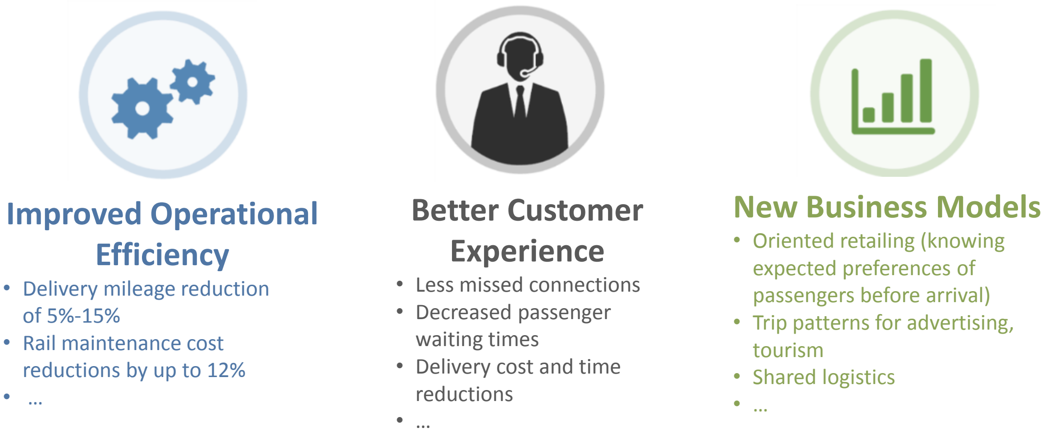

Figure 3: Value dimensions for big data (based on: DHL (2014))

Below we elaborate the concrete innovations within the TransformingTransport pilot domains. Based on a project-internal analysis of these innovations, we indicate how they contribute to the aforementioned big data value dimensions. More details on these innovations can be found in the TransformingTransport public project deliverables (D4.1 to D10.1 available from http://www.transformingtransport.eu).

Table 5: Project innovations and links with value dimensions

Pilot Domain	Innovation	Efficiency	Customer Experience	Business Models
Smart Highways	Descriptive model of road traffic considering multiple criteria.	++	++	o
	Prediction technique for traffic flows and infrastructure use.	++	++	o
	Scheduling algorithms for staff and maintenance operations.	++	+	o
	Predictive, real-time analytics for accident prevention	++	++	o
Sustainable Connected Vehicles	Car breakdown estimator system.	++	++	o
	Emission reduction system based on real-time analytics.	++	+	o
	Real-time traffic jam detector system.	+	++	o
Proactive Rail Infrastructures	Quality control of asset data for accurate predictive maintenance.	++	+	o
	Predictive analytics of degradation of infrastructure.	++	+	o
Ports as Intelligent Logistics Hubs	Optimization algorithms for crane operation.	++	+	o
	Predictive maintenance models for cranes.	++	+	+
	Terminal productivity cockpit for better decision making.	++	+	o
	Predictive process analytics considering prediction reliability.	++	+	o
Smart Airport Turnaround	Predictive optimization module for operation management.	++	+	o
	Descriptive models and analytics of passenger behaviour.	+	++	+
	Turnaround optimization algorithms.	++	+	o

Pilot Domain	Innovation	Efficiency	Customer Experience	Business Models
Integrated Urban Mobility	Tools for diagnosis of traffic status and mitigating impact of roadworks.	+	++	o
	Solutions for drivers and travellers regarding traffic status and parking spaces.	+	++	o
	Traffic model capturing freight transport in cities.	+	++	o
	Planning tool for analysing and optimizing delivery fleets.	++	++	o
Dynamic Supply Networks	Expanding shared logistics to reverse logistics supply chains.	+	+	+
	Identify patterns of problematic deliveries and forecast problematic situations.	o	++	+
	Dynamically identify alternative delivery options.	o	++	+

The main innovations centre on improved operational efficiency, which in turn oftentimes implies better customer experience. These are the value dimension where big data leads to the most immediate impact. Predictive data analytics (e.g., see Metzger & Föcker (2017), Metzger & Bohn (2017), and Metzger et al. (2015)), are considered one key enabling technology to bring about these innovations. With respect to new business models, innovations in TransformingTransport focus on dynamic supply networks and in particular new ways to support e-commerce business requirements (see Zampou et al. (2018)).

6 Data Management Concerns

When applying big data in transport and logistics, we can identify two important aspects of data management: data protection, as well as data integration.

6.1 Data Protection

Data protection concerns two kinds of data assets: commercial data (intellectual property), as well as personal data. Based on an analysis of the TransformingTransport data sources, 68% of the data sources are of the former kind, while only 1% of the data sources are of the latter kind. This suggests that – compared with other sectors, such as health, finance, or telecommunications – the mobility and logistics sector may face less legal barriers for what concerns the use of *personal* data to deliver value.

Nevertheless, concerns related to personal data in the mobility and logistics domain should be taken seriously. Accordingly, TransformingTransport clearly defines, for each of its data assets, a data controller who is responsible for compliance with data protection rules and who ensures purpose limitation and data minimization. Reasonable safeguards are applied to protect the personal information from unauthorised access, loss, misuse, modification and disclosure by ensuring data processing and storage will occur on data centres owned by TransformingTransport members; e.g., such as private clouds. These safeguards are expressed as part of a Data Management Plan, which defines data governance and protection procedures to ensure fairness and lawfulness of data usage, considering legal constraints and country-specific legislation.

Data protection concerns in particular become of utmost importance with the implementation of the European Data Protection Regulation (GDPR), which will have a profound impact on managing data and IT infrastructures (e.g., see NESSI (2016)).

6.2 Data Integration

As explained in Section 2.1, TransformingTransport follows two patterns for data integration (vertical and horizontal), thus foreseeing the creation of data supply chains along these integration dimensions. To ensure data sharing and integration, TransformingTransport has defined specific procedures which cover data integration methodologies with the aim of establishing lightweight data links between pieces of data that refer to the same logical entity across different data sources. The data integration methodologies aim to avoid (as much as possible) complex and long lasting efforts for mapping a lot of different data schemas and thus to establish lightweight data links between pieces of data that refer to the same logical entity across different data sources, including both data-in-motion and data-at-rest.

Several emerging standards – such as the DCAT standard for EU open data for transport, the NETEX / SIRI standard for data sharing in public transport, or the OASC work towards open data platforms – may offer additional solutions to data integration, but obviously require that all stakeholders involved along the data supply chains have to adopt these standards.

7 Conclusion

Big data promises to deliver profound economic and societal impact in mobility and logistics, as evidenced by the ambitious aims and innovations of the TransformingTransport project presented in this paper. TransformingTransport pursues big data use cases in all areas of major importance for the mobility and logistics sector in Europe, demonstrating the technical and economic viability of big data to reshape transport processes and services.

Acknowledgments

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