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PETRA: Governance as a key success factor for big data solutions in mobility

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A B S T R A C T

The promise of big data in the field of mobility is great, for example for mobility-as-a-service solutions. Having a better sense of the existing flows over the network would allow for much improved modelling of future flows and nudging users into behaviours targeting collectively better outcomes. Because of this promise the interest that cities have in big data for mobility is high. They are looking for ways in which a mobility data platform gathers the relevant data, allow for advanced modelling of current and future network states, and ways to drive travel behaviour. We participated in the EU funded PETRA project that built such a platform for the cities of Haifa, Rome and Venice. In this paper, we are looking for key governance mechanisms that affect the success of mobility data platforms, and how they are related to technical features. The project and an additional study into 10 cases revealed that the more ambitious a platform is on a technical level, the more governance challenges they will encounter, thus the more advanced governance arrangements are necessary. However, many governance arrangements are a given rather than a subject to design. This implies that for success, the technical ambition of the platform should be aligned with the institutions of the city in which the platforms will be implemented.

1. Introduction

Two major trends are apparent in the field of mobility: smart cities[1] and big data (see also Caragliu, Del Bo, and Nijkamp (2009)). Hancke, Silva, and Hancke (2013) and Townsend (2013) state that more widely available data drives a more integrative understanding of the cities processes, giving better efficiency and sustainability, to which Batty et al. (2012) and Schaffers et al. (2012) add that through modelling and simulation with that data, a better prediction of those processes will be possible, further strengthening the value of big data for the city. The smart city and big data meet in mobility data platforms; portals for mobility data to make that data easily and purposefully available to provide value to the city. These platforms combine a wide variety of data sources to support the creation of an overview of network status and flows (historical, current, and future), and allow for use of that information from real-time travel planning to long-term infrastructure planning. For providing the future perspective, needed to have accurate travel planning, platforms include modelling of transport stream over infrastructure networks in the city.

In mobility, a key example of mobility data platforms is the development of mobility-as-a-service (MaaS). The platform for MaaS can provide the integration on the key elements of MaaS services, on the three T's (Hirschhorn, Veeneman, Paulson, & Sørensen, 2018). On **travelling**, the platform provides the possibility to plan and reserve trips. On **transaction**, the platform can provide the possibility to pay and identify the person doing the transaction. On **tailoring**, the platform could package services over providers and optimise the package for the different individuals. The key of MaaS is that the landscape of mobility services is becoming more fragmented, with shared services and automated vehicles, and that a platform approach can help users integrate the informational interactions with all these services and their providers, consequently merging the services for end users. This could strengthen the position of these services vis-à-vis the car, currently the most integrated mobility option of all. Most current platforms are only providing a subset of the services of the three T's.

The challenge for mobility data platforms has long been considered a technical one (Batty et al., 2012, p. 487): how to get the right data, aggregate that data, model future network states on that data, and make that available to the right people. Challenges exist in creating reliable network flow data from various sources (from induction loop counting

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[1] The smart city concept started in Australia, Adelaide in 1994, with a focus on computer literacy (see Tokmakoff and Billington (1994)), where Hall et al. (2000) got closer to its current focus on infrastructures for transport and ICT and a knowledge economy. Caragliu et al. (2009) broadened it adding elements of participation and aims like quality of life and sustainability.

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via Bluetooth, Wi-Fi, RFID, and number plate tracking, to GPS traces) (Giannotti, Nanni, Pinelli, & Pedreschi, 2007). Also, making the planning effective in an uncertain environment with a wide variety of multimodal options (spanning from private modes like cars, cycling and walking, via shared modes, like cars and cycling, to public modes, like train and bus) in easily usable travel plans that support public goals, has proven challenging (Botea, Nikolova, & Berlingerio, 2013). In addition, the role of simulating realities to predict future network states in the management of networks has been a challenge (Raghothama, Baalsrud Hauge, & Meijer, 2017).

The technical challenges are to be overcome by multiple actors, all involved in the provision, processing or use of the data. This includes not only platform developers, but also transport service providers, transport authorities, infrastructure managers, travellers, etc. This leads to a different kind of challenge. How is the coordination among all these actors arranged? We call these challenges 'governance challenges'. Our main assumption is that not only technical arrangements, but also governance arrangements are critical to the success of mobility data platforms. In this paper, we are looking for key governance mechanisms that affect the success of mobility data platforms, and how they are related to technical features.

In the next section, we will define governance and apply this concept to data mobility platforms. The third section will introduce the setup of our empirical study, of which the outcome will be described in section 4. Since this is an exploratory contribution, we will close this paper with a discussion section.

2. Governance complexity: a variety of relations

Governance refers to processes, social practices and activities, performed by institutions or actors (Bevir, 2013). "Governance" is related to "governing" in a context where multiple actors are into play. This is relevant for mobility data platforms, because data have to cross several institutional borders, including organizational borders, borders between departments, public-private borders and the border between supply and demand. Governance is important because it is believed to contribute to the efficiency and effectiveness of arrangements over those borders (Provan & Kenis, 2008).

Classic governance theory distinguishes three governance modes as coordination mechanisms (Powell, 1990). They are hierarchy, market and network mechanisms. This is of course a typology. Real-world governance arrangements typically involve a mixture of these mechanisms (i.e. Rhodes, 1997). Crucial here is that 'hierarchy' is only one of these mechanisms. Governance theory shows some departure from the idea of hierarchical control as the main standard (i.e. Mayntz, 2003). Market mechanisms and network mechanisms are not about control. They are about reciprocity, either by creating added value to a customer to win his/her trust (market) or by 'tit for tat'- transactions driven by mutual dependencies on the long run (networks; Bruijn et al., 2010). The governance literature provides us with clues of the key factors that allow us to understand the strengths and weaknesses of different governance models for mobility data platforms. For example, data could be shared under three different mechanisms: market, hierarchy and network (Powell, 1990). Powell shows how the different governance modes have strengths and weaknesses. There is currently a competitive market that is providing locational data, with both mobile phone operators and app developers competing, the latter with the likes of Google and TomTom.

