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AUTONOMOUS URBAN MOBILITY PLATFORMS: A governance analysis within big data contexts

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AUTONOMOUS URBAN MOBILITY PLATFORMS:
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1. Introduction

Big data is revolutionizing the way businesses operate in many industries (Lee, 2017) and the automotive and urban mobility industries are no exception, given the great availability of real time data on users as well as on transport modes.

As pointed out by Ferràs-Hernández, Tarrats-Pons and Arimany-Serrat (2017), shared and self-driven electric vehicles are being seen as the main disruptive and innovative feature within the automotive industry. In this sense, Antonialli et al. (2019) proposed four future scenarios of business data platforms in which Autonomous Vehicles (AVs) are considered as a transport mode as a way to help enhance mobility in urban environments.

According to Stone et al. (2016), this is justified given that AVs and peer-to-peer (P2P) transportation services have great potential to reduce (or even in some contexts) to eliminate the need of car ownership. Given such contexts, the ownership and management of huge datasets (big data) is inherent for the creation of new business models within the automotive industry as well as for describing new scenarios of urban mobility systems.

These features bring up the need of choosing proper governance mechanisms for data-based transportation systems and mobility platforms (Veneeman et al 2018; Yap & Munizaga 2018). Governance mechanisms represent the study of relations between firms concerning its transactional features. These mechanisms could be established through market practices, internalized within firms (hierarchy), or mixed into contractual or hybrid mechanisms (Williamson, 2005; Crook, et al, 2013).

Considering all scenarios of mobility platforms proposed by Antonialli et al. (2019), in which AV's could be analyzed both within unimodal transport solutions as well as within multimodal P2P or B2C mobility platforms, the guiding question of this present research is: **How can big data impact on governance structures in autonomous urban mobility platforms scenarios?**

Therefore, the present study aims to characterize distinct types of governance models in different scenarios of autonomous urban mobility platforms considering the big data context. The research justifications are two-fold: first, big data is increasingly present within the automotive industry and in mobility platforms contexts (Seiberth & Gründinger, 2018; ITF, 2015), and second, further research is needed regarding the contributions and characterization of the most appropriate governance mechanisms to analyze and enhance the usage of big data in mobility platforms (Veneeman et al., 2018; Yap & Munizaga, 2018).

2. Theoretical background

2.1. Urban mobility business platforms

With more than a half of the world's population currently living in (or around) urban areas and with automobility as the dominant mode of transportation (European Comission, 2017; Urry, 2004), cities around the world are coming to the realization that they need to spearhead efforts to develop more sustainable transportation systems (Pancost, 2016; Rosenzweig et al., 2010).

Thus, new shared mobility forms are gaining ground, such as car-, scooter- and bike-sharing platforms; Peer-to-Peer ride hailing platforms as well as Mobility-as-a-Service schemes (Amirkiaee & Evangelopoulos, 2018; Jittrapirom et al., 2017).

The majority of these new mobility services are enabled by the so-called "business platforms" which work by bringing together two or more distinct and interdependent groups (people or companies), creating value by connecting them via transacting data without necessarily having the possession of any physical asset (Evans & Gawer 2016; Parker, van Asltyne & Choudary 2016). Furthermore, these new forms of mobility are likely to be catalyzed by the arrival of autonomous vehicles, and autonomous shuttles, thus building a new paradigm of urban mobility, catalyzing the development of "smart cities" (Attias, 2017).

Based on that, Antonialli et al. (2019) proposed four future scenarios for urban mobility platforms based on levels 4 and 5 AV's (SAE, 2016) as one possible transport mode. In order to exemplify each scenario, the authors sought for real examples present in urban mobility today, and extrapolated them to a future reality where AVs would be considered as additional mode of transport. Figure 1 displays the proposed scenarios, their prevailing business model as well as their respective explanatory management theories.

