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Technological breakthroughs and dynamics of an industry: the transition towards electromobility case

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Rupture technologique et dynamique d'une industrie, la transition vers l'électromobilité

Thèse de doctorat de l'Institut Polytechnique de Paris
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Thèse présentée et soutenue à Palaiseau, le 18 décembre 2020, par

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RESUME

Après une décennie de débats et d'initiatives d'impact limité, contraints par des réglementations environnementales qui imposent des réductions drastiques des niveaux d'émission de CO2 et de polluants ainsi qu'un nombre croissant d'initiatives d'interdiction des véhicules à combustion interne, tous les constructeurs automobiles mondiaux investissent massivement dans la production de véhicules électriques. Si l'impact des percées technologiques sur l'architecture d'une industrie est une question ancienne et récurrente en économie et en gestion, le passage de la motorisation thermique à la motorisation électrique, par l'ampleur des enjeux et des conséquences, en est un exemple emblématique. L'électrification des véhicules est une innovation systémique, car elle nécessite l'intervention de plusieurs acteurs complémentaires pour sa mise en œuvre, et sa massification devrait bouleverser la conception dominante des véhicules. La question est alors de savoir si cette perturbation pourrait déstabiliser durablement l'architecture industrielle de ce secteur, qui est considéré, par de nombreux auteurs, comme très résilient.

Grâce à une étude empirique originale de grande échelle (14 constructeurs automobiles dans le monde), concernant la production de véhicules électriques, de systèmes de batteries haute tension et de propulsion électrique, cette thèse confirme, à ce jour, la résilience de cette industrie. Les constructeurs automobiles ont intégré les systèmes d'électrification grâce à une combinaison d'innovations modulaire et architecturale ; ils ont ainsi réussi à préserver leur rôle d'acteur central, leurs actifs de production et, surtout, leur modèle économique dominant dans le B2C. Le terme "statu quo" décrit parfaitement la dynamique actuellement observable. Malgré la tendance lourde et continue à la dé-verticalisation / externalisation de l'industrie automobile au cours du 20ème siècle et la modularité supérieure de la traction électrique par rapport à la traction thermique, il n'y a aucun signe visible d'une alternative où des fournisseurs spécialisés fabriqueraient des systèmes de traction électrique à la place des fabricants.

La conclusion qui s'impose alors est que l'électrification, même si elle modifie la conception d'un véhicule, n'est pas suffisante pour provoquer une déstabilisation de l'industrie. Mais la dynamique que connaît actuellement l'industrie automobile se caractérise par la conjonction de trois grandes ruptures, qui vont bien au-delà de la simple électrification des véhicules. Considérées ensemble, elles augmentent le périmètre systémique de la perturbation induite, ce que le cadre théorique de la transition sociotechnique permet de qualifier ainsi :

1. La convergence d'innovations technologiques qui favorisent l'émergence du véhicule connecté, autonome, partagé et électrique ainsi que le développement de nouvelles offres de services de mobilité (Mobility as a Service - MaaS),
2. De nouveaux challenges sociétaux : urbanisation galopante, nouveaux besoins de transports urbains, changements de comportement des consommateurs vis-à-vis de la propriété et de la mobilité automobile,
3. L'arrivée, sur le marché de la mobilité, de nouveaux acteurs venant du monde des technologies digitales et particulièrement puissants tant technologiquement que financièrement.

La mise en évidence du contexte systémique de cette perturbation conduit alors à une réorientation de la question de recherche : "Cette conjonction de facteurs internes et externes à l'industrie pourrait-elle ouvrir la voie, au-delà de l'électrification, à une dynamique de perturbation de son architecture" ?

Cette thèse s'inscrit alors dans un programme de recherche international du laboratoire d'accueil, associant de nombreux partenaires académiques dans le monde, tous experts de l'industrie automobile, et ayant pour objectif des études de cas d'initiatives de mobilité innovantes.

D'un point de vue empirique, le champ d'analyse des études de cas est caractérisé par trois facteurs clés :

1. Etude des initiatives de services de mobilité innovants au sens large : la multitude et la diversité des initiatives en cours montrent un très large éventail de possibilités tant en ce qui concerne l'orientation précise de cette dynamique que son impact potentiel sur l'architecture de l'industrie. En effet, les constructeurs automobiles, qui avaient tous adopté le concept de conduite autonome dans le cadre d'une montée en gamme classique de leur offre, ont, dans certains cas, franchi le pas et se positionnent résolument comme de (futurs) opérateurs de mobilité.
2. Une portée mondiale de la recherche : les innovations étant actuellement développées aux Etats-Unis, en Europe, en Chine et au Japon, les acteurs, étant mondiaux, sont en mesure de transférer l'apprentissage d'une zone géographique à une autre.
3. L'analyse de chaque cas doit caractériser la nature de l'innovation observée, c'est-à-dire caractériser le service ainsi que les valeurs qu'il apporte. Elle doit également caractériser sa capacité à favoriser une dynamique d'apprentissage qui permettra une future mise à l'échelle,

ce qui amène à se demander qui seraient les acteurs capables de soutenir un tel déploiement, quels en seraient les facilitateurs ou les goulets d'étranglement.

Sur le plan méthodologique, les études de cas ont été menées sous forme d'entretiens basés sur un questionnaire structuré. Ce dernier vise à caractériser, pour chaque cas : (i) la nature du service proposé, (ii) les valeurs individuelles ou collectives visées, (iii) l'écosystème de soutien, (iv) les capacités d'apprentissage de cet écosystème pour construire une trajectoire de mise à l'échelle future.

Basée sur l'analyse détaillée de 10 des 14 cas étudiés, cette thèse apporte les contributions suivantes :

1. Il n'y a pas d'histoire déjà écrite ni de voie unique pour l'avenir du véhicule autonome, comme le montre la mise en évidence de trois types de mobilité idéale : "*service de mobilité ajouté au produit*", "*robotaxi*" et "*plate-forme de mobilité ouverte territorialisée*". Ceux-ci constituent des cibles idéalisées des trajectoires identifiées dans les initiatives étudiées, qui sont sensiblement différentes par (i) leur nature, (ii) les performances recherchées, et (iii) les écosystèmes qui les sous-tendent.
2. Si le premier idéal type est un prolongement naturel de l'activité actuelle des constructeurs automobiles en tant qu'entreprise focale, le second montre une percée technologique plus profonde, soutenue par une logique de leadership de plate-forme, qui peut également être saisie par des acteurs qui ne sont pas à l'origine des constructeurs. Enfin, le troisième, qui nécessite un apprentissage collectif au sein d'un écosystème hétérogène, pourrait conduire à l'émergence de nouveaux leaders tels que les autorités locales ou les opérateurs de mobilité. En tout état de cause, les deux derniers ont le potentiel de déstabiliser l'industrie automobile bien au-delà de sa résilience naturelle.
3. L'importance des projets, en tant que vecteur d'apprentissage dans les écosystèmes émergents, est confirmée puisqu'ils permettent le partage de connaissances entre acteurs de différentes industries ainsi que l'expérimentation d'innovations ciblées. Cela souligne également l'importance d'une analyse de la performance d'apprentissage collectif des écosystèmes.
4. Une comparaison de cas aux États-Unis, en Europe et en Chine montre que l'apprentissage des écosystèmes dépend également d'un contexte national qui favorise plus ou moins l'alignement des acteurs sur des perspectives communes ou la mise en œuvre des expériences nécessaires à leur réussite.

5. L'étude de cas, consacrée à la transition du produit vers le service au sein de l'industrie automobile, permet de mettre en évidence des modèles génériques pour la stratégie de service d'une entreprise : (1) "*services ajoutés centrés sur le produit*" lorsque l'offre de service complète une offre de produit sans véritable intrusion sur le produit, (2) "*produit facilitateur de l'offre centrée sur le service*" lorsque le projet est centré sur le service et que le produit (véhicule) est l'un des catalyseurs de son fonctionnement, et (3) "*facilitateur du service centré sur le produit*" lorsque le développement de technologies de pointe, intégrées dans le produit (véhicule), est le principal catalyseur du fonctionnement du service. Pour les constructeurs automobiles confrontés à ces deux derniers cas, il s'agit de situations typiques d'ambidextrie managériale, car elles impliquent des projets de nature et d'horizon temporel hétérogènes par rapport aux projets de développement de gamme traditionnels.
6. La transition du produit au service entraîne également un passage de la gestion du cycle de vie du produit à la gestion du cycle de vie du service. Les conséquences, en termes de gestion de projet, sont les suivantes : (1) l'importance des expérimentations dans les phases amont pour mieux décrire le service et les conditions de son acceptation par les clients utilisateurs finaux, (2) la nécessité d'introduire une nouvelle discipline d'ingénierie, à savoir "l'ingénierie des services de mobilité", (3) la nécessité d'introduire de nombreuses boucles de conception pour traiter la commercialisation du service et ses impacts sur le produit dans sa conception même, (4) la nécessaire adaptation du processus de validation comme conséquence de la validation conjointe du produit et du service, et enfin, (5) la nécessité pour une industrie d'aller au-delà d'une logique d'homologation de produit, par rapport à une réglementation, pour aller vers une logique de certification, au sens des pratiques de l'industrie aéronautique. La mise en œuvre de cette dernière est un processus très lourd et long pour les services d'ingénierie des entreprises automobiles.

La recherche a également exploré l'impact des réglementations environnementales qui sont à l'origine des changements en cours depuis dix ans et qui influencent largement la direction et la vitesse des dynamiques actuelles. Une comparaison empirique entre la Chine et l'Europe sur la gouvernance des réglementations environnementales et leur impact sur l'évolution de l'industrie a abouti aux résultats suivants :

1. D'un point de vue stratégique, la Chine a décidé de construire, presque à partir de zéro, une industrie des véhicules à énergie nouvelle, tandis que la Commission européenne, ancrée dans une longue tradition de compromis tant avec les entreprises qu'avec les états, présente un cas de transformation progressive du paradigme existant.

2. En ce qui concerne le champ d'application des réglementations, l'Europe s'attache à limiter les nuisances environnementales et à laisser le marché réguler les performances. À l'inverse, les réglementations chinoises traitent simultanément des questions industrielles et environnementales et sont donc intrusives dans les performances mêmes de la mobilité automobile.
3. Enfin, ce n'est plus la triade USA, Europe et Japon qui impose ses normes au secteur automobile mondialisé : c'est désormais la Chine qui donne le rythme, par l'importance de son marché et une capacité de planification originale alliant volontarisme dans l'orientation des acteurs et agilité pour s'adapter dans un domaine d'innovation incertain et instable.

D'un point de vue théorique, cette thèse apporte des contributions intéressantes dans les domaines suivants :

1. Les théories de la relation entre le changement technologique et la dynamique industrielle ainsi que les conditions menant à la stabilité d'une industrie sont confirmées par l'étude empirique de la chaîne de valeur de la traction électrique.
2. Cette thèse démontre la possibilité et l'intérêt de construire, sur la base du paradigme des transitions sociotechniques, un dispositif d'analyse empirique pour éclairer les transitions émergentes dans le domaine de la mobilité automobile tout en caractérisant leurs directions ou leurs cibles. Elle contribue au renforcement de la théorie de la transition sociotechnique en précisant la nature et le rôle des acteurs impliqués dans une telle transition. En l'occurrence, il s'agit ici, des acteurs du projet. En pratique, cette thèse illustre la pertinence de combiner l'analyse des facteurs de pression externes et les moyens déployés par une industrie pour comprendre sa dynamique évolutive.
3. Elle contribue également à développer à la fois les domaines de la gestion de l'innovation et de la servitisation en adoptant un espace de conception innovant, englobant toutes les variables de conception impliquées dans le développement d'une offre de service de mobilité innovante (MaaS). Elle permet de caractériser les différents types de gestion de l'innovation dans les projets déclenchés par les différents types de transition d'une stratégie centrée sur le produit à une stratégie centrée sur le service. Cela conduit à une nouvelle typologie de gestion de l'innovation dans les projets, basée sur le caractère intrusif du développement de services innovants dans le cadre du développement de nouveaux produits. Dans cette perspective, nous différencions les trois catégories suivantes : "*services ajoutés centrés sur le produit*", "*facilitateur de services centrés sur le produit*" et "*produit facilitateur de l'offre centrée sur le service*".

4. Les études de cas des initiatives de mobilité ont également confirmé l'importance du projet en tant que vecteur d'apprentissage d'un écosystème naissant, car il offre à la fois la possibilité d'une connaissance mutuelle entre acteurs de contextes différents et la possibilité de mettre en commun la gestion des incertitudes de l'innovation ciblée. La thèse souligne également l'importance de la composition et de la structure de l'écosystème sur l'orientation et les choix effectués dans la trajectoire d'apprentissage collectif au sein du projet ; elle montre également l'intérêt de mettre en œuvre des stratégies d'apprentissage à travers des projets successifs. Enfin, elle pose la question de savoir quel acteur est le mieux placé pour gérer les stratégies d'apprentissage : l'entreprise leader de la plate-forme, lorsqu'elle existe dans la configuration de l'écosystème, ou l'opérateur de mobilité ou l'autorité de régulation de la mobilité territorialisée.

En conclusion, les résultats actuels de cette thèse soutiennent l'hypothèse d'une avalanche de causalités convergentes conduisant à la déstabilisation de l'architecture historique de l'industrie automobile. Conformément à la théorie des transitions, ce sont les modes de régulation entre ces différents facteurs ou, en utilisant des notions issues du domaine de la gestion des projets d'innovation, les modes d'apprentissage collectif de ces différentes variables, qui joueront un rôle déterminant dans ces déstabilisations potentielles.

SUMMARY

After a decade of debates and initiatives of limited impact, constrained by environmental regulations that impose drastic reductions in CO₂ and pollutant emission levels as well as a growing number of banning initiatives of internal combustion vehicles, all global carmakers are investing heavily in the production of electric vehicles. While the impact of technological breakthroughs on the architecture of an industry is a long-standing and recurring issue in economics and management, the transition from thermal to electric motorization, in terms of the scale of the stakes and consequences, is an emblematic example. Vehicle electrification is a systemic innovation, since it requires the intervention of several complementary actors for its implementation, and its massification should disrupt the vehicle dominant design. The question is then to know if this disruption could durably destabilize the industrial architecture of this sector, which is considered, by many authors, as very resilient.

Thanks to an original large-scale empirical study (14 carmakers worldwide) concerning the production of electric vehicles, high-voltage battery systems and electric propulsion, this thesis confirms, to date, the resilience of this industry. Carmakers have integrated electrification systems through a combination of modular and architectural innovations, thus preserving their central role, their production assets and, above all, their dominant business model in B2C. The term "status quo" perfectly describes the dynamics currently observable. Despite the heavy and continuous trend towards de-verticalization / outsourcing of the automotive industry during the 20th century and the superior modularity of electric traction compared to thermal traction, there are no visible signals of an alternative where specialist suppliers would manufacture electric traction systems instead of manufacturers.

The obvious conclusion is that electrification, even if it modifies the design of a vehicle, is not enough to cause a destabilization of the industry. But, the momentum that the automotive industry is currently experiencing is characterized by the conjunction of three major breakthroughs, going far beyond the simple electrification of vehicles. Altogether, they increase the systemic perimeter of the induced disruption that the theoretical framework of sociotechnical transition allows us to qualify:

1. The convergence of technological innovations enabling the emergence of the Connected, Autonomous, Shared and Electric Vehicle (CASE) as well as the development of innovative mobility services (Mobility as a Service - MaaS) offers,

2. New societal challenges: growing urbanization, new urban transportation needs, changes in consumer behavior with regard to automobile ownership and mobility,
3. The arrival on the mobility market of new players, particularly powerful technologically and financially, from the world of digital technologies.

Bringing out the systemic context of this disruption then leads to a reorientation of the research question: "Could this conjunction of factors internal and external to the industry pave the way, beyond electrification, to a disruptive dynamic of its architecture"?

This thesis was then part of an international research program of the host laboratory, associating many academic partners worldwide, all experts of the automotive industry, and having as objective the case studies of innovative mobility initiatives.

From an empirical viewpoint, the scope of analysis for the case studies is characterized by three key factors:

1. Study of innovative mobility services initiatives in the broadest sense: the multitude and diversity of initiatives underway show a very wide range of possibilities both in terms of the precise direction of this dynamic and its potential impact on the architecture of the industry. In fact, carmakers, all of whom had adopted the concept of autonomous driving as part of a classic move to move upmarket in their offerings, have, in some cases, taken the plunge and are resolutely positioning themselves as (future) mobility operators.
2. A worldwide scope of research: as innovations are currently being developed in the USA, Europe, China and Japan, players, being global, are able to transfer learning from one geographical area to another.
3. The analysis of each case must characterize the nature of the innovation observed, i.e. characterize the service as well as the values it brings. It must also characterize its capacity to foster a learning dynamic that will enable future scale-up, i.e. who would be the actors capable of supporting such deployment, what would be its enablers or its bottlenecks.

Methodologically, the case studies were conducted as interviews based on a structured questionnaire. This latter aims to characterize, for each case: (i) the nature of the proposed service, (ii) the individual or collective values targeted, (iii) the supporting ecosystem, (iv) the learning capacities of this ecosystem to build a trajectory of future scale-up.

Based on the detailed analysis of 10 of the 14 cases studied, this thesis makes the following contributions:

1. There is no already written history or single path for the future of the autonomous vehicle, as shown by the highlighting of three ideal types of mobility: “*mobility service added to product*”, “*robotaxi*” and “*territorialized open mobility platform*”. These constitute idealized targets of the trajectories identified in the initiatives studied, which are significantly different in (i) their nature, (ii) the performances sought, and (iii) the ecosystems that underpin them.
2. If the first typical ideal is a natural extension of the carmakers' current business as a focal company, the second shows a deeper technological breakthrough, supported by a logic of platform leadership, which can also be seized by players who are not originally OEMs. Finally, the third, which requires collective learning within a heterogeneous ecosystem, could lead to the emergence of new leaders such as local authorities or mobility operators. In any case, the last two have the potential to destabilize the automotive industry well beyond its natural resilience.
3. The importance of projects, as a vector for learning in emerging ecosystems, is confirmed since they allow the sharing of knowledge between actors from different industries as well as the experimentation of targeted innovation. This also emphasizes the importance of an analysis of the collective learning performance of ecosystems.
4. A comparison of cases in the USA, Europe and China shows that ecosystem learning also depends on a national context that more or less favors the alignment of stakeholders on shared perspectives or the implementation of the experiments necessary for their successful implementation.
5. The cases study, devoted to the transition from product to service within the automotive industry, helps to highlight generic models for a company's servicing strategy: (1) “*product centric added services*” when the service offer complements a product offer without any real intrusion on the product, (2) “*product enabler of service centric offer*” when the project is service-centric and the product (vehicle) is one of the catalysts for its operation, and (3) “*product centric service enabler*” when the development of breakthrough technologies, embedded in the product (vehicle), is the main catalyst for the operation of the service. For vehicle manufacturers faced with the last two cases, these are typical situations of ambidextrous management, as they involve projects that are heterogeneous in nature and in terms of time horizon compared with traditional range development projects.

6. The transition from product to service also involves a shift from product lifecycle management to service lifecycle management. The consequences, in terms of project management, are as follows : (1) the importance of experimentation in the upstream phases to better describe the service and the conditions of its acceptance by end-user customers, (2) the need to introduce a new engineering discipline, namely "mobility service engineering", (3) the need to introduce numerous design loops to deal with the marketing of the service and its impacts on the product in its very design, (4) the necessary adaptation of the validation process as a consequence of the joint validation of the product and the service, and finally, (5) the need for an industry to go beyond a logic of product homologation, in relation to a regulation, to move towards a logic of certification, in the sense of the practices of the aeronautical industry. The implementation of the latter is a very cumbersome and long process for the engineering departments of automotive companies.

The research also explored the impact of environmental regulations that have been driving the changes that have been underway for the past decade and largely influence the direction and speed of current dynamics. An empirical comparison between China and Europe on the governance of environmental regulations and their impact on the evolution of the industry led to the following results:

1. From a strategic viewpoint, China has decided to build, almost from scratch, a New Energy Vehicle industry, while the European Commission, anchored in a long tradition of compromise both with companies and with states, exhibits a case of gradual transformation of the existing paradigm.
2. In terms of the scope impacted by regulations, Europe is focusing on limiting environmental nuisance and letting the market regulate performance. Conversely, Chinese regulations simultaneously address industry and environment issues and therefore are intrusive on the very performance of automobile mobility.
3. Finally, it is no longer the triad of the USA, Europe and Japan that imposes its standards on the globalized automotive sector: it is now China that sets the pace, through the importance of its market and an original planning capacity combining voluntarism in the orientation of players as well as agility to adapt in an uncertain and unstable field of innovation.

From a theoretical viewpoint, this thesis brings interesting contributions in the following fields:

1. The theories of the relationship between technological change and industrial dynamics as well as the conditions leading to the stability of an industry are confirmed by the empirical study of the electric traction value chain.
2. This thesis demonstrates the possibility and the interest of constructing, on the basis of the paradigm of sociotechnical transitions, an empirical analysis apparatus to shed light on emerging transitions in the field of automobile mobility while characterizing their directions or targets. It contributes to the strengthening of the theory of socio-technical transition by specifying the nature and role of the actors involved in such a transition. In this case, these are the actors of the project. In practice, this thesis illustrates the relevance of combining the analysis of external pressure factors and the means deployed by an industry to understand its evolutionary dynamics.
3. It also contributes to develop both innovation management and servitization domains by adopting an innovative design space, encompassing all the involved design variables in the development of a MaaS. It enables to characterize different kinds of innovation management in project triggered by the different types of transition from product centric strategy to service centric strategy. This leads to a new typology of innovation management in project based upon the intrusiveness of the innovative service development within the new product development. With this perspective, we differentiate “*product-centric added services*”, “*product-centric service enabler*” and “*product enabler of service centric offer*”.
4. The case studies of mobility initiatives have also confirmed the importance of the project as a vehicle for learning about a nascent ecosystem, as it offers both the possibility of mutual knowledge between actors from different contexts and the possibility of pooling the management of the uncertainties of targeted innovation. The thesis also points out the importance of the composition and structure of the ecosystem on the orientation and the choices made in the collective learning trajectory within the project; it also shows the interest of implementing learning strategies through successive projects. Finally, it raises the question of which actor is the best placed to manage learning strategies: the leading company of the platform, when it exists in the configuration of the ecosystem, or the mobility operator or the regulatory authority of territorialized mobility.

In conclusion, the current results of this thesis support the hypothesis of an avalanche of converging causalities leading to the destabilization of the historical architecture of the automotive industry. In accordance with the theory of transitions, it is the modes of regulation

between these different factors or, using notions from the field of innovation project management, the modes of collective learning about these different variables that will play a decisive role in these potential destabilizations.

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1. INTRODUCTION

The purpose of this chapter is to present the theoretical and empirical research path that has been developed throughout this thesis. How, starting from an empirical question of major socio-economic importance: «*what future for the automotive industry in the context of current upheavals in technologies and uses?*», different theoretical frameworks have been mobilized to shed light on this question, put forward hypotheses and build empirical protocols to test them. This chapter presents this path, explains the changes in theoretical frameworks that have been necessary to address the research question, presents the studies that have been developed. Each of the studies presented has been developed in a dedicated paper, currently being submitted to a journal, and each paper is a specific chapter of this thesis. The main lessons they have produced are summarized in the general conclusion. A detailed presentation of the theoretical frameworks and methodologies used is made in subsequent papers (chapters as there is a chapter per paper).

Lastly, this introduction synthesizes an original capacity to broaden an initial field centered on the relationship between technology and industrial dynamics to a multifactorial approach, technological but also societal, to identify and analyze the conditions that can influence the stabilization or destabilization of the architecture of an industry. In the final conclusion, it thus allows to discuss the epistemological teachings of this research.

This thesis is part of a cooperative research program conducted at the Centre de Recherche en Gestion (CRG, Management Research Center) / I³ of Ecole Polytechnique and, is supported by the Institute for Sustainable Mobility¹ (IMD), created by the Renault foundation, as well as the Cai Yuanpei research program².

1.1. The forced march of carmakers towards electrification

Apart some first movers, such as Toyota and Honda with hybrids in the 2000s or Renault, Nissan, Tesla with Battery Electric Vehicles (BEV) in the 2010s, global players are not moving towards electrification on their own will. They are constrained by a global set of increasingly stringent environmental regulations including:

¹ Institute for Sustainable Mobility is a multidisciplinary platform dedicated to research on the future of transport and mobility solutions <https://group.renault.com/en/news-on-air/news/sustainable-mobility-institute-5-years-in-5-questions-2/>

² Cai Yuanpei is a program supporting cooperative research between academic teams from France and China (<https://www.campusfrance.org/en/node/2361> for the 2020 program)

1. Reduction of the level of greenhouse gas emissions³ (GHG - CO₂) leading to the definition of a maximum threshold, e.g. 95 gCO₂ /km in 2021 in Europe,
2. Reduction of the level of pollutants emissions (particulate matter, nitrogen oxides, unburnt hydrocarbons and carbon monoxide) also leading to the definition of maximum thresholds, such as Euro6d in Europe for the latest applicable regulation,
3. Electric vehicles mandate imposing a minimum percentage of sales of electrified vehicles such as 12% by 2020 in China or 22% in 2025 in California (plus nine other states representing 30% of new car sales in USA),
4. Worldwide internal combustion engines vehicles (ICEV) banning or phasing out initiatives (Burch and Gilchrist, 2018) whose first concrete impacts should be visible 2025 onwards,
5. The objective of carbon neutrality by 2050, resulting from the Paris Agreement which, given the length of time the car fleet is used, means a total ban on the sale of new internal combustion cars by 2035.

Therefore, in the next fifteen years, the automotive industry must definitively switch from ICEVs to electric vehicles (EVs). While different technological strategies⁴ have been observed and decisions to go to electrification have expanded over the past two decades, there appears to have been a general movement toward BEVs over the past three to four years.

Reuters⁵ estimated that 29 car manufacturers have invested about \$300 billion in electrification, showing that the industry has definitely taken the plunge. In fact, all global players announce the arrival on the market of BEVs and Bloomberg⁶ has identified 500 EV models on the market by 2022.

As far as market shares, under the effect of COVID19, in the first half of 2020 compared to 2019, passenger car sales collapsed worldwide, falling 28% while EV sales fell only 14%. In China, New Energy Vehicles (NEV) sales fell 42% compared to 20% for the overall vehicle market, due to lower subsidies and stricter technical requirements⁷. However, in Europe, in the second quarter of 2020 compared to 2019, where the market declined by more than 50%,

³ The contribution of EVs to reducing GHG emissions must be effective over the entire life cycle of the vehicle, which requires complete decarbonization of the energy used during the vehicle's life cycle. The author of this thesis, who fully shares this opinion, specifies that this issue is not included in the research summarized in this manuscript.