The *market* in this field has its specific governance issues, with monopolistic behaviour driving up the prices or fierce competition leading to unwanted behaviour, like disregard for privacy of those generating the data. These issues are often regulated outside the realm of the platform and that governance can heavily influence the possible success of a platform by respectively being a large burden on the resources for getting the data, and lowering the willingness to share data by under-securing privacy or lowering the usefulness of the data by over-securing privacy. There is an institutional context in which the market for data-in of the platform functions that has a strong influence on its effectiveness and most effective solution.

Some of the relations are more *hierarchical*. For example, when a municipal public transport operator is demanded to provide GTFS data to the platform. Hierarchy also has its particularities as for example the contractual hierarchy might be subject to strategic behaviour. In this field, the bus operator might have a clear idea of the data it really has available, but not willing to share that data. This regard of the data as a strategic asset and behaving accordingly in a hierarchical relation showed up regularly in the cases.

Finally, in a *network* relation the key is that mutual benefits will drive the cooperation and transaction. Data is provided because it is expected to provide a mutual gain. For example, because access to other data ca be acquired or because future gains are expected.

As a further application of the concept of "governance" to mobility data platforms, we anticipated mobility data platforms to be a chain of actors exchanging data. With this perspective, we can break down the processes around platforms as the process of getting data into the platform ('data-in'), data on the platform ('data-on'), and data out of the platform ('data-out'). Three questions were key. What kind of data is relevant and could be valuable in a mobility data platform? Obviously, the research focused on mobility related data that would provide information on flows over the network, mobility services and infrastructure. For that data, from governance perspective a second question was relevant. What types of actors generate and own that data? This would provide us with a focus on the governance for data-in and data-out. The governance of data-on asked for a slightly different question, looking at the relation of the platform with its patron, more internal governance. This in turn would trigger the third question. What kind of relations do these actors have with a platform manager that could drive the governance? The governance literature learns us that these relations can be based on authority (hierarchy), mutual adjustment (networks) or exchange of services (market) and that these relations matter for the functioning of the platform.

3. Approach taken

We participated in the EU funded project PETRA. Participants of this project have built mobility data platforms for Haifa, Rome, and Venice, to allow the platforms to contribute to reaching mobility goals in these larger cities, by addressing the challenges mentioned above. A key topic going beyond these technical challenges was the understanding of how existing governance in cities helps and hinders the effective development of mobility data platforms. To do so, in the cities above, participative observation was used to understand the relation between governance and the mobility data platform solutions that were implemented in these cities. In addition, 10 case studies were carried out of other mobility data platforms that showed the relation between the governance of the platforms and their long-term success in supporting public goals in the field of mobility.

Table 1 Provides an overview of the cases. More information on the case studies is included in the appendix.

We took an empirical approach to study the relation between governance choices and the functioning of a mobility data platform was analysed took two different tracks. First of all, we defined key governance complexities with the help of governance literature. Secondly, we applied these complexities to the feature of mobility data platforms. Thirdly, data collection was performed.

Data collection took two routes. A first focus was on the demonstrator projects in Haifa, Rome and Venice, through participatory observation. In these three cities, the mobility data platform was developed with a different objective, (i) event related mobility, (ii) public transport mobility and (iii) touristic mobility respectively. While the team as a whole was developing the platforms, the governance research took an inventory of the existing governance of mobility data, services,

Table 1
Overview of cases.

Name	Covering	Key data*	Planning functions
CarFree AtoZ	Washington DC area, US	Network, network loads, schedules	Multimodal trip planning
MaaS Global	Helsinki, FI	Cost and schedules, vehicle availability	Multimodal trip planning and booking
Optimod	Greater Lyon, FR	Network, network loads, schedules and vehicle availability	Multimodal trip planning, public transport, walking, cycling, driving
OV9292	NL	Network and schedules	Multimodal trip planning, public transport and walking
Plan a Journey	London, UK	Network and schedules	Multimodal trip planning, public transport and walking
PTV	Victoria, AU	Network and schedules	Multimodal public transport trip planning, walking and cycling
Qixxit	DE	Network, schedules and vehicle availability	Multimodal trip planning public transport, walking, cycling, driving
Reittiopas	Helsinki, FI	Network and schedules	Multimodal trip planning public transport, walking, cycling
TIA	Vienna, AT	Network, schedules, network loads	Multimodal trip planning public transport, walking, cycling, driving
VSS	Stuttgart, DE	Network and schedules	Multimodal trip planning public transport, including tariff information

infrastructure. This led to an iterative process between the data and hardware oriented parts of the project and the governance oriented parts of the project, which provide great insight in the intrepid dependencies between the technological development and governance development.

Whilst learnings from these three demonstrators were deep, per se they lacked width and generalizability. Consequently, the second route of data collection involved 10 case studies were carried out to further understand the relation between the technological and governance realities of mobility data platforms. Those case studies included desk research, looking into the goals, technology, functioning and governance of mobility data platforms, complemented with interviews (both local and on the phone) to gather additional information and review outcomes of the desk-research.

For the selection of case studies, a worldwide longlist of mobility data platforms was developed. A first 80-case set was developed to vary from technically and institutionally simple to complex. In the selected 10 cases, complexity would vary on 5 axes: from single to multi modal, from focus on flow data to inclusion of contextual data, from individual (fastest travel time) to collective optimization (less congestion or pollution), and from a single jurisdiction to multiple jurisdictions. To illustrate: on the simple side was the public transport planner for Victoria in Australia, the more complex CarfreeAtoZ in the Washington DC area. The variety in terms of the organisational context is illustrated by the cases with a strong focus on multi-modality; Maas Global is a private initiative focusing on planning and sales tying together various services including those provided by local governments, and Verkehrsauskunft Österreich serving the population of several Austrian public authorities with providing a shared multi-modal trip planning platform.

The interviews were organized around three topics: a characterization of the platform including both technical and governance aspects, the main governance challenges, and future perspectives. The key question was to understand the way in which the governance was built up. All cases have shown a strength in the sense that they existed for several years and apparently had an effective business model.

The aim was not to develop a single approach to the governance of mobility data platforms, but rather to discover key mechanisms in the governance side that influence the success of such mobility data platforms. This was done by analysing key governance elements in one case and compare and contrast them with the other cases and the demonstrators. More robust outcomes were selected to be included in a governance handbook. The aim of the handbook is to support different types of actors in the field of mobility data platforms to understand the governance context in which they are working, to be able to assess the possibilities to improve the governance for the platform, and to realise changes in the governance that support the platform. Obviously, from a research perspective, these are only the first hypotheses on governance issues on mobility data platform that can drive and direct further research into the matter with more quantitative approaches.

4. Markets, hierarchies and networks in the cases

As stated above, the literature makes a key distinction in governance between markets, hierarchies and networks. In the cases we analysed how markets, hierarchies and networks played their role in the development and survival platform. According to some of our interviewees, platform innovation is expected to be brought to market by private players. However, in wider set of cases, we saw how hierarchies and networks play an important role in making the platform a success. In fact, a lot of interaction is apparent between private players in public players. Public players in the cases have control over many of the mobility services available in the area. They provide concessions and subsidies to public transport operators, support the start of innovative services, provide an integrated ticketing scheme, etc. In all these examples, private players can also play a role.

Market governance is prevalent in those cases when the actors “buy” services in a competitive context. In the cases these were mostly public actors buying mobility-related services. Think about governance set up of the provision of public transport services by private bus operators under tendered concessions. Or the governance of touchless ticketing provided by private players under full service contracts. In other situations, under contracts or within organisations, *hierarchy* is the key governance mode. Think about the delivery of services by municipal “in-house” operators. Or about a contracted provider of bike sharing and the hierarchical control that can provide to the government party in that contract. Finally, *network* governance prevails, for example when authorities support private car sharing schemes that want to enter a region through parking spaces or subsidies. Or when other governments in the region can provide access to data, crucial for the platform.

The cases show that *market governance* plays a limited role in the set-up of platforms themselves, in the interaction between the authorities and the platform developers. Several characteristics of the platforms play a role. First, innovation and tailoring are key drivers of platform development, which drives away from market governance. Markets works best with commoditized goods and services, with many suppliers. In most cases we see specialised innovative service providers directly target authorities, or authorities starting development with known innovators or internally, with little formal market mechanisms. Second, some of the bigger platform developers seek or are given long term monopolistic market positions. However, in the context market governance does play an important role. In Europe and Australia, operators have come under a competitive regime, more and more. The position towards innovations like platforms seems to be different in the cases, with in-house operators not under a competitive regime being more active in co-developing the platform, while operators under competition are less prone to do so. There is one exception, when authorities are pushing for platforms (for example MaaS) to be included in bids, operators develop an interest in platforms, for example by taking a stake in global platform developers.

The cases show *hierarchical governance* plays an important role in realising platforms for mobility services, but not in the straightforward way that might be expected. Government's control of key data sources (often in a specific corner of the governmental organisation) makes them an important player in realising the platforms. Think of all the data that is coming of road networks with camera's, the public transport schedules (planned and real-time) the demand from operators, vehicle availability in sharing schemes they subsidies, etc. Often the interests differ between the providers and generators of the data, the platform builders and those seeking to improve the public values related of mobility, even if all are operating within one hierarchical organizational structure. In our cases, we saw situations where platform developers would like to have GTFS (scheduled transport service data) from operators, while the direct responsible for the data with the operators (both within hierarchy through contract or ownership) were not very willing to change the data types given the costs the change would incur. In the cases hierarchical governance shows to be highly susceptible for principal-agent problems, with information asymmetry and diverging interests hampering innovations around platforms. On the other hand, two examples in the cases showed broad governmental legislation on opening of data for payment, planning, and reservation, in general and as such available to platforms. In three cases (in Finland, France, and The Netherlands) this helped create an environment in which platforms could thrive. The Dutch intervention focused directly on establishing travel information platform, a fully integrated solution. The platform became the de facto monopolist *under control of operators* with inertia driving a slow but steady innovation towards more open data. In Finland the focus was on opening up the data, *without a platform developed*, which seems to drive swifter innovation. In the French example, the platform was developed by the government with a focus on availability of the data, rather than developing a fully integrated solution. This seemed to have hit a sweet spot supporting innovation of services to travellers more than the Dutch hands-on and Finnish hands-off approach.

The *network governance* played a far stronger role in the cases then expected. Platforms are built on data sharing. Oftentimes sharing that data is in the interests of those providing that data. For example, German train operators changed the data types of their schedule information to allow Google to include the data in Google Transit. Or Dutch operators work together to open up schedule data as this provides more options for app development and stops with real-time departure times. The operators were not forced to do this (hierarchy) nor were those operators not doing it losing business (market), but operators saw the value of this and the wider context. Still, we saw environment with a stronger cooperative culture and environments with less of a cooperative culture. And in addition, having a guidance on how the platform innovations can support public goals also seemed to help in a subset of cases, like in Austria. Network governance seemed to be helped around platforms when the platform is set-up to support public values.

In conclusion, platform innovations (like MaaS) are often expected to rely heavily on innovation brought in by the private sector under market pressure. Although this plays a role, many of the platform providers aim for monopolies. And these monopolies can be both valuable, in creating world-wide standards (like Google and its GTFS schedule data type in one of the British and German cases), and problematic, as with the loss of competitive pressure innovation is lost too. However, we also saw string roles of authorities in our cases that drive innovation, based on hierarchical positions towards other parties, and the direction of platform development. In addition, a strong basis is found in the alignment of incentives for the various actors involved in platform development, as this will empower network governance to cooperatively innovate supporting the values of a wider set of actors involved, public, private and end-user.

5. Key outcomes

5.1. Five models and their consequence for governance

A metropolitan mobility data platform can be implemented in several levels of functionality. Here we discuss various models a data platform could take and what consequences the models chosen have for governance. We show progressions of platform development on the first T for MaaS (see above), which is trip planning and reservation. Similar progression can be built for transactions, which we will illustrate briefly. For tailoring, platforms currently play a less relevant role.

First model: Open data policy. One of the key features of the data mobility platform is the wide availability of mobility related data. Data is the key prerequisite for the functionality and much of that data is in the hands of municipal or metropolitan governmental actors. In various cases, value was created in terms of improved travel pattern, transport operations or infrastructure planning due to available data, with other using that data for their own modelling, controlling, and planning. This model can be advanced some more by centralizing or localizing licensing conditions, standardizing or tailoring data types or structuring the interaction between the data streams and other applications through API's. The governance of this model is straightforward. Data is simply provided as open data, with data streams available. MaaS solutions can be built on top of these open data platforms. For transactions this would mean open API's for transaction systems, like smart card system or other ticketing solutions.

Second model: A data-oriented platform. A major step beyond open data policy is the development of a data platform, as a single point of entry for the mobility data in the metropolitan area. Such a single point of entry might serve as a single point of access for licensing and the API's mentioned above. It might also provide opportunities for quality control, data retention and data aggregation. Technically, this most basic form of the platform could be run on a cloud platform and as such, it is not relying on hardware of a possible metropolitan mobility platform manager. However, the need for a clear metropolitan organizational unit with the role of platform manager is obviously substantially higher than in an open data model. Moreover, when retention and aggregation become added functionalities, that retention and aggregation need to be purposeful, aligned with the goals of the metropolitan authority that is funding and possibly hosting the platform, staff and facilities. This means that governance has to be set up to keep that alignment with for instance the mobility department. It can be easier to build tailored solutions for a specific area, for example for MaaS. For transactions the regional or national platform could provide a one-stop-shop for all providers of service integration. For example, the platform could set-up payment and identification services that can be used by (semi-) public mobility providers.

Third model: A network status modelling platform. Building on the data, the platform could provide for the modelling of trip chains based on the raw data streams, to get a better perspective of the real-time network status. For example, GPS measuring points can be translated into paths and speeds, which can be amalgamated into current network status. In addition to this, the modelling could be aimed at getting a predictive network status and the platform could be used to evaluate the effect on the network status of specific policy interventions, for instance to drive people to use more public transport.

For governance, the fact that the platform now has added focus is relevant. New actors come into view that might want to demand functionality from the platform and drive its development in a certain direction. The cases showed us that in this state of maturity, it becomes very relevant for the development of the platform who is taking the role as platform manager. For example, when the manager is the road traffic control centre of the metropolitan area, road network status aimed at aiding car flow becomes the focus. When the manager is a public transport operator, the public transport trip planning and operational control of the bus fleet become the focus of the modelling. For transactions, the platform can go beyond the ability to pay and could share and predict mobility service use.

Fourth model: A trip modelling platform. Again, building on the model above, the captured and modelled status of the networks, both historically and real-time, allow for the predictive modelling that provides travellers with an optimized multi-model trip advice. This come close to traditional trip planners, however it is more sophisticated because of the variety of data in the platform and the quality of the network status. A further element that can be added is the coordination between influencing the travellers through the trips they plan, and other interventions in the transport system, like managing traffic flows, traffic lights, information panels, etc. The platform would also allow for the evaluation of various interventions.

For governance, the modelling for trip planning and adding specific goals, further increases how the influence of mobility policy on the way that the platform is set up. The platform become less a general service to be used by other and more a specific service of government actors to the possible users. It also adds complexity and this means that the platform is entering a new market, with new clients and new competitors. The success of the platform now is less easily managed by internally selling the strengths of the platform to metropolitan authorities and allowing them to harvest the benefits. The competitions for trip planners is fierce and the function will only be successful if the uptake with travellers is substantial. The parallel in transactions can be found in the area of optimising transactions for users, bringing it close to tailoring, the third T (see above).

Fifth model: A trip planning app connected to the platform. The platform can be further matured by a proprietary app. This could add an additional data stream of real-time travellers flows over the networks of the various modalities. If the number of users of the app in a metropolitan area is high enough, this could further enhance the real-time understanding of the status of those networks. Moreover, it would allow for quality improvement, awarding travellers for choices, and eventually, erecting a dashboard to dynamically prioritize the values that they deem important and nudge the travellers. As governance challenges, privacy and trust obviously come to the fore. Travellers should allow for the app to track them and will do this if they trust the app and the actors behind it. Privacy legislation further condition the efforts to make a viable trip planning app. The parallel in transactions is can be found in.

5.2. The survival of a platform doesn't just depend on its actual performance

Regardless of its technical maturity level, to survive, a platform must convince a critical amount of people – including users spending money or time – that it adds value. If this doesn't happen, it is very well possible that well-performing systems still dissolve in obscurity. That interest has to be sustained by institutions that support the platform. As such, institution building and governance prove to be as important for the sustained operation of the platform as the quality of the platform and its services.

An obvious critical feature is the funding of the platform. The demonstrator projects, as well as one of our other cases, were funded by the EU for a predefined term. After this time, a natural evaluation moment emerges. This is critical, because there is a risk that the features of the system – cutting edge and expensive as they are – will be rejected by powerful actors, such as governments funding projects, authorities managing systems, and users preferring platforms developed by competitors. This is not just about performance, but also about political priorities, ambition levels and the willingness for organizations to pay its management costs. The demonstrators couldn't find enough political support in the cities they are implemented once funding stopped. As a result, they became orphans. They are now framed as ‘experiments’ by the engineers that developed them.

Projects developed by an institution in the regions themselves are less vulnerable to this risk. A dedicated problem owner – such as transport authorities, or a joint venture of transporters backed by public authorities in the Netherlands and Stuttgart – helps to overcome any time of doubt. They might continue the project if the number of users doesn't meet expectations yet or if technical problems arise. They have already invested in the system or in the cooperation with other actors to a certain extent, making them willing to continue even if performance is not ideal.

Risks for privately funded platforms are somewhat different. Commercial parties such as MAAS and Ubigo offer a concept and a platform to their clients. The main commercial and governance challenges faced by these platforms concern their ability to partner with transport operating companies (both public and private) that will have their services included in the platform. The more partners these platforms find, the easier it will be to attract customers and also spread their risk. However, these private platforms must convince transport operating companies to let go customer access and relationships, which is one of their main assets, and accept to be a secondary player. The emergence of commercial parties taking spaces that were traditionally occupied only by traditional public transport services raises uncertainties about the role of traditional public transport stakeholders. Shall they cooperate with private platforms? The amount of willingness to do this and the willingness to trust market parties such as MAAS may depend per country, region or city. And it is relatively independent from performance.

5.3. Governance is key for success platform, but tailoring governance is tough

Because governance challenges and technical maturity are related design of governance is important, even for survival of the platform. This seems simple, design the governance of a mobility data platform so that it can reach its maximum potential. However, mobility data platforms get implemented in an existing governance context. There is a metropolitan transport authority or there is not. This authority is having control over public transport operators, through tendering or ownership, or it has not. There are strict privacy rules on the use of mobility data, or there are not. And so on.

This means that a large part of the governance context for the mobility data platform is a given. Key elements that seem to drive success are not there. For example, when a strong metropolitan authority has clear responsibility on transport (for example by tendering out public transport service provision, with responsibility for key infrastructure design and traffic control possibilities), their position does greatly simplify the process of setting up a mobility data platform.

The idea is that advanced mobility data platform that have to align with governance. The cases offered us a striking example. Multi-modality can be at odds with the modal focus of the responsible actor, on both data-in and data-out. In one of the cases the platform had to be rolled out by a public transport operator, as a metropolitan authority was lacking. The operator focused heavily on public transport data and struggled to secure the input of other data needed, for example from the police or municipalities. In other cases, integrated metropolitan transport authorities found it much easier to secure data input from other public actors in the area. On the data-out side, the operator mentioned above could easily create value with the platform for its existing public transport travellers. However, the original aim of the platform to be more multi-modal would not be beneficial to the operator. Positioning the platform at the operator secured easy data-in (vehicle flows, passenger flows) and easy data-out (travel plans for public transport travellers). However, the intention of the policy makers to provide travellers with a truly multi-modal planning tool was thwarted by this choice. This metropolitan area is currently setting up a metropolitan authority, but the timeline for that is way beyond the implementation of a mobility data platform.

6. Discussion

We were looking for the key governance mechanisms that affect the success of mobility data platforms. Those platforms merge two major trends in the field of mobility, being smart cities and big data. As such they hold many promises for the traveller, for the traffic controller, for the policy maker, for the infrastructure planners and for commercial parties. Our participatory observation and cases disclosed huge differences among platforms in terms of ambition. The full potential is hardly reached. Per platform, there are plenty possible extra functions to think of. The ambition levels vary. Mobility-as-a-Service is one of the possible implementations of mobility data platforms.

We found that many platforms start with a strong technical ambition. That technical ambition is often not aligned with the goals that key actors, including the end-users, have. This in turn drives in many cases major governance challenges. We found three mechanisms. First, the more technical ambition, the more misfits with existing institutions. This is most obvious for privacy regulations. The more a platform relies on personal data, the more privacy regulations condition the set-up of the platform. A second mechanism is the ambition level being related to the number of actors that feel to have a stake in the platform. The more stakeholders are involved, the harder it is to accomplish direction. For instance, if the platform is used for both mobility and sustainability ends, multiple departments and external parties (such as ngo's) are interested and try to express their needs. If the platform development does not have a guiding principle, this is problematic. The principle provides focus, consequently limiting actor complexity. This doesn't mean the platform has limited use. The focused development of the platform can still provide a basis for many other actors to build their services on, as is the goal of a platform in the first place. Related to this is a third mechanism: the more aims a platform has – and the more actors have a stake – the more important the governance set-up is. We found the importance of coordination, for example by a clear metropolitan organizational unit with the role of platform manager. To manage the stakeholders, this would introduce more authority to have more drive in the platform governance.

However, we also found that the governance set-up is largely a given. For instance, the very existence of a metropolitan authority proves vital for the more ambitious platforms, but erecting such an authority takes much more time than platform initiators have. If this authority is not there, technical ambitions can hardly be fulfilled. As a consequence, permanence is only loosely related with technical performance in terms of functions and ambitions. A more important success factor seems alignment with existing institutions, including political will, laws and regulations, formal institutions and the willingness of travellers to give trust to a platform. This is even more so if the timespan of platform ownership is only limited, for instance by EU-funded platforms. Still for all platforms key success factor is getting institutionalized, even if this might imply compromising the data platform's technical potential.

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Appendix. 10 smart mobility cases

CarFreeAtoZ

Platform: CarFreeAtoZ.
Coverage area: Washington DC metropolitan area.
Stakeholders:

- Arlington County Commuter Services (ACCS): the transport demand management agency of the Arlington County, a bureau of Arlington County's Transportation Division
- Transport operators from multiple jurisdictions (Washington DC, Virginia, Maryland): ART, DASH, DC Circulator, Fairfax Connector, MTA, PRTC, Ride-On, VRE, and WMATA.
- Developer: Conveyal

Organisation and management: Platform was commissioned to private developer by the ACCS as part of the Mobility Lab of Arlington County. ACCS' mission involves reducing traffic congestion, decreasing parking demand, promoting maximum use of High Occupancy Vehicle (HOV) infrastructure, and improving air quality and mobility in and around Arlington.

Source of funding: Mobility Lab's Transit Tech Initiative is funded through a Demonstration grant by the Virginia Department of Rail and Public Transportation. The programme is part of the Mobility Lab which encompasses a series of Transport Demand Management initiatives and is funded by Arlington County (Virginia) Commuter Services, the U.S. Department of Transportation, the Virginia Department of Transportation, and the Virginia Department of Rail and Public Transportation.

Initial Investment: CarFreeAtoZ was created out of a partnership with Virginia's Department of Rail and Public Transportation. The county allocated $100,000 for development of the website in fiscal year 2013, while the state paid $400,000 via a "demonstration grant". In 2015 Arlington county has moved to "phase two" for CarFreeAtoZ that was expected to cost USD1 million, also coming through a grant from the Department of Rail and Transportation.

Development history: CarFreeAtoZ's history coincides with the emergence and growth of their developer Conveyal in 2011. In that year, ACCS's research arm Mobility Lab announced a fellowship program for aspiring transit techies. Conveyal's fellowship produced promising results, leading to a grant for the project, awarded from the Virginia Department of Rail and Public Transportation. ACCS matched the DRPT funds.

Modes of transport included: metro, bus, private car, carpooling (formal and 'slugging'), private bike, shared bike.

Service Features: (i) **multi-modal** journey planner, including option to register for carpooling schemes, private bike and shared biked (ii) **trip duration** estimate, (iii) **carbon footprint** of the trip options, (iv) comparison of **trip costs**; (v) information on **calories burned**. Therefore it is a platform that serves both **individual and collective optimization** purposes.

The platform does not provide real-time information – it is essentially aimed at serving as a general planner for defining a daily commuting plan. ACCS has other services that offer this functionality though (Car-free Near Me).

Source of data:

- OpenTripPlanner (http://www.opentripplanner.org/)
- OpenStreetMap (http://www.openstreetmap.org)
- GTFS (Transit data feeds from the following providers: ART, DASH, DC Circulator, Fairfax Connector, MTA, PRTC, Ride-On, VRE, and WMATA)

Data flow: Operators providing GTFS data are in different jurisdictions. There is no formal agreements or legal obligation regulating the transfer of data from these operators to ACCS and/or the developer. Conveyal receives and treats the information for later publication. Two main issues faced to obtain data: (i) technical difficulties due to non-standardized data format; (ii) lack of institutional capacity and workforce in these operators to collect, treat and transfer data – especially in the smaller ones.

Open data policy: Information is only shared with entities who are contractually acting upon behalf of CarFreeAtoZ.

MaaS Global

Platform: MaaS Global.

Coverage area: ‘Whim’, the platform's mobile app launched in Helsinki in 2016. The owners intend to expand the use of the platform to other areas and countries in the near future, first of the expansions being Birmingham and Amsterdam.

Stakeholders:

- Company owners: the biggest single owners in MaaS Global with a 20 per cent interest are Transdev, a French transportation giant offering land, rail and passenger transport services and Karsan Otomotiv Sanayii and Ticaret AS, a leading car-industry family of Turkey. Sampo Hietanen holds a ten percent stake in the company. Other shareholders include InMob Holdings of Cyprus; Neocard; Korsisaari; GoSwift; MaaS Australia; Goodsign; IQ Payments; and Delta Capital Force.
- Local Transport providers
- Service providers (restaurants, grocery shops etc.)

Organisation and management: Privately owned company.

Source of funding: Private investors, Finish Funding Agency for Technology and Innovation. Eventually funding will rely on user-fees.

Initial investment: MaaS commenced operations on 1 February 2016 raising a total of EUR 2.2 million in its first call for funding from private investors and the Finnish Funding Agency for Technology and Innovation Tekes.

Development history: The company started to be operational in February 2016. The mobile application that offers MaaS services is to be launched in Helsinki in 2016.

Modes of transport included: taxi, bus, train, bike and car, all rented or shared.

Service Features: MaaS concept relies on the idea that ‘the money lies on the freedom of mobility allowed by cars’ – that is something people are willing to pay for. MaaS intends to serve users as an alternative to owning a car however providing them with the freedom of movement offered by a private vehicle. It will work as a one-stop-shop combining options from different transport providers into a single mobile service that will offer users different mobility packages with monthly fees. The company's business model involves providing services to clients rather than providing them with means to service themselves like journey planning platforms do. This assistance takes place with respect to 2 main components: ticket purchase and offering the transport option through mobility packages.

Source of data: Transport providers.

Data flow: Information supplied by transport providers is used to feed the MaaS platform creating trip options to users. The mobility packages are built through agreements between MAAS and transport providers: these providers grant access to their data/mobility services and MAAS buys these services to later resell to end users. Transport providers accept to grant MAAS access to their clients and services mainly because the company does not act as a regular intermediary taking a percentage of the ticket revenues, but simply buys them to resell to end user.

Open data policy: N/A.

OV9292

Platform: 9292.

Coverage area: The Netherlands.

Stakeholders:

REISinformatiegroep B.V. owns the platform. The company's shareholders are (–)

Organisation and management: 9292 was founded in 1991 as the central source of information for public transport in Holland. Besides the travel planner the REISinformatiegroep B.V., manages the NDOV point, which is a central platform where all the public transport information is publicly shared. This information point contains planned and real-time travel information, prices, and other information.

Source of funding: the REISinformatiegroep is self-funded with income from; (i) advertisement on their services; (ii) their telephone travel information services; (iii) the reisinformatiegroep sells there travel information API; (iv) the reisinformatiegroep develops dynamic travel information systems.

Initial investment: N/A.

Development history:

In 1991 the Dutch public transport companies decided to work together on a central travel information system. In 1992, 9292 started as a telephone number that travellers could call to obtain trip information. From 1998 the company launched the possibility to plan your travel from address to address on their website.

Modes of transport included: bus, train, metro, tram and ferryboat.

Service Features: The platform's core components are information on bus, metro, ferryboat, tram and railway stops/stations. In general it provides (i) **multi-modal public transport** or **walking** journey planner, (ii) **trip duration** estimate, (iii) **real-time planning and situational info**, (iv) **price** information (v) **personalised needs** – users with special accessibility requirements.

Source of data: each transport provider supplies their data to the NDOV (open) data platform.

Data flow: 9292 uses the data from NDOV for their journey planning services.

Open data policy: The reisinformatiegroep sells, from 2013, the 9292 API for use within companies own systems.

Plan a Journey

Platform: Plan a Journey.

Coverage area: London metropolitan area.

Stakeholders:

- Transport for London (TfL) - transport authority: Plan a Journey department
- Transport operators: bus (private companies), metro (TfL), National Rail (national government), Overground, DLR, river bus, shared bike (TfL)
- TfL's departments responsible for each mode of transport
- MDV in Germany (‘data system’)

Organisation and management: TfL is responsible for all transport strategy, going beyond public transport and including all surface transport, including urban planning, traffic management strategies, congestion charges, taxis etc. TfL has a department dedicated to the gathering, treatment and publication of all data collected from the different transport modes included in the platform. This department manages Plan a Journey.

Platform is not part of TDM initiative at TfL – Plan a Journey is not within TDM department.

Source of funding: TfL - Mayor of London.

Initial investment: N/A.

Development history: the journey planner became available in the early 2000s.

Modes of transport included: National Rail, Bus, London Overground, metro, River Bus, Emirates Air Line, DLR, TfL rail, tram, coach.

Service Features: The platform's core components are information on bus and railway stops/stations. In general it provides (i) **multi-modal public transport** or **bike** or **walking** journey planner, (ii) **trip duration** estimate, (iii) **real-time planning and situational info**, (iv) **personalised preferences** – option amongst fastest route, route with least walking, route with least transferences, (iii) **personalised needs** –

users with special accessibility requirements.

Source of data: each transport provider supplies the Plan a Journey department with the respective data.

Data flow: (i) bus feeds are automatically imported to the platform; (ii) metro data goes to the back office system (MDV) that tests all data accuracy before they are included in the platform; (iii) smaller modes have their data provided in excel files and these information are manually inserted in the platform; (iv) national railway provides blocks of data weekly (TfL does not run the process in this case). This requires that the department responsible for Plan a Journey keeps in close and constant contact with all TfL departments in order to obtain information to be able to publish notifications on services related to stops, disturbances and schedule.

Open data policy: Plan a Journey has a unified API and that single API is also provided to developers interested in creating apps.

Public Transport Victoria

Platform: Public Transport Victoria.
Coverage area: Victoria.
Stakeholders:

- Public Transport Victoria (Transit Authority)
- Transport operators (rail and tram services are franchised while bus services are contracted out or franchised)

Organisation and management: PTV is the system authority for public transport. Amongst other functions, PTV functions as a single contact point for information on public transport services, fares, tickets and initiatives. The travel planning platform is an element of these services.

Source of funding: Public Transport Victoria (Victoria Government).

Initial investment: N/A.

Development history: PTV's travel planner was initially developed outside the entity, however it was internalised and is now managed by the authority.

Modes of transport included: train, tram and bus services.

Service Features: PTV's travel planner provides route information based on static timetable information – it does not provide real time information, just indicates general status of lines (colour alerts). The justification for not providing real time information is the concern authority and operators have in relation to quality of data.

Source of data: transport operators.

Data flow: PTV determines the data to be provided by the operators. Trams and trains have also their specific journey planning platforms. The information may not be exactly the same as the one provided by PTV.

Open data policy: all modes, except for buses, have their information available at Google Transit.

Qixxit

Platform: Qixxit.
Coverage area: Germany.
Stakeholders:

- Qixxit: corporation owned by Deutsche Bahn.
- Transport providers that celebrated partnership agreements: DB, Flixbus, Bla Bla Car, Call a Bike, Konrad Bike, Opodo, Matzes Minibus, StadRAD Hamburg, StadRAD Luneburg, Citybus, Busandfly, Avis, Better Taxi, Sixt, Flinc acr sharing, HKX.
- User involvement has always been significant. Active feedback and frequent researches are used since the development of the platform. Users' input is steered by Qixxit as they develop their questionnaires based on their algorithms.

Organisation and management: Qixxit is a corporation owned by DB however acting autonomously as a business unit. Qixxit is an outside sales channel through which DB aims to gain new customers. It's open to any mobility service and no preference is given to any mode (neutral advice).

Source of funding: DB.

Initial investment: N/A.

Development history: Qixxit was developed within DB to offer journey advice for users in Germany. It was launched in 2013.

Modes of transport included: Train, Tram, Bus, private car, taxi, shared car, bike.

Service Features: The trip advice provided is door-to-door, however Qixxit's main focus is the long leg of the journey given that for most trips within cities already have specific platforms. Travel advice is multi-modal including public transport options, private car, taxi, car-rental, car-sharing options, bike, and bike-sharing. Besides offering trips in different modes, Qixxit also has different options of providers within the same mode. Qixxit indicates the cheapest option as well as the option that emits less CO2. Users are able to create personal profile indicating trip preferences so as to personalise the search/planning tool. Users are not nudged to make specific choices. One of Qixxit's principle since its inception, even though being owned by DB, is to provide **neutral advice**. At the moment users can purchase DB tickets through Qixxit, but purchase options for other modes are still not integrated. The information and advice are real-time. Updated with disruptions or delays. The app also follows the trip indicating the remaining time and alerting for transferences.

Source of data: The information available at the platform is supplied by DB as well as all other partner transport providers.

Data flow: The information flow is regulated by formal partnership agreements that specify the transfer of information as well as the manner in which it is displayed by Qixxit. The company does not reveal whether these agreements are remunerated.

Open data policy: Qixxit does offer open access to its data. At the moment all effort is dedicated to improve the tool and develop more functionalities. There is no interest in providing an open API.

Reittiopas

Platform: Reittiopas.
Coverage area: seven municipalities of Helsinki Metropolitan Area.
Stakeholders:

- HSL (Helsinki Regional Transport Authority)
- Transport operators

Organisation and management: HSL now owns the platform – it acquired it from a private vendor - however the technological development of Reittiopas depends on the vendor.

Source of funding: Funding for the projects comes from HSL. The authority's budget is composed by funds from the seven member municipalities (50%) and from user tariffs (50%)

Initial investment: N/A.

Development history: Reittiopas was developed by a start-up company (made up of 3 students) in 2001. Currently the company is CGI. HSL, Public Transit Authority for Helsinki Metropolitan Region (7 communities), bought the services of this tech company. This beginning caused some problems to HSL (vendor lock-in).

Modes of transport included: Public transport modes – bus, tram, metro, commuter train, ferry. A separate link offers advice for walking and cycling.

Service Features: Reittiopas offers itinerary information including different modes of transport within HSL member municipalities, however it is essentially a service to provide info on how to move from point A to point B. There is no real-time information and the data uploaded to the platform is merely based on 'static data', i.e. the transit timetables defined by HSL. It was identified that 65% of users are accessing Reittiopas from mobile devices, however the platform is not optimal for mobile devices as it was developed for desktop use.

Source of data: transport operators API.

Data flow: data originated from transport operators is used to feed the platform.

Open data policy: HSL offers access right to Reittiopas interface for applications and services that support public transport usage and transport information availability. The use of these interfaces is free of charge. Access to the downloads and interfaces is granted an account registration form. HSL has the right to inspect applications and services before granting access to the interface and may revoke access rights whenever necessary, for example in case of excessive traffic to the interface or misuse of the service.

Traffic Information Austria (VAO)

Platform: Traffic Information Austria (VAO)

Coverage area: Austria - The VAO traffic information is used in journey planners by a variety of platforms, among them; AnachB.at, the motorway operator ASFINAG and 9 other institutions. VAO is offered as a stand-alone traffic information platform, but also serves as the basis for the respective traffic information provided by its partners.

Stakeholders: VAO is a collaborative project of ASFINAG (coordinator), the working group of Austrian transport association organisers (ARGE ÖVV), ITS Vienna Region, Ö3 traffic editorial staff, ÖAMTC, the City of Graz as well as the federal provinces of Burgenland, Carinthia, Lower Austria, Salzburg, Styria, Tyrol and Vienna. Co-opted partners are Austro Control, the Austrian Association for Rehabilitation (ÖAR), the Austrian Federal Ministry of the Interior and the Federal Province of Upper Austria.

Organisation and management:

Source of funding: 50% are subsided by the Climate and Energy Fund. The other 50% are paid by the stakeholders involved in the project, such as the provinces and the cities. For example, the state of Upper Austria funds the project to develop a real-time traffic overview of the states of Upper Austria and Salzburg.

Initial investment: The VAO project has a total financing volume of EUR 4.700.000. and was made possible by the Climate and Energy Fund, receiving a 50% subsidy under the framework programme "Public Transport". The VAO II - a second phase to improve the project by use of additional data, optimisation of detection of traffic data and real time data, and integration of new mobility services (sharing concepts). Also, improving usability and performance of end-user services was targeted - project has a total financing volume of EUR 9.800.000, and also receives a 50% subsidy of the Climate and Energy Fund under the framework programme "Public Transport".

Development history: The VAO is a project that started September 2009, with the launch of the journey planner in the summer of 2014. The VAO II project had the goal to further improve the services. The VAO II project started in 2012 and finished in mid-2015.

Modes of transport included: bike, foot, car, bus, train, metro, tram and airplane.

Service Features: The journey planner provides: (i) intermodal Austrian-wide door-to-door routing; (ii) comparison of travel times and environmental aspects of the trip.; (iii) public transport timetables; (iv) real-time and forecast of traffic situation; (v) information on Park&ride and Kiss&ride facilities, parking areas; (vi) map information and alerts related to roadworks, detours and traffic problems. The platform's advice is neutral - there is no preference or discrimination of individual transport companies.

Source of data: VAO is based upon: (i) GIP. at and GIP. gv.at are the source for digital map for routing – authorized by federal states, ASFINAG, ÖBB Infrastructure; (ii) Basemap. at for background map tiles – source: GIP and geographical data; (iii) all data from its partners.

Data flow: The core component is a public database: the Graph Integration Platform (GIP) which enables the different partners to maintain and share content in partial networks.

Open data policy: N/A.

VSS

Platform: Verkehrs-und Tarifverbund Stuttgart (VVS)

Coverage area: The network area includes the city of Stuttgart and four neighbouring counties - Böblingen, Esslingen, Ludwigsburg and Rems-Murr-Kreis - with a total of just over 3000 square kilometers and 2.4 million inhabitants.

Stakeholders:

- Public transit authorities: Land Baden-Württemberg, Landkreis Böblingen, Verband Region Stuttgart, Landkreis Ludwigsburg, Landkreis Esslingen, Landeshauptstadt Stuttgart, Landkreis Rems-Murr-Kreis
- Over 40 transport operators

Organisation and management: VSS is an association owned by: (i) Stuttgart Local Authority and authorities of 4 districts around Stuttgart (50%) and (ii) bus and train operators in the area (50%). VSS main roles: (i) organise common fare system; (ii) design public transport schedule; (iii) manage the journey planning platform.

Source of funding:

Initial investment:

Development history:

Modes of transport included: subway, commuter trains, bus.

Service Features: Static timetable of public transport. Real-time data on commuter trains. Tariff information is also integrated into the platform. VSS recently developed a separate platform for bike journey planning.

Source of data: VSS is directly responsible for the static timetable of public transport and hence includes this data directly into its platform. Real-time data on commuter trains comes from operators.

Data flow:

Open data policy: Data is currently open to third parties only through a contractual agreement that imposes two main conditions to data receivers: request must come from a real person and no statistic use of the data can be made. MOOVEL, owned by Daimler (https://www.moovel.com/en/NL), for instance, uses VSS database. Tendency is that the use of these contracts will be discontinued – VSS is moving towards fully open data.

Optimod

Platform: Optimod.

Coverage area: Lyon Metropolitan Area.

Stakeholders:

- Lyon Métropole (Metropolitan authority)
- Sytral (transit authority)
- Keolis Lyon (transport operator)

Organisation and management: Since January 2015 Lyon Métropole (La Grand Lyon) assumed roles that previously were held by the Rhône Department and the Municipality of Lyon. Grand Lyon manages public transport policy for its 59 members. Grand Lyon owns Optimod.

Source of funding: La Grande Lyon + EU funds.

Initial investment: 7 million Euro.

Development history: The platform was developed in three years (2012–2014) by thirteen partners from public and private sectors: Le Grand Lyon, City of Lyon, Renault Trucks, IBM, Orange, CityWay, Phoenix ISI, Parkeon, Autoroutes Trafic, Geoloc Systems, Le laboratoire d'Économie des Transports (LET – Lyon II), le Centre d'Études

Techniques de l'Équipement (CETE) de l'Est et le laboratoire LIRIS (INSA).

Modes of transport included: private car, train, metro, bus, bike (private and shared), airplane.

Service Features: the platform envisages three major services (i) 1 h traffic prediction; (ii) an urban navigator on mobile phone; (iii) a navigator for urban freight & an optimisation tool for delivery rounds in the city. The navigator service, app developed by Cityway, is the main feature and involves. This service offers (i) **multi-modal public transport** or **private car** or **bike (private or shared)** or **walking** journey planner, (ii) **trip duration** estimate, (iii) **real-time planning and situational info**, including availability of public bikes and bike parking places in stations; (iv) incentivizes carpooling and car sharing. Therefore Optimod promotes **individual and collective optimization**.

Source of data: All data on public transport modes is gathered by Keolis Lyon.

Data flow: Keolis transfers all its data to Sytral (contractual obligation). The data is owned by Sytral. This data is used by Sytral in their own platforms providing information to travellers – travel plan and schedule but is also provided to the Grande Lyon. Data format is NETEX and GTFS.

Open data policy: The platform supports open data. The move to open data led to improvement in data quality. However a licensing agreement was devised and is used to ensure business secrecy, know-how, and contact with clients.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.retrec.2018.07.003.

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