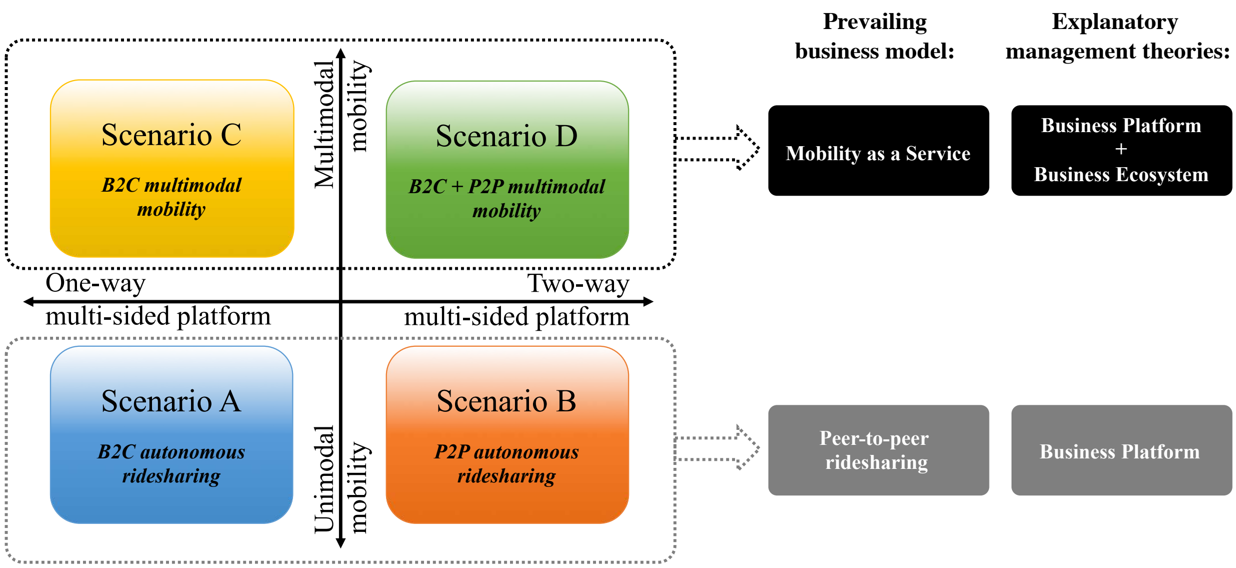

Figure 1. Future scenarios for urban mobility with AVs as a transport mode.
Source: Antonialli et al. (2019).

Scenario A entails one-way multisided platforms offering a single transport mode solution. That is, one firm by subsidizing the consumer segment would offer complete journeys from point A to B on an Autonomous Vehicle. Such scenario can be exemplified by Uber, Lyft and Waymo's current operations with their experimental fleets of AVs in different cities of the United States (Hawkins, 2017; Wayland, 2017; Madrigal, 2018).

Regarding scenario B, the premise is also to offer journeys from point A to B in a single transport mode; however, the platform provider would not need to subsidize neither side of the platform – such model is referred in the literature as two-way multi-sided platforms (Osterwalder & Pigneur, 2010). This scenario would entail ordinary peers offering their private AV's on P2P ridesharing platforms to other peers, being analogous to the current operation business model of P2P companies such as Uber, Lyft and Didi Chuxing with human drivers and their private vehicles.

Moving to the upper quadrants of Figure 1, Antonialli et al. (2019) considered a multimodal mobility solution for getting from point A to B. Thus, scenario C has a similar approach to scenario A in a sense that the platform provider – by owning the fleet – subsidizes the consumer segment (one-way multi-sided platform). The example considered was the experimental project planned for the city of Las Vegas, named "SHIFT – Project 100". As described by Kamargianni et al. (2016) and Loveday (2015) the project aim was to provide a privately owned multimodal fleet of 100+ on-demand drivers, 100+ shared cars, 100+ shared bikes, and 100+ shared shuttle bus stops as well as a valet service - all under one single monthly membership. For the sake of exemplification in scenario C, all vehicles and shuttles would be autonomous driven.

At last, Scenario D would entail a platform provider offering multimodal mobility by matching offerings via a single user interface with unified payment system - however, without needing to possess any transport mode. Thus, the premise of Scenario D, falls within the definitions of – Mobility-as-a-Service (Mulley, 2017; Hietanen, 2014). The examples given by Antonialli et al. (2019) was the Swedish Mobility-as-a-Service (MaaS) scheme of UbiGo and the Finnish example of Whim, which when extrapolated to a future reality with AVs would be comprised of: P2P AVs (similar to Scenario B); business to consumer- B2C- autonomous cabs (similar to scenario A); shared bicycles and; public transport (encompassing: buses, trains, tramways and metro). According to Antonialli et al. (2019), this scenario is likely to be the most complete, however, the most complex to be executed, mainly due to governance and regulatory issues.

Nevertheless, a common feature among all scenarios is the role played by data. As pointed out by Redman (2015) data become the strategy; with that, it not only improves existing processes and functions, but enable entirely new business models. Thus, urban mobility is of the industries with the most data volume being generated (Seiberth & Gründiger, 2018), this growing volume of data both structured and unstructured has considerable potential to drive new opportunities and refine existing ones.

Thereby, for transportation research, the availability of new sources of data about mobility, transport supply and usage, presents opportunities to analyze transportation infrastructure and behavior in new ways (Tranos & Mack, 2018). These dynamic strategies are made possible by the availability of data and the widespread connectivity of individuals (Stone et al., 2016), hence, data integration and analysis become increasingly important for urban mobility platforms.

2.2. Big data and governance models on mobility platforms

Big data is represented by extremely large data sets able to be acquired, stored and interpreted through analytics technology. It is composed both by structured and unstructured data (Gandomi & Haider, 2015; ITF, 2015) which impacts business operations and decision-making in real time, through mining insightful information (Sheng, Amankwah-Amoah, & Wang. 2017).

Research in transportation is strongly driven by data (Birkin, 2018). Big data is currently being applied for real-time sensing and traffic prediction, route calculations, peer-to-peer ridesharing as well as for self-driving vehicles trials (Stone et al., 2016). Recent trends suggest that it is inevitable that automatically recorded, digital data will come into mainstream usage both for academic studies and for the practical planning of transport systems (Milne & Watling, 2018) as vehicles become increasingly "connected" they produce more data that can be used for management (West Oliver et al., 2014).

The current challenges to stimulate further and faster use of big data in practice – e.g., to improve the quality of transport for users – are predominantly institutional instead of technical (Veeneman et al., 2018). Hereupon, a proper governance model is considered a critical element for enhancing all possibilities that these new transportation data platforms could achieve.

According to Yap & Munizaga (2018), in mobility data platforms, technical challenges can be solved easier, whereas institutional or governance challenges tend to be more complex. Thus, the greater the level of a mobility platform the more difficult it is to define and reach consensus on the directions of the platform.

The studies of governance mechanisms have an applied orientation, with emphasis on the modes of contractual relations among firms (Williamson, 2005). Over the past three decades, numerous studies have examined transaction cost economics' directing managerial decisions and the resulting performance about whether to organize firms' activities via market (exchange of services), hybrid (mutual adjustment), or hierarchy (authority) (Crook et al., 2013; Veeneman et al., 2018).

As depicted on Figure 2, asset specificity and frequency of disturbances are elements which drive the choice of governance mechanisms more suited to each economic context (Kupfer & Hasenclever, 2002; Mesquita et al., 2013). When an asset has low specificity, governance via market is the best coordination system for reducing opportunistic behaviors, uncertainty degree and transaction costs. In a medium level of specificity, a hybrid mechanism is more adequate for reducing transaction costs. At last, when asset has a high specificity, hierarchy is the best alternative to minimize the degree of uncertainty, transaction costs and opportunistic behavior of economic agents (Antonialli; Antonialli & Santos, 2017; Williamson 1991).

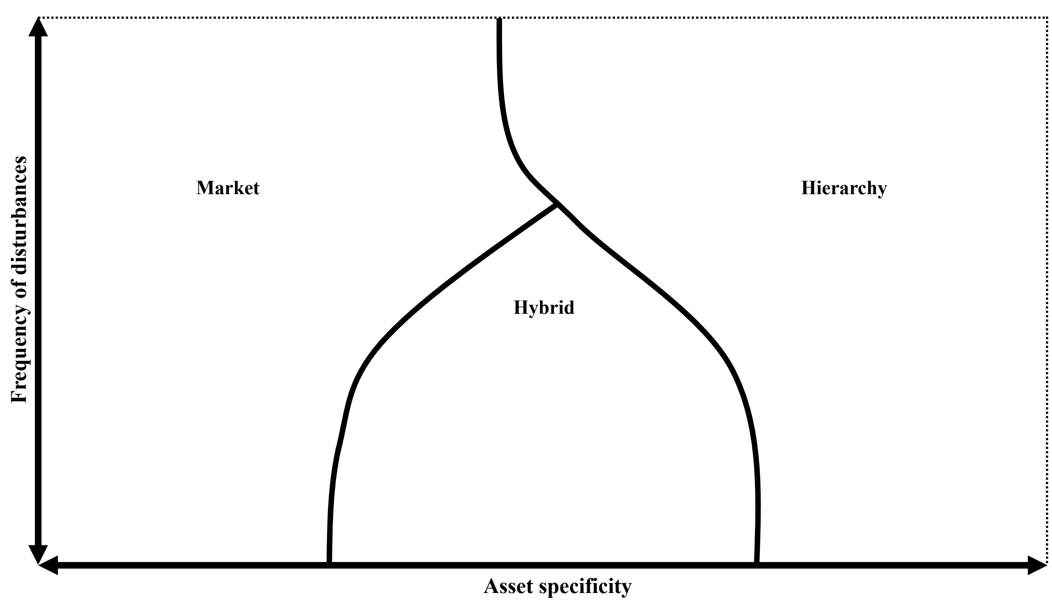

Figure 2. Governance responses to changes in disturbances frequency and asset specificity.
Source: Adapted from Williamson (1991, p.292).

Summarizing, governance mechanisms are analyzed and chosen under conditions of transactions' uncertainty between and within firms (Gibbons, 2010). As for mobility platforms contexts, governance mechanisms play an important role. According to Veeneman et al. (2018), governance arrangements are critical for the success of mobility data platforms. For instance, P2P mobility companies such as Uber, Lyft and Didi Chuxing are very good on efficiently selling reductions in transaction costs, via their data platform by connecting buyers and nearby sellers (Munger, 2018).

According to Veeneman et al. (2018) in this scenario of the mobility platforms three main questions emerges: 1) what kind of data is relevant and could be valuable in a mobility data platform? 2) what types of actors generate and own that data? and 3) what kind of relations do these actors have with a platform manager that could drive the governance? These questions will assist on conducting the analysis of the results of the present study.

3. Methodology

Based on a qualitative and exploratory research design, we initially sought to gather secondary data (on both academic and grey literature) as a way of subsidizing the identification of big data sources for urban mobility platforms.

The second stage was carried out based on secondary data and with the help of two professors, experts on urban mobility from the Terrestrial Mobility Laboratory of Federal University of Lavras, Brazil (LMT/UFLA), it consisted on the identification of specific assets (tangible and intangible ones) to plot the governance models for each proposed scenario described on Figure 1.

As depicted in Figure 3, the transport modes for each scenario were considered as tangible assets and the data needed to run each scenario's business platforms were considered as intangible assets, a total of 24 assets were ranked for the governance models' plotting. It is worth highlighting that these data sources considered as intangible assets do not represent the totality existent for each scenario, that is, the search was carried out to provide a set of trivial components for the distinction between the governance models for each scenario.