⁴ Namely hybrids, Plug-in Hybrid Electric Vehicles (PHEV), BEVs and Fuel Cell Vehicles (FCV)

⁵ <https://graphics.reuters.com/AUTOS-INVESTMENT-ELECTRIC/010081ZB3HD/index.html>

⁶ <https://about.bnef.com/electric-vehicle-outlook/>

⁷ Source of information: <https://www.ev-volumes.com/>

rechargeable car sales increased by 53.3% to reach a market share of 7.2%⁸ thanks to proactive subsidy policies, especially in France.

In its global outlook 2020⁹, the International Energy Agency highlights that even if global electric passenger car sales are sluggish in 2019, although better than in 2018, the global stock has now exceeded 7 million vehicles underpinned by policies that “... *have set clear, long-term signals to the auto industry and consumers that support the transition in an economically sustainable manner for governments*”. On its side, prior to the current crisis, Bloomberg⁵ expected sales of 8.5 million EVs by 2025 tripling in 2030 up to 26 million and considers, in its latest forecast¹⁰, that “*The long-term trajectory has not changed, but the market will be bumpy for the next three years.*”

1.2. What are the impacts of electrification on the automotive industry?

Therefore, this thesis is based on a very strong initial conviction strengthened by concrete facts: The scaling up of EVs is ongoing, with the ICEVS to EVs tipping point expected to occur around 2035, although the ramp-up is delayed because of COVID-19! This leads to formulate an empirical question: how is the automotive industry managing this transition from internal combustion vehicles to electric vehicles? What are the impacts of the technological evolutions linked to electrification on the structure of this industry?

This empirical question is in line with the rich tradition of academic work on the question of the relationship between technological change and industry dynamics summarized by Nelson as follows “... *firm and industry structure ‘coevolve’ with the technology*” (1994, p. 47). Elaborating on this stream of research allows us to formulate the initial question of this thesis as follows: « *Technological breakthrough and dynamics of an industry, the transition towards electromobility case* ».

1.2.1. An initial question founded on strategic theories

All the research work of this stream highlights the importance of distinguishing between two types of technological innovation: incremental innovation, which is a succession of minor changes that improve the performance of a design, and *radical* innovation, which, on the contrary, involves fundamentally different design rules and scientific principles.

⁸ <https://www.acea.be/press-releases/article/fuel-types-of-new-cars-petrol-51.9-diesel-29.4-electric-7.2-market-share-se>

⁹ <https://www.iea.org/reports/global-ev-outlook-2020>

¹⁰ <https://about.bnef.com/blog/electric-vehicle-sales-to-fall-18-in-2020-but-long-term-prospects-remain-undimmed/>

Abernathy and Utterback (1978, p. 42) have shown how these two types of innovation, although opposite to each other, can combine to contribute to "*A Transition from Radical to Evolutionary Innovation*" or how the introduction of a radical innovation can lead to the emergence of a dominant design that will then be regularly optimized by a succession of incremental innovations. They also explain that the emergence of a dominant design leads to the creation of a mass manufacturing industry, of which the automotive industry is one of the most emblematic examples.

However, noting that these two notions are insufficient to describe all cases of innovation, Henderson and Clark (1990), by emphasizing the importance of the relationships between the different components (the interfaces) within a technical solution, added the notions of *modular innovation* (overturned core concepts of a solution with unchanged interfaces) and *architectural innovation* (reinforced core concepts of a solution with changed interfaces). They add (1990, p. 12) "*The essence of an architectural innovation is the reconfiguration of an established system to link together existing components in a new way*". As, for incumbent companies in the mass production industry, which tend to remain in the dominant field of design (Abernathy and Utterback, 1978), the bulk of the innovation focuses on components whose interrelationships are defined within the framework of a stabilized product architecture, they conclude that, when faced with architectural innovation, incumbent companies may have two main problems: (1) recognizing that an innovation is of architectural type and (2) having the capacity to implement it.

On their side, Bowen and Christensen (1995) have described *sustaining* and *disruptive* technologies, the latter being characterized by the proposition of an offer whose performance characteristics are below the usual expectations of customers; here again, the differentiation between these two concepts has made it possible to contribute to the study of the importance of technology management choices on business dynamics. Indeed, they have shown that many established companies, that had ignored these disruptive technologies because they were focused on their own customers' satisfaction, have seen their market share decrease or even be reduced to zero when these technologies, thanks to their rapid performance progression, have allowed new entrants either to capture their traditional customers or to create new markets. Finally, it is worth mentioning that a *disruptive* innovation can only emerge because there are potential customers who are willing to accept lower performance than that appreciated by dominant customers because it meets their specific expectations (Kim and Mauborgne, 2005).

In his analysis of the reaction of incumbent firms to new technologies, Nelson indicates that, in a phase of stabilized dominant design, they are focused on optimizing their business processes and infers: « *this suggests that established firms may have considerable difficulty in adjusting, in gaining control of needed different capabilities, when important new technologies that have the potential to replace prevailing ones come into being* » (Nelson, 1993, p. 54). He, thus, confirms the difficulties encountered by incumbent companies faced with the introduction of a new technology whatever its nature.

When Porter, in his paper focusing on the competitiveness of firms, states « *Everything a firm does involves technology of some sort* » (1985a, p. 62), he emphasizes the importance of technology in the functioning of firms, but also makes it very clear that any technological change is important, not intrinsically, but because it changes the competitiveness of a firm; he also explains that the impact of a value-creating technology goes far beyond the firm that developed it, since its diffusion within an industry can greatly contribute to changing both its structure and its attractiveness.

These theoretical frameworks, which are important for understanding and studying the emergence of an innovative technology, have very often been used only at the level of a company, whereas a systemic innovation must be deployed in an ecosystem, well beyond the perimeter of a single company: its benefits “*can be realized only in conjunction with related, complementary innovations*” (Chesbrough and Teece, 1996, p. 128) developed by a set of external actors playing their part (Afuah and Bahram, 1995; Tushman and Anderson, 1986). This statement refers to the notion of complementarity and co-specialization of offers (Teece, 1986), i.e. the fact that the players in the ecosystem develop different, non-generic offers, which cannot be obtained simply through the market, the combination of which brings value. A systemic disruption can also be defined as a transition that combines four characteristics : (i) the level of radicalism in the disruption introduced; (ii) the extent and heterogeneity of the scope of the players they mobilize; (iii) the scale of the projects; (iv) the speed of the expected transitions (Maniak et al., 2014b; Midler and von Pechmann, 2019; von Pechmann et al., 2015).

The introduction of electric traction has already been described as a *systemic* disruption (von Pechmann et al., 2015), which is correct insofar as the cost and range performance of an electric vehicle is still below that of a combustion vehicle, or as being *systemic* because its success requires the intervention, within an ecosystem, of many actors with complementary and co-specialized offers (Teece, 1986) such as energy suppliers, electric batteries, charging systems (Donada and Attias, 2015; Donada and Perez, 2018; Vazquez et al., 2018). Finally,

there is also the question of whether the integration of high-voltage electric battery and electric propulsion systems into a vehicle is an area of *architectural innovation* and, if so, whether established manufacturers are able to seize this opportunity.

The concept of industry architecture is also part of the theoretical framework that needs to be mobilized; broadening the concept of bilateral relationships, which refers to the highly centralized way in which companies manage their value chains through numerous dyads of parallel buyer-supplier relationships (Porter, 1985a; Williamson, 1985), Jacobides et al. (2006, p. 1205) synthesize the notion of industry architecture as “*Thus, industry architectures provide two templates, each comprising a set of rules: (1) a template defining value creation and division of labor, i.e. who can do what (2) a template defining value appropriation and division of surplus, or revenue, i.e. who gets what*”. An industry architecture emerges in the early days of the industry, shaped by product design decisions (Baldwin and Clark, 2000), by regulations, industry standards, technology or, generally speaking, interfaces (Jacobides et al., 2006; Jacobides and MacDuffie, 2013; Jacobides and Winter, 2005), as well as knowledge and technical capabilities of firms (Zirpoli and Camuffo, 2009). The ability to act, vis-à-vis the end customer, as a guarantor and responsible party for the quality of the products and compliance with regulations relating to safety and health issues is also a fundamental characteristic of a focal firm in an industry architecture, especially in the automotive industry (Jacobides and MacDuffie, 2013). The consolidation of a dominant design contributes greatly to shaping the architecture of an industry, and indeed dominant design and industrial architecture are highly interdependent and mutually reinforcing (Abernathy and Utterback, 1978; Jacobides, 2006; Tushman and Anderson, 1986).

1.2.2. The automotive industry is and remains resilient

Building on these strategic theories, several authors have argued that the automotive industry is particularly resilient and that automakers have the means to keep control of the industry (Jacobides et al., 2016; Jacobides and MacDuffie, 2013; MacDuffie and Fujimoto, 2010; Wells and Nieuwenhuis, 2012). To support their assertion, they state that carmakers act as system integrators because they drive innovation, product strategy and higher value-added manufacturing segments (Gereffi et al., 2005). As it includes the assembly and final inspection of the complete automotive system, they thus retain control of the most strategic assets. De facto, they are then the only ones able to respond to the trend towards integral design imposed by increasingly stringent regulations (Fujimoto, 2017; MacDuffie, 2013) as well as to act as guarantors of quality for end customers and compliance with regulations relating to safety and

health issues (Jacobides et al., 2006 ; Jacobides et Mac Duffie, 2013). They are at the top of a hierarchical value chain that they control (Wells and Nieuwenhuis, 2012) and guide future developments. Moreover, the architecture of this industry, after numerous outsourcing operations in the late 1990s, has now been stable for many years (Donada, 2013; Jacobides and MacDuffie, 2013; MacDuffie and Fujimoto, 2010). Finally, mastering the relationship with the customer, through a vehicle distribution and repair network, offering services (financing, insurance, maintenance, to name a few) or the ability to guarantee quality and compliance with regulations relating to safety and health issues (Jacobides et al., 2006; Jacobides and MacDuffie, 2013), is certainly one of the major reasons explaining the dominant position of carmakers.

While some authors, prior to the EV scale-up that is currently taking place, predicted that vehicle electrification will not change this long-lasting situation (Jacobides et al., 2006; Jacobides and MacDuffie, 2013), this assertion deserves to be re-examined since electrification radically transforms the technological core of conventional mobility which is the oldest fundamental of the dominant design of the automotive industry.

It is therefore to answer this theoretical question « *Will the scale-up of electric vehicles (EV) disrupt the architecture of the automotive industry?* », that this thesis begins with an empirical study. The analysis focuses on how the electric traction value chain is constructed, and more specifically: "*the current strategic choices (observable in early 2020) of car manufacturers, namely to manufacture, buy or ally, to develop electric vehicles as well as the two main systems of electric traction, namely those of the high-voltage battery and electric propulsion*". For each car manufacturer observed, there are three units of analysis: the manufacture of electric vehicles, the value chain of the high-voltage battery system (a key component, both from a technical and economic point of view) and that of the electric propulsion system. This study includes both incumbent (cumulating roughly 70% of the global market share) and new entrants (EVs top selling companies), all global players from different countries of origin, to determine whether or not seniority in the automotive sector or regional/national conditions have an influence on their strategy. The characteristics of the selected carmakers are listed in the table below.

Seniority in the industry Country of origin	Incumbent companies	Newcomers	Total
USA	2	1	3
Asia	4	1	5
Europe	6		6
Total	12	2	14

Table 1: Characteristics of selected carmakers for electric traction value chain empirical study

This empirical study shows that the elements put forward to explain the resilience of the automotive industry are, to date, confirmed:

1. The ability to achieve integral design (Fujimoto, 2017 ; MacDuffie, 2013), the design agility linked to the continuous integration of product evolutions (Wells and Nieuwenhuis, 2012), and the persistence of operational routines (Zirpoli and Camuffo, 2009), effectively enable car manufacturers to master the design and production of electric traction systems as well as to produce electric and thermal vehicles on the same assembly lines (Alochot and Midler, 2019),
2. Their hierarchical mastery of the value chain and the rules of its operation (Wells and Nieuwenhuis, 2012), allows them to treat suppliers of electric traction system components, new entrants or established Tier 1 suppliers, as commodity suppliers¹¹ ,
3. Their capacity to deploy the stringent regulations to reduce CO2 and pollutants emission still assert themselves as guarantors of the quality of the final product (Jacobides et al., 2006; Jacobides and MacDuffie, 2013),
4. In doing so, they exploit the powerful business model that has supported this industry for almost a century and the deeply rooted cultural, social status that makes the automobile the preferred means of individual mobility (Wells and Nieuwenhuis, 2012).

The results of this study apply to all the global manufacturers observed, regardless of their country of origin, even if some of them, which started later in the development of BEVs, have entered into cooperation, with electric traction specialists or other carmakers, to catch up with the market.

As far as the two new entrants are concerned, BYD, which comes from the battery industry, is highly integrated on the axis of electric traction systems. On its side, Tesla, which is recognized as a disruptive new player, has developed vertical integration strategies that Henry Ford would have no trouble recognizing as an early automotive practice. As a result, in terms of value chain management, they have both followed in the footsteps of installed manufacturers.

This study is the first result to be credited to this thesis, as it is the first contribution to a wide-ranging empirical validation of the hypothesis of resilience of the historic architecture of the automotive industry to the rise of electrification.

¹¹ Even if the components concerned are not yet easily substitutable from one supplier to another

Beyond this observation of stability which confirms, to date, the theoretical framework based on the strategy paradigm, another theoretical framework makes it possible to put forward different hypotheses for the future dynamics of this industry.

It is based on the double helix model, introduced by Fine and Whitney (1996), : "*the double helix illustrates the oscillation in supply chain structure between vertical / integral and horizontal / modular*" (Fine, 2009, p. 216).

While car manufacturers rely, in the short term, on their integration capabilities, a second stage of electrification could be envisaged, leading electric traction specialists to manufacture high-voltage battery and electric propulsion systems instead of car manufacturers.

Three major arguments can be put forward in favor of this hypothesis

1. The heavy and continuous trend towards de-verticalization and outsourcing of the automobile industry during the 20th century (Fourcade and Midler, 2005, 2004; Sako, 2003; Sako and Murray, 1999) which has led suppliers to produce between 70 and 75% of the value of a vehicle,
2. The superior modularity of electric traction compared to thermal traction which favors an outsourcing and specialization effect,
3. The ability of electric traction specialists, thanks to greater series effects, to achieve production cost and quality levels that are much more efficient than those of manufacturers.

In this new context, suppliers of high-voltage battery and electric propulsion systems could take over a significant share of the industry's activity and value without destabilizing the industry's overall architecture, as it is already the case for "big" modules (seats, cockpit, etc.).

Fine's work is inspired by the microelectronics industry, where the speed of change in major components, makes it possible to reshuffle the cards at the speed of Moore's law. He indicates (2009) that the same phenomena are also occurring in highly capital-intensive sectors such as the automotive industry, but at a slower pace because Very-large-scale integration (VLSI) design is significantly different from mechanical design (Whitney, 1996).

However, this movement is not yet visible for at least two reasons. Firstly, because, for carmakers, faced with the massive conversion of their internal combustion engine plants, in-house manufacturing of high-voltage battery or electric propulsion systems makes it possible to cushion the impact of electrification on jobs in a context where a redundancy strategy, combined with massive outsourced supplies, would be difficult to justify socially and politically.

Secondly, the battery system, including its power management strategy, has a major impact on the performance of an EV, whether in terms of range, maximum speed, charging speed or overall energy efficiency. Even if the intrinsic performance of the cell, the basic electrochemical component of a battery pack, is important to meet the criteria mentioned above, it requires, above all, strong automotive design skills, such as weight optimization, cooling system design, electrical and thermal risk management, system integration, etc... On the other side, as all the improvements of the last decade have been done in the dominant design of liquid lithium ion technology, electrochemistry specialists haven't had a chance, so far, to impose their technological pace to carmakers. Consequently, in the current state of knowledge¹² of both battery suppliers and carmakers, the latter are in the best position to achieve this.

The obvious conclusion is that electrification, even if it modifies the design of a vehicle, is not enough to cause a destabilization of the industry. This conclusion calls for a new empirical question *“Could the current situation of resilience of the automotive industry change over time?”*

1.3. What is the future of this industry made of?

At this stage of the research, in order to address this new empirical question, it is then necessary to redirect future work. This is what has been done by stepping back and making an analysis of what the future of this industry could be.

In addition to the environmental pressure highlighted at the beginning of this introduction, this industry is also subject to new societal challenges: increasing urbanization, new urban transportation needs, changes in consumer behavior with regard to car ownership and mobility.

The galloping urbanization which, according to the United Nations¹³, will add 2.5 billion to the world's urban population by 2050, increases the level of congestion and casualties in urban and peri-urban areas. As a result, it worsens the already problematic traffic conditions in large metropolises, due to the increasing distance between places of residence and places of work caused by the rising cost of housing in urban centers, and accelerates the necessity to improve the urban conditions of transportation. Till now, the car is still the cheapest means of passenger transport, even compared with public transport, when one adds the share of public subsidies to

¹² The potential introduction of solid-state technology could be a game-changer, but if the expected break in performance is confirmed, it will take five to ten years to see the effects on the automotive value chain (see for instance <https://asia.nikkei.com/Business/Technology/Toyota-s-game-changing-solid-state-battery-en-route-for-2021-debut>)

¹³ <https://population.un.org/wup/Publications/Files/WUP2018-Highlights.pdf>

the ticket price. However, changes in consumption habits, particularly among young urban dwellers, towards shared mobility, could call into question the traditional business model of car manufacturers. This move could be amplified by the convergence of technological innovations enabling the emergence of Connected, Autonomous, Shared and Electric Vehicle (CASE) and Mobility as a Service (MaaS) offers.

Having in mind this societal context, two different paths of analysis have been followed, almost in parallel. The first aims to assess the current dynamics of the automotive industry while the second is an exploratory analysis of innovative mobility services.

1.3.1. The momentum of the automotive industry

The reality of the rise of car mobility services

Although car manufacturers have all embraced the concept of autonomous driving, from its inception, by adopting the six autonomous driving levels (0: no autonomy, 5: complete autonomy in all situations) formalized by the SAE (J3016 from 2016), this was initially in a logic of upgrading the functions offered to customers in the classic business models of selling vehicles in B2C or B2B (sales to fleets). Initially, several manufacturers of premium vehicles launched vehicles equipped with level 2 or 3 functions (Tesla model S, BMW copilot assistance driver but also Audi A8) and, moreover, they continue to develop such functions, such as DRIVE PILOT which will soon be offered by Mercedes. The ambition announced at the time was to provide, thanks to the highest levels of automation, additional usage values, such as the possibility of using the time freed up in automatic driving phases, for example, for work (mobile office) or leisure activities.

With the deployment of new mobility services, some car manufacturers are positioning themselves as suppliers of vehicles (pre-equipped or to be equipped) for mobility operators such as Volvo with Uber or Fiat Chrysler Automobiles (FCA) and Jaguar Land-Rover (JLR) with Waymo, while others are taking the plunge and positioning themselves resolutely as (future) mobility service operators. This recent and spectacular shift in the car manufacturers' strategy is, of course, manifested by the fact of operating mobility services, but also by strategic orientations and massive investments, as well as by alliances, acquisitions and even corporate reorganizations, as illustrated by the few examples below.

To name but a few, BMW, Daimler, Ford, GM, Hyundai/Kia, Nissan, PSA and Renault already operate electric vehicle sharing services, while Tesla has announced its intention to launch its own Peer to Peer (P2P) car sharing service.

In terms of strategic direction, as early as 2016, GM acquired Cruise automation to make it its autonomous driving division and has continued to invest in it continuously, joined by other investors including Honda which, in 2018, has committed to invest \$2.75 billion over 12 years to contribute to the development of a new vehicle dedicated to autonomous mobility. It was at CES 2018 that A. Toyoda, President of Toyota said *"It's my goal to transition Toyota from an automobile company to a mobility company"* and announced that, thanks to Toyota Connected, a company resulting from the alliance with Microsoft, Toyota hopes to be a leader in the field of the mobility services platform.

Volkswagen announced that it will invest more than 34 billion Euros by 2022 to develop electric mobility, autonomous driving, digital connectivity and new mobility services. This is a perfect example of the massive investments made to support this new strategy.

In January 2019, Volkswagen and Ford announced a comprehensive cooperation agreement that could also include future cooperation on electric, autonomous vehicles and mobility services. In February 2019, BMW and Daimler announced the pooling of their mobility services to create a new global player offering sustainable urban mobility to its customers. The two companies are investing a total of more than €1 billion to develop and bring together their offers in carpooling, ride-hailing, multimodal transport, charging network and parking space search. In June 2019, the Renault group and Nissan announced an exclusive agreement with Waymo to explore driverless mobility services. In addition to these alliances, we can also mention acquisitions, other than the already mentioned acquisition of Cruise automation by GM, such as Renault acquiring the VTC Marcel platform, or BMW, Mercedes and Audi jointly acquiring HERE, a company specializing in high-definition mapping, a major technology for automated driving.

In addition, Daimler has reorganized itself in 2019 by creating three legally independent joint stock companies to operate its three main activities: vehicles and vans (Mercedes-Benz AG), trucks (Daimler Truck AG) and finally mobility and finance (Daimler Mobility AG), which shows that the group is equipping itself to be a major player in the field of mobility.

Finally, many present concepts of electric, autonomous and versatile vehicles such as Toyota with E-Pallet, Mercedes Benz with Urbanetic, Renault with EZ-Pro or finally, Volkswagen with POD.

In summary, after considering that they would integrate automated driving technologies into their traditional line-up to increase the perceived value of the car, almost all car manufacturers have moved to apply these technologies to mobility services. As a result, they have entered into

cooperation agreements, or even made acquisitions, with technology companies to acquire the skills needed to develop these services. Moreover, many of them are already developing and operating electric car pooling or car sharing services that enables them to gain experience and reputation in this industry. Finally, it can also be noted that in a large part of the experiments they are conducting, including all prototypes and demonstrators, the vehicles have electric traction, a high level of driving automation and that many of these proposals concern vehicles offering versatility of use.

... And the irruption, in the automotive sector, of powerful new players from the world of digital platforms ...

Innovative mobility services (Mobility as a Service, MaaS), which allow, through a single application, integrated access to multiple forms of transport, public or private, offer a response to current societal challenges; proof of this is that one of the clearly expressed purposes of this type of offer is also to provide an alternative to the use of the private car that is more ecological, more practical and more economical¹⁴. The appearance of the MaaS concept is very recent, since it was formalized during a congress held at the end of 2014 at the Finnish Science Center in Helsinki; it has contributed, thanks to this societal but also systemic vision, to the development of mobility services well beyond the ride-hailing that the leading companies in the sector had previously been created (for example, Uber in 2009, Lyft and Didi Chuxing in 2012).

They have since been joined by numerous competitors, two of which, Cruise (a subsidiary of GM and Honda) and Waymo (a subsidiary of Alphabet-Google), have the ambition and the means, both technological and financial, to develop autonomous robotaxis services on a global scale ; these developments, which are made possible by the simultaneous convergence of four major technologies: electrification, connectivity, autonomous driving and digitalization, make it possible to improve the profitability of the service by eliminating the highest recurring cost item, that of driver remuneration estimated at 88% of the total cost (Bösch et al., 2018, p. 82). Uber, for its part, aims to operate a fleet of robotaxis supplied by Volvo, while Lyft has reached an agreement with Waymo to make the latter's offer accessible via its own platform, and Didi Chuxing has announced the commissioning of a first fleet of robotaxis in Shanghai.

These newcomers have a clear ambition, very well summed up by D.Ammann, the CEO of Cruise: *“That’s why at Cruise it is our mission to improve safety by removing the human driver, reduce emissions by being all-electric, and reduce congestion through making shared rides*

¹⁴ What is MaaS? <https://maas-alliance.eu/homepage/what-is-maas/>

more compelling by providing an awesome experience at a radically lower cost. Only then will we truly move beyond the car to the transportation system that we deserve — one that is safer, more affordable, and better for us, for our cities, and for our planet”.

This statement confirms the ambitions of these new mobility operators and that they are indeed one of the actors that could cause a potential destabilization of the automotive industry.

The electric, autonomous, connected and shared vehicle, a new and credible horizon for automotive dynamics

Even if it is not the first time that carmakers make very important investments outside their core business and, in the past, they had to face serious setbacks (such as the car rental business), this time the conditions that could destabilize the automotive sector seem credible. Indeed, under the dual influence of recent technological developments (electrification, connectivity, automated driving as well as digital technologies) and societal issues (growing urbanization and new urban transport needs as well as changes in consumer behavior with regard to property and mobility), these new offers are pushing for the transformation of the business model from the sale of vehicles in B2C or B2B to that of the sale of mobility services. In addition, the number of new mobility services experimentations as well as the extent of these are highly representative of an *era of ferment* (Anderson and Tushman, 1990), which further strengthens the plausibility of a future destabilization of this industry. However, if the conditions for a potential destabilization of the automotive industry are met, this leaves a very wide field of possibilities regarding the precise orientation of this dynamic as well as the impact on its architecture. If the notions of "Electric, Autonomous, Connected and Shared Vehicle" appear in all the speeches of car manufacturers (CASE for Daimler and Toyota) or the prospective studies of international consulting firms (ACES for McKinsey or EACSY - Yearly updated - for PWC), it is certainly a concept that carries multiple ambiguities: is it a "ride hailing" strategy (Uber, Lyft, Didi)? Or is it car sharing (Autolib, SHARE NOW, Free2Move)? Is it Peer to Peer or via a service offered by an operator? Or more simply, is it the application of the more traditional strategy of car manufacturers that of an evolution of driving aids towards autonomy for high end vehicles?

1.3.2. An exploration of future mobility services

To what extent are these mobility services a radical innovation? Are they going to provoke an escape from the dominant design of the industry?

To answer these questions, the key idea behind the exploration of future mobility services is to identify certain design parameters, not yet utilized, whose activation could lead to a disruption in the automotive industry.

The application of the theory of concept knowledge (Hatchuel and Weil, 2009), makes it possible to study an ill-defined and uncertain but appealing and demanding concept: “*Best Total Cost of Mobility Service for a versatile and sustainable mobility service centered on customers’ needs*”. The use of very basic variables (1) “*what is transported?*”, (2) “*who drives the vehicle*”, (3) “*who owns the vehicle*” and associated values for each of them, as listed in the table below, facilitates the definition of the offer presented in the figure “A mapping of Mobility as a Service exploration.

Variables	Associated parameters
What is transported	Individual mobility Collective mobility Goods transportation Services and industries @ customers (where the customers are) Multiple usages (versatility of usages)
Who drives the vehicle	Driver Vehicle owner Self-driving system
Who owns the vehicle	Driver owner User owner Mobility operator

Table 2 : Framework for an exploration of an innovative mobility service

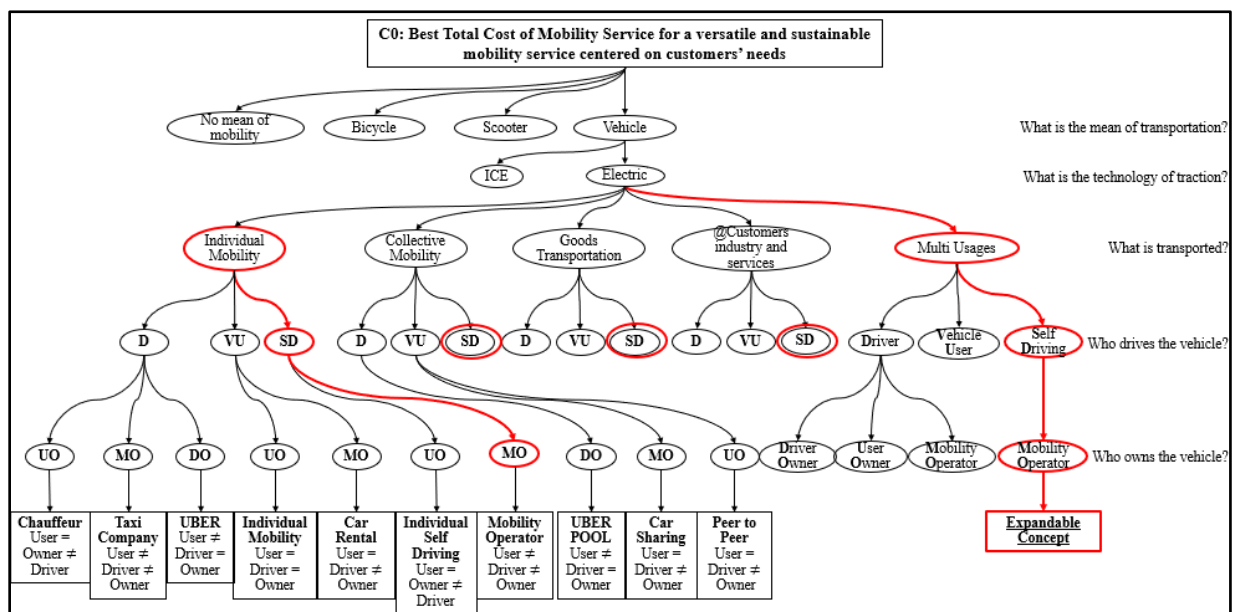


Figure 1 : A mapping of Mobility as a Service exploration

Focusing on individual or collective mobility of persons, we can draw two straightforward conclusions:

1. Firstly, as we can describe, thanks to the use of these simple variables, most of the existing mobility services, including ride hailing (see UBER in above figure), it just demonstrates that all these configurations can be implemented through the existing innovation featuring process of car manufacturers. In fact, mobility innovations as ride hailing can be considered as an extension more than a disruption of the dominant design. The car is a traditional and rather high-end sedan, sold by OEM to ride hailer as customer-driver, and the ride hailing system and app can be considered as an aftersales equipment of the car. We are in the field of the “*Service added to product*” articulation previously described.
2. Secondly, only the red thick branches of this mapping (individual mobility on the left side, all non-developed branches starting from (SD) in the middle, and multi usages on the right side) appear as radical innovation moves as defined by Abernathy et Clark (1985).

These innovative mobility services are characterized by (1) new usages (autonomous, dedicated or versatile mobility), (2) a new product (dedicated or versatile robotaxi), (3) a new business model (from B2C to B2B2C) and (4) the involvement of a new player, namely a mobility operator, having the capability of acting as the focal firm of a new ecosystem of mobility.

Altogether, these two analyses emphasize the existence of technological but also societal factors that combined with regulatory ones, could have the capacity to disrupt the industry.

Exhibiting a potential disruption of the industry under the influence of these factors is a second major result to be credited to this thesis. It then encourages to broaden the analytical framework to other disruptions to which the automotive industry is subject and which, according to a cascade or system effect, could, by aggregating with the technological disruption of electric drivetrain, lead to a more radical destabilization of the industry. It also paves the way to a new research question that explores, beyond the current resilience of the automotive industry, the potential conditions for its future destabilization: «*Could the convergence of socio-technical factors, both internal and external to the automotive industry, drive a future disruption of its architecture?* ».

It is thus necessary to identify another theoretical current of interest to explore this question of resilience or, on the contrary, the destabilization of the architecture of the automobile industry.

1.4. A theoretical pivoting induced by this new research question

The theoretical current of interest to explore this question is that of socio-technological transitions that we now introduce.

The sociology of technology stream of research considers that a technology only has an impact if it fulfils a function within a society, and thus is part of a social system or organization; building on the finding that a technology is a “*configuration that works*” (Rip and Kemp, 1998), which means that it fulfils a function that makes sense for society, Geels (2002) infers that the functions of society are fulfilled by *sociotechnical configurations*. These are the grouping of heterogeneous elements, technical, but also regulatory, organizational, financial, etc., whose combination allows the realization of a function necessary to the functioning of the society. Their stability is the result of the links between the heterogeneous elements that make it up, which are produced, thanks to organizational and cognitive routines, by the actors of the said system who are aligned and coordinated with each other; as these routines also exist at the technological level, they contribute to forming a “*technological regime*” (Nelson and Winter, 1982; Rip and Kemp, 1998). Actors of a regime are either technological ones, such as engineers, firms, suppliers, universities, etc. and non-technological ones, e.g. users, policy makers or special interest groups, Non-Governmental Organization, etc. (Geels, 2006).

Continuing to exploit the concept of “*technological regime*”, and (1) highlighting the fact that such a regime leads to the implementation of a “*technology trajectory*” as a result of concerted actions by all the technological actors and (2) that these are also influenced by all the non-technological actors in the regime, Geels (2002) concludes that it is more appropriate to adopt the term “*sociotechnical regime*”. A “*sociotechnical transition*” is then described as a move from one “*sociotechnical regime*” to another one, which does not occur spontaneously in an established regime, since the latter is based on a logic of lock-in and path dependency that favors incremental changes (Geels, 2010; Geels and Schot, 2007). In contrast to the strategic paradigm, where major changes in the system are linked to competition between actors around the deployment of technological substitution, a STT is a multi-actors¹⁵ process, which requires multiple interactions and cooperation between technological and non-technological actors (Geels, 2006; Geels and Schot, 2010).

¹⁵ Smith and al. (2005) mentioned that the STT paradigm pays little attention to the role of the actors involved in transitions. Geels and Schot acknowledged that the descriptive figure of the Multi-Level Perspective does not show them, for the sake of simplification, and stated that “... agency is always present in the MLP” (2007, p. 413). This thesis will contribute to make more explicit the role of agency in transitions by showing the importance of project managers in the transition of the automotive industry towards electromobility.

These key notions, and all the rich literature about the STT paradigm, bring two strong principles, particularly relevant, to address our research question:

1. Significant transitions can only occur when a combination of external and internal industry factors come together (Geels and Kemp, 2000; Kemp, 1994; Rip and Kemp, 1998; Schot et al., 1994; Van den Ende and Kemp, 1999),
2. The dynamics of technology is only one of them (Dijk et al., 2016; Geels, 2006; Marletto, 2014; Van Bree et al., 2010).

In addition, Smith et al. (2005, p. 1494) stress that, in order to explore the causes of a transition, it is necessary to focus on the governance of all the external and internal factors affecting a regime, by analyzing : “(1) *the shifting of selection pressures bearing on the regime*, (2) *the coordination of resources available inside and outside the regime to adapt to these pressures*”.

The Multi-Level Perspective (MLP), as it understands transitions as the result of alignments between multi-level developments, and considers radical changes and stability both inside and outside of a regime, provides an useful framework for understanding system changes and transitions; therefore, this naturally applies to the study of STT, which are multi-dimensional phenomena (Geels, 2020, 2010, 2006; Geels and Schot, 2007). The use of the MLP framework makes it possible to describe a dynamic of sociotechnical change as a movement unfolding on three analytical and interacting levels (Kemp et al., 1998; Rip and Kemp, 1998). At the macro level, it is within a "*sociotechnical landscape*" that non-technological influencing factors are located, being economic, cultural, social, regulatory, etc.; at this level, developments are generally quite slow in view of the actors and energies that need to be mobilized. At the meso level, there is a set of *sociotechnical regimes*, each representative of a function in society, such as transport, communication, food, etc.; each of these regimes has its own characteristics and, through alignment and coordination between its constituent players, ensures the gradual development of the technologies necessary for its smooth operation (Geels, 2002). Finally, at the micro level, there are the *niches of innovation* which, being isolated from the sociotechnical regime while sharing the same type of structure, offer a more favorable context for the emergence of radical innovations and their eventual subsequent growth (Geels and Schot, 2007; Hoogma et al., 2002; Kemp et al., 1998, 2001).

Concerning how a change happens to come, Geels and Schot have (1) summarized that there is not a single cause of evolution but the convergence of multiple processes, (2) described more precisely the interactions between each of the three levels of a MLP framework as well as over

time, and (3) explained the mechanisms implemented within a socio-technical regime, including those leading to the construction of a dominant design (see Geels and Schot, 2007, p. 401 for a description of Multi Level Perspectives on transitions).

... Broadening the analytical framework to include factors considered by the stream of socio-technical transitions

To feed this new analytical framework, applied to the analysis of the current context of the automotive industry, I consider some previous contributions (Dijk et al., 2016; Geels, 2002; Van Bree et al., 2010) and elaborate on my own analysis of the factors which will influence the transformation of the automotive industry. Therefore, six broad categories have been identified, to which are associated the actors that activate them:

- *Regulation*, whom the influence is major in the current transition towards electrification and can be activated by supranational, national but also local public authorities,
- *Social trends and customer usage and values* which support the deeply rooted cultural, social status that makes the automobile the preferred means of individual mobility,
- *Infrastructure* such as roads, expressways, traffic management system or charging networks that can be activated by public authorities and/or private companies (construction companies, expressway operator, charging network operator, etc.),
- *Technology*, which at the beginning of the transition towards electrification can be considered as consisting in the ICEV dominant design involving carmakers and tier X suppliers, as well as the suppliers of the parts and components of the high voltage battery and electric propulsion systems,
- *Industry architecture*, which encompasses all the actors of the automotive value chain (carmakers, tier X suppliers, retail and maintenance / reparation networks),
- *Product and market strategy*, the classic B2C and B2B sales of multipurpose vehicles (and some added services) as one of the major levers of action for carmakers.

The identification of these factors enables to build a framework to describe the transition to electromobility we described. At the landscape level, this is an *avalanche* type change (Geels and Schot, 2007; Suarez and Oliva, 2005) as the regime has to face the simultaneous and cumulative pressure of three changes of high intensity: climate change, increasing urbanization and changing consumption patterns. Similarly, at the niche¹⁶ level, the emergence of MaaS,

¹⁶ In this research, actors at niche level are very powerful both technically and financially and are very far away from a situation where “*Niche-innovations are carried and developed by small networks of dedicated actors, often*

which is one of the possible responses to these societal changes, can only take place if there is a simultaneous convergence of four major technologies, at high levels of frequency, amplitude, speed and scope, namely electrification, connectivity, autonomous driving and digitalization. This convergence, similar to that of tectonic plates, adds a new typology of change to the one used (Geels and Schot, 2007; Suarez and Oliva, 2005), which will be referred to as an *earthquake*. Consequently, the following MLP framework is proposed to describe the ongoing transition towards electromobility.

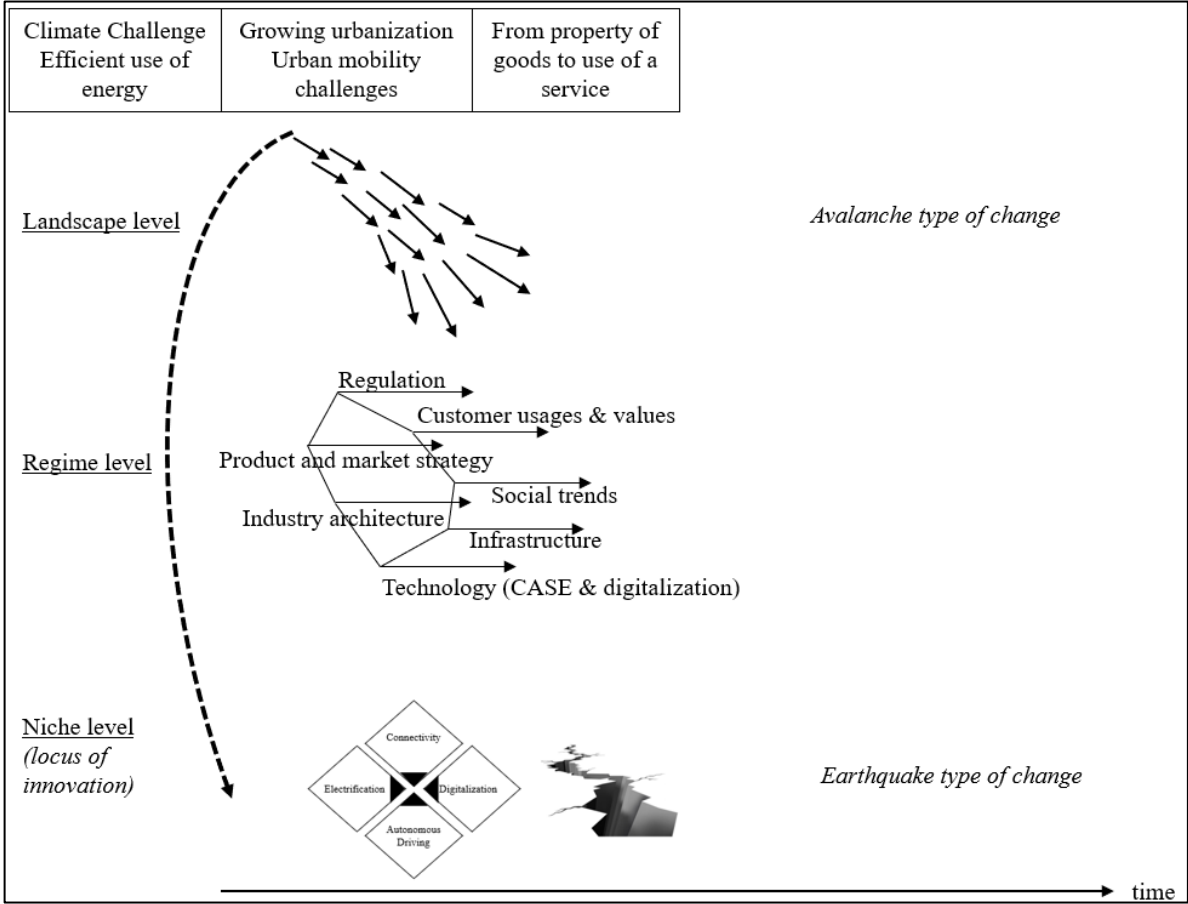


Figure 2 : A MLP framework to study Electromobility
 Adapted from (Geels and Schot, 2007, p. 401)

Once this new analytical framework was established, further research then focused on assessing the reality of these factors, and evaluating their impact on the architecture of the automotive industry. In this respect, two factors were particularly analyzed: on the one hand,

outsiders or fringe actors” (Geels and Schot, 2007, p. 400). However, the technology actors contributing to the development of MaaS, through the deployment of full-scale experiments, provide a very favorable context for the emergence of radical innovations and their possible further development, which is consistent with the definition of *niches of innovation* that has been adopted in this thesis (p 17).

the rise of mobility services, encompassing Customer usages & values, Social trends, Technology, and, on the other hand, the impact of Environmental Regulations.

1.5. An international benchmark about innovative mobility services

As introduced previously, if the conditions for a potential destabilization of the automotive industry are met, this leaves a very wide field of possibilities regarding the precise orientation of this dynamic as well as the impact on its future architecture. In the light of these ambiguities and uncertainties, a team of CRG researchers has decided to launch a large-scale study on new automotive mobility initiatives (Presentations at the IMD - Paris, July 2019 and Program on Vehicle and Mobility Innovation (PVMI) - Paris, January 2020 seminars), based on the following hypotheses:

1. Firstly, drawing on one of the most robust social science findings on technological change, assume that there is no technological determinism, but only learning determinisms (Midler and Charue-Duboc, 1994) or, in the language of economists, path irreversibility (Dosi, 1982). It is therefore by studying and comparing the various experiments in progress, by studying their meaning and by evaluating their performance in leading, more or less rapidly, to operational realities that we will shed light on the uncertainties of possible destabilization scenarios.
2. Then, in coherence with the theoretical progression that took place during this thesis, the space of the initiatives studied widens from electric vehicles to electric, connected, shared and autonomous mobility initiatives.
3. The actors' space considered is that of the actors involved in such initiatives, i.e. not only car manufacturers, but all stakeholder industries: transport operators, technology or service providers, digital companies as well as territorial public operators who play a key role in the design of current mobility experiences.
4. The "playground" for this learning of new mobility services is global. The "triad" of USA, Europe and Japan, which traditionally set the pace and direction of innovation in the sector, is now being contested by Asian countries, especially China, because of the size of their markets and the dynamism of their automobile industry, but also because of political initiatives giving a large place to ambitious experiments in the field of transport.

1.5.1. An original empirical framework

The robustness of these hypotheses led to the construction of a collaborative research program (Research Initiative Presentation, December 2019), in which this thesis is part, and which is characterized by the following points:

1. A cooperative research design associating expert academic teams from the automotive industry and covering the major markets concerned: USA, Europe, Japan, Korea and China,
2. A multi-case study method, one case being a mobility initiative,
3. A questionnaire with four objectives:
 - First of all, characterize the precise nature of the mobility experience. This characterization is based on a theoretical definition of the design variables of a mobility service offer. As a matter of facts, building on servuction literature (Eiglier and Langeard, 1987) and design theory (Hatchuel and Weil, 2008), Lenfle and Midler (2009) have proposed an analytical framework to characterize the design space of a service innovation. This framework has been completed and adapted to characterize the design space of MaaS in six integrated domains: (1) the definition of the service, (2) the vehicle offering supporting the service, (3) the required infrastructure for its efficient operation, (4) the back-office functions such as fleet or hub management, (5) the front-office functions such as single trip reservation or integrated ticketing, and (6) the business and revenue model,
 - Characterize the value targeted by these initiatives, both individual and collective values,
 - Characterize the ecosystem that supports the initiatives. What is the nature of the ecosystem? What is the strength of the leadership? What are the actors contributing to it?
 - Characterize the learning performance of these initiatives. What are the bottlenecks? What is the observed maturity? What is the ecosystem lineage capability?
 - Administration of the questionnaire to the actors involved in these initiatives. In an attempt to cover all the factors influencing this transition, both internal and external to the automotive industry, we have sent these questionnaires to the traditional players in the sector, manufacturers and equipment suppliers, but also to all stakeholders such as public authorities, technology or service suppliers, etc. The questionnaires were sent to all the stakeholders involved in these initiatives. From a methodological point of view, the aim is to obtain direct information through interviews with the executive managers

of the companies or institutions involved in these new mobility services, as well as with operational staff, such as those responsible for initiatives under development.

- A process of restitution of the results as they are produced, aimed at the research collective on the one hand, the community of researchers in these fields on the other, and finally the public and private professional actors involved in these changes.

The specific contribution of the author of this thesis to this research program was as follows:

- Contribution to the construction of the questionnaires in the first half of 2019,
- Participation in the first tests of the methodology on two cases with a French automotive company (September - October 2019),
- Administration of the questionnaire to 5 Chinese companies (3 car manufacturers and 2 technology companies) giving access to 8 cases during the October 2019 mission,
- Continuation of the analysis of two other cases of French companies and treatment of two other cases by analysis of second sources only (December 2019 - February 2020),
- Writing of two papers for conferences to be held in 2020 (December 2019 - February 2020),
- Parallel processing¹⁷ of the data collected and presentation of the results at the first research seminar of the international network at the end of January 2020.

The problems associated with COVID19 have obviously disrupted the deployment of this research. It will be recalled that the epidemic broke out at the end of December 2019, first in Wuhan, one of the major centers of the Chinese automobile industry, where a mission was to take place in spring 2020. Similarly, the other missions planned in 2020, i.e. Japan in March, USA in June and China in October had to be cancelled.

It will therefore not be possible to carry out all the actions planned for the year 2020 under this research program. Nevertheless, to date, fourteen cases have already been carried out that allow producing significant results within the framework of this thesis, by the end of 2020.

The results already obtained in the study of ten cases (over fourteen) will be presented here. They concern various mobility initiatives at different levels of maturity (concept formulation, development, field experimentation and operation) which have been developed and/or operated in the USA, Europe and China as summarized in the table below (SCx means Study Case number x).

¹⁷ The methodology for analyzing the interviews is described in the papers relating to the presentation of the results

Maturity Localization	Concept formulation	Development	Field experimentation	Operation	Total
USA			1 (SC7)	1 (SC5)	2
China		2 (SC2, SC4)		2 (SC9, SC10)	4
Europe	2 (SC1, SC3)		2 (SC6, SC8)		4
Total	2	2	3	3	10

Table 3 : Maturity and Localization of the ten cases

Because of the problems associated with COVID19, the questionnaires were filled in, in eight cases by using direct interviews, possibly supplemented by public information, while only information from second sources was used in the other two cases (SC5 and SC7).

1.5.2. Ten cases in a nutshell

Study Case 1 (SC1) aims to solve the problems of saturation of public transport, generally congestion problems when travelling between the suburbs and the city center. The proposed solution consists of setting up rapid transit lanes open to electric vehicles (buses, shuttles, taxis or even private cars), equipped with the software and hardware package (level 3-4 of AD¹⁸) allowing them to be handled by an automated control system which secures the entrances and exits of the rapid transit lanes as well as ensures a high flow of passengers. While, per se, the natural project owner of such an initiative is a public authority, a wide European consortium of carmakers, digital, construction and infrastructure companies, mobility operators, technology providers, etc., is in charge, under the leadership of a public/private research institute, of the development phase leading to experiments in the field.

Study case 2 (SC2) is a typical example of an automated electric shuttle for person transportation (AD level 4). It is developed under the leadership of a City authority in charge of implementing traffic conditions enabling the functioning of the transportation system. The shuttle is developed by a vehicle maker and transformed into an autonomous vehicle by a very recently created Chinese technology company that provides vehicle autonomous driving and road perception systems.

Study case 3 (SC3) is a very innovative concept of autonomous urban mobility, involving versatile electric robotaxis (AD level 5) which aims at moving persons, goods, and also bring services where people are (service mover). Urban governance of all these different types of mobility should reduce the number of vehicles needed and thus reduce pollution and congestion. This concept is jointly studied and developed by a carmaker and a city public authority, the latter being in charge of defining the urban mobility governance rules.

¹⁸ All Autonomous Driving (AD) levels cited in this section refer to SAE definition (SAE, 2019)

Study case 4 (SC4) addresses a problem of logistics transportation in a port area, i.e. moving containers from docks (boats) to containers yards and vice-versa; there are a few routes learnt by advance and a dispatching system is in charge of optimizing the number of trucks necessary to move containers. It involves special electric vehicles (AD level 4), dedicated to this mission and developed by a special vehicle maker, while the AD package is developed by a very recently created Chinese technology company. The project owner is the public authority in charge of operating the port.

In **study case 5** (SC5), the targeted mobility solution is a ride-hailing service involving an electric robotaxi with AD level 5 that operates without any interaction with the road infrastructure or any traffic management system; the electric vehicles are supplied by carmakers while the mobility operator performs the adaptation to autonomous driving by installing its own software / hardware package in its own factory. The case is in a very advanced situation of field's experimentation as it is already in operation with paying customers, while for obvious reasons of safety and security, safety officers are still present in vehicles; it is also operated in a fully driverless mode for some early testers in a restricted area. It is developed and operated by a subsidiary of an American giant technology company.

Study case 6 (SC6) proposes a solution to deal with the problem of transporting people on the first / last mile, between a train station and different residential or activity areas. It is developed under the direction of an urban public authority, which designed the integration of this offer into the current system, and is operated by a transport company. The carmaker provides an electric robotaxi with AD level 4 capability, requiring exchanges with land-based driving decision support systems in a few specific cases such as roundabouts.

Study case 7 (SC7) is very similar to study case 5, the main difference being that it is developed and operated by a subsidiary of two global carmakers (and other shareholders); the vehicle used for the first experimentation and operation phases is produced by one of the carmakers and adapted to autonomous driving. The mobility operator has presented, at the beginning of this year, a dedicated robotaxi jointly developed by its two shareholders.

Study case 8 (SC8) is another example of ride-hailing service involving an electric robotaxi with AD level 4 which interacts with some dedicated road infrastructures in complex contexts. The case is in a situation of field's experimentation and the service is operated by a carmaker, acting here as a mobility operator.

Study case 9 (SC9) addresses a service of automated delivery of goods. A very recently created Chinese technology company provides a logistics operator with an AD level 4 package

integrated in existing trucks and the service is only operational on routes learnt in advance by the system. Consequently, there is no connection between the vehicle and any road infrastructure or traffic management system and a safety officer is present in the vehicle to deal with any possible system failure.

Study case 10 (SC10) concerns a Chinese car manufacturer, newcomer to the automotive industry, which recently launched two high-end electric SUVs with AD level 2, equipped with in-car navigation and entertainment systems. In order to capture new value beyond the traditional business scope of a car manufacturer, the company has developed numerous mobility services (recharging, repair, maintenance, etc.) and "multi-service personal application" type services (social networking, entertainment, merchandising, leisure, travel, etc.); it also offers a P2P car sharing service reserved to the owners of the vehicles.

After presenting each case, following the framework of analysis of the questionnaire, a specific exploitation of the empirical data is carried out in five directions. The first contributes to characterize each mobility initiative by describing the mobility service, its values, ecosystem and learning performance. The compilation of all information leads to the definition of three ideal types (Weber, 1978). The second one wonders whether each ideal type has or not the capacity to disrupt the architecture of the automotive industry. The third one highlights the importance of learning in projects when they are systemic and developed in an ecosystem that goes far beyond that usually concerned by the automotive product alone. The fourth proposes a typology of service development projects while the fifth deals with the impacts induced on project management, for car manufacturers, by the development of mobility service offers.

1.5.3. Characterizing the study cases

1.5.3.1. Definition of the mobility service

The ten cases analyzed were chosen, among the fourteen studied, because they show the diversity of current attempts to innovate with respect to the dominant model of automobile mobility: the driver owning a vehicle purchased from a carmaker. The cases reveal evidently different levels of maturity of the initiatives, but more interesting, different configurations in the variables of the service design space (Lenfle and Midler, 2009a) that are activated.

SC10 exhibits the strategy of *service added to a vehicle* (Verstrepen et al., 1999), long known in the automotive industry, which makes it possible to continue selling vehicles on a B2C basis. What is innovative, here, is the addition of a new mobility service capability to the vehicle through the use of new technologies, as particularly illustrated by the P2P car sharing service proposed by this carmaker. In this case, the vehicle, back-office (repair, maintenance,

but also innovative functions for vehicle charging) and front office variables are mainly activated as they are the main vectors of the offer. On the other hand, only the classical traffic infrastructure functions are necessary to operate this service.

SCs5, 7, 8 take over from the ride-hailing model at Uber or the car-sharing model at Autolib by offering a fleet of automated vehicles (robotaxi) that supports the service. It is extended, in SCs4 and 9, to transportation of goods. There are two key variables activated here: (i) the vehicle, an electric robotaxi with AD level 4 or 5 functions, and (ii) the back-office functions i.e. hubs ensuring maintenance, battery charging, etc. that are of first order to guarantee the quality and the availability of the service. The APP, which enables communication between the service operator and end-user customers, very similar to that already used in existing UBER services, also plays a very important role in SCs5, 7 and 8. As explained below, in SCs4 and 9, the actors are in a classical B2B relationship; therefore, the front office function is rather a platform for communication between them and is therefore both more classical (than an APP) and less visible in our observation. Only the classical traffic infrastructure functions are necessary to operate the service in SCs5,7,8,9 while we assume that some port infrastructure modifications are required to enable the autonomous transport of containers in SC9. SCs5, 7, 8 are in a B2B2C model where the mobility operators integrate components and features from their suppliers / complementors to provide a mobility service to end-user customers. SCs4 and 9 are in a very classical B2B relationship where a technology provider supplies (and probably integrates in vehicles in these particular cases), an autonomous driving software and hardware package to a project owner.

SCs 1, 2, 3 and 6 are oriented towards solving collective mobility problems specific to certain territories. Therefore, the infrastructure, back and front office functions are playing a key role in enabling the transportation service. Here, the vehicles are constituents, among others, of the service. This is even truer in SCs1 and 3 as the implementation of the mobility solution is much more distributed, with open standards allowing a variety of actors to contribute to the development and operation of the system. While SC2 exhibits a B2B business model very similar to the one already described for SCs4, 9 and SC6 a B2B2C model similar to SCs5, 7 and 8, SCs1 and 3 introduce a new type, namely Business to Territory to Customers (B2T2C). In this model, a local or territorial authority contracts with a company (or companies) to design, experiment and, finally, provide an innovative mobility service to end customers. The proposed service responds to a precise need, anchored in a territory and specific to it. The specificity of the service is not only in its objectives, which can be quite common, such as the resolution of

travel problems between peri-urban areas and a city center, but also in the solutions envisaged, which may be imposed by a particular geographical configuration or social context to give a few examples. The other specificity lies in the fact that the contracting authority, which is responsible for designing the offer, is a public authority that considers the values of transport efficiency, control of financial impacts for both the community and customers, and reduction of environmental, noise, etc. nuisances to be essential.

These observations are summarized in the table below where we indicate, for the vehicle, infrastructure, back-office and front-office variables, their importance for the operation of the service described and their maturity of activation in the observed initiative. The value “3” means this is a major variable in operation, the value “2”, means major variable in field experiments, the value “1” means major variable in upstream phases while the value “0” indicates it is a less important variable.

Study case	What is transported?	Vehicle supporting the service	Infrastructure for operation	Back Office functions	Front Office functions	Business Model
SC1	Persons	0	1	1	1	B2T2C
SC2	Persons	0	1	1	1	B2B
SC3	Persons, goods, services	0	1	1	1	B2T2C
SC4	Containers	1	1	1	0	B2B
SC5	Persons	3	0	3	3	B2B2C
SC6	Persons	2	0	2	2	B2B2C
SC7	Persons	2	0	2	2	B2B2C
SC8	Persons	2	0	2	2	B2B2C
SC9	Goods	3	0	3	0	B2B
SC10	Persons	3	0	3	3	B2C

Table 4 : Summary of the service variables activated in the study cases

It can be noted that the back and front office variables, regardless of the maturity of the services observed, are not as discriminating as the vehicle, infrastructure and business model variables. On the one hand, the operation and maintenance of a relatively large fleet of vehicles require significant resources and, on the other hand, a front-office function is a major asset of a mobility service. Therefore, it is quite logical to find a high level of activation of these two variables in the services observed.

Consequently, in further syntheses, only the discriminant variables, i.e. vehicle, infrastructure and business model will be used.

1.5.3.2. What values do they carry?

SC10 mainly exhibit “*basic individual values*” (I1) such as and comfort, cleanliness, safety, security, etc. and “*efficiency of transport*”, i.e. flexibility of use, reliability...(I2). More original, it also offers values related to “*travel time valorization*” (I3) thanks to the use of the MSP-APP. In terms of collective values, proposing an EV demonstrates an interest in reduction of car emissions, fight against global warming and, in a lesser value, noise reduction which belong to a category one can name as “*reduction of externalities*” (C1).

SCs1, 2, 3 (for person transportation), 5, 6, 7 and 8 are also focused on individual values including, in addition to those already cited, “*cost of transport*” (I4) and others characteristics related to “*travel time optimization*” (I5) such as punctuality, availability, accessibility to cite a few of them. It should be noted that cost and efficiency of transport are relevant both for the transport of persons and for the transport of goods if one considers, for the latter, the values expected by the customer from the delivery and therefore apply to SCs4 and 9.

In terms of collective values, one must analyze the contribution to the fight against global warming, reduction of casualties, congestion and noise, i.e. “*reduction of externalities*”. Operating fleets constituted of EVs brings a strong contribution to the fight against global warming¹⁹ and the usage of AD levels 4 or 5 should contribute to the reduction of casualties as promoted by leading companies in their development (Waymo and Cruise) or carmakers association (ACEA) and forecasted by different studies²⁰. The impact on congestion is more questionable for SCs 5, 7, 8 (ride hailing service). If the study conducted on Lisbon²¹ had shown a gain of 9 cars out of 10 and an average rate of use of 2.5 people per vehicle for a current situation between 1.1 and 1.3 (when the car is running ...), the arrival of Uber in New York had led to an increase of 50% of vehicle passenger car with chauffeur or cab causing a decrease of 19% in average speed and increased pollution²². It is assumed that study cases 4 and 9 could face the same drawbacks.

¹⁹ At minimum at local level (i.e. around the vehicle). The global contribution on the complete lifecycle depends on the level of decarbonization of energy utilized during construction and usage phases.

²⁰ For example, National Highway Traffic Safety Administration <https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety>

²¹ <https://www.itf-oecd.org/sites/default/files/docs/2016-07-05-mobilite-partagee-amelioration-acces.pdf>

²² The Impact of Uber Technologies on the New York City Transportation Industry - Jonathan K. Alley University of Arkansas, Fayetteville – accessible at The Impact of Uber Technologies on the New York City - Core

But other collective values are exhibited by SCs1, 2, 3, 6 and are more related to (1) “*efficiency of collective transport systems*”, namely low cost of transport, high flow rate of passengers per hour, restitution of the urban space to the inhabitants, etc.(C2) and (2) “*reduction of the cost of transport to the community*”, such as the control of investment, the ability to reuse existing assets, the level of subsidies needed to make transport affordable and inclusive, and so on (C3).

This analysis exhibits five different types of individual values: (I1) basic individual values, (I2) efficiency of transport, (I3) transport time valorization, (I4) cost of transport and (I5) travel time optimization. As far as collective values, (C1) reduction of externalities, (C2) efficiency of collective transport systems and (C3) reduction of the cost of transport to the community and have been identified.

The table below summarizes the list of individual and collective values carried by each study case.

Type of values Study cases	Individual values	Collective values
1	I1, I2, I3, I4, I5	C1, C2, C3
2	I1, I2, I3, I4, I5	C1, C2, C3
3	I1, I2, I3, I4, I5	C1, C2, C3
4	I3, I4	C1
5	I1, I2, I3, I4, I5	C1 (positive impact on congestion is questionable)
6	I1, I2, I3, I4, I5	C1
7	I1, I2, I3, I4, I5	C1 (positive impact on congestion is questionable)
8	I1, I2, I3, I4, I5	C1 (positive impact on congestion is questionable)
9	I3, I4	C1
10	I1, I2, I3	C1

Table 5 : Summary of the values carried by the different study cases

1.5.3.3. Characterization of their ecosystem

The first characteristic to describe is the nature of the ecosystem that supports the mobility initiative, bearing in mind that the current reference for the automotive industry is that of the value chain (Porter, 1985b). In their paper “Towards a theory of ecosystems”, Jacobides et al. summarize three main streams of ecosystems as follows: “*“business ecosystem” stream, which centers on a firm and its environment; an “innovation ecosystem” stream, focused around a particular innovation or new value proposition and the constellation of actors that support it; and a “platform ecosystem” stream, which considers how actors organize around a platform.*” (2018, pp. 2256, 2257).

In SC10, the carmaker runs a value chain encompassing the classical perimeter of the automotive industry extended to technology companies supporting the digitalization platform strategy and third-party suppliers providing services.

In SCs5, 7, 8, this is typically a situation of “*platform ecosystem*” with a platform leader (M. A. Cusumano and Gawer, 2002) having the capacity to define its own solutions, impose them to the complementors and to successfully achieve the integration of the complete system. The platform leader has an offer-push approach which consists in (1) validating, in real conditions and at a (sufficiently) large scale, its offer and (2) duplicate it for many customers.

In SCs2, 4, 6 and 9, this is also a situation of “*platform ecosystem*” but in a demand-pull logic. The platform leader, which is an urban authority in SCs2, 6, a port operator in SC4 and a logistics operator in SC9, has many B2B relationships with different suppliers providing components for the entire system, which it then operates in B2B or B2B2C (SC6). Its main motivation is to optimize its operations (SC4, SC9) or the quality of service provided to its customers who can be companies (SC2) or end users (SC6).

SCs1, 3 exhibit a different situation which is close to the notion of “*innovation ecosystem*”, as there are innovative proposals to solve issues of commuting or urban mobility governance, and also introduces the notion of territory. These projects exist only because they respond to a precise need located in a territory and specific to it, or, in other words, because they propose to address the “*shared fate*” of a territory as a whole (Iansiti and Levien, 2004, p. 69). In conclusion, naming this ecosystem as “*territorially embedded innovation ecosystem*” keeps the notion of innovation ecosystem and precise both its aim and particularity. These two study cases are in very upstream phase and it is quite difficult to precisely identify which company or institution will be leading the ecosystem in downstream phases.

Therefore, four different types of ecosystem have been identified: (E1) value chain, (E2) techno-push platform ecosystem, (E3) demand-pull platform ecosystem and (E4) territorially embedded innovation ecosystem.

What is the strength of the leadership?

For SCs2, 4, 5, 6, 7, 8, and 9, the platform leader provides strong ecosystem leadership, as does the carmaker in the case of SC10.

Elaborating on B.Flyvbjerg’s work, Lehtinen et al., define Megaprojects as “*Megaprojects are multi-actor and multi-technology constellations that create value for the society*” (2019, p. 43). The literature on megaprojects demonstrates the consequences of an ecosystem complexity on the political management of these projects, creating blocking or, on the contrary, escalation

phenomena that penalize their effectiveness. Without, of course, claiming that SCs1, 3 are Megaprojects, this definition corresponds fairly well to their *raison d'être* as well as to the diversity and multiplicity of the types of actors, not necessarily accustomed to collaborating all together, that need to be brought together to carry them out. In addition, the reference to Megaprojects allows to qualify the potential risks related to the governance of SCs1 and 3. As mentioned above, it is difficult to identify an ecosystem leader for the downstream phases of the project; coupled with the necessary organizational complexity to manage such a project, there is a high risk of weak ecosystem leadership.

What are the actors contributing to it?

The analysis of the different case studies allowed the identification of five categories of actors that can contribute to the ecosystems, which have been determined, and whom the roles are now analyzed.

Carmakers as they produce the vehicle which is the vector of the service and benefit from a long experience and knowledge in managing the relationship with the end customer including sales of services. They have a strong role in SCs6, 7, 8, 10 where they still act as OEM while they act as commodity suppliers in the other study cases.

Transport operators as they can manage B2B relationships with carmakers, are very skilled with hubs and fleets management and have stepped, for most of them, into the use of digital platforms for managing the customer relation. In addition, they are used to cooperate with local or territorial public authorities and can aggregate robotaxis with their usual solutions of mass transportation. They are key players in SCs2,5,7,9 as they really operate the service, and could also play a leading role in SC1.

Public authorities as they specify mobility needs, are responsible of the efficiency of local transportation systems and have the capacity to support programs that foster the emergence of mobility innovations that are conducive to experimentation. They are the project owners in SCs2, 6 and could play the same role in SCs1, 3.

Construction companies and / or infrastructure operators²³ as they have long been the privileged interlocutors of the territorial authorities to build and operate local infrastructures and provide the necessary financing for such infrastructure within the framework of Public

²³ more and more often, construction companies also play the role of infrastructure operator within the context of public / private partnerships

Private Partnerships (PPP). It is considered that they could also be project owners in SCs1, 2, 3 and 6.

Last but not least, technology companies who bring in all their technological and financial power to design, develop and operate these innovative mobility services. In SCs2, 4, 9, they play a key role as they provide the technologies enabling the mobility service; it is also worth mentioning the very important role played by the parent companies of mobility operators in SCs5, 7 in the development of the enabling technologies.

The type of ecosystem, the strength of leadership as well as the types of actor contributing to it summarized in the table below. The sign “+” indicates that a category of actor has a strong contribution to the ecosystem while the sign “-” indicates it has a weaker contribution.

Study case	Type of ecosystem	Strength of leadership	Carmaker	Transport operator	Public authority	Construction company	Technology Company
1	E4	Weak	-	+	+	+	-
2	E3	Strong	-	+	+	+	+
3	E4	Weak	-	-	+	+	-
4	E3	Strong	-	-	-	-	+
5	E2	Strong	-	+	-	-	+ (parent company)
6	E3	Strong	+	-	+	+	-
7	E2	Strong	+	+	-	-	+ (parent companies)
8	E2	Strong	+	-	-	-	-
9	E3	Strong	-	+	-	-	+
10	E1	Strong	+	-	-	-	-

Table 6 : Summary of ecosystem type, strength of leadership and involved actors

Reminder: (E1): value chain, (E2): techno-push platform ecosystem, (E3): demand-pull platform ecosystem and (E4): territorially embedded innovation ecosystem

1.5.3.4. What is the learning performance of the ecosystem?

As in any innovation project, the analysis of its bottlenecks, which could "...prevent the scaling up of systemic innovation in the emerging phase" (Baldwin, 2015, p7), is crucial to understand what is the capability of the project to expand from an experimental limited initiative to a complete and massive expansion; this is especially true in as this research work addresses the transition of the automotive industry towards electromobility. Therefore, three main categories of bottlenecks are defined: (1) maturity of the technologies and associated standards,

(2) system complexity (both from a technological and an organizational viewpoint) and (3) the amount of costs involved in both the development and operation of the project. If a category does not have bottlenecks for the service in question, then it can either be an enabler or have a neutral impact.

For SC10, maturity of technologies and standards are fairly neutral as the car manufacturer keeps control over the platformization strategy and speed of introduction of the various services that complete the vehicle offer. The same reasoning applies to the complexity of the system, which is more of an enabler since the carmaker acts, de facto, as a leader in the value chain imposing its solutions on suppliers. As far as investment / business model, the case exhibits a bottleneck as the economic viability is questionable: is it economically viable to sell premium vehicles with (almost) free premium mobility services and expect to obtain benefits mainly related to the use of the Multi Service Personal -Application?

For SCs4, 5, 6, 7, 8 and 9, the current technologies of traffic management systems are enablers as the vehicles embark autonomous driving packages that don't need any communication with traffic management systems²⁴. They also share the same positioning as focal company acting as a platform leader and imposing its solution to complementors and their organization is an enabler. However, CSs5, 6, 7, 8 face different situations regarding vehicle complexity compared to SCs4 and 9: while SCs5, 7, 8 which use robotaxis (AD level 5) face a high technological complexity, the situation is more neutral for SCs4 and 9 where vehicles are AD level 4 relying on routes learnt by advance. Lastly, they all share a business model presenting a risk on "quick" return on investment.

As the complexity of SCs1, 2, 3 is largely situated in the global control of the transportation system, vehicle technology is an enabler while the complexity of infrastructure and transport management system is very high. From an organizational viewpoint, the management of different stakeholders coming from different industries and not used to work together in such a big consortium with no natural leader is a source of complexity in SCs1 and 3. Finally, there are so much involved stakeholders to make this transportation work that there is an uncertainty related to the capacity of the business model to provide sufficient revenues for all of them in SCs1 and 3.

²⁴ In SC6 and 8, an off-board equipment is part of the road infrastructure. It is complementary to the vehicle on-board strategy in particular configurations (complex roundabouts) but not significant enough to change the overall opinions on these cases.

The situation is different for SC2, both in terms of the complexity of the organization and the business model, as there is a focal company acting as a leader in the value chain and contracting in B2B with the public authority acting as the project owner.

Bottlenecks and enablers as summarized, for each ideal type, in the table below. The sign “+” indicates this is an enabler case while the sign “-” indicates it is bottleneck; the sign “=” indicates it is neutral.

Study case	Maturity of technologies and standards	System complexity (Technology, organization)	Investment / Business Model
10	=	+ Focal firm acting as a value chain leader	- Viability of the business model
5,6,7,8	- AD level 5 robotaxis + No interactions with traffic management system	- Vehicle complexity + Focal firm acting as a value chain leader	- risk on “quick” return on investment
4,9	= AD level 4 robotaxis with routes learnt by advance + No interactions with traffic management system	= Vehicle complexity	+ B2B contract between companies
1, 3	+ Vehicle embarked autonomous driving functions	(-) Infrastructure and monitoring system (-) Organization	- uncertainty related to the capacity of the business model to provide sufficient revenues for all stakeholders
2	+ Vehicle embarked autonomous driving functions	(-) Infrastructure and monitoring system + Focal firm acting as a value chain leader	+ B2B contract between companies

Table 7 : Bottlenecks and enablers of the different study cases

What is the maturity of each initiative?

As introduced in Table 3, the cases show very different levels of maturity. The direct consequence is that the companies or institutions involved in these initiatives, anything equal besides²⁵, do not all have the same ability to project a rapid deployment of their solutions in the short term.

As shown in Table 3, companies or institutions participating in SCs 5, 9, and 10 have the potential to deploy their solutions fairly quickly, followed quite closely by those participating in SCs 6, 7, and 8. Conversely, companies or institutions involved in SCs 2,4 must first conduct

²⁵ In particular, it is considered that all companies or institutions have assigned the same levels of priority and, therefore, resources to carry out these experiments, which may not always be the case

real experiments and operations before undertaking large-scale deployment, while those involved in SCs 1 and 3 are further away from any potential deployment.

What is the ecosystem lineage capability?

The concept of project lineage capability (Maniak and Midler, 2014; Midler, 2013) has been defined as the capability to organize the project to project learning process in order to sustain on the middle or long term a strategy. As Kock and Gemünden have further elaborated (2019), this strategy can be emergent and then the lineage is an ex post step by step learning process or it can be deliberated and then the lineage is of the explicit roadmap type.

Ben Mahmoud-Jouini and Charue-Duboc introduce the concept of « *complete solution experiments* » (2017) and show the importance of experimentations when they are complete to structure and learn about both the capacity of the supply system to produce the solution and the capacity of the demand system to evaluate and use it (2017).

Therefore, the concept of ecosystem lineage capability, introduced here, encompasses: (1) the components lineage capacity, namely a « *bowling alley logic* » (Moore, 1991; Moore and Fabis, 1995), (2) the complete solution lineage capacity, i.e. project lineage strategy (Kock and Gemünden, 2019; Maniak and Midler, 2014; Midler, 2013) and complete solution experiments (Ben Mahmoud-Jouini and Charue-Duboc, 2017) as well as (3) the scope leveraging capacity. This latter is a combination of the maturity of the initiative as previously assessed, the strategy of the company, as it can be inferred by second sources analysis, and components lineage and complete solution lineage capacities as evaluated below.

In SC10, the carmaker has developed both a component lineage capacity, through its digital platform strategy and a complete solution lineage capacity thanks to its vehicle line-up and the extension of the number of third-party service providers. As it is already operating the service and has funding backed by strong investors, its scope leveraging capacity is high.

SCs2,4 are in the development phase and the Chinese technology company, created very recently, is developing projects in a « *bowling alley logic* » (Moore, 1991; Moore and Fabis, 1995) where, from some technological bases, each project makes a new contribution to the offer. SC9 is, in fact, the project that initiated this strategy and was based on a relatively short time horizon, minimizing the financial and technological risks in order to quickly arrive at solutions of the type « *minimum viable product* » (Adner, 2006) which are really usable and marketable. On the other hand, the risk of performance remains high in the face of more ambitious players who would be capable, in the long term, of imposing a more accomplished autonomy solution that would impose itself as a global standard. Consequently, for these study

cases, the complete solution lineage capacity, is at least, not visible, while the scope leveraging capacity could be limited versus more ambitious players.

SCs1 and 3 are in very upstream phases and the ecosystem lineage capacity is not yet visible. However, as far as can be observed, SCs1 and 3 aim to be open mobility platforms allowing a large number of component or solution providers to contribute to the development of the mobility services under consideration. This approach promotes high capabilities both in terms of component lineage and complete solution lineage. However, considering that these projects aim at developing very innovative and strongly anchored mobility services integrated in an urban context, they are highly contingent to the local context and actors. Consequently, the scope leveraging capacity is handicapped by this anchoring in a territory; indeed, it is foreseeable that the deployment of these services will require strong adaptations to the new targeted territory, whether because of purely geographical or topological constraints or because of different mobility strategies driven by the local or territorial public authorities.

SCs5, 6, 7 and 8 also present a contingent character to the context and to local actors but the mobility operators are global companies which have the capacity to develop both strong component lineage and complete solution lineage capacities. As this contingent character may also constitute many barriers to their large scale deployment, this is typically where a learning strategy from one project to another (Lenfle and Loch, 2010) is required to overcome these constraints and the leaders of these study cases, being global players, have the capacity to do so. As far as scope leveraging capacity, in SCs5, 7 the leading companies have been created by their parent companies to develop this business and have the technological and financial capacities to achieve this goal and their scope leveraging capacity is high. The situation is different in SCs6, 8 where the leading companies are carmakers which have decided to jump in this new business of mobility. Without prejudging their intrinsic capacity to carry out projects of this scale, it must be noted that, since they are in an ambidextrous management situation including the electrification of vehicles (Midler et al., 2019; Midler and von Pechmann, 2019), their deployment potential is likely to be lower than that of SCs5 and 7.

Learning performances are summarized, for each ideal type, in the table below. The sign “+” indicates this is a main capacity while the sign “-” indicates it is a lesser one.

Study cases	Components Logic Capacity	Complete solution lineage Capacity	Scope leveraging capacity
1	+	+	-
2	+	-	-
3	+	+	-
4	+	-	-
5	+	+	+
6	+	+	-
7	+	+	+
8	+	+	-
9	+	-	-
10	+	+	+

Table 8 : Learning performance of the ecosystem per study case

1.5.4. Uncovering three ideal types

The concept of ideal-type, per se, would require a complete literature review and the idea, here, is to summarize Weber's work in a few words: an ideal-type is a category, which helps to understand or theorize certain phenomena, without claiming that the characteristics of this type are always and perfectly found in the observed phenomena (1978). The intention is therefore, based on the detailed analyses of the case studies, to characterize abstract theoretical models with coherence between the variables that constitute them. Then, it is a question of seeing if there are cases close to these models or not and, if not close, how far they are from the theoretical model.

Practically, the panel analysis shows that it is possible to group the case studies according to the discriminant design variables that they mostly activate, the values they carry, the type of ecosystem and the learning performance.

While a case-by-case presentation would have been tedious and a bit confusing, each ideal type discovered is presented in a table that also includes all cases "close enough" to be considered part of the same model. Then, the main characteristics of the ideal type as well as the relative position of each case with respect to the model are described and analyzed. The capacity of some types of actors to lead an ideal type is also discussed, considering carmaker, transport operator, public authority, construction company and technology company.

Mobility service added to product ideal type

There is only one case study, SC1, which corresponds to this ideal type, but its characteristics are so marked and consistent with each other that this single case is sufficient to identify a model as summarized in the table below. The sign "+" means that a characteristic is important for this ideal type when the sign "-" indicates it is less important. Individual and

collective values refer to coding previously introduced (I1, I2, I3, I4, C1, C2, C3) as well as the type of leadership (E1, E2, E3, E4).

	Design variables			Values		Ecosystem		Learning capacity				
	Vehicle	Infra	Business Model	Individual	Collective	Type	Strength of leadership	Bottlenecks	Maturity of initiative	Component lineage capacity	Complete solution lineage Capacity	Scope leveraging capacity
Model: SC1	+	-	B2C	I1, I2, I3	C1	E1	+	Business model	+	+	+	+

Table 9 : Mobility service added to product ideal type summary

This ideal type is very well targeted:

- Focused on vehicles, mobility services and MSP-APP added to the vehicle,
- Individual and collective values very consistent with the offer,
- Strong leadership and learning capacity of the ecosystem leader ruling a value chain extended to digital technologies and services providers,
- A single, but significant, bottleneck: viability of the business model which, by the way, is not surprising in the case of an emerging mobility service.

Without any doubt, the only natural actor having full capability to lead a project belonging to this ideal type is a carmaker.

Robotaxi ideal type

The model of this ideal type as well as the cases belonging to it are summarized in the table below.

	Design variables			Values		Ecosystem		Learning capacity				
	Vehicle	Infra	Business Model	Individual	Collective	Type	Strength of leadership	Bottlenecks	Maturity of initiative	Component lineage capacity	Complete solution lineage Capacity	Scope leveraging capacity
Model: SC5	+	-	B2B2C	All	C1	E2	+	Vehicle complexity Business model	+	+	+	+
SC7	+	-	B2B2C	All	C1	E2	+	Vehicle complexity Business model	+	+	+	+
SC8	+	-	B2B2C	All	C1	E2	+	Vehicle complexity Business model	+	+	+	-

Table 10 : Robotaxi ideal type summary

This ideal type is also very well targeted:

- Focused on ride-hailing with electric robotaxi AD level 5,
- Numerous and attractive individual mobility values, but dealing with only one collective value (reduction of externalities), even if the contribution to congestion reduction is questionable,
- Strong leadership and learning capacity of the ecosystem leader ruling a platform ecosystem in a push offer strategy,

- Two significant bottlenecks: vehicle complexity and the business model which presents a high risk on return of investment.

The leaders of the three study cases present the same capacities even if we have commented that carmakers (SC8), being in an ambidextrous management situation, have probably more difficulties to concentrate resources on these projects than the two mobility operators in SCs5 and 7.

As they know how to run the business, incumbent transport operators and, as they have strong technological and financial capacities, newcomers transport operators turn out to have a natural scope leveraging capacity. On their side, with strong and appropriate co-operation activities, carmakers can build on two strengths: (i) they are able to develop, new vehicles according to the new requirements of mobility services, and (ii) they can use their brand image and long experience in customer relations to introduce new services. But, they face a main drawback: taken separately, electrification, connectivity, autonomous driving and digitalization of the industry are, by themselves, fairly complicated, and moving forward in parallel towards new mobility service is a very complex issue which requires a huge amount of resource. This is where technologies company gain a significant advantage since, as summarized by J.Krafcik, the CEO of Waymo²⁶, they have built trajectories for the deployment of disruptive innovations by capitalizing on learning from successive projects encompassing both technological developments and user experiments. Lastly, the ability to finance costly projects over such a long period of time is an important resource that not all actors seem to share at the same level and which could be discriminatory in their respective trajectories. This difference in financing capacity has much more to do with the intrinsic strengths of the firm or the confidence placed in it by the financial markets than with the category of actors to which it belongs.

²⁶ <https://blog.waymo.com/2019/09/waymo-iaa-frankfurt-2019.html>

Territorialized open mobility platform ideal type

The model of this ideal type as well as the cases belonging to it are summarized in the table below.

	Design variables			Values		Ecosystem		Learning capacity				
	Vehicle	Infra	Business Model	Individual	Collective	Type	Strength of leadership	Bottlenecks	Maturity of initiative	Component lineage capacity	Complete solution lineage Capacity	Scope leveraging capacity
Model: SC1	-	+	B2T2B	All	C1, C2, C3	E4	-	Infrastructure and monitoring system Complexity of organization Business model	-	+	+	-
SC2	-	+	B2B	All	C1, C2, C3	E3	+	Infrastructure and monitoring system	-	+	-	-
SC3	-	+	B2T2B	All	C1, C2, C3	E4	-	Infrastructure and monitoring system Complexity of organization Business model	-	+	+	-
SC4	-	+	B2B	I3, I4	C1	E3	+	/	-	+	-	-
SC6	+	-	B2B2C	All	C1	E3	+	Vehicle complexity BM	+	+	+	-
SC9	-	+	B2B	I3, I4	C1	E3	+	/	+	+	-	-

Table 11 : Territorialized open mobility platform ideal type summary

Our model, based on SC1, also presents a rather remarkable overall consistency between its characteristics:

- The main design variables that are activated are infrastructure and a B2T2B business model, both of which are compatible with initiatives aimed at developing innovative mobility services that significantly improve local transportation conditions. Therefore, the vehicle is an enabling component, among others, of this strategy.
- The values have a very strong collective component while remaining sufficiently well balanced with individual values to remain attractive enough for end-user customers.
- Being a “*territorially embedded innovation ecosystem*” involving many different players not used to work altogether, it exhibits a weak leadership which is also one its key bottlenecks as well the infrastructure and the business model.
- Finally, the ability to develop lineage components and global solution capabilities does not turn into a strong enough scope leveraging capacity to overcome the contingencies of another territory at the time of scale-up.

SC3 is very close to SC1 while SCs2, 4, 6 and 9 exhibit some similarities and differences:

- In terms of similarities, all these projects are rooted in a territory, have values very close to the model for SC2, and relatively close for SCs4, 6 and 9, at least in terms of the balance

between individual and collective values. Their scope leveraging capacity is also fairly low, even if for different reasons, namely a restricted capacity, at least at the time being, of the focal company in SCs 2,4 and 9 to develop a strong global solution capacity. For SC6, it is linked to the ambidextrous situation of the carmaker taking part to this initiative

- As far as differences, the B2B relationship is between a technology company and project owners which are either in contact with the end-user customers (SC2) or operate the system for their own needs (SCs4 and 9); in SC6, this is a B2B2C and the carmaker has a B2B contract with the mobility operator. It must be noted that, for all these four cases, the ecosystem type is fully consistent with the business model. It can be assumed that being rooted in a territory is more important for belonging to this ideal type than different business models.

The figure below proposes a mapping of the three ideal types taking into consideration the most significant variables, namely vehicle infrastructure and business model as well as the type of ecosystem supporting the initiative.

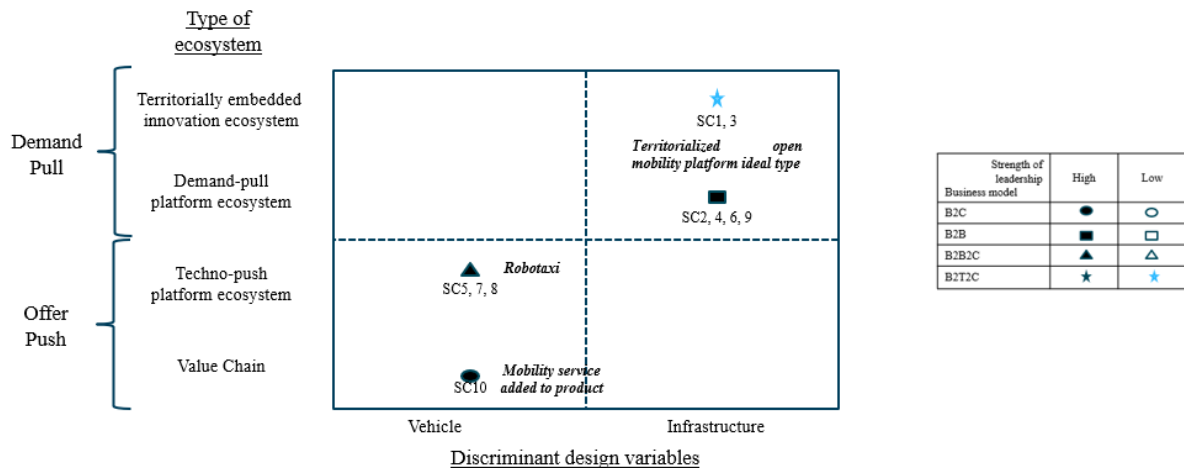


Figure 3 : Ecosystem types / discriminant design variables mapping of ideal types

What are the types of actors who can claim the leadership of such an ideal type? Construction companies are here key players as (i) they have long been the privileged interlocutors of the territorial authorities to build and operate local infrastructures and (ii) they provide the necessary financing for such infrastructure within the framework of Public Private Partnerships. Transport operators, who have a strong competence to co-operate transport systems with local authorities are also natural key players. As the strong territorialization of experiences and their contingent character to the context and to local actors, constitute many barriers to their large scale deployment, this is typically in a learning strategy from one project to another (Lenfle and Loch, 2010) where transport operators and construction companies are

probably the most skilled actors to ensure lineages and economies of scale beyond local innovations.

Carmakers will certainly favor “vehicle centric” ideal-types because (i) they can mostly maintain their historical dominant design and (ii) they do not have the skills to manage cooperatively these deployments of mobility systems with public authorities, due to their B2C business culture. The latter comment is also relevant as far as technology companies which should have more appetences to run private businesses as in SCs 4, 5, 7, 9. However, as exhibited by some cases, carmakers or technology companies can decide a strategic pivoting and play the role of transport operators; in this context, these two actors could be considered as potential leaders for this ideal type.

Could the public authorities in charge of transport become the leader of the platform dynamics? On the one side, Maniak and Marccochia (2018), have shown the importance of public innovation support programs in order to bring about the emergence of innovations in mobility, which are conducive to experimentation. On the other side, the strong investment of territorial public actors, a guarantee of local sustainability, will not be found in other contexts. Finally, the deployment of this model can probably only be achieved through a combination of local experimentations and leadership from a higher level of public authority(ies), capable of placing local initiatives in a more global plan at the national or international level. This is what countries, such as China and France, are trying to do at different levels and according to different mechanisms, through incentive plans for the deployment of complementary experiences and the pooling and generalization of their teaching.

Are they the only theoretically possible ideal types? Intuitively, a simultaneous activation of vehicle and infrastructure variables at a very high level, within the same mobility service, seems counter-productive in terms of the levels of investment required, the increased complexity of validation and the satisfaction of functional needs. Even if, in some of the cases studied (SC6 and 8), off-board equipment is part of the road infrastructure, it is complementary to the vehicle on-board strategy in particular configurations (complex roundabouts) and not significant enough to pave the way to a new ideal type.

One could imagine different combinations of activation of variables and, more specifically new combinations of vehicle, infrastructure and business model variables as the back-office and front-office variables are less discriminating as the others. These new combinations, which we have not yet observed, could pave the way for one or more new ideal types with different values, ecosystem type, or learning capacities.

1.5.5. Could the emergence of each ideal type destabilize the architecture of the industry?

The empirical study, addressing the emerging electric traction value chain, has confirmed the resilience of the automotive industry and the role of carmakers as focal actors playing the role of system integrators at the top of a hierarchical value chain that they control. Consequently, this question is firstly asked from the carmaker viewpoint and thus extended to the capacity of other actors to destabilize or not the architecture of the industry.

Concerning the *mobility service added to product ideal type*, carmakers integrate new technologies into the dominant technological design and, therefore, enhance their *technology* portfolio; they maintain the *industry architecture* by extending the value chain management to third parties operating different services, and continue to sell mass-produced multi-purpose vehicles to individual and fleet customers accordingly to their *product and market strategy* while the role of the automobile as the preferred means of personal travel is marginally questioned. Moreover, in case 10, the carmaker is clearly developing a planned project lineage strategy (Kock and Gemünden, 2019; Maniak and Midler, 2014; Midler, 2013) oriented towards mobility services, from the very foundation of the company. It demonstrates, if needed, the capacity of carmakers to drive such a strategy. From a theoretical viewpoint, accordingly to STT paradigm type of changes, this move is pretty similar to the one leading to the appropriation of electrification by the industry and is of *reconfiguration* type (Geels and Schot, 2007). Consequently, as the make domain of the carmaker is maintained, it is considered that this ideal type doesn't contribute, to date, to the destabilization of the industry. As it is an extension of the current dominant design of the automotive industry, the question is: how long will carmakers have the ability to extend this state of affairs if the emergence of MaaS is confirmed?

As far as *robotaxi* ideal type, the cases show that this key role of robotaxi fleet operator can be occupied by actors who occupied different roles before the transition such as carmakers (cases 7 and 8), technological firm (cases 4, 5, 9). It paves the way to two very different situations for carmakers: in cases 7 and 8, carmakers keep, in their make domain, the role of integrator and the relation with the end customer, even if the latter is fairly different from the existing B2C model of sales of vehicles and added services. In case 5, the carmakers may lose the role of final integrator of the product (as the examples of FCA and JLR in the cooperation with Waymo) and, for sure, lose the mastery of the relationship with the end customer, which is one of their main assets. Consequently, this ideal type could cause a destabilization of the architecture of the automotive industry. In terms of transition pathway accordingly to STT

paradigm, *technological substitution* (Geels and Schot, 2007) is undoubtedly the first step involved in the move towards this ideal type as a robotaxi is in direct competition with a multipurpose vehicle and could overcome it. If mobility services do indeed take precedence over individual mobility, it could be followed by a *de-alignment* of the regime of the automotive industry, i.e. a destabilization of its architecture. As far as *re-alignment*, we can hypothesize two different paths (i) a contraction of the current regime where carmakers would be reduced to the role of commodity suppliers for mobility operators leading the dominant regime of mobility services or, (ii) an extension of the current regime where carmakers would also play the role of transport operators.

The *Territorialized open mobility platform ideal type* is just emerging and its impact on the automotive industry is not yet visible; however, considering galloping urbanization and the influence of local public authorities on urban mobility services, these latter could co-lead the ecosystem, as project owners collaborating with solution providers (construction companies, transport operator) to deliver a mobility system. In terms of influence on the architecture on the industry, the carmakers lose, for sure, the role of final integrator of the product (as the hardware and software package enabling access to the service is part of the mobility open platform) and can keep the mastery of the relationship with the end customer. As a matter of fact, in case of inclusivity of the system (SC1 for instance), allowing private owners of cars to be part of the mobility solution, that could allow carmakers to maintain a significant B2C business in parallel. As far as transition pathway accordingly to STT paradigm, we hypothesize that next steps could be *technological substitution* and *de alignment* of the regime (Geels and Schot, 2007).

The figure below summarizes the capacity of each ideal-type to destabilize the current architecture of the automotive industry.

Ideal Type	Impact on the industry architecture	Reference to Transition pathways identified in the literature (Geels and Schot, 2007)
<i>Mobility service added to product</i>	Limited A pure continuity of both current value chain management and B2C BM extended to the world of mobility and personal services	Reconfiguration “the new regime grows out the old one”
<i>Robotaxi</i>	Strong New type of focal actor (mobility operator) and ecosystem (platform), new product, different business model (B2B2C)	Technological substitution A robotaxi may overcome the multipurpose vehicle De-alignment followed by re-alignment Two scenarios : contraction of the regime, extension of the regime
<i>Territorialized open mobility platform ideal type</i>	(Potentially) Strong B2T2C BM where the demand would be strongly pulled by societal / collective values and the vehicle only an enabler of the mobility system	Reconfiguration or technological substitution ? De-alignment? What is the future of mobility made of?

Figure 4 : Could ideal types destabilize the current architecture of the automotive industry?

1.6. Systemic innovation and project learning

The cases studied confirm the importance of projects as a playground for the emergence of ecosystem innovations (Ben Mahmoud-Jouini and Charue-Duboc, 2017; Marcocchia and Maniak, 2018). Indeed, these innovations imply a double learning process: that of the content of the project itself and that of the cooperation between participants who are heterogeneous both in the nature of the industry from which they come and, in the role, they play in the project. The project, by proposing an operational space for the commitment of a concrete cooperation on the one hand, and by limiting the risks of these commitments by the limited perimeter in duration and in objectives, constitutes a favorable space to encourage this learning; this role corresponds exactly to the function of "*temporary exchange area*" analyzed by Lenfle et Söderlund (2019).

The cases studied show very different logics of ecosystem construction. In cases 5, 7 and 10, it shows an ecosystem clearly controlled by the solution provider in a platform leader configuration (M. A. Cusumano and Gawer, 2002). The leading company invests heavily, contracts with companies to complete the solution, and drives the learning process. The strategic model is therefore the capture, by this platform leader, of a significant portion of the profit generated by the B2B2C solution. In case 10, the company relies on development agreements signed with major partners in the digital industry as well as service contracts with service providers to offer a premium digital services platform and capture additional value to the traditional B2C business model. For the providers of the driver automation solution (cases 5 and 7), it is nothing less than capturing a local mobility market. Moreover, in these two cases, the public players, in the territories concerned, are more akin to experimental field suppliers to test a solution that will then be proposed to other local authorities, according to an already packaged formula. In the first case, the role of the territorial authorities is major: as the benefit is rather of a collective type at the level of a territory (B2Territory) and, due to the very important place of the development or modification of road infrastructures, it seems obvious that the territorial authorities would play a major leadership role in the ecosystem. In the ninth case, the technology supplier is involved in a fairly traditional B2B project relationship between a project owner who defines its needs and a prime contractor who develops a solution accordingly.

In terms of internal learning and risk management within the project, there are, again, very contrasting situations. In the tenth case, the solution built from successive aggregations of offers in a platform designed as a multi-service capability, allows both a rapid initial deployment and

a gradual ramp-up; there is an initial capital risk for the design and implementation of the platform, while profitability depends both on the ability to mobilize partners offering quality offers and the distribution of value along the B2B2C chain. In the ninth case, typical of a start-up strategy, the project is based on a relatively short time horizon, minimizing the financial and technological risks in order to quickly arrive at solutions of the type « minimum viable product » (Adner, 2006) which are really usable and marketable. The systemic risk is quite low as the projects are developed in a « *bowling alley logic* » (Moore, 1991; Moore and Fabis, 1995) where the supplier specifically designs a B2B solution for each customer. On the other hand, the risk of performance remains high in the face of more ambitious players who would be capable, in the long term, of imposing a more accomplished autonomy solution that would impose itself as a global standard. In cases 5 and 7, on the other hand, the focus company sets itself a particularly ambitious and distant target solution (fully automated robotaxis), even if it has to deal with degraded and costly transitional solutions. Through the strength of its leadership and ambitious performance objectives, it then frees itself from systemic risk by imposing its solutions on the players that complete its offer. This is a typical platform leader strategy, common in the digital domain, where the "winner takes all"; we will see later whether this strategy is valid in the field of mobility characterized by important contingencies of the territorial context. Case 1 presents an intermediate strategy in successive stages, based on a hybridization of existing concepts (peer-to-peer carpooling and dedicated public transport lanes) to gradually develop, thanks to the contribution of on-board and off-board technologies, a more efficient mode of public transport than existing solutions. While the technological risk is minimized on the vehicle side, the financial risk, which can be very high on the infrastructure side, is gradually being shared between the actors providing the vehicles and the infrastructure. On the other hand, the systemic risk here is maximum, since it is a question of coordinating learning trajectories from worlds as different as the car, infrastructure and public transport.

The Project Management stream has identified several project-based learning processes: lineage management, a selectionism approach in differentiated project portfolios, but are they compatible with the systemic nature of the innovations explored in projects? In case 10, the solution built from successive aggregations of offers in a platform designed as a multiservice capability, is part of an offer line management logic; technological learning and customer usage is fairly rapid and the sustainability of the offer is a function of the quality and attractiveness of the services that are offered. In case 9, the configuration of the ecosystem is, a priori, less favorable to inter-project learning, due to the succession of clients and projects that do not have the same mission orientations. In this case, the technology provider must ensure inter-project

learning, at the level of functional and technological building blocks, by adapting standardized technological elements to differentiated missions; the difficulty of this strategy is precisely to organize this compromise between standardization of technological bricks and the design of customized offers in order to satisfy the different expectations of each client. Case 1 seems to be the case where the specificity of the territorial context is the strongest, and therefore the least favorable to easy inter-project learning, but it can also be argued that the solution developed in cases 5 and 7 will have to be adapted to the specificities (signalization peculiarities, driving habits, etc.) of the new territories where it will be established. Beyond the power of (global) leading companies to impose their learning trajectory on the ecosystem, and although most of the companies involved in these projects have a global dimension (with the exception of case 9), the learning trajectories we have described in these cases take place in specific territories: United States of America, China or Europe, and more precisely at the level of a local territory. We find here the characteristic of dependence on context that has been highlighted by the literature on ecosystems: alignment is also linked to territorial specificities that create constraints and challenges common to the actors and thus explain the alignment of their strategies with the projects. These are regulations or mobility uses such as forms of housing and transport use. The territorializing of learning will require, in order to have inter-project learning, that the regulatory authorities also organize this learning on the mobility specifications.

Finally, if the direction of the trajectory is probably marked by the identity of the territories, so is the speed of learning. The two Chinese cases presented here show an exceptional performance in reducing the effective time to market for innovative mobility solutions both by a start-up created in 2017 and by a manufacturer created in 2014. Similarly, the American cases show a situation where it is possible to experiment with autonomous transport technologies that are still experimental in nature, on a large scale and over time. These two contexts, although obviously profoundly different, share two characteristics that favor the rapid learning curve of breakthrough innovation. On the one hand, the ease of raising significant funds (whether private in the United States or public in China) to support ambitious promises of disruptive innovation; on the other hand, regulatory authorities that are permissive with regard to experimentation in real situations. The European case certainly takes place in a context of regulation that is less permissive towards innovation. Obviously, these ten cases cannot serve as evidence for a theory on the capacity of a socio-political context to stimulate or foster systemic innovations such as new mobility systems, but this provides an incentive for further research at this broader policy level.

1.7. From product-centric innovation to service-centric innovation

More than thirty years ago, Vandermerwe and Rada introduced the concept of servitization “*Modern corporations are increasingly offering fuller market packages or ‘bundles’ of customer-focused combinations of goods, services, support, self-service and knowledge*” (1988, p. 314).

The aim of this work is, thus, to analyze how the transition from products to services impacts the management of innovative projects. This leads to the introduction of a research question: “*How does servitization impact on the management of product-oriented innovation projects?*” supported by the analysis of SC1, 7 and 10 of the empirical study on emerging mobility services.

While the literature exhibits that there are three different types of Product Service System, namely product-oriented, use-oriented and result-oriented, Verstrepen et al., (1999) explain how car manufacturers develop services that take place after the initial sales transaction, such as the installation of additional equipment, maintenance or repair of the vehicle, quality control, etc. Since then, many innovative services have been introduced in vehicles, such as telematics, navigation, etc. but the dominant design of the automotive industry is still product-oriented service type.

The third contribution of the case study is to enrich the typology of services that can be developed by highlighting what is the focus of the offer: is it centered on the product (product centric) which is then enriched by one or more associated service(s)? Or is it centered on the service, the product being a facilitator, among others, of the service (service centric)?

Whether the service is simply added to the product, or whether it is deeply embedded in the product, or indeed whether the product is deeply embedded in the service, will influence the nature and organization of all design and validation activities.

For each case, an analysis of what are the service design variables which are activated, at which stage of the development process they are activated and what are the relations between the different variables which are activated enables a precise description of the articulation between the product and the service during design and validation activities.

In SC10, which is a product-oriented service, it is proposed to name the product-service articulation as “*product-centric added services*”. It is founded on the “*Service added to product*” type exhibited in the literature review but the linkage between the product and the service at development level is much deeper. In fact, the operation of the service requires a specific design

of the product, associated to dedicated validation plans, as shown by the examples of the battery exchange and P2P car sharing functions.

In SC7 the service is deeply rooted in the product and in SC1, it is the product that is deeply rooted in the service, therefore the impacts regarding the development of product-oriented innovation projects are definitely different from what is the current situation of a product-oriented service.

SC1 exhibits a pattern of product-service articulation which is named as: “*Product enabler of service centric offer*”, and is characterized by the fact that the product specifications include, of course, the fundamentals of the product to meet market expectations but also the functions that will enable the service to achieve its performance objectives.

SC7 offers a very contrasted situation as the product is the key enabler of the service which exists only because the product exists. This is another pattern of product-service articulation that is named as “*Product centric service enabler*”.

The comparison with the product innovation life cycle, adapted from Beaume et al. (2009) to a mono-project context exhibits, that the switch from product to service also drives a switch from product life cycle management to service cycle management. The consequences, in terms of project management are as follows: (1) the importance of « *complete solution experiments*” (Ben Mahmoud-Jouini and Charue-Duboc, 2017) in upstream phases to better describe the service and the conditions of its acceptance by end-user customers, (2) the necessity to introduce a new engineering discipline, namely “*mobility service engineering*”, in order to have the capability to quickly assess the interest and feasibility of a new service, (3) the necessity to introduce numerous design loops to deal with the marketing of the service and its impacts on the product in its very design, (4) the necessary adaptation of the validation process as a consequence of the joint validation of product and service, and lastly, (5) the need for an industry to go beyond a logic of product homologation, in relation to a regulation, to a logic of certification, in the sense of the aeronautics industry practices. The implementation of the latter is a very cumbersome and long process for the engineering departments of automotive companies

1.8. The influence of public environmental regulations on the automotive industry: a comparison between Europe and China

This paper addresses a key issue associated to the challenge of reducing CO₂ emissions from mobility, namely the influence of public policy, one of the key factors of the automotive industry regime, on the performance of innovation of the automotive industry.

In addition to the fact that China is both the world's largest producer and market for vehicles, and also the largest producer of CO₂ and transport-related pollutants, it seemed interesting to conduct a comparison between Europe and China for two main reasons²⁷.

First, over the last decade, the 'triad' of the US, Europe and Japan, which traditionally sets the pace and direction of innovation in the sector, has been displaced in favor of China, which has become the world's largest auto market and the primary outlet for many global players, particularly European ones. Second, Europe and China both have adopted environmental policies that are very ambitious although different in the way they translate their objectives into regulations for the automotive sector.

What is the impact of these differences between European and Chinese regulations on the transition towards carbon-free mobility? More precisely, we want to understand: *are Chinese regulations shaping the worldwide Electric vehicles (EV) industry directly or indirectly?* Or, compared to the European context, *“are Chinese regulations capable of conferring on the Chinese players and/or the players present in China a comparative advantage such that the world standard is, de facto, Chinese?”*

This paper is based on a longitudinal study of European and Chinese environmental regulations over the last decades. On the European side, the “classic” regulations addressing CO₂ and pollutants emissions are examined. As a comprehensive work has already been done by some authors (for some examples, Chen and Midler, 2016; Gong et al., 2013; Yuan et al., 2015; Zhang and Bai, 2017) to identify and analyze all the regulations promulgated by the Chinese State Council to support the uptake of the NEV market, the analysis was focused on the regulations published, separately or jointly, by the so-call “four ministries”. The “four ministries” encompass the National Development and Reform Commission (NDRC), the

²⁷The author is perfectly aware of the fundamental differences that exist between the Chinese political regime and those of the European democracies. He therefore specifies that the comparison carried out within this thesis is strictly limited to environmental and industrial policies concerning the development of the electric vehicle industry for the sake of research in this field.

Ministry of Science and Technology (MOST), the Ministry of Industry and Information (MIIT) and the Ministry of Finance (MOF), and are the key institutions deploying the strategic plans decided by the State Council in this matter. This set of regulations is of particular interest because it covers many operational aspects of the development of New Energy Vehicles (NEV), such as battery system and vehicle performance characteristics, battery manufacturers' catalogs, subsidy regulations, approval of new NEV manufacturing projects, etc. Among other dispositions, they require for the satisfaction of criteria, which are becoming increasingly stringent, concerning the performance of a high-voltage battery system or vehicle in order to obtain authorization to place a NEV on the market: they are all aimed at strengthening the design and integration capacities of vehicle manufacturers. One example is the one that sets an overall energy performance target for the vehicle, since it requires optimizing not only the energy efficiency of the electric drive system (battery + propulsion) but also the mass, aerodynamics or overall electricity consumption of the vehicle, while offering satisfactory overall vehicle performance.

This paper makes five main contributions:

1. An original approach that combines recent and proven theories to analyze this interaction, such as Geels' TEF framework and institutional learning theory (Mantzavinos et al., 2009) as well as a longitudinal approach of European and Chinese regulations, the latter having been little studied until now. This framework allows understanding how these public regulations have evolved, and which actors have been dominant in this evolution.
2. Given the importance of the Chinese auto market for global manufacturers, especially for EVs, the effects of environmental regulations on this perimeter have a major knock-on effect for the whole sector and well beyond China. Consequently, this study highlights that what is currently happening in China is shaping one of the major transitions of the automotive industry. As this industry is one of the main sources of employment and wealth in the countries in which it operates, this ongoing transition has a major impact on the global economy.
3. The comparison shows how differences in regulatory approaches between Europe and China produce very different industrial dynamics. In western countries, the legislator focuses mainly on the effect of carbon reduction measures, and let the market and the competitive game of firms take care of the impacts induced by technological options on other value criteria of offers. Conversely, the study of the Chinese regulations shows that environmental and industrial policies are strongly linked. Chinese policy makers, because

they define prescriptive scenarios that are more precise in their scope and broader in their field of action, have a greater capacity to structure the innovation strategies of companies in the sector, leading, in the medium term, to a better coordinated industrial dynamic between the players.

4. Policy making philosophy differences regarding the business visibility given to firms are also identified. The philosophy of European regulation is to introduce stability over a relatively long period of time in order to limit uncertainty for players in the supply system. Conversely, Chinese regulation is much more pragmatic, experimental and agile, which adapts more quickly to the effects induced by its previous decisions and the consequent market reactions. This philosophy, which combines advanced planning and rapid learning capacity, two hitherto antagonistic characteristics, is more in line with the precepts of innovation management that are widely accepted in the business world: the ability to quickly mobilize relevant groups on clearly identified, value-generating targets, even if it means stopping just as quickly ("fail fast") when obstacles that were not initially foreseeable show up or, on the contrary, adapting when new opportunities appear in the learning trajectory.
5. Empirically, we conclude that Chinese regulations have a much greater impact on the global EV industry than European ones for three main reasons: (i) the Chinese EV market was, prior to the current economic crisis, the largest in terms of volume and stock, has experienced the most dynamic growth and is likely to remain so after the current economic crisis. (ii) As the Chinese government, through the use of subsidy allocation policies, influences the nature and the pace of NEVs' performance improvements, it clearly shapes the industry at the national level. And, (iii) as the majority of global OEMs already produces or will produce EVs in China, either for the local market or for export, it is a very important part of future global EV production that could be shaped by Chinese regulations.

1.9. Methodology: description of an interactive research trajectory

This thesis has mobilized two dynamics: that of empirical questioning inspired by the ongoing changes in the automotive industry, and that of relevant theoretical frameworks to analyze, report on and project future developments. It is the original and varied epistemological path of this research, which, starting from a very empirical question, called upon many theoretical fields to provide empirical, theoretical and managerial answers that this chapter intends to describe.

It will show how the research questioning evolves as the reality of the companies observed changes. Indeed, it will show that empirical studies have made it possible to make precise assessments of these transformations, that they have triggered intuitions and that, under the dual influence of results and intuitions, the theoretical and analytical apparatus has had to move and adapt in order to keep up with these changes in issues; finally, it will stress that the movement of the theoretical and analytical apparatus makes it possible to identify and explore new fields of empirical study.

A long experience in interactive research, particularly in the automotive industry

The author of this thesis, having himself had a long career in the automotive industry, joined a research team with almost 40 years of experience in analyzing the dynamics of the automotive industry. The epistemology of this team, based on interactive research (Berry et al., 1978; Lundin and Wirdenius, 1990; Moisdon, 2015) using problems from the field, led the researchers to analyze the various changes in the industry during this period. In particular, the evolution of the relationship between the various players in its value chain has been the subject of numerous studies including the reorganization of the value chain into "ranks", modularization, the development of co-development relationships with Tier 1 suppliers, and the transition from co-development to co-innovation (Fourcade and Midler, 2005, 2004; Garel and Kessler, 1998; Maniak and Midler, 2008). The broadening of the classical design domain of car manufacturers, from the development of automotive services (Lenfle and Midler, 2003), made easier thanks featuring capabilities (Maniak et al., 2014b), up to the management of electric vehicle deployment, was also studied. In particular, the integration of key players as well as relevant variables to manage the systemic innovation that is the electric vehicle has also been the subject of strategic studies (Midler and Beaume, 2010a; von Pechmann, 2014; von Pechmann et al., 2015) which have been complemented by a focus on the development of the market in China (Chen and Midler, 2016). The capacity of the laboratory to develop multiple viewpoints around this industry such as innovation strategies (Beaume and Midler, 2009; Midler et al., 2013; Midler, 2019; Midler and Beaume, 2010a; von Pechmann et al., 2015) or project management and related learning processes (Ben Mahmoud-Jouini et al., 2007; Ben Mahmoud-Jouini and Charue-Duboc, 2017; Benghozi et al., 2000; Lenfle and Söderlund, 2019; Maniak and Midler, 2014; Marcocchia, 2019) has, from the very beginning of this thesis, made it possible to construct a research approach that goes far beyond the mere theoretical analysis of the impact of a technological breakthrough, however strong it may be, on the future of an industry.

It is in this shared field of research, largely ploughed by numerous academic works, including well beyond the hosting laboratory, but still as fertile as shown by the numerous academic works, public reports or reports by international consultants around the emergence of "Electric, Autonomous, Connected and Shared Vehicle" or innovative mobility services (Mobility as a Service - MaaS), that the thesis has found a strong foothold.

A first large-scale empirical study that confirms the relevance of industrial strategy theories

The thesis starts at a time when the question, hitherto uncertain and debated, of the growth of the electric vehicle as a mass market (Bakker and Farla, 2015; Dijk et al., 2013, 2016; Fréry, 2000; Midler and Beaume, 2010a) no longer arises. Until then, this research, which began in 2009 with Renault's major strategic move, had focused on experimentation and "first movers" strategies in a market that remained niche. In the end, the aim was to assess the interest of these new technologies in the face of the dominant design trend and to analyze the forms of innovation management that would allow them to emerge. At the end of 2017, these questions have certainly not been exhausted, but it is clear that the hypothesis of a mass market in the long term for the battery BEVs has been validated, even if it is not an outright replacement for ICEVs but rather the emergence of a new segment to complement those of petrol and diesel engines. At the end of 2020, under the impact of COVID19, the ramp-up of the EV scale-up is delayed, but most of the forecasts confirm a tipping point from ICEVS to BEVs around 2035.

The questions raised are then those of the transition horizon and its impact on the organization of the automotive industry (Donada, 2018; Fournier et al., 2012; Klug, 2013; Perkins and Murmann, 2018; Teece, 2018a). Obviously, this transition is a major one since it involves a radical change in the heart of the vehicle, namely the powertrain as: "*since the 1920', the internal combustion engine is established as the dominant design in the automotive industry*" (Borgstedt et al., 2017). It also involves the emergence of the high-voltage battery system, produced by suppliers historically outside the automotive value chain, which is of major importance in the design and performance of the vehicle as well as in the economic equation of the whole. The impacts of the transition to electrification have been well identified by numerous studies. They have made it possible to highlight upheavals in mainstream design (Fuchs et al., 2013; Fujimoto, 2017; Klug, 2013; Luccarelli et al., 2013; Muniz and Belzowski, 2017), de nouvelles opportunités de modularité (Christensen, 2011; Fuchs et al., 2013; Luccarelli et al., 2013) as well as a potentially new organization of the value chain (Dinger et al., 2010; Donada, 2018; Hensley et al., 2009; Valentine-Urbschat and Bernhart, 2009).

Hence the first phase of research focused on the question: will the mass growth of vehicle electrification change the architecture of the automotive industry? While much theoretical work by experts in the industry has suggested that vehicle electrification will not impact the resilience of the automotive industry (Jacobides and MacDuffie, 2013; Jacobides et al., 2016; MacDuffie and Fujimoto, 2010; Wells and Nieuwenhuis, 2012), the time was ripe for an empirical study to test their proposals by confronting theory and industry field operations. The conclusions of the work of this first phase can be summed up in an observation that is both surprising and in line with the hypotheses of researchers in the field: this major technological breakthrough, even when deployed on a large scale, has not, in the short term, destabilized the architecture of the automotive industry. Thanks to the superior modularity of electric powertrains compared to thermal equivalents, carmakers have electrified vehicles through architectural innovations; consequently, this technological breakthrough has, in a way, been absorbed into the dominant design of the industry. Certainly, new players such as Tesla or BYD, to name a few of the best known, have emerged, but they have developed strategies of vertical integration that Henry Ford would have no trouble recognizing as a practice from the early days of the automobile. It is also true that battery suppliers are new key players in the automotive industrial system, but they mainly supply cells and not complete systems, as the manufacturers have integrated the latter into their scope of make. Overall, manufacturers remain the focal point of the industry, continue to sell multi-purpose vehicles to B2C customers and suppliers of electric powertrain components are already almost in a position to produce commodities.

The use of Fine's double helix model, i.e. "*the double helix illustrates the oscillation in supply chain structure between vertical / integral and horizontal / modular*" (Fine and Whitney, 1996; Fine, 2009, p. 216) suggests a reorganization of activities and a redistribution of income within the industry. In fact, electric traction specialists, thanks to greater series effects, could achieve production cost and quality levels that are much more efficient than those of manufacturers and take over this scope of make. But this movement, which is similar to what is already being done today for big modules (seats, cockpits, etc.), would not lead to a destabilization of the automotive industry.

This observation then leads to a new empirical question: "*Could the current situation of resilience in the automotive industry change over time?* »

That causes a theoretical pivoting ...

These results, surprising at the outset, but "a posteriori" rational in the context of strategic analysis, produce a tension between, on the one hand, the rigor of a factual validation of the

present reality and, on the other hand, the intuition that the electrification of vehicles is only the first step in a movement, much broader, which could move the foundations of the automobile industry. This tension then leads to a shift in the questioning, since after having validated the short-term rationality of this resilience of the dominant design to preserve the industry's assets, a more speculative research phase was initialized. This, consisting of a theoretical creativity exercise based on the Concept Knowledge methodology (Hatchuel and Weil, 2008), allowed the exploration of new concepts of innovative mobility systems. The idea was to assess the existence of a disruptive potential, still unexploited today, but achievable as soon as other design parameters could be activated either by current industry players or by new entrants driven by new mobility needs. This phase forged an intuition and even a conviction: alternative scenarios for breaking with the current system were potentially credible, obviously in a more distant horizon, due to the potential value inherent in the new technology in terms of environmental benefits as well as customer value and cost. But these scenarios were only achievable if industrial actors could activate the corresponding design variables. At the same time, another reflection, more focused on the industrial system of EV production, raised the following questions: (i) To what level of disruption, in terms of product design and mobility services, can car manufacturers continue to manufacture EVs in their current industrial system? (ii) What impact would the production of an innovative electric vehicle designed for new mobility systems have on the manufacturers' existing industrial system? (iii) Which players would have the capacity to implement industrial system evolutions that go well beyond the current capabilities of carmakers?

From then on, there is, in a way, a reversal of the initial problem: rather than wondering whether the technological breakthrough could, by becoming massive, destabilize the architecture of the automobile industry, the question shifts to the system of actors who could implement a transition in the industry. The question is then to ask about the breaks in the system of actors that could make it possible to activate the design variables capable of exploiting the potential advantages of the technological breakthrough induced by the electrification of vehicles.

From an intuition, based on a speculative exploration of new mobilities and then combined with a reflection on new systems of actors, to hypotheses that can be formulated and then tested empirically, a more open theoretical framework was needed to account for the wider transformations of the automotive system. Because it posits that important transitions can only occur when a combination of external and internal factors within an industry (Kemp, 1994 ;

Schot et al., 1994 ; Rip and Kemp, 1998 ; Kemp et al., 1998 ; Van den Ende and Kemp, 1999 ; Rip, 2000 ; Geels and Kemp, 2000 ; Kemp et al., 2001), and that technology dynamics is only one of them (Dijk et al., 2016; Geels, 2006; Van Bree et al., 2010), the theoretical framework of socio-technical transitions considers an aggregation of diverse causalities that allows the necessary openness for further research. In addition, it is the understanding of governance of both external and internal industry factors that contributes to the analysis of the causes of transitions. The introduction of these governance principles, i.e. (i) the ability to shift external pressures on a regime, and (ii) the coordination of resources available inside and outside the regime to adapt to these pressures (Geels and Schot, 2007; Smith et al., 2005), also addresses the role of actors in these transitions and, thus, answers the question of the conditions for activating design variables specific to the effects of vehicle electrification..

This theoretical pivoting then favors the emergence of a questioning, no longer limited to the consequences of a technological breakthrough, but open to a convergence of factors of a socio-technical nature: *«Could the convergence of socio-technical factors, both internal and external to the automotive industry, drive a future disruption of its architecture? »*

Which makes possible a new empirical questioning

This second question, which can refer to numerous studies highlighting transition phenomena (Dijk et al., 2016; Marletto, 2014; Moradi and Vagnoni, 2018; Nykvist and Whitmarsh, 2008; Smith et al., 2010; Van Bree et al., 2010; Wesseling et al., 2014), can only be addressed through an empirical study of new mobility initiatives under development or deployment. Indeed, this issue also encompasses a major change in the composition of the players implementing this transition: under the influence of the many factors both internal and external to the industry that are causing this change, the scope of the players has expanded well beyond car manufacturers, their network of suppliers of parts and modules or also of capital goods, and their vehicle sales and repair network. Current mobility experiments are mobilizing technology suppliers, construction companies, mobility operators and also the public authorities in charge of defining, or even operating, these new mobilities. Moreover, it must also be considered that the field of experimentation that is being mobilized is also changing: the domination of the traditional triad (USA, Europe, Japan) over the global automotive industry is being eroded by the rise in power of both the markets and industrial capacities in Asia, of which China is obviously the spearhead.

This assertion on the need for empirical studies on new mobilities is also based on one of the strongest social science conclusions on technological change, which posits that there is no

technological determinism, but only determinisms of learning (Midler and Charue-Duboc, 1994) or, in the language of economists, of the irreversibility of the path (Dosi, 1982). It is therefore by studying and comparing the various experiments in progress, by studying their significance and by evaluating their performance in leading, more or less rapidly, to operational realities that it is possible to shed light on the uncertainties of possible destabilization scenarios. Finally, the complexity and diversity of these new mobility initiatives, as well as the fact that they are emerging phenomena, then make it necessary to carry out a global empirical study. This must be based on case studies which are both targeted in their objective and open in their scope in order to be able to deal with the diversity of the initiatives in progress.

With the convergence, within the host laboratory, of this research devoted to the scale up of electrification and another research on the development of autonomous vehicles, it is then possible to undertake an international benchmark study of innovative mobility initiatives and, therefore, to continue research in this new direction. The study undertaken is then a multi-case study, one case being an innovative mobility initiative analyzed as a project that can be in different phases, from the upstream exploratory study to the implementation or operation phase.

From this integration, a whole work of construction and formulation of the analytical apparatus of the benchmark must be carried out since it is a question of observing, on the one hand, the nature of the breaks associating the vehicle with the design variables of the service, and on the other hand, the nature of the breaks in the ecosystem of actors involved in these initiatives. But, first of all, as the disruptive mobility initiatives become the observable ones, it is a matter of characterizing the precise nature of the mobility experiences. This characterization is based on a theoretical definition of the design variables of a mobility service offer which draws on the literature on servitization, servuction and previous work on the definition of design variables of mobility services (Lenfle and Midler, 2003, 2009a).

In addition to characterizing the value targeted by each of these experiments, this analytical framework also provides access to the definition of the ecosystem that carries the initiative: Which stakeholders are involved? What is their role and their capacity for action on the orientation and implementation of the initiative? Who is the leader of the constituted ecosystem and why is he or she best placed to assume this role? It also makes it possible to characterize the performance of the learning achieved within these ecosystems: what are the main risks and opportunities encountered? What are the new technological, organizational and managerial skills that need to be mobilized? What is the speed and what are the horizons of outlets for this

learning? What are the modes of appropriation, deployment and "rebound" of these experiments by the actors involved?

The results, to date, show the solidity of the intuition: while the electrification of vehicles alone cannot destabilize the sector, electric, autonomous, communicating and shared mobility can bring about transition scenarios. Indeed, because it associates new players capable of activating new variables, such as the definition of a mobility service or infrastructure choices, which impose the specifications of the support vehicle, it can contribute to the emergence of new ecosystems in which manufacturers would no longer be the focal point. Beyond the kaleidoscope of different initiatives, the empirical study identifies and formulates three possible trajectories: (i) the continuation of the current dominant design and industry architecture, (ii) the robotaxi scenario, which highlights a new focal actor, the car mobility service operator, and (iii) a territorialized mobility service scenario relying massively on infrastructure manufacturers and/or managers as well as territorial public authorities.

To finally mobilize the fields of innovation and project management

While the initial question, centered on EV scale-up, concerned a break more limited in scope and also more easily qualified in its trajectory, the identification of these three scenarios leads back to the analysis of an emergence stage of a transition. How will or will not these three scenarios unfold? This is an issue of analysis of the design and learning capacities of a planned innovation, on a perimeter that is now wider in terms of the content of the rupture and the system of actors involved. While the case study confirms the importance of projects as a field for the development of innovations, both in terms of the intrinsic content of the offer and the coordination between its members, it also refers to a theoretical framework, derived from previous research, which makes it possible to account for innovation trajectories shaped by successive projects carried out by a company: the notion of project lines. It therefore seemed interesting to remobilize this framework in order to analyze the possible ways of deploying these scenarios. Who could act as a lineage manager? How could it be done? These questions open the way to new research that goes beyond the scope of this thesis, but it is already possible to formulate the following hypotheses. Scenario 1 continues the lineage management conducted by manufacturers for years on communication services and driving aids associated with the vehicle. Scenario 2 clearly designates the robotaxi operator as the focal actor able to build learning lines on the 6 design variables of the service. Whether this now dominant place in the architecture of the car mobility system is occupied by a former car manufacturer, a public transport operator or a technology provider such as Google is obviously possible depending on

the strategic choices and opportunities developed by these companies. But in any case, the current automotive value chain with an OEM integrator and B2C distributor of vehicles will have been disrupted, as the vehicle has become one component among others of a transport system. Scenario 3 is much more innovative than the two previous scenarios and, therefore, remains to be studied and the consequences for the automotive industry have yet to be fully described. At this stage, it can only be assumed that it too is likely to cause disruptions both in terms of the ability of public authorities and infrastructure manufacturers/managers to specify the rules governing the use of vehicles and in terms of their ability to take ownership of the direct relationship with the end customer.

The research frieze proposed below summarizes this approach while highlighting its richness based on this alternation of empirical questions, theoretical and analytical frameworks.

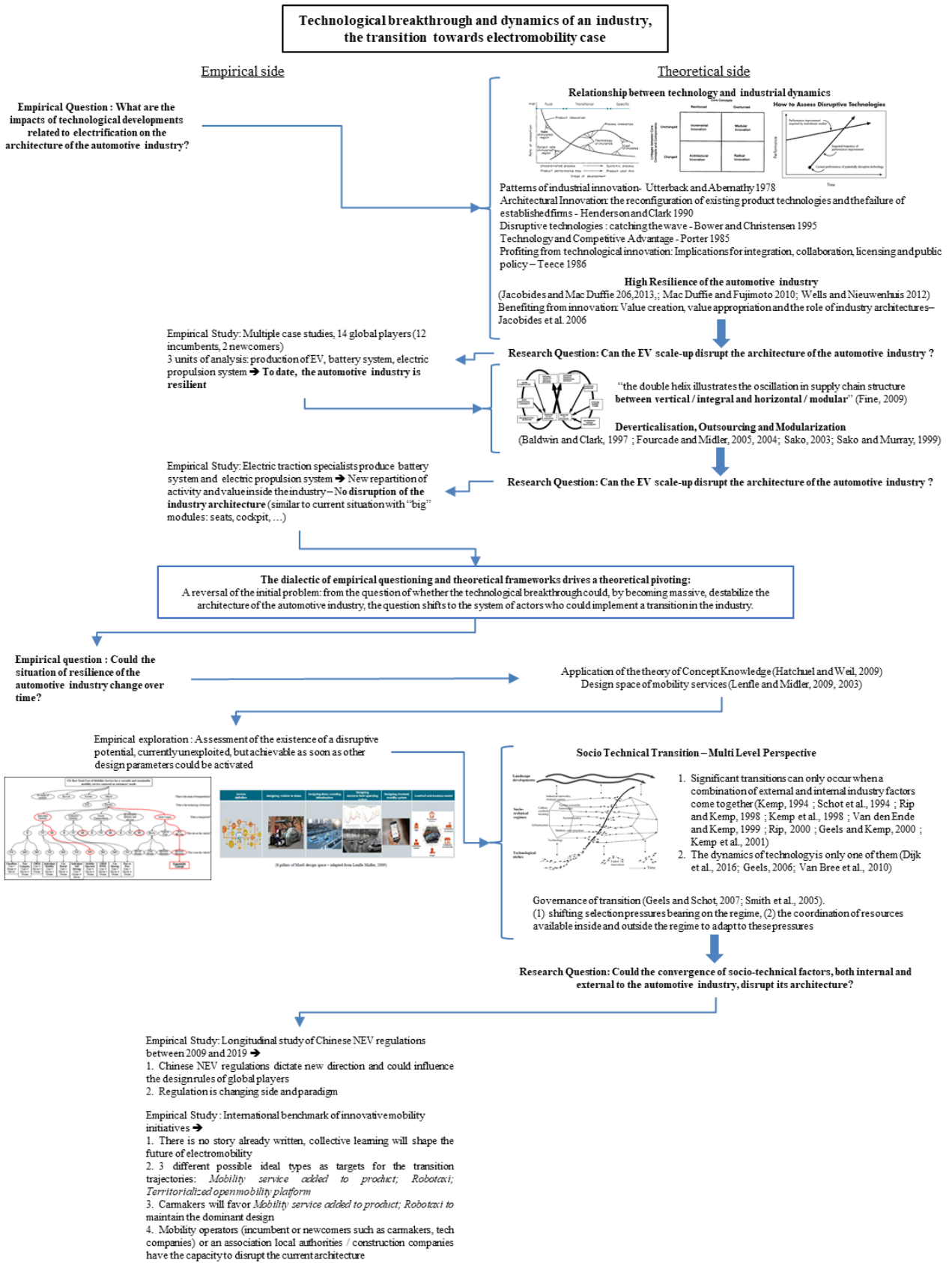


Figure 5 : Research frieze

2. Outline of the thesis

The outline of this thesis is organized as follows and is represented in figure 6 at the end of this chapter:

- An introductory chapter that describes the theoretical and empirical path of the research, presenting its results in a synthetic way,
- Five chapters, each of which includes one paper presenting the methodologies used at the different stages of the research and highlighting the different outcomes of the studies,
- The last concluding chapter presents the empirical results and the theoretical and managerial contributions. It also discusses the dialectic of empirical questioning and theoretical frameworks. Lastly, it summarizes what are the limitations of this research work.

The first paper (chapter 3) « *Will the scale-up of electric vehicles (EV) disrupt the architecture of the automotive industry?* » presents the empirical study that has been conducted to challenge the assertion that the automotive industry is resilient to the rise of electrification. The study, which addresses fourteen global car manufacturers, including two new entrants, examines the constitution of the electric traction value chain (vehicle production, high-voltage battery and electric propulsion systems) and concludes that the automotive industry is resilient in this phase of intense electrification. This paper has been submitted to the journal *Industrial and Corporate Change* and is an upgraded version of the communication « *How is the emerging E-traction value chain shaped by EV scale-up?* » which was accepted and presented at the 27th international colloquium of GERPISA held in Paris, June 2019.

The second paper (chapter 4) « *Automobile industry, towards an electric autonomous mobility service industry? A sociotechnical transition-based approach* » outlines the value of a paradigm shift from a strategic study, based on the influence of a change in technology, to a socio-technical transition study, based on the influence of multiple internal and external factors including a change in technology, to describe and explain the contemporary, complex and uncertain transition that the automotive industry is undergoing towards electromobility. It provides both the theoretical and analytical framework for the various case studies presented in this thesis. Most important, this paper is the one that highlights the three different ideal types: (i) *mobility service added to product*, (ii) *robotaxi* and (iii) *territorialized open mobility platform* and discuss the role of key players in the transition towards each of them. If the hypothesis of using the theoretical framework of sociotechnical transition had been evoked in

the paper « *Reorienting electric mobility research focus on industrialization issues* » (Alochet and Midler, 2109) published in International Journal of Automotive Management, volume 19, number 3/4, pages 229-256, a paper deeply modified and enhanced, has been submitted to the journal Technological Forecasting and Social Changes.

The third one (chapter 5), « *Systemic innovation and project learning: from firm to ecosystem learning capability* » deals with the impact of systemic innovation and project-based learning in the context of the emergence of new mobility services (MaaS). Based on the study of three cases of mobility services with different maturity, project leadership and region of the world for experimentation or operation, this work highlights the importance of projects as a playground for the emergence of ecosystem innovations as well as the nature of learning according to (1) the ecosystem leader, (2) the technological brick management strategy and (3) the geographical context in which the mobility offer is deployed. The paper presented, currently in the review process with the Project Management Journal, is the text of the accepted communication « *Systemic innovation and project learning: from firm to ecosystem learning capability - Theoretical framework and preliminary empirical analysis of automotive mobility transition* » for the « IRNOP 2020 » conference which should have been held in Uppsala, June 2020 and has been rescheduled for June 2021.

The fourth one (chapter 6), « *How does servitization impact on the management of product-oriented innovation projects? The case of Mobility as a Service* » deals with the impact of the transition from product to service development. Based on the study of three cases of mobility services with different maturity, project leadership and region of the world for experimentation or operation, this work introduces a new typology of innovation management in project based upon the intrusiveness of the innovative service development within the new product development, namely: “*product-centric added services*”, “*product-centric service enabler*” and “*product enabler of service centric offer*”.

It also exhibits that the switch from product to service also drives a switch from product life cycle management to service cycle management and draws the consequences in terms of project management. The paper presented, still in a "working paper" state, is an edited version of the accepted paper « *The transition from product centric to service centric innovation projects, the case of the automotive industry* » at the « Annual Conference 2020 » EURAM which should have been held in Dublin, June 2020. As the EURAM conference has been rescheduled, as an online conference, in December 2020, it will serve as a basis for the communication. It is then

planned to submit it to the International Journal of Project Management after a thorough review in early 2021.

Lastly, the fifth paper (chapter 7) « *Are Chinese regulations shaping the worldwide EVs industry?* » presents the empirical study carried out on Chinese regulations concerning NEV products and industry. This study shows how these regulations contribute to the resilience of the automotive industry in the context of electrification and could influence the design strategies of global manufacturers. It also presents an interesting comparison of the use of regulations by the Chinese government and the European Commission to develop the electric vehicle market and industry. A paper has been submitted for a special edition “Mobility, Climate Change, and Economic Inequality” of the Journal of Operations Management, and is a reworked version of the accepted paper "*Are Chinese regulations shaping the worldwide EVs industry?*" for the 28th International Colloquium of GERPISA which should have been held in Detroit, June 2020 and has been rescheduled for June 2021. This chapter is a slightly updated version of the presented paper.

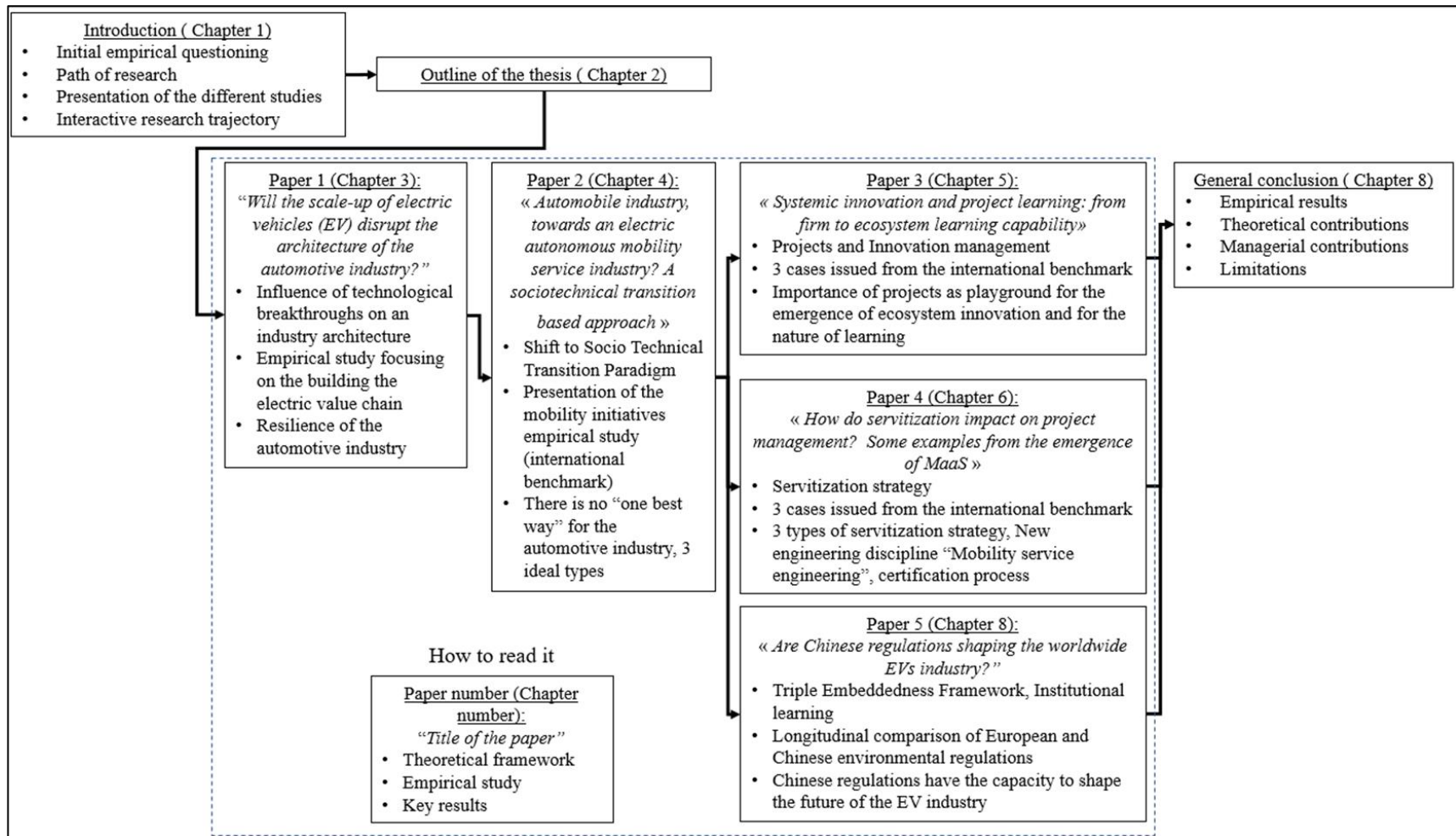


Figure 6 : Outline of the thesis

3. ESSAY 1: Will the scale-up of electric vehicles (EV) disrupt the architecture of the automotive industry?

Abstract

Electrification is transforming the oldest fundamentals of the dominant design of the automobile. We investigate whether the scale-up of electric vehicles (EVs) will disrupt the architecture of the industry with data from 14 automakers worldwide, concluding that, to date, incumbent firms have proven resilient in the face of these innovations.

We argue that EVs are a case in which a gradual change in the **product** dominant design is being absorbed successfully by industry incumbents – but that rapid change towards a new business model -- **mobility-as-a-service** – will pose a far greater challenge.

Keywords: industry architecture, technological change, dynamics of industry, product architecture, electrification

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STATUS OF THE PAPER: SUBMITTED

3.1. Introduction

Several authors have argued that the automotive industry is particularly resilient and that automakers have the means to keep control of the industry (Jacobides et al., 2016; Jacobides and MacDuffie, 2013; MacDuffie and Fujimoto, 2010; Wells and Nieuwenhuis, 2012). To support their assertion, they state that car manufacturers (1) act as system integrators, (2) are at the top of a hierarchical value chain that they control, (3) master the relationship with the end customer and (4) have the capacity to guarantee quality and compliance with regulations relating to safety and health issues.

While some authors, prior to the EV scale-up that is currently taking place, predicted that vehicle electrification will not change this long-lasting situation (Jacobides et al., 2006; Jacobides and MacDuffie, 2013), this assertion deserves to be re-examined since electrification transforms the technological core of conventional mobility – the drive train, including the energy source and the propulsion system – perhaps the oldest and most fundamental feature of the dominant design of the automobile.

This leads to an empirical question: how is the automotive industry managing this transition from Internal Combustion Engine Vehicles (ICEV) to Electric Vehicles (EV)? What is the impact of the technological evolution linked to electrification on the structure of this industry? This empirical question is in line with the rich tradition of academic work on the question of the relationship between technological change and industry dynamics summarized by Nelson as follows “... *firm and industry structure ‘coevolve’ with the technology*” (1994, p. 47). Elaborating on this stream of research allows us to reformulate our research question as follows: “*Will the scale-up of electric vehicles (EV) disrupt the architecture of the automotive industry?*”

This paper is organized in five sections. In Section 1, we develop our theoretical framework around the relationship between technological change and industry dynamics. In Section 2, we introduce the research design and methodology including the depiction of the current architecture of the automotive industry. In Section 3, we present the results of our empirical study focusing on the current strategic choices (observable in early 2020) of global players, both incumbent and newcomers: whether to manufacture, buy or join forces to develop electric vehicles as a whole as well as the two main subsystems of electric drive trains, namely high-voltage batteries and electric propulsion. In Section 4, we confirm the stability and resilience, to date, of the automotive industry and introduce two other theoretical frameworks which make it possible to put forward different hypotheses for the future dynamics of this industry, namely the double helix model (Fine and Whitney, 1996; Fine, 2009) and sociotechnical transition

(Geels, 2002). The fifth and concluding section draws the implications of these findings for both academic and managerial purposes and proposes perspectives for future research.

This paper, by addressing the transition from internal combustion engine vehicles to electromobility -- one of the most significant contemporary industrial transitions -- makes the following contributions:

1. Our empirical study focusing on how global players, both incumbents and new entrants, are building the electric value chain, confirms, to date, the resilience of the automotive incumbents. It demonstrates that: (i) for 80% of traditional automakers, the EV value chain is organized for “make” rather than “buy” for battery packs and electric drive trains; (ii) the outsourcing (e.g. of battery cells) is done from a high base of internal R&D knowledge, consistent with a “know more than you make” (Brusoni et al., 2001) strategy for firm capabilities; and (iii) that nearly 100% of global automakers have adapted their current manufacturing process to produce EVs in their existing plants vs. outsourcing or establishing separate production processes.
2. Theoretically, this research shows that technological innovation alone is not enough to bring about a change in industry architecture. Therefore, we hypothesize that only a rapid and fundamental transition in mobility, encompassing many technological, legal, economic and social factors, both internal and external to the industry, could disrupt its resilience. Put differently, we argue that EVs are a case in which a gradual change in the **product** dominant design can be absorbed by industry incumbents but that a rapid and fundamental change towards a new business model -- **mobility-as-a-service** for humans and goods -- poses a far greater challenge.

3.2. Literature review

3.2.1. An empirical question, in line with the rich tradition of research on the relationship between technology and industrial dynamics

Several scholars (Abernathy and Utterback, 1978; Bower and Christensen, 1995; Henderson and Clark, 1990; Porter, 1985; Teece, 1986) have studied the impact of the introduction of major technological changes on established companies and the consequences for their respective industries.

All of this research work highlights the importance of distinguishing between two types of technological innovation: incremental innovation, which is a succession of minor changes that

improve the performance of a design, and radical innovation, which, conversely, involves fundamentally different design rules and scientific principles.

Abernathy and Utterback (1978, p. 42) have shown how these two types of innovation, although opposite to each other, can combine to contribute to "A Transition from Radical to Evolutionary Innovation" or how the introduction of a radical innovation can lead to the emergence of a dominant design that will then be regularly optimized by a succession of incremental innovations. They also explain that the emergence of a dominant design leads to the possibility of scaling up and the creation of a mass manufacturing industry, of which the automotive industry is one of the most emblematic examples.

However, noting that these two notions are insufficient to describe all cases of innovation, Henderson and Clark (1990), by emphasizing the importance of the relationships between the different components – and the interfaces among them -- within a technical solution, added the notions of *modular innovation* (overturned core concepts of a solution with unchanged interfaces) and *architectural innovation* (reinforced core concepts of a solution with changed interfaces). They also add "*The essence of an architectural innovation is the reconfiguration of an established system to link together existing components in a new way*" (1990, p. 12). Firms in the mass production industry tend to remain in the dominant field of design (Abernathy and Utterback, 1978) and concentrate most innovation on components whose interrelationships are defined within a stabilized product architecture. Therefore, they conclude that, when faced with architectural innovation, incumbent companies may have two main problems: (1) recognizing that an innovation is of the architectural type and (2) having the capacity to implement it.

On their side, Bower and Christensen have described *sustaining* and *disruptive* technologies, the latter being "*not radically new or difficult from a technological point of view*" (1995, p. 44). They point out two main characteristics of a *disruptive* technology: (i) the proposition of an offer whose performance characteristics are below the usual expectations of customers and (ii) a pace of improvement much faster than the technologies that incumbent companies use and improve year after year. Many incumbent companies ignore these disruptive technologies because "*they stay close to their customers*" (1995, p. 43). They seek to satisfy them with ever more efficient products, according to the criteria that are then valued by customers, as well as more profitable. Revisiting the concept, Christensen et al. (2015) summarize that new entrants build legitimacy with the market by successfully targeting neglected segments with more appropriate functionality and often at a lower price. Once this step is completed, "*Entrants then move upmarket, delivering the performance that incumbents'*

mainstream customers require, while preserving the advantages that drove their early success” (2015, p. 44) and incumbent companies may see their market share decrease or even be reduced to zero. Finally, it is worth mentioning that a *disruptive* innovation can only emerge because there are potential customers who are willing to accept lower performance than that appreciated by dominant customers because it meets their specific expectations (Kim and Mauborgne, 2005)²⁸.

In his analysis of the reaction of incumbent firms to new technologies, Nelson indicates that, in a phase of stabilized dominant design, they are focused on optimizing their business processes and infers: « *this suggests that established firms may have considerable difficulty in adjusting, in gaining control of needed different capabilities, when important new technologies that have the potential to replace prevailing ones come into being* » (1993, p. 54). He, thus, confirms the difficulties encountered by incumbent companies faced with the introduction of a new technology whatever its nature.

When Porter, in his paper focusing on the competitiveness of firms, states « *Everything a firm does involves technology of some sort* » (1985a, p. 62), he emphasizes the importance of technology in the functioning of firms, but also makes it very clear that any technological change is important, not intrinsically, but because it changes the competitiveness of a firm; he also explains that the impact of a value-creating technology goes far beyond the firm that developed it, since its diffusion within an industry can greatly contribute to changing both its structure and its attractiveness.

These theoretical frameworks, which are important for understanding and studying the emergence of an innovative technology, have very often been used only at the level of a company, whereas a systemic innovation must be deployed in an ecosystem, well beyond the perimeter of a single company. Its benefits “*can be realized only in conjunction with related, complementary innovations*” (Chesbrough and Teece, 1996, p. 128) developed by a set of external actors playing their part (Afuah and Bahram, 1995; Tushman and Anderson, 1986).

²⁸ In this paper, we remain cautious about using the term “disruptive innovation”. Its ubiquity in the popular discourse about new technologies and its widespread application beyond academia has created ambiguity and confusion about its precise definition and significance. Strategy scholars (King and Baatartogtokh, 2015; Markides, 2006) have identified multiple cases in which the term is applied that don’t come close to matching the original criteria set forth in Bower and Christensen (1995) and Christensen (1997). Christensen himself recognized this problem, writing “*Despite broad dissemination, the theory’s core concepts have been widely misunderstood and its basic tenets frequently misapplied*” (2015, p. 44). We prefer the concept of “systemic disruption” (see below).

This statement refers to the notion of complementarity and co-specialization of offerings (Teece, 1986), i.e. the fact that the players in the ecosystem develop different, non-generic offerings, which cannot be obtained simply through the market, the combination of which brings value.

A somewhat different perspective arises by combining elements of the frameworks described above. A *systemic disruption* is defined as a transition that combines four characteristics : (i) the degree of radicalism in the disruption introduced; (ii) the extent and heterogeneity of the scope of the players they mobilize; (iii) the scale of the projects; (iv) the speed of the expected transitions (Maniak et al., 2014b; Midler and von Pechmann, 2019; von Pechmann et al., 2015). Accordingly, these authors describe the introduction of electric drive trains as a *systemic disruption* because its success requires the intervention, within an ecosystem, of many actors with complementary and co-specialized offers (Teece, 1986) such as suppliers of energy, high-voltage battery systems or charging systems (Donada and Attias, 2015; Donada and Perez, 2018; Vazquez et al., 2018). A related question is whether the integration of high-voltage electric battery and electric propulsion systems into the existing dominant design of a vehicle is instead better viewed as a combination of *modular (new concepts, same interrelationships)* and *architectural (same concepts, different interrelationships) innovations*, per Henderson and Clark (1990); and, if so, whether established manufacturers are able to identify and respond appropriately to the opportunity that these intertwined innovations present. This requires that we consider when the extent of modular and architectural innovations changes the dominant design sufficiently that the resulting set of changes qualifies as a systemic disruption.

The concept of industry architecture is also part of the theoretical framework that needs to be mobilized; broadening the concept of bilateral relationships, which refers to the highly centralized way in which companies manage their value chains through numerous dyads of parallel buyer-supplier relationships (Porter, 1985a; Williamson, 1985). Jacobides et al. (2006, p. 1205) summarize the notion of industry architecture as follows: “*Thus, industry architectures provide two templates, each comprising a set of rules: (1) a template defining value creation and division of labor, i.e. who can do what (2) a template defining value appropriation and division of surplus, or revenue, i.e. who gets what*”. An industry architecture emerges in the early days of the industry, shaped by product design decisions (Baldwin and Clark, 2000), by regulations, industry standards, technology or, generally speaking, interfaces (Jacobides et al., 2006; Jacobides and MacDuffie, 2013; Jacobides and Winter, 2005), as well as knowledge and

technical capabilities of firms (Zirpoli and Camuffo, 2009). The ability to act, vis-à-vis the end customer, as a guarantor and responsible party for the quality of the products and compliance with regulations relating to safety and health issues is also a fundamental characteristic of a focal firm of a given industry, especially in the automotive one (Jacobides and MacDuffie, 2013). The consolidation of a dominant design contributes greatly to shaping the architecture of an industry, and indeed dominant design and industrial architecture are highly interdependent and mutually reinforcing (Abernathy and Utterback, 1978; Jacobides, 2006; Tushman and Anderson, 1986).

3.2.2. A resilience hypothesis of the current industry architecture supported by strategic theories

Building on these strategic theories, several authors have argued that the automotive industry is particularly resilient and that automakers have the means to keep control of the industry (Jacobides et al., 2016; Jacobides and MacDuffie, 2013; MacDuffie and Fujimoto, 2010; Wells and Nieuwenhuis, 2012). To support their assertion, they state that carmakers act as system integrators because they drive innovation, product strategy and higher value-added manufacturing segments, including the assembly and final inspection of the complete automotive system (Gereffi et al., 2005) and thus retain control of the most strategic assets (Jacobides and MacDuffie, 2013). De facto, as they “*know more than they make*” (Brusoni et al., 2001), they are the only ones able to respond to the trend towards integral design imposed by increasingly stringent regulations (Fujimoto, 2017; MacDuffie, 2013) as well as to act as guarantors of quality and regulations’ compliance for end customers (Jacobides et al., 2006 ; Jacobides et Mac Duffie, 2013). Consequently, they are at the top of a hierarchical value chain that they largely control (Wells and Nieuwenhuis, 2012) and can guide future developments. Finally, mastering the relationship with the customer -- through a vehicle distribution and repair network, offering services (financing, insurance, maintenance, to name a few), and the ability to guarantee quality and regulations’ compliance (Jacobides et al., 2006; Jacobides and MacDuffie, 2013) -- is certainly one of the major reasons explaining the dominant position of car manufacturers.

The automotive industry has a deeply and strongly anchored dominant design: “*since the 1920’, the internal combustion engine is established as the dominant design in the automotive industry*” (Borgstedt et al., 2017, p. 76), but electrification drives some disruptions in the vehicle dominant design (Fuchs et al., 2013; Fujimoto, 2017; Klug, 2013; Luccarelli et al., 2013; Muniz and Belzowski, 2017). Faced with the emergence of innovative technologies,

incumbent companies in the mass production industry, with efficient production technology and highly integrated product and process systems, tend to remain in the dominant design domain, unless forced to do so through an external pressure such as, for example, regulation (Abernathy and Utterback, 1978). As the move towards electrification is strongly fueled by very stringent regulations addressing CO2 and pollutants emission, many have predicted that the automotive industry will escape from the dominant design, destabilizing its long-lasting architecture.

Therefore, as the EV scale-up is currently taking place, the assertion about the resilience of the automotive industry, even in case of electrification of vehicles (Jacobides et al., 2006; Jacobides and MacDuffie, 2013), deserves to be re-examined.

3.3. Methodology

3.3.1. Architecture of the automotive industry

The automotive industry is a very representative archetype of the “*Hierarchy-based Value System*” defined by Jacobides et al. (2018). Utilizing the concept of industry architecture (Jacobides et al., 2006), we concretely present, in broad terms, the most common organization of production of carmaker which may differ either for some specific products or some specific countries depending upon the level of local integration and sourcing strategy.

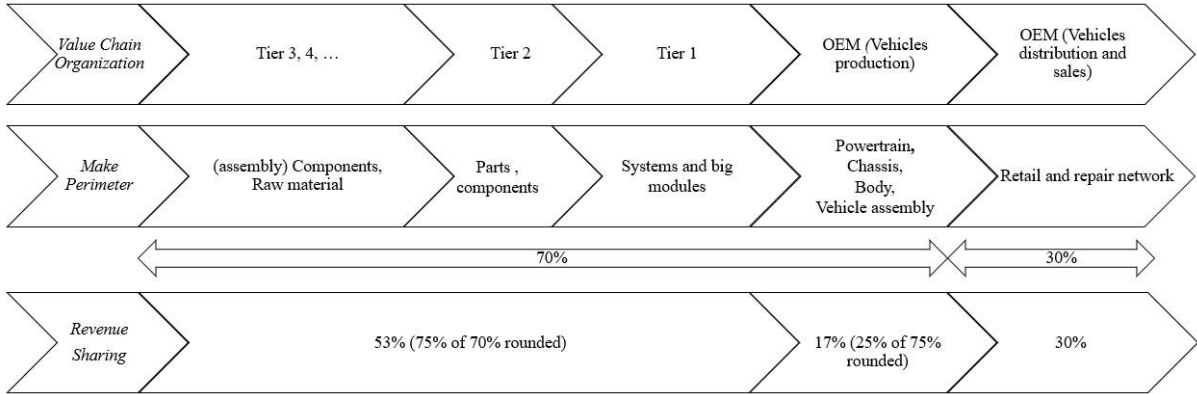


Figure 7: A simplified presentation of the automotive industry architecture

It describes a hierarchical organization of a value chain, strongly managed by a focal firm, namely a carmaker (Original Equipment Manufacturer), acting as an integrator by means of its capability to create and manage an integrated value chain; a carmaker has many parallel relations with its suppliers (Tier 1 suppliers), who also manage their own supply chains in the same way.

It also presents a division of activities (make perimeter) where OEMs make in-house powertrain and chassis components or systems as well the painted body and the final assembly

of the vehicle. On their side, Tier 1 suppliers deliver systems (as braking system for instance) and big modules (such as a collection of assembled seats). Following down the path of a hierarchical value chain, Tier 2 suppliers usually deliver main parts or components and Tier 3 (or even deeper levels of supply) provide (assembly) components, raw material and so on.

Lastly, distribution and sales are under the single responsibility of carmakers that spend a lot of money in advertising, marketing, and so on; carmakers also drive retail and repair network constituted of their own subsidiaries and independent companies. To give some rough and rounded figures, and accordingly to our own research, the value of a vehicle is usually composed of 30% from distribution and sales and 70% from production. The latter is further divided between automakers (25% of the cost of the vehicle) and suppliers (75% of the cost of the vehicle). This is equivalent to an overall share of value in production of 17% for automakers (25% of 70%) and 53% for suppliers (75% of 70%)²⁹.

We will use this model of hierarchical organization of the automotive industry to represent the impacts of electrification on the current architecture of the automotive industry according to the different theoretical frameworks that we mobilize.

3.3.2. Theoretical sampling

In order to contribute to the reduction of greenhouse gases or, more broadly pollutants at the global level, regulations set targets either for the penetration rate of electrified vehicles such as, for instance, 12% by 2020 in China, 22% in 2025 in California (plus nine other states representing 30% of new car sales in USA), or for a maximum threshold such as, in Europe, 95 gCO₂ /km in 2021.

²⁹ These figures reflect heuristics commonly used in the global automotive industry, reflecting the calculations of value added at different stages of the overall value chain made by industry analysts and consultants. Compared to the early history of the industry, the percentage spent on sales and distribution has grown as brands and models have proliferated (even as the number of automakers has dropped through consolidation) and product markets have expanded to ever-larger geographical territories. Also changing over time has been the division of value-added between automakers and suppliers. Henry Ford famously sought to vertically integrate close to 100% of production from the 1920s on, including rubber plantations in Brazil to make tires. U.S. automakers were the most vertically integrated in the world in the period following WWII, followed by Europe and then Japan. Over time, through a steady move towards outsourcing, U.S. and European automakers have converged on a similar level of vertical integration – 25% for automakers, 75% for suppliers -- according to most accounts. Japanese automakers are more difficult to characterize; they have always relied heavily on suppliers via their *keiretsu* networks in what could be considered quasi-vertical integration. But these automakers have also opened up those networks considerably to global suppliers outside their *keiretsu*, making them more similar to the rest of the world. (MacDuffie & Helper, 2006, p. 422-24). For any given vehicle, these figures need adjusting depending upon the type of vehicle, its size and market segment, its complexity and level of equipment.

As significant results are expected very quickly, not all carmakers have made the same technological choices to ensure this transition and, above all, have not committed themselves to it at the same time. For example, Toyota and Honda have been engaged in a strategy of hybridization for more than twenty years, while Renault, Nissan, GM or Tesla embarked on Battery Electric Vehicles (BEV) about ten years ago and other global players much more recently. This could lead to very numerous and diversified strategies for managing the value chain and pave the way to different kinds of potential changes in the architecture of the industry.

Consequently, since we face different strategic orientations in the field of electrification, we choose to include both incumbent (cumulating roughly 70% of the global market share) and new entrants (EVs top selling companies) in the scope of the empirical study.

3.3.3. Case definition

There is a long history of studies in the automotive industry field and different units of analysis have been considered : a manufacturing plant to study manufacturing performance (Krafcik, 1988), the product itself to compare performance in development (Clark and Fujimoto, 1991) while Maniak et al. (2014b) selected embedded technologies to study innovation management. Our quick summary confirms that determining the correct unit of analysis is fundamental to answering our research question: “*Will the scale-up of electric vehicles (EV) disrupt the architecture of the automotive industry?*”

Many authors have hypothesized that because of the greater modularity of electric drive train systems, the higher level of complexity and higher price, especially of the high-voltage battery system, compared to conventional internal combustion engine systems, specialized suppliers would reverse the traditional hierarchical relationship in favor of car manufacturers and gain a dominant position in the industry. Therefore, keeping in mind the fundamental question asked by Abbott (1992) “*What do cases do?*”, our empirical study aims to assess the variations in activity (*who can do what*) and value repartition (*who gets what*) caused by the electrification of vehicles. As we assess its impact on the two key templates of an industry architecture (Jacobides et al., 2006), we can determine whether or not it is plausible that electrification is likely to cause a disruption in the architecture of the industry (*plausibility probe case study*, Eckstein, 1973).

To do so, considering that a case study concerns a contemporary (Yin, 1981) and relatively limited phenomenon (Gerring, 2004) and being aware that there can be no complete description of a phenomenon (Dumez, 2016), we define our context as “ *the current strategic choices (observable in early 2020) of global players, both incumbent and newcomers: manufacture,*

buy or join forces to develop electric vehicles as well as the two main systems of electric drive train, namely high-voltage battery and electric propulsion". We have two different kinds of unit of analysis: on the one side, the production system of a vehicle and, on the other side, the value chain of each system, which means three units of analysis per case. We will conduct a multiple case study encompassing both incumbents and new entrants, being global players from different countries of origin to determine if the seniority in automotive business or regional / national conditions have an influence or not on their strategy. By doing so, we have designed an embedded (multiple units of analysis) multiple cases study (Yin, 2009a) which is described in figure below.

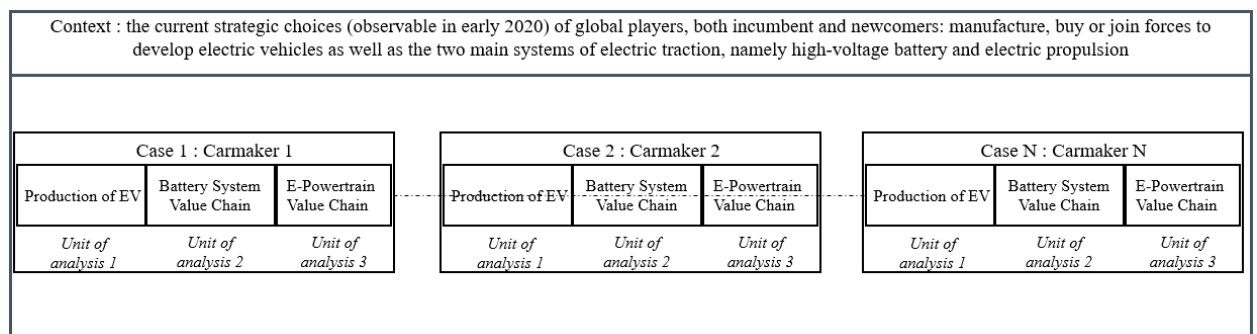


Figure 8: Multiple case study description

Considering the global players coming from different regions of the world, with the highest cumulative sales, to which we have added two newcomers, Tesla and BYD, we have selected the following carmakers to be part of our study:

Company name	Region of origin	Seniority in industry
BMW	Europe (Germany)	Incumbent
BYD	China	Newcomer
Daimler	Europe (Germany)	Incumbent
FCA	USA / Europe (Italy)	Incumbent
Ford	USA	Incumbent
GM	USA	Incumbent
Honda	Asia (Japan)	Incumbent
Hyundai	Asia (South Korea)	Incumbent
Nissan	Asia (Japan)	Incumbent
PSA	Europe (France)	Incumbent
Renault	Europe (France)	Incumbent
Tesla	USA	Newcomer
Toyota	Asia (Japan)	Incumbent
VW	Europe (Germany)	Incumbent

Table 12: List of selected carmakers for case study

3.3.4. Framework

With regard to the production system of a vehicle, we want to know (1) whether car manufacturers produce EVs in their own factories, and (2) whether the production of EVs requires a new, specially designed manufacturing process due to specificities that prevent the use of the dominant design. While the answer to question (1) is pretty straightforward, once we know in which plant the vehicle is produced, we apply a dedicated reasoning to determine the answer to question (2). If we observe that EVs are (1) produced according to the standard manufacturing process (shops for stamping, body assembly, body painting and vehicle assembly), and (2) that required process modifications, in all shops, are achieved by reusing the dominant design rules of the ICEV, then we affirm that it is produced according to an *adapted standard process*; if at least one of the two conditions above is not met, then it is a *specific process*. Therefore, we use the template presented below to observe the vehicle production system.

Carmaker	Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Type of process
Name of the carmaker	Nameplate of the vehicle	Name and location of the plant	Yes / No	Yes / No	<i>adapted standard process or specific process</i>

Table 13: Template for vehicle production system observation

In order to be able to define each of the two value chains, it is first necessary to define the constitution, from an aircraft perspective, of each of the systems concerned and to determine the relevant perimeter on which to focus for the purposes of our study.

The battery system consists of modules, electrically interconnected by wiring and connection devices, a cooling system and a management system located in a battery pack consisting of a lower tray, an upper cover and structural reinforcements. The modules, themselves, are made up of cells, comprising components such as electrodes, electrolyte, etc., electrically connected to each other by wiring and connection devices and integrated in a specific housing. Focusing on the key innovative components, namely the battery system, the modules, the cells, and considering that all the other components we have listed usually belong to the buy perimeter of a carmaker, we set the framework describing the battery system value chain as presented in the table proposed below.

DESIGN PERIMETER	MAKE, BUY, ALLY						
	Global Players Strategies – Incumbent companies and newcomers						
Battery system	MAKE	BUY	MAKE	MAKE	ALLY	MAKE	MAKE
Modules			BUY			BUY	
Cells			BUY	BUY		ALLY	ALLY

Table 14: Template for battery system value chain observation

We identify seven possible strategies for a carmaker to rule the value chain of the battery system:

- Vertical integration (column 1),
- Buy or Ally battery system (columns 2,5),
- Buy or Ally modules, design and assemble the battery system (columns 3,6),
- Buy or Ally cells, design and assemble modules and the battery system (columns 4,7).

As far as electric powertrain, it is constituted of an electric motor, a transmission, a management and control system, a power control including inverter and converter; when all these constituents are integrated together in a (big) module, it is named as electric drive.

As summarized in the table below, we apply exactly the same approach as for the battery system, by focusing on electric drive, electric motor and transmission; we identify the same seven strategies applied to the relevant perimeter of the electric powertrain.

DESIGN PERIMETER	MAKE, BUY, ALLY						
	Global Players Strategies – Incumbent companies and newcomers						
Electric drive	MAKE	BUY	MAKE	MAKE	ALLY	MAKE	MAKE
Electric motor			BUY			BUY	
Transmission			BUY	BUY		ALLY	ALLY

Table 15: Template for electric powertrain value chain observation

3.3.5. Data collection

We use the same method of data collection for all the observations: we refer to second source data, addressing technological announcements extracted from relevant websites for the automotive industry such as carmakers, suppliers, consultant companies, and electromobility dedicated websites (all the websites used as sources are identified and associated to the relevant data in Annexes, section 3.7.). Very often, the data are directly available; otherwise, data cross-checking and/or correlation operations between different websites are necessary. When additional operations have been necessary, this is mentioned next to each data.

3.4. Empirical study of the electric traction value chain

While the presentation of all the cases, one after the other, would have been rather tedious as well as not conducive to a sufficient height of view, we present successively the synthesis of the observations concerning the vehicle production system, the value chain of the battery system and then that of the electric powertrain for all the carmakers we have selected in our set of observation; all the detailed study cases are presented, company by company, in Annexes (section 3.7.). To provide quite a broad overview of the value chains of the battery and of the electric powertrain systems, each dedicated sub-section starts with a summary of what is proposed on the offer side. Finally, we end with a summary of the role of the different actors (carmakers and suppliers, incumbent and newcomers) which will provide interesting inputs for the discussion section.

3.4.1. Observation of the vehicle production system

For Ford, producing BEVs and ICEVs in the same assembly lines is quite an obvious decision since the company plans to apply the Adapted Electric Platform strategy (Muniz and

Belzowski, 2017) to electrify its most iconic models³⁰. More widely, many carmakers openly state they (will) produce ICEVs and BEVs mixed in the same assembly line since it provides flexibility by means of a quick and efficient adaptation to the demand while it guarantees a high level of quality thanks to the utilization of validated production standards.

Carmakers have taken advantage of their core knowledge to introduce EV-adapted facilities in their existing manufacturing assets. Let's take the example of the Mercedes EQC, one of the available models in the market equipped with one e-motor per axle which is a strong example of the disruption of the vehicle dominant design since there is one single internal combustion engine in a car (Borgstedt et al., 2017). And yet, this vehicle is produced in Bremen plant, and the well-known marriage principle³¹, highly representative of modularity in production, is reused in two steps for the assembly of the EQC: (1) assembly of the two electric powertrains and (2) assembly of the battery pack³².

Based upon our detailed observation (see table below), we summarize that, apart the BMW i3 (constituted of two assembled modules - drive and life - with Carbon Fiber Reinforced Polymer external trims) and the Renault Twizy (a quadricycle with a tubular body), 42 over 44 models are produced in an *adapted standard process*. In the case of Toyota, whose first EVs are expected to be produced in 2020 in China, we cannot observe which manufacturing processes have been chosen, but we can expect to reach the same conclusion.

Carmaker	Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Type of process
BMW	i3	Leipzig (Germany)	No	No	<i>specific process (1)</i>
	Mini Electric	Oxford (England)	Yes	Yes	<i>adapted standard process (1)</i>
BYD					
Daimler	Smart ForFour ED	Novo Mesto (Slovenia)	Yes	Yes	<i>adapted standard process (6)</i>
	EQC (X)	Bremen, Rastatt, Sindelfingen (Germany) Hambach (France) Tuscaloosa (USA)	Yes	Yes	
FCA	New 500 BEV	Mirafiori (Italy)	Yes	Yes	<i>adapted standard process (2)</i>
	New Jeep BEV	Detroit (USA)	Yes	Yes	

³⁰ <https://www.reuters.com/article/us-autoshow-detroit-ford-motor/ford-plans-11-billion-investment-40-electrified-vehicles-by-2022-idUSKBN1F30YZ>

³¹ Assembly between the body and modules / components of the powertrain, fuel system and suspension functions (including components of the steering and braking systems), the elements of which are pre-installed on a pallet

³² <https://www.daimler.com/products/passenger-cars/mercedes-benz/production-eqc.html>

Ford	Next generation BEV	Flat Rock Assembly plant (Michigan USA)	Yes	Yes	<i>adapted standard process (2)</i>
	All electric performance SUV	Cuautitlan (Mexico)	Yes	Yes	
GM	Bolt / New BEV	Orion Assembly plant (Michigan USA)	Yes	Yes	<i>adapted standard process (3)</i>
	Electric Cadillac				
	All electric trucks and SUV	Detroit-Hamtramck (Michigan USA)	Yes	Yes	
Honda	Clarity Electric	Saitama Factory – Sayama (Honda)	Yes	Yes	<i>adapted standard process (2)</i>
	Everus VE-1	Guangzhou Plant Guandong Province (China)	Yes	Yes	
Hyundai / Kia	Hyundai Ioniq electric	Ulsan (Korea)	Yes	Yes	<i>adapted standard process (4)</i>
	Hyundai Kona Electric	Ulsan (Korea) Nošovice (Czech Republic)	Yes	Yes	
	Kia Soul EV	Gwangju (Korea)	Yes	Yes	
	Kia E-Niro	Hwaseong (Korea)	Yes	Yes	
Nissan	New LEAF	Oppama (Japan) Sunderland (GB) Smyrna (TE USA)	Yes	Yes	<i>adapted standard process (4)</i>
	E-NV 200	Barcelona (Spain)	Yes	Yes	
PSA	e-208	Trnava (Slovakia)	Yes	Yes	<i>adapted standard process (4)</i>
	DS3 crossback New Opel SUV	Poissy (France)	Yes	Yes	
	Electric version Opel Astra	Russelsheim (Germany)	Yes	Yes	
Renault	Twizy	Busan (Korea)	No	No	<i>specific process (1)</i>
	Kangoo 2 ZE	Maubeuge (France)	Yes	Yes	
	ZOE	Flins (France)	Yes	Yes	
	Renault City K-ZE	China	Yes	Yes	
	Twingo ZE	Novo Mesto (Slovenia)	Yes	Yes	
Tesla	All models (X, Y and 3)	Freemont CA USA	Yes	Yes	<i>adapted standard process (5)</i>
	Model 3 Model Y (mid 2020 ?)	Shanghai China	Yes	Yes	
Toyota	<i>Future BEV</i>	<i>China</i>	<i>Not observable yet</i>		
VW	E-Golf	Wolfsburg (Germany)	Yes	Yes	<i>adapted standard process (4)</i>
	E-Up	Bratislava (Slovakia)	Yes	Yes	
	Audi e-Tron	Brussels (Belgium)	Yes	Yes, mixed with ICEVs at launch	
	ID on MEB	Zwickau (Germany)	Yes	Yes	

Table 16: Observation of vehicles production system

3.4.2. Observation of the battery system value chains

Electrochemistry specialists (mainly Korean, Japanese and Chinese companies) have a strong technological offer, based on liquid lithium-ion technology, which encompasses cells, modules, battery management systems either as a single product or integrated in a complete

battery system. In a context where the EV scale-up is underway, one would expect these specialized companies to have captured the market for battery systems at the detriment of carmakers.

“The battery is a key component of electric mobility and an integral part of the vehicle architecture. The intelligence of the battery lies in a total package of hardware and software. Development, production and integration of complex battery systems are among the core competencies of Mercedes-Benz Cars”³³.

Even if not so boldly expressed, many carmakers share this strategy and the table below (and Annexes section 7 for details) clearly demonstrates the lopsidedness of the current situation with almost 80% of MAKE battery system.

DESIGN PERIMETER	MAKE, BUY, ALLY						
	Global Players Strategies – Incumbent companies and newcomers						
Battery system			MAKE Renault FCA	MAKE VW GM Ford		MAKE Honda	
Modules	MAKE BYD	BUY Renault (China) Nissan	BUY	Daimler BMW Tesla Honda (China) PSA Hyundai	ALLY Ford with VW in Europe	ALLY Honda with GM in USA	MAKE Toyota
Cells				BUY			ALLY

Table 17: Summary of Make, Buy Ally strategies for battery system perimeter

None of the car manufacturers in our sample, with the exception of BYD, which comes from the battery industry, manufacture cells. This is indeed where the complexity of electrochemistry lies and where the level of CAPEX (CAPital Expenditure) to become a major global player is very high, with a high risk of return on investment almost non-existent, as Bosch points out in its decision to abandon cell manufacturing³⁴. Consequently, as there is no

³³<https://media.daimler.com/marsMediaSite/en/instance/ko/Expansion-of-the-global-battery-production-network-Mercedes-Benz-Cars-lays-foundation-for-a-battery-factory-at-the-Untertuerkheim-site.xhtml?oid=42972795>

³⁴ <https://www.bosch-presse.de/pressportal/de/en/the-go-to-partner-for-electric-driving-boschs-electromobility-strategy-147008.html>

competitive advantage in producing them as stated by BMW³⁵, the vast majority of them have concluded contracts for the supply of cells (modules) from different suppliers, depending on where the vehicles are produced, which also allows them to reduce costs and technological risks as well as to obtain a volume guarantee. Consistently, most of them (intend to) deploy a battery system production network, as, for instance, BMW, Daimler, Tesla, Volkswagen, PSA group. In a way, we can consider that carmakers integrate a new sub-assembly line in the vehicle assembly workshop, namely the battery system assembly.

In addition to the historical cooperation between Tesla and Panasonic (although Tesla has opened the door to other suppliers in China), recent cooperation between Toyota (with Panasonic and BYD) and Honda (with GM in USA) or Ford (with VW in Europe) to enable them to catch up with the market are worth noting. Ford and VW also emphasize high synergy effects in terms of portfolio, volume and cost³⁶.

3.4.3. Observation of electric powertrain system value chains

“Drive systems have always been an area that has set the BMW Group apart from the competition. And exactly the same applies to electric drive systems” (same BMW reference as above).

And yet, unlike the ICE situation, incumbent carmakers are not the only one to master the production of electric motor or, more widely, electric powertrain and they are strongly challenged by incumbent global tier1 suppliers and Chinese newcomers. These latter come to the market with integrated offers, such as power control or complete electric drive systems, and directly compete with carmakers at the heart of their core knowledge.

Carmakers are less talkative about electric powertrains than about battery systems, but as a quick look at our observation demonstrates it (See table below), the asymmetry of the situation is even more glaring than for battery systems, since almost all global players produce the electric powertrain in-house³⁷.

³⁵ https://www.bmwgroup.com/content/bmw-group-websites/bmwgroup_com/en/innovation/technologies-and-mobility/electro-mobility.html

³⁶ <https://www.volkswagenag.com/en/news/stories/2019/07/together-with-ford-towards-the-future.html>

³⁷ Situation of FCA is still unknown

Design Perimeter	MAKE, BUY ALLY – Global players strategies, Incumbent companies and newcomers	
Electric Drive	MAKE	MAKE
E-motor	BMW, BYD, Daimler, GM, Honda (except North America), Hyundai,	ALLY (PSA, Toyota), Honda with GM in North America, Ford with VW in Europe
Transmission	Nissan, Renault, Tesla, VW, Ford USA	MAKE

Table 18: Summary of make, Buy, Ally strategies for electric propulsion system

We can also mention that some of them have concluded some alliances with suppliers to quickly catch-up with other competitors such as Toyota or PSA. In this specific case, PSA has recently started the production of electric powertrain in its own factory, located in the eastern region of France, which confirms the technical and economic interests of carmakers for the make strategy.

In our literature review, we asked ourselves if carmakers could recognize they can deal with the introduction of electrification through an architectural innovation. Henderson and Clark (1990, p. 14) describe very well what is the most ancient feature of the car dominant design “For example, the dominant design for the car encompassed not only the fact that it used a gasoline engine to provide motive force but also that it was connected to the wheels through a transmission and a drive train and was mounted on a frame rather than on axles”. Basically, OEMs, thanks to the superior modularity of electric powertrains compared to thermal equivalents, have integrated e-motor "everything equal besides" (which is much easier to say in this paper than it is to do on mass-produced vehicles!) and introduce electrification through an architectural innovation.

3.4.4. Summary of the role of the actors

Based on the different observations from our case studies, we summarize the role of the actors in the table below; as far as carmakers, these elements will be useful for the discussion section of this paper. However, we can already comment the situation of suppliers. Firstly, the high voltage battery business is the prerogative of electrochemistry specialists because of the high level of specialization of the offer (Teece, 1986) and, consequently, the huge amount of CAPEX which is required to become a global player. Secondly, regardless of the seniority of the suppliers in the automotive value chain, both old and new entrants, and even if they have a highly integrated product offering, such as high-voltage batteries or complete electric axle systems, they are, to date, limited to the supply of parts or components of electric drive train systems.

Actors	Carmakers	Tier 1 ...X
Incumbents	Global Players remain integrator Maintain control on vehicle design, value chain, maximize use of existing assets, (try to) maintain employment in historical plants (make electric powertrain, battery system)	Are not in the cell manufacturing business Use core assets and/ or develop new assets to •Expand business to electric drive trains •Develop new integration capacities (power-control, e-axle) •Catch up with electric drive trains
Newcomers	TESLA: Highly integrated BYD: Fully verticalized	Are integrated accordingly to a controlled contribution → commoditization of electric drive train components (for instance, cells or modules, inverter, converter)

Table 19: Summary of role of actors in the emerging electric vehicle (EV) value chain

3.5. Discussion

3.5.1. Observation of the current situation

This empirical study shows that the resilience of the automotive industry is, to date, confirmed. In this situation, which we consider to be the result of a *status quo* dynamic (see figure below), the hierarchical structure of the production value chain and the division of activity (“*who can do what*”), of course adapted to the new bill of materials associated to electrification technologies, are maintained similar to ICEVs’ situation, while a new repartition of revenue (“*who gets what*”) is induced by the variation of cost between an ICEV and a BEV drive train system. As far as value share is concerned, it is quite difficult to assess precisely what the situation is, but we assume that, all in all and thanks to their significant make perimeter, carmakers have slightly maintained their position.

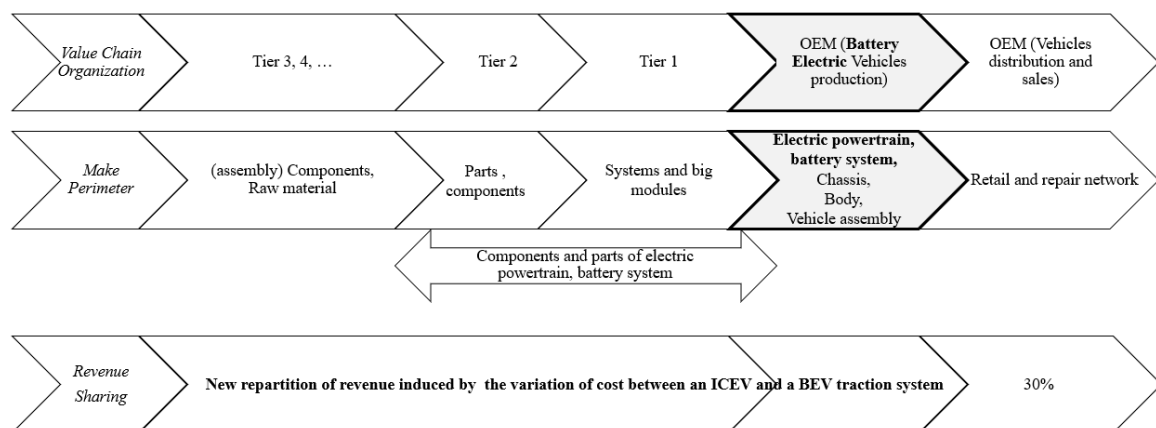


Figure 9: Illustration of the status quo dynamic

Despite a very high level of outsourcing of vehicle components (75% of the value of a vehicle, cf. 3.3.1.), car makers retain considerable power and centrality as system integrators for the whole vehicle design, because they "*know more than they make*" (Brusoni et al., 2001). As they have acquired a deep knowledge addressing many facets of electric drive trains and batteries, through a large number of patents related to EVs or cooperation agreements with expert companies, they have been able to reuse their core knowledge issued from the long-lasting dominant design and introduce electrification through an architectural innovation. The first example in support of our claim is the design of a battery system³⁸: this requires strong automotive design skills, such as, for example, weight optimization, cooling system design, electrical and thermal risk management, system integration, and they are in the best position to achieve this. Secondly, they also take advantage of modular design in design and manufacturing to offer scalability in performance, such as Tesla, which offers single or dual electric motor options, or Volkswagen, which points out that the new ID battery system will offer different range capabilities³⁹.

Lastly, they have been able to deploy, through electrification, the stringent regulations to reduce CO₂ and pollutants emission and still assert themselves as guarantors of the quality of the final product (Jacobides et al., 2006; Jacobides and MacDuffie, 2013). In doing so, they keep on exploiting the powerful business model that has supported this industry for almost a century and the deeply rooted cultural, social status that makes the automobile the preferred means of individual mobility (Wells and Nieuwenhuis, 2012).

The results of this study apply to all the global incumbent manufacturers observed, regardless of their country of origin, even if some of them, which started later in the development of battery electric vehicles, have entered into cooperation, with electric drive train specialists or other carmakers, to catch up with the market and benefit from synergies. As far as the two new entrants are concerned, BYD, which comes from the battery industry, is highly integrated on the axis of electric drive train systems. On its side, Tesla, recognized as a disruptive new player that has shifted the landscape of EV competition, has developed vertical integration strategies that Henry Ford would have no trouble recognizing as an early automotive

³⁸ We are aware that more detailed information on battery cell technology, its evolution, the logic of their integration into a complete battery system would be useful to elaborate on this statement. We understand this issue and have chosen not to address it in this paper.

³⁹ <https://www.volkswagenag.com/en/news/stories/2018/10/powerful-and-scalable-the-new-id-battery-system.html>

practice. As a result, in terms of value chain management, they have both followed in the footsteps of installed manufacturers.

Could new entrants disrupt this dynamic and gain significant market shares at the expense of incumbent car manufacturers thanks to an undeniable technological lead and/or a superior capacity for innovation? To date, they have gained market share, but the flow of BEVs from incumbent car manufacturers is on its way. The current economic crisis, already present at the end of 2019 and exacerbated by the COVID19 pandemic, could delay the ramp-up of BEVs and the observation of market share trends. However, given that new and incumbent players have decided to continue exploiting the powerful business model that has underpinned the automotive industry for more than a century, we hypothesize that incumbent automakers should achieve significant market shares for BEVs, at least in the mature Western and Japanese markets. The situation could probably be different in China where local carmakers already have very significant market shares for BEVs.

3.5.2. Description of the redistribution dynamic

An alternative theoretical framework, for proposing a different hypothesis for the future dynamics of the automotive industry, is based on the double helix model, introduced by Fine and Whitney (1996): "*the double helix illustrates the oscillation in supply chain structure between vertical / integral and horizontal / modular*" (Fine, 2009, p. 216).

While car manufacturers rely, in the short term, on their integration capabilities, a second stage of electrification could be envisaged, leading electric drive train specialists to manufacture high-voltage battery and electric propulsion systems instead of car manufacturers. We propose to name this dynamic *Redistribution* (see figure below) as it is a modification of the division of activity and distribution of value and income without destabilizing the industry's overall architecture as it is already the case for "big" modules (seats, cockpit, etc.).

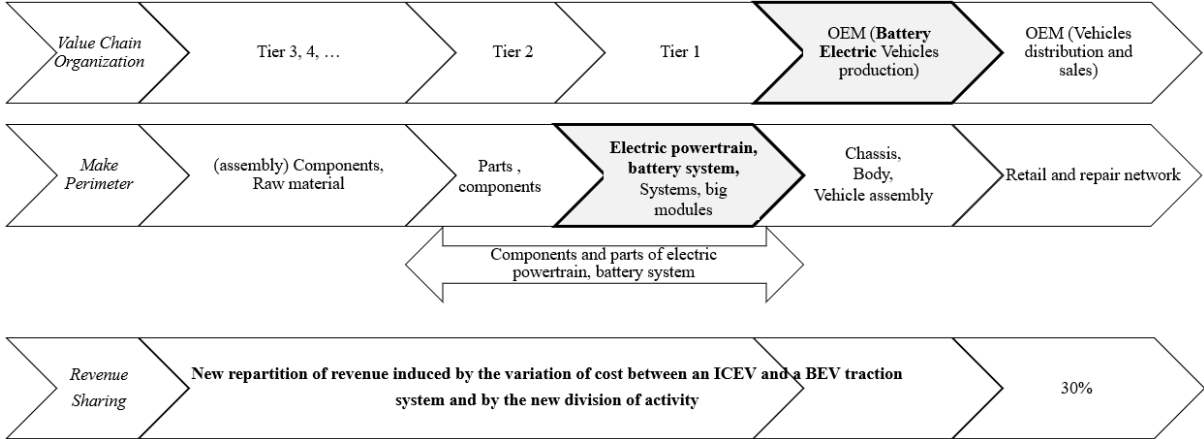


Figure 10: Illustration of the redistribution dynamic

Considering what bottlenecks are, in a situation of massive introduction of new technologies, the suppliers of the high voltage battery and of the electric powertrain systems could become the bottlenecks of their industry (Baldwin and Clark, 1997a; Iansiti and Levien, 2004) and drive value creation as well as value distribution their way (Jacobides, 2006; Jacobides and MