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► To cite this version:

Wale Arowolo, Isabelle Nicolai. Understanding the process of institutional change for sustainable future urban mobility: Insight on shared automated electric vehicle integrated in MaaS innovation from the ULTIMO European project.. *Le droit des mobilités*, LexisNexis, pp.441-450, 2023, 978-2-7110-3833-6. hal-03987471

HAL Id: hal-03987471

<https://centralesupelec.hal.science/hal-03987471v1>

Submitted on 14 Nov 2023

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Understanding the process of institutional change for sustainable future urban mobility: Insight on shared automated electric vehicle integrated in MaaS innovation from the ULTIMO European project.

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Abstract

This paper contributes to the debate on integrating shared automated electric vehicles (SAEV) in Mobility-as-a-Service (MaaS) in Europe's public transport system. Using the ongoing Horizon Europe ULTIMO project as a case study, we attempt to explain the process of institutional change from the old to the new dynamic institutional equilibrium when SAEVs are integrated in public transport systems. We explain that understanding the conditions, shape and form of a new institutional governance requires careful analysis, and the actors need to understand the impacts of the change. We also argue that designing generic and context-dependent formal and informal regulations in Europe's local, national, and international public transport systems requires meticulous analysis to achieve a new dynamic institutional equilibrium acceptable to all the actors. Moreover, understanding the process of institutional change could provide insight into the workable governance framework in the new dynamic institutional equilibrium.

Keywords: SAEV, MaaS, institutional change, public transport system, governance.

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1. Introduction

The transportation ecosystem for people and goods has evolved to promote sustainable mobility in cities. The urban mobility of the future will be multimodal, service-oriented, connected, shared, autonomous and electric (Sperling, 2018). Automated vehicle (AV) represents a potentially disruptive yet beneficial change to the transportation system with the potential to impact vehicle safety, congestion, and travel behaviour (Fagnant and Kockelman, 2015). When commuters share AV, it is expected to reduce congestion and offer economic and environmental benefits. Automating electric vehicle driving under shared mobility conditions is called Shared Automated Electric Vehicle (SAEV). There is also the burgeoning innovation of Mobility-as-a-Service (MaaS). MaaS is an integrated system with an online interface that enables commuters to plan, book, and pay for trips with different mobility providers. MaaS provides a system for integrating new service options with traditional transport modes as a promising alternative to overcome some negative externalities associated with private automobiles. MaaS also offers an opportunity to significantly reduce the sources of under-priced environmental pollution, accident, noise, and congestion externalities. The shift towards MaaS is also partly driven by changing trends associated with increased ride-sourcing applications use and reduced car ownership among younger populations (Hörcher and Graham (2020); Butler et al. (2021); Utriainen and Pöllänen (2018)). Then, SAEV can be integrated in MaaS to harness the potential benefits of both innovations in the public transport system (hereinafter 'SAEV in MaaS'). 'SAEV in MaaS' proponents anticipate that the innovation could be a potential game-changer in the future of mobility.

Despite the promising offer of 'SAEV in MaaS', it is worth noting that 'SAEV in MaaS' will inevitably bring about an institutional change in the current public mobility paradigm. Institutions are the humanly devised constraints that shape human interaction and structure incentives in human exchange, whether economic, political or social. Institutional change is a complicated process because marginal changes can result from changes in rules, informal constraints, and the kinds and effectiveness of enforcement. Moreover, institutions typically change incrementally rather than in a discontinuous fashion and institutions in the past and future are interlinked in a complex manner (North, 1990; Aoki, 2007). The process of institutional change is incremental because the economies of scope, complementarities and externalities that arise from a given institutional matrix of formal rules, informal constraints, and enforcement characteristics typically bias costs and benefits in favour of choices consistent with the existing governance framework. The larger the number of rule changes, *ceteris paribus*, the greater the number of losers and opposition (North, 1994). A new dynamic institutional equilibrium is a state or is achieved when institutions have evolved, adapted to changes in the institutional environment and established a stable and legitimate balance between different forces and interests.

The institutional landscape comprises an interdependent web of institutions and consequent political and economic organisations (North, 1991). Although formal rules may change overnight due to political or judicial decisions, informal constraints embodied in customs, traditions, and codes of conduct are much more impervious to deliberate policies (North, 1990). The constraints imposed by the institutional framework define the opportunity set and the kind of organisations that will come into existence (North, 1994). Furthermore, societal interest groups heavily influence the political process of institutional design and redesign. The process is characterised by struggle and conflict because a change of rules almost

always implies adjusting the distribution of costs and benefits. Consequently, markets are perceived as evolving systems in which individual and collective actions result in both intended and unintended consequences. Moreover, informal institutions are not explicitly formulated and written down but internalised in community members' hearts and souls. Informal institutions change slowly and are not subject to economic calculative behaviour. Individual economic actors, and even groups of actors in collective action, are rarely in the position to purposefully (re)design informal institutions (Correlje et al., 2014).

In this paper, we contribute to the debate on the adoption of 'SAEV in MaaS' innovation within the urban mobility ecosystem. We build upon the framework of Groenewegen and de Jong (2008) to explain the process of institutional change of 'SAEV in MaaS' innovation using the European ULTIMO project as a case study. The Horizon Europe-funded ULTIMO project aims to lay the foundation to deploy economically viable SAEV-based public transport services in Germany, Switzerland, and Norway.

This paper proceeds as follows: Section 2 discusses SAEV innovation for sustainable economic development. Section 3 discusses 'SAEV in MaaS' innovation. Section 4 explains the process of institutional change with the ULTIMO project case study. Section 5 concludes the paper.

2. SAEV innovation for sustainable economic development

The current mobility paradigm comprises over 1.3 billion cars globally, and the number is increasing (Grindsted et al., 2022). In the EU, passenger cars' share of inland passenger transport is about 87% (Eurostat, 2022). Moreover, the global demand for passenger mobility is estimated to double in cities by 2050. Along with the continuously increasing demand for mobility, the negative externalities of congestion, air pollution, noise and accidents could increase. Therefore, mobility innovation is required to surmount the challenges of the current resource-intensive, privately-owned, car-based mobility paradigm. Among others, emerging mobility innovations include automated driving, electric vehicle, shared mobility, mobility-on-demand, trip intermodality and multimodality, and Mobility-as-a-Service (MaaS). The innovations aim to achieve a connected, electric, and automated mobility paradigm (Grindsted et al., 2022; Nemoto et al., 2022).

Automating electric vehicle driving and shared mobility is coined as Shared Automated Electric Vehicle (SAEV). SAEV include robotaxis and automated shuttles integrated in public transport. SAEV can provide on-demand ride services within a fixed route with fixed stops, a fixed route with on-demand stops, door-to-door on-demand services, unimodal and intermodal door-to-door trips (Nemoto et al., 2021). SAEV innovation can contribute to sustainable, inclusive economic development by increasing transport accessibility for low-income households and helping people with reduced mobility. SAEV can also reduce cold-start emissions, improve roadway capacity, reduce vehicle ownership and fleet size requirements, parking demand, labour costs, fuel consumption, operating costs, and productivity losses, thus contributing to sustainable development and inclusive economic growth (Singh et al., 2023; Huber et al., 2022; Mira Bonnardel, 2021). Moreover, integrating SAEV as an innovative urban mobility solution with dynamic ridesharing services could promote sustainable, social and transport equity and adoption (Golbabaei et al., 2021). SAEV can also be integrated in a MaaS and connected in the future of mobility. We discuss 'SAEV in MaaS' innovation in the next section.

3. 'SAEV in MaaS' innovation

MaaS entails the integration of mobility options through the definition and commitment to a standardised interface to offer passengers a seamless multimodal and intermodal trip for on-demand, door-to-door services (Korbee et al., 2022). 'SAEV in MaaS' will provide an alternative solution to privately-owned vehicles, for example, by offering first and last-mile passenger trips and logistics services on infrequently plied routes. SAEV offers more benefits as a fleet of shared vehicles integrated in a 'citizen-centric MaaS' in public transport system than privately-owned automated vehicles (AVs) or a fleet of SAEV competing with public transport such as robotaxis. The advantages of 'SAEV in MaaS' over privately owned AVs or robotaxis include its attractive mobility offer and lower negative externalities. 'SAEV in MaaS' also avoids the dominant market position problem (Fournier et al., 2022; Golbabaie et al., 2021).

Integrating MaaS solution in public transport networks should make public transport attractive and competitive, especially in areas with low public transport coverage. A study in Oslo, Norway, to understand the impact of integrating SAEV in public transport shows that in a scenario where all the existing Internal Combustion Engine Vehicle (ICEV) users switch to SAEV, there will be drastic traffic reduction in Oslo as about 7% of the current vehicle fleet will be required to meet transport demand during the peak period (Ruter, 2019). Related studies show similar results, such as the OECD International Transport Forum's Lisbon studies (5%), Helsinki study (4%), Dublin (2%), Auckland (7%) and Stuttgart study (7%) (ITF, 2015; 2016; 2017; 2018; Helsinki (2017), Dublin (2018), Auckland (2017), Friedrich et al., 2018). The results illustrate that a significant reduction in ICEVs, air pollution, accidents, noise, and congestion externalities is achievable with SAEV integrated in public transport. Nonetheless, integrating SAEV in public transport and MaaS systems will require new transport infrastructure and transport system governance. Traffic congestion may also increase if MaaS becomes more attractive than traditional public transport.

4. The process of institutional change (the ULTIMO project case study)

4.1 The ULTIMO project case study

The Horizon Europe research and innovation-funded ULTIMO project (2022-2026) aims to lay the foundation to deploy economically viable SAEV-based, on-demand, door-to-door and user-oriented shared public transportation services. The project aims to advance sustainable user-centric mobility with automated minibuses for safe, resilient transport and smart mobility services for passengers and goods. The ongoing ULTIMO project will run SAEV pilots at three European cities (Oslo, Norway; Kronack, Germany; and Geneva, Switzerland) representing different geographic positions, traffic and socio-economic contexts, ecosystems, and readiness levels toward pre-commercial shared, cooperative, and connected automated mobility (CCAM). The project will deploy at least 15 driverless SAEVs (mini-shuttles) from different OEMs in an interoperable manner. Twenty-three (23) partners are collaborating on the project². Besides, the project will also directly or indirectly impact other actors³ in the

² The project partners are RBO Regionalbus Ostbayern GMBH (Deutsche Bahn-DB), Hochschule Pforzheim (HSPF), Ruter AS, Navya, Yogoko, Sensible4 OY, Modaxo Europe AS, Union Internationale des Transport Publics (UITP), Padam Mobility, Altran Innovation SL, Bax Innovation Consulting SL, Greek National Centre for research and technology (CERTH), Siemens, CentraleSupélec (Paris Saclay University), Arthur's Legal BV, University of Geneva, Transports Publics Genevois (TPG), MobileThinking SARL, ArgYou AG, Department of economics and

automated mobility ecosystem. We use the project as a case study to explain the process of institutional change of 'SAEV in MaaS' innovation.

4.2 The process of institutional change of 'SAEV in MaaS' innovation

The interplay between the polity and the economy and the many actors with varying degrees of bargaining power to influence institutional change contribute to the complexity of institutional change (North, 1990). We adopt the framework of Groenewegen and de Jong (2008) to explain the dynamic, stepwise process of institutional change of 'SAEV in MaaS' innovation as follows:

- *In the old institutional equilibrium⁴ with particular institutional rules and organisational forms, some actors' preferences are fulfilled more substantially than others.*

The largely fossil fuel-based mobility paradigm can be understood as the old institutional equilibrium. For example, actors such as subsisting multinational ICEV manufacturers (Volkswagen, Stellantis), oil and gas companies (Shell, Total) are some of the dominant actors in the old institutional landscape. They have their preferences fulfilled more than other actors, such as burgeoning SAEV manufacturers (Navya, Sensible4) and software and technology solution providers (Yogoko, Modaxo Europe).

- *Over time, satisfaction among some actors falls below a certain level. Then, the need for institutional change among some actors (for example, public actors) becomes too strong to resist.*

Dominant (public) actors such as the European Commission (EC) and the national governments (such as the Swiss) are dissatisfied with the high level of negative transport externalities and its consequent impact on the environment, health and sustainable economic growth and development. For example, the transport sector accounts for about a quarter of EU's emissions (EC, 2019). In Europe, road accidents are responsible for about 120,000 deaths and 2.4 million injuries annually, economic loss of up to 3% of a country's gross domestic product, and the leading cause of death among young people between 5-29 years old (WHO, 2009). Therefore, there is a policy push for institutional change from dominant public actors on all fronts, including in research and development (R&D). For example, the EU and Swiss governments are facilitating institutional change to achieve sustainable urban mobility with the ULTIMO project.

- *Some actors become institutional entrepreneurs (IEs) searching for new ideas and alternative institutional arrangements.*

IEs are actors interested in a particular institutional landscape and leverage resources to create or transform existing institutions (Garud et al., 2013). For example, SAEV manufacturers (Navya, Sensible4), software and technology solution providers (Yogoko,

employment (Swiss Government), Swiss Association for Autonomous mobility (SAAM), Association Open Geneva, and ZF CV Systems Global GMBH).

³ The other actors in the automated mobility ecosystem include ICEV manufacturers, oil and gas companies, charging and battery infrastructure manufacturers and allied industries, insurers, electric utilities, environmental non-governmental organisations, industry lobby groups, standardisation bodies, and other research institutions.

⁴ Institutional equilibrium is a situation where, given the bargaining strength of the actors and the set of contractual bargains that make up the total economic exchange, none of the actors would find it advantageous to devote resources to restructuring the agreements (North, 1990)

Modaxo Europe, Padam Mobility, Altran Innovation (Capgemini engineering), MobileThinking, ZF, Siemens); Bax innovation, Swiss Association for Autonomous Mobility (SAAM) and Arthur's legal BV are IEs in the ULTIMO project. The IEs offer services to enable the intelligent operation and optimisation of fixed or on-demand automated mobility services and the interface with commuters, transport operators and mobility providers for 'SAEV in MaaS' innovation. Once IEs identify new ideas and are willing to deploy their resources to initiate the transformation, they promote their ideas to change other actors' perceptions and preferences. The more the other actors, such as public transport authorities/operators (for example, Ruter, Deutsche Bahn, TPG in the ULTIMO project), governments at all levels, civic associations are dissatisfied with the status quo, the more likely they will adopt the new ideas of IEs and be willing to change their preferences. Some new ideas being promoted by IEs include transport electrification and automation, MaaS, Logistics-as-a-Service (LaaS), car sharing, SAEV and integrating 'SAEV in MaaS' and LaaS innovation. 'IEs are promoting SAEV in MaaS' as a potential solution to the fossil fuel-based mobility paradigm.

- *In an environment with many actors operating at different (international) levels, IEs benchmark the current system with their new ideas.*

There has been much effort from IEs such as Navya, Sensible4, ZF, Yogoko, Padam Mobility, MobileThinking, Modaxo Europe, Altran Innovation (Capgemini engineering), Siemens, Bax innovation, SAAM and Arthur's legal BV to inform other actors, such as public authorities, civic associations, and other stakeholders (EU, Swiss and other national governments, Open Geneva, International Association of Public Transport (UITP)) on the added value of their ideas benchmarked against the current mobility paradigm. IEs use their resources, such as knowledge, funds, human resources, political lobbies, and legal power, to strategically achieve a new institutional landscape. For example, IEs attempt to change formal institutions (such as regulations) or lobby for new regulations at the EC or member states to support 'SAEV in MaaS' innovation projects.

- *A window of opportunity arises for IEs when some dominant actors feel a deep sense of urgency. The stage is set for IEs to have their ideas accepted and institutionalised.*

A deep sense of urgency from dominant actors such as the EC, Swiss, and other national governments on climate change mitigation, sustainable public transportation and economic development has led to the inclusion of SAEV in 'the future of mobility' scenarios. The dominant (public) actors can also provide incentives to remove barriers to SAEV development. For example, the EC and Swiss government will incentivise the procurement of SAEV for public transport operators/authorities in Norway (Ruter), Switzerland (TPG), and Germany (Deutsche Bahn) in the ULTIMO project. Moreover, the EC and some member states fund other past and ongoing large-scale SAEV-based R&D projects⁵ to promote SAEV market development. The EC and member states' national and local governments are also enacting legislation and regulations to support SAEV pilot projects. Thus, SAEV is now accepted by some dominant (public) actors and institutionalised.

⁵ Other ongoing EU-funded SAEV projects include SHOW (2020-2023), MODI (2022-2026), TAURO (2020-2023), FR8RAIL II (2020-2023). Past EU-funded projects include AVENUE (2018-2022), nIoVe (2019-2022); Drive2theFuture (2019-2022), Trustonomy (2019-2022), Saaave (2019-2022), Pascal project (2019-2022). National government-funded projects include SMO (2020-2022, German BMVI), HEAL (2020-2023, German BMVI), AUTOPIA (2020-2022, Research Council of Norway), STOR (2017-2022, Norwegian Ministry of Transport)

- *The conditions of the change and the shape and form of the new institutional equilibrium will be decided. Although IEs and their allies now find themselves in a position of power and can take the initiative to change some of the rules of the game, they depend to some extent on the reactive moves of some former dominant actors.*

At this crucial stage, understanding the conditions, shape and form of the new dynamic institutional equilibrium becomes paramount as it poses a demanding challenge for all the public transport ecosystem stakeholders (the EC, Swiss and other national/municipal governments, the IEs mentioned above, Deutsche Bahn, Ruter, TPG, UITP, SAAM, Arthur's legal BV, ArgYou AG, Open Geneva) including research institutions (HSPF, CentraleSupélec, University of Geneva, CERTH) to integrate 'SAEV in MaaS' in the ULTIMO project. All the actors need to fully understand the conditions and impacts of the change. Moreover, IEs and their allies, such as the EC and national governments, are taking initiatives to change some of the rules of the game. There are now new regulations from the EC and some member states supporting SAEV pilot projects in operational design domains (ODD⁶), such as in Germany. Nonetheless, IEs and their allies are mindful of the reactive moves of the former dominant actors. Some key questions to address at this stage include:

- What reactive or strategic moves are being made by some former dominant actors, such as the multinational ICEV manufacturers and oil and gas companies that perceive SAEV could threaten their business models?
 - What reactive or strategic moves from the union of transport operators or public transport drivers that perceive SAEV could significantly threaten their job security?
 - What generic and context-dependent formal and informal regulations are needed in Europe's local, national, and international public transport systems?
 - Who wins in the new dynamic institutional equilibrium? Who loses?
 - What will be the changing role of the actors (see footnotes 2 and 3) in the new dynamic institutional equilibrium?
 - How to equitably share the costs and benefits to achieve the fairest possible outcome for actors in the new dynamic institutional equilibrium?
- *A new dynamic institutional equilibrium is reached where all the actors adopt the new policy belief system, perceptions, and preferences. However, the new equilibrium is stable to the extent that most actors feel their interest is protected. Otherwise, the unsatisfied actors may become IEs who, in turn, initiate an attempt to reverse the process.*

The coming years will reveal whether a new dynamic institutional equilibrium acceptable to all the actors will be reached. For example:

- Will citizens be willing to use or pay for 'SAEV in MaaS' innovation?
- Will the existing dominant actors, such as Shell and Total, be satisfied with the new institutional equilibrium or become IEs who will attempt to reverse the process?
- Will public transport drivers' associations or unions such as the Norwegian Confederation of Trade Unions (Landsorganisasjonen: (LO)), Association of German Transport Companies (Verband Deutscher Verkehrsunternehmen: (VDV)), or the Swiss Union of

⁶ ODD is the specific operating domain(s) a SAEV is designed to operate, such as roadway types, speed range, environmental conditions (weather, daytime/night-time), and other domain constraints.

Public transport (Union des transports publics: (UTP)) accept or reject the new institutional equilibrium?

In a nutshell, a meticulous analysis of the process of institutional change is required to facilitate informed decision-making to achieve an equitable distribution of costs and benefits among the actors involved in 'SAEV in MaaS' innovation diffusion. Moreover, understanding the process of institutional change could provide insight on the robust and effective governance approach in the new institutional equilibrium.

5. Conclusion

In this paper, we use the ULTIMO project as a case study and attempt to provide insight into the process of institutional change from the old institutional dynamics to the new dynamic institutional equilibrium in the future of mobility with 'SAEV in MaaS' innovation. We explain that the process of institutional change is complex, and understanding the conditions, shape and form of the new dynamic institutional equilibrium is crucial for 'SAEV in MaaS' innovation. The actors in the institutional matrix need to fully understand the impacts of the change and the consequent new institutional equilibrium. In addition, we explain that meticulous analysis is required to gain insight into the reactive moves of former dominant actors that may perceive SAEV as a threat to their business model or jobs in the new institutional equilibrium. Designing new rules of the game and generic or context-dependent formal and informal regulations in Europe's local, national, and international public transport systems will require a thorough analysis if a new dynamic institutional equilibrium acceptable to all the actors will be achieved. Moreover, a thorough analysis of the process of institutional change is required to facilitate informed decision-making to achieve an equitable distribution of costs and benefits among the actors involved in 'SAEV in MaaS' innovation and the future of mobility. The analysis could also help to provide insight into the robust governance approach in the new dynamic institutional equilibrium.

Acknowledgement

This research received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101077587 (The ULTIMO project).

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