	Tangible assets (transport modes)					Intangible assets (data)																		
Scenarios	a. Autonomous vehicles (AV)	b. Bicycles	c. Autonomous Shuttles	d. Autonomous Taxis	e. Public Transport (PT)	a_1. AV's location	a_2. AV's availability	b_1. Bicycle's location	b_2. Bicycle's availability	c_1. Shuttle's location	c_2. Shuttle's availability	d_1. Taxi's location	d_2. Taxi's availability	e_1. PT's location	e_2. PT's availability	f. Passenger's location	g. Trip's demand	h. User's evaluation	i. Trip's travel time	j. Modal's occupancy	k. Weather	l. Traffic	m. Trip's revenues	n. Trip's costs
A	✓					✓	✓									✓	✓	✓	✓	✓	✓	✓	✓	✓
B	✓					✓	✓									✓	✓	✓	✓	✓	✓	✓	✓	✓
C	✓	✓	✓			✓	✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
D	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 3. Surveyed assets for plotting the governance charts.
Source: prepared by the authors.

Inspired by the works of Antonialli, Antonialli & Santos (2017) and Otto and Chobotová (2013), stage 3 of this research consisted on conceptually plotting the specific assets for the given examples on each scenario based on Williamson's (1991) discrete structural analysis for governance models (Figure 2). This stage was subdivided in three sub-steps:

i) The authors plotted a preliminary governance version for each scenario by ranking each asset, regarding how specific they are to the platform provider, (ranging from 0 to 8 on the *x*-axis) and how uncertainty and disturbances regarding each asset influence on the platform's business model (ranging from 0 to 4 on the *y*-axis).

ii) Each scenario's core characteristics were explained in details to 12 researchers in urban mobility both in France (*Laboratoire Génie Industriel – CentraleSupèlec*) and in Brazil (LMT/UFLA) – this group of researchers was comprised of professionals in both technical and non-technical areas related to urban mobility, therefore following the premise posited by Gandia et al. (2018) of the importance of pluridisciplinarity for the advancement of research on vehicular automation. Thus, the researchers were split in pairs and were invited to plot their versions of the graphs (also ranking the assets on the *x*-axis from 0 to 8 and the *y*-axis from 0 to 4) for each scenario.

iii) At last, the results found on sub-steps (i) and (ii) were compared, discussed and refined and a final governance graph for each scenario was plotted based on the arithmetic means and standard deviations.

After plotting the graphs, stage 4 was carried out with the analysis and discussion of the governance models for each scenario, via descriptive qualitative analysis (Sanderlowski; 2010; Kim, Sefcik & Bradway, 2016). Also, secondary data was used to support the findings.

4. Results and discussion

4.1 Assets' identification and governance plotting for each scenario

As depicted on Figure 4, regarding scenarios A and B, eleven assets were used for plotting the governance models; being those: (**a**) autonomous vehicle; ($\mathbf{a_1}$) data on AV's location; ($\mathbf{a_2}$) data on AV's availability; (**f**) data on passenger's location; (**g**) data on trip's demands; (**h**) data on user's evaluation; (**i**) data on trip travel time; (**j**) data on modal's occupancy; (**k**) data on weather; (**l**) data on traffic; (**m**) data on trip's revenues and (**n**) data on trip's costs.

Scenario C encompassed, in addition to these eleven previous assets, two other transport modes (**b** – bicycle and **c** – private autonomous shuttles) as well as their respective data on location and availability ($\mathbf{b_1}$, $\mathbf{b_2}$ and $\mathbf{c_1}$, $\mathbf{c_2}$), totaling 17 assets plotted.

Scenario D also holds the eleven assets from scenarios A and B in addition to the modal bicycle and its data on location and availability depicted in scenario C as well as two other transport modes (**d** – autonomous B2C taxis and **e** – public transport) and also their respective data on location and availability ($\mathbf{d_1}$, $\mathbf{d_2}$, $\mathbf{d_3}$ and $\mathbf{d_4}$), thus, totaling 21 assets plotted. Following all scenarios and respective governance mechanisms are analyzed.

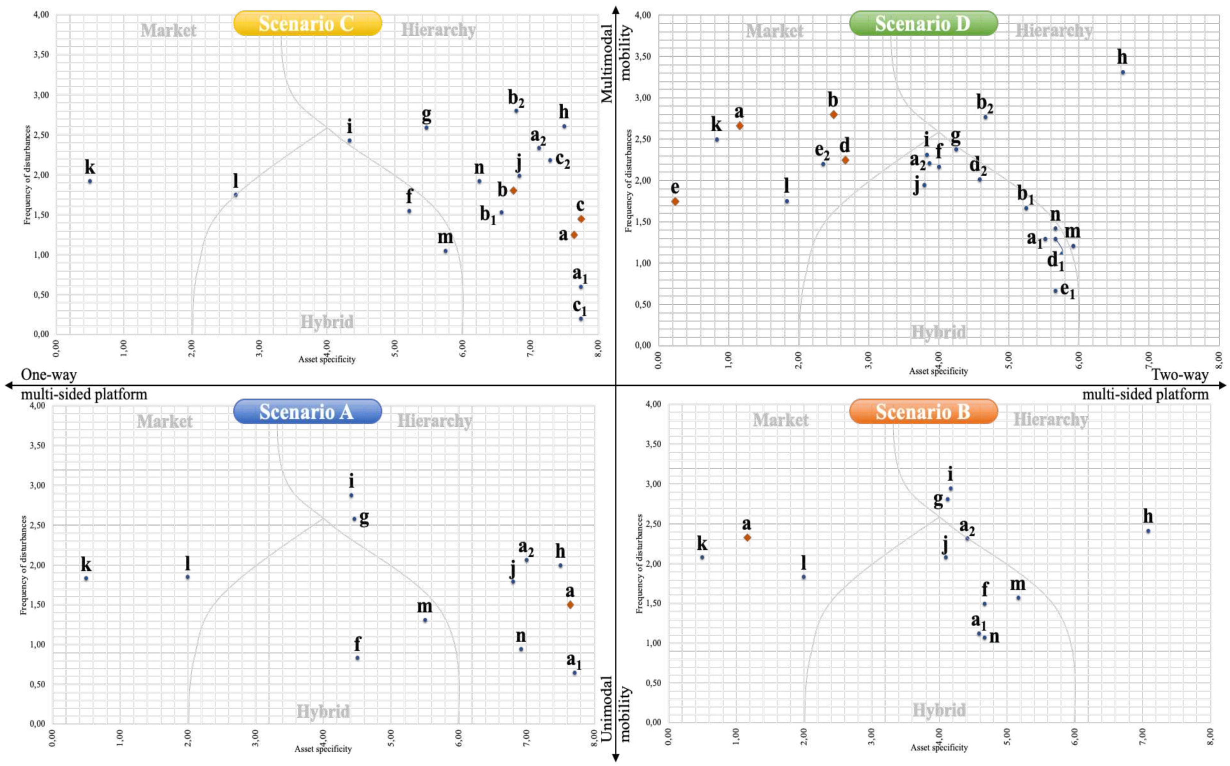

Figure 4. Scenarios' assets distribution towards specificity and disturbance frequency.
Source: prepared by the authors.

Scenario A: B2C autonomous ridesharing.

In this scenario, the platform provider subsidizes the consumers' segment by being responsible for all direct and indirect costs regarding both the fleet and the platform itself.

The tangible asset (Autonomous Vehicle) presents a high specificity degree (7.65) and an intermediate frequency of disturbances (1.50). Thus, with the platform provider owning the fleet (B2C business model), the number of AVs available to commuters is likely to be smaller when compared to traditional P2P mobility platforms, hence, this peculiarity could raise operational issues to both commuters and platform provider. On the other hand, however, by owning the fleet, the platform provider would has more control over supply and reallocation of its vehicles in face of demand fluctuations.

As for intangible assets, most of the data was anchored within the hierarchical side of Williamson's (1991) model (**a_1**, **a_2**, **g**, **h**, **i**, **j**, **n**), since for one-way multi-sided platforms, producing such data internally may be considered strategical for the business model efficiency and success. The only two intangible assets acquired via market for this scenario, are data on weather (**k**) and on traffic (**l**) due to their low specificity degree.

At last, data on passenger's location (**f**) and on trip's revenues (**m**) are anchored on the hybrid portion of the graph, in both cases the platform provider cannot produce this data internally nor acquire them directly on the market, thus contractual relations among the involved stakeholders are necessary. The user (commuter), by agreeing to the platform's terms of service (e.g. Uber), agrees to assign his/her location data to the company as well as to allow his/her credit card carrier to make financial transactions on each completed journey.

Regarding the frequency of disturbances, most of the assets in this scenario were plotted as having an intermediate disturbance frequency. Data on weather (**k**), traffic (**l**), modal's occupancy (**j**), vehicle's availability (**a_2**) and user's evaluation (**h**), all displayed a frequency of disturbance around 2,00. Data on passenger's location (**f**), trip's revenue (**m**), trip's costs (**n**) and vehicle's location (**a_1**) presented lower frequency of disturbance, while data on trip's demand (**g**) and trip's travel time (**i**) ranked higher on disturbances frequency.

Thus, the governance model for scenario A is mainly hierarchical, because, by internalizing most of the data (72.8%), the number of transactions carried out via market or hybrid forms is likely to be minimized, hence reducing the need of formal contracts as well as reducing the odds of information asymmetry and opportunistic behavior by the involved stakeholders (Veeneman et al., 2018; Yap & Munizaga, 2018).

Scenario B: P2P autonomous ridesharing.

Scenario B entails unimodal mobility were AVs (**a**) were tangible assets of low specificity (1.17) and intermediate uncertainty (2.33), coordinated mainly by market mechanisms. As for intangible assets, since AVs' ownership now belongs to ordinary peers, vehicles' usage as well as their data, rely on contractual and consensual relationships among the vehicle's owners (ordinary peers) and the platform provider (e.g., Uber).

In this sense, the majority of these assets once anchored within hierarchical mechanisms in scenario A, have now migrated towards hybrid structures – data on modal's occupancy (**j**), AV's location (**a_1**) and availability (**a_2**) as well as trip's costs (**n**) being anchored within the hybrid governance structure alongside passenger's location (**f**) and trip's revenue (**m**) – while data on user's evaluation (**h**), trip's demand (**g**) and trip's travel time (**i**) are still plotted within hierarchy, however leaning a bit towards hybrid governance, which according to Sundararajan (2016) the reality of AVs brings up a more distributed or networked economic structure derived from the digitalization of economy. At last, data on weather (**k**) and traffic (**l**) continue to be acquired via the market (as in scenario A).

As for frequency of disturbances, this scenario presented similar averages to scenario A, with most of the assets displaying intermediate uncertainty degree. However, with the platform provider not owning the fleet, all assets presented a slight rise on disturbances when compared to the previous scenario, except for data on traffic, which remained basically unchanged.

Scenario C: B2C multimodal mobility.

Scenario C offers a multimodal solution from point X to Y with the service provider (e.g., SHIFT – Project 100) owning all multimodal fleet. With that, the tangible assets (**a**) autonomous vehicles, (**b**) bicycles and (**c**) autonomous shuttles were all anchored within hierarchy and presenting intermediate to low disturbances frequency, in a sense that by owing the fleet, the platform provider is likely to have more control over its tangible assets, where through preventative maintenance, scheduled fleet's cleaning, among other factors, may reduce the frequency of disturbances with its fleet.

Overall, the business model logic behind this scenario is very similar to scenario A, however, due to a higher number of transport modes, asset specificity tends to move further into hierarchy and intangible assets' frequency of disturbances also tends to be somewhat higher. Therefore, the governance structure of this scenario is the most hierarchical among the analyzed scenarios, confirming Van den Broek and Van Veenstra's, (2018) argument that the more closed or sensitive the data is, the more centralized or hierarchical approaches of governance is needed.

Scenario D: B2C + P2P multimodal mobility.

Scenario D perfectly fits the definitions of Mobility-as-a-Service (MaaS) as proposed by Jittrapirom et al. (2017), Mulley (2017) and Hietanen (2014). Furthermore, in the same way that scenario C resembles scenario A, the present scenario is very similar to scenario B regarding its business model operation.

By analyzing the upper-left quadrant of Figure 4, one can notice that the multimodal fleet composed of (**a**) P2P autonomous cars, (**b**) B2C bicycles, (**d**) B2C autonomous taxis and (**e**) B2C public transport are all plotted within the market governance structure with intermediate to high disturbances frequency.

Since the platform provider (e.g., UbiGo) does not own the fleet, the company relies on third parties to carry out its operations, thus, much of the data (62.5%) required for the correct functioning of its business model are anchored in the hybrid governance structure, those being: data on AVs' location (**a_1**) and availability (**a_2**), bicycles location (**b_1**), autonomous taxis' location (**d_1**) and availability (**d_2**), public transport location (**e_1**), passengers' location (**f**), trip's demand (**g**), trip's travel time (**i**), modals' availability (**j**) and trip's costs (**n**).

In this sense, the frequency of disturbances tends to be from intermediate to high, therefore well-defined contracts and trust relationships among the involved stakeholders are fundamental for reducing information asymmetry and thereby reducing opportunistic behaviors, as well as for value to be generated and distributed fairly among all actors in the platform ecosystem. As this platform became more digitalized, not only transactions costs are likely to be reduced, but also value creation might be enhanced (Munger, 2018; Souza et al, 2018).

4.2. Platforms' costs and the role of institutions towards regulations and standards

By analyzing Figure 4, it is in fact clear the governance similarity between scenarios A and C and scenarios B and D. However, with regards to operating and transaction costs, a mirror-like behavior was observed.

As depicted on Figure 5, the evolution of transaction costs among the scenarios presents a N-type curve behavior starting on scenario A and ending in scenario D with the highest transaction costs, while operational costs tend to evolve in the opposite trajectory, starting on scenario B, moving up to D and them to A and finally being the highest on scenario C.

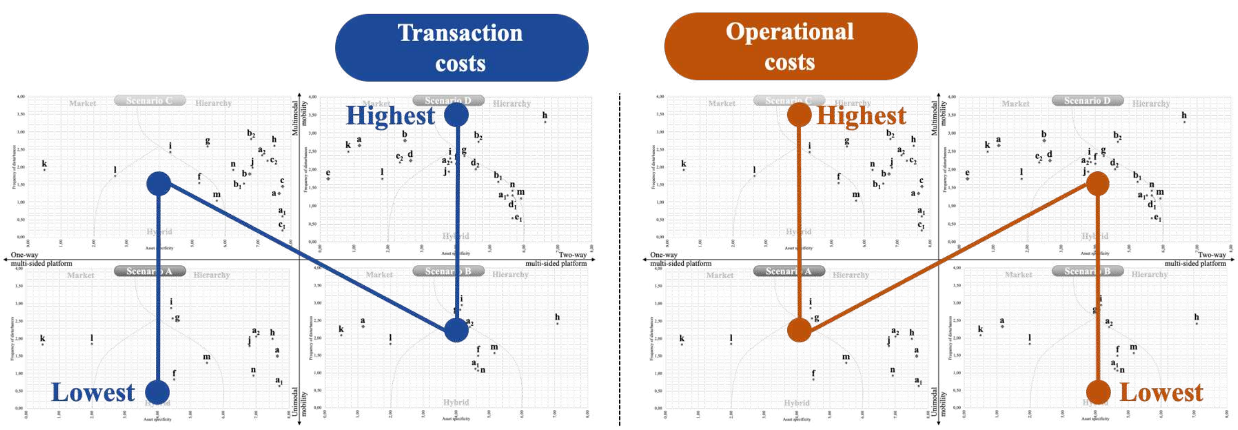

Figure 4. Operational and transaction costs among the plotted scenarios.
Source: prepared by the authors.

By offering a subsidized unimodal commute between two points, scenario's A market dependence is restricted to commoditized data, such as weather (**k**) and traffic (**l**), hybrid governance is limited to contracts on user's location data (**f**) and data on trip's revenue (**m**), resulting in all other tangible and intangible assets being produced internally; which, in turn, leads to reductions in transaction costs and tends to mitigate opportunistic behavior among the stakeholders in the platform ecosystem (Williamson, 2005; Crook et al., 2013). This same analysis can be applied to scenario C, however, since the platform provider owns a multimodal fleet, the frequency of disturbances affecting the assets tends to be higher, which causes transaction costs to slightly rise as well.

As for scenario B, by also offering a unimodal solution between two points, its operation logic resembles scenario A, however, by not owning the fleet, the platform provider becomes more dependent on market transactions (assets: **k**, **a** and **l**) and hybrid transactions (assets: **j**, $\mathbf{a_1}$, $\mathbf{a_2}$**,** **f**, **n** and **m**), thus making transaction costs higher than the two previous scenarios, thus corroborating Williamson's (2005) premises.

At last, scenario D presents the highest transaction costs among all; by not owning the multimodal fleet, the platform provider is at the mercy of several market transactions (assets: **e**, **k**, **a**, **l**, $\mathbf{e_2}$, **b** and **d**) and a wide range of hybrid relations with the most varied stakeholders in its ecosystem (assets: **j**, $\mathbf{a_2}$, **i**, **f**, **g**, $\mathbf{d_2}$, $\mathbf{b_1}$, $\mathbf{a_1}$, **n**, $\mathbf{d_1}$ and $\mathbf{e_1}$) such peculiarities also make the frequency of disturbances higher in this scenario for a large part of the assets. Such results corroborate the assertive proposed by Souza et al. (2018) that within the digital economy, hybrid governance structures on data platforms are likely to prevail. Sundararajan (2016) also confirms this argument highlighting that generally, platform structures of digital economy such as Uber entails hybrid governance between pure market and hierarchy.

Regarding direct and indirect operating costs, the results show an opposite behavior to the evolution of transaction costs. By executing its business via a single transport mode and by not owning the fleet, scenario B presents the lowest operating costs among all scenarios; having to bear only the costs related to the platform maintenance and the data needed to its functioning. The same goes for scenario D, however, due to its multimodal approach more data needs to be managed, which in turn slightly raises the operating costs.

Operating costs go beyond maintaining the platform and data; direct and indirect costs with the fleet (such as maintenance, insurance, cleaning, recharging, relocation, etc.) become crucial to the platform's governance structure. In this sense, scenario A presents higher operating costs to scenarios D and B; and scenario C, presents the highest operating costs among all models, which can lead to the failure of the business model if management is not well planned and implemented – which in fact happened to SHIFT's operations in Las Vegas (Loveday, 2015; Rothberg, 2015).

Such findings are aligned with Veeneman et al. (2018) work, in which they reached a conclusion that the more ambitions a mobility platform has, the more governance challenges arise due to several mechanisms. In this sense, as stated by Yap and Munizaga (2018) a higher ambition level of a mobility platform and the number of stakeholders to get involved, makes it more difficult to define and realize consensus about the platform directions, increasing the need for a clear governance structure and coordination.

With that, another important element for the governance of mobility data platforms is the role of the institutional environment and the respective local transport authorities (Yap & Munizaga, 2018). These entities play a fundamental role in directing the governance structures to be adopted by the platforms. As IET (2017) point out local authorities nowadays plays a part in a wider technological ecosystem.

As highlighted by Veeneman et al. (2018) and Yap and Munizaga (2018), to successfully institutionalize the use of big data in mobility platforms, the technical ambitions should be aligned with the given institutional environment that the platform is positioned in. Furthermore, efforts towards enabling and easing the use of big data by transport authorities are fundamental for the success of platforms' (Yap & Munizaga, 2018).

In response to these issues, the blockchain technology is proving to be a viable alternative to ensure a more ethical, decentralized and transparent usage of data (Geiregat, 2018). Thus, blockchain provides a viable method of coordination of parties that do not trust each other by offering a decentralized network of "verifiers" to clear transactions, rendering moot the need of a central authority (Sundararajan, 2016). Thus, blockchain and smart contracts may therefore benefit all the scenarios here studied.

Smart contracts are guaranteed to execute as coded without any manipulation from the parties, such contracts are essentially "code containers" that encode and mirror the real-world contractual agreements in the cyber realm (Macrinici, Cartofeanu & Gao, 2018; Geiregat, 2018). Once a it has been created it cannot be changed, this gives its participants a guarantee of what will happen (Andersson & Torstensson, 2017).

At last, Table 1 summarizes the main results found in the present conceptual study as well as it answers the two remaining questions posited by Veeneman et al. (2018) in the end of the present study theoretical background section.

Scenario C is the most hierarchical in terms of governance structure, closely followed by scenario A. In this sense, their regulation structure could be more centralized on transport authorities since both these mobility platforms have their assets less dispersed and distributed among its respective business ecosystems, as corroborated by IET (2017).

Scenarios B and D have a predominantly hybrid governance structure, noting that scenario D relies on a greater number of market transactions due to the inherent characteristic of its tangible assets. In this sense, Sundararajan (2016) points out that the business platforms which are into sharing economy features present more networked-based relations instead of traditional centralized ones.

Scenario	**Main features**	**Governance model**	**Data ownership**	**Regulations**
A	B2C unimodal mobility	Hierarchy	Centralized on platform provider	Centralized on transport authorities
B	P2P unimodal mobility	Hybrid	Spread among different stakeholders	Smart contracts via Blockchain
C	B2C multimodal mobility	Hierarchy	Centralized on platform provider	Centralized on transport authorities
D	B2C + P2P multimodal mobility	Hybrid	Spread among different stakeholders	Smart contracts via Blockchain

Table 1. Scenarios' summary of governance of autonomous urban mobility platforms
Source: Prepared by the authors.

Yap & Munizaga, (2018) confirm this argument by stating that when it comes to data-based mobility platforms, it is necessary to build up trustworthy relations among the involved stakeholders as well as to secure data sharing among them via contracts and standards. Ménard (2013) also highlights that adequate contracts are the underlying hybrid structures of governance.

Therefore, scenario D deals with greater complexity, bringing up the need of improved hybrid arrangements, bringing to light technologies such as blockchain and smart contracts. As Veeneman et al. (2018) point out the more complex a mobility platform is on a technical level, governance challenges are higher.

5. Concluding remarks

By considering the growing importance of big data in urban mobility systems, the conceptual analysis of governance structures carried out in this paper, pointed out that the level of data ownership is related to each scenario's features (mobility platforms' characteristics and all their respective assets), which therefore, delineates the most proper governance mechanism for autonomous mobility platforms.

Scenarios C and A (respectively) presented governance structures predominantly hierarchical, and, due to that, such scenarios displayed the highest operational costs among all four. By owning the fleet, the platform provider not only has to bear the costs of maintaining the platform itself, but also has to bear all direct and indirect costs of its fleet.

Meanwhile, Scenarios D and B (respectively) presented more hybrid governance modes, which, in turn, reduces the operating costs, but raises transaction costs. By not owning the fleet, such platforms rely on contractual and trust relations with other parties, hence, given margin to information asymmetry, which might lead to opportunistic behaviors and therefore raising transaction costs. In order to circumvent this situation, contracts and control mechanisms must be very clear and previously established in order to generate value for all involved parties.

As for frequency of disturbances, findings showed that the greater the number of transport modes are, the greater is the frequency of disturbances. Thus, for those scenarios, where the platform provider is also the owner of the fleet (A and C), the frequency of disturbances tends to be smaller than in scenarios where the platform provider does not own such tangible assets (B and D). By owning the tangible assets (transport modes), the platform provider also owns several data generated by such assets, thus reducing the need to acquire them via market or via partnerships (hybrid structures), which, in turn, gives greater control and, consequently, tends to reduce the frequency of disturbances, but, on the other hand, significantly increases operating costs.

One contribution of this present study is to address conceptually, issues related both on big data as well on governance within mobility platforms as described by Yap & Munizaga, (2018) and Veeneman et al. (2018). Generally, it was possible to characterize different governance modes, according to the types and ownership degree of tangible (transport modes) and intangible assets (big data) in each mobility platform analyzed.

As for research limitations, data collection with mobility researchers instead of industry members and practitioners could bring up subjective aspects into the research method performed - however, due to the difficulty of access to professionals in the urban mobility market, conducting the present study with urban mobility researchers was the most viable option. In the same way, the adopted methodology (by itself) presents subjective biases, so the conceptual and exploratory character of the present study requires validation through computational modeling and more robust databases. Therefore, future studies with urban mobility industry professionals are recommended. Also, this recommendation would imply in a larger variation specifically of intangible assets (data sources), since it would be collected not only via researchers, and literature review.

In summary, governance mechanisms will always be imperfect. There will always be a certain degree of information asymmetry and externalities. However, the more sophisticated the governance is, more it will encourage the ecosystem's stakeholders to take action. Thus, the governance cannot be static; in contrast, it must be adjusted according to the future scenarios in the market, new user behaviors, conflicts, and risks, allowing the whole ecosystem to be flexible to take decisions quickly (Parker, Van Alstyne & Choudary, 2016). Therefore, within big data contexts, complex platform structures bring up the need for more sophisticated governance structures (e.g., hybrid modes via blockchain and smart contracts), and a more proactive behavior of all involved stakeholders.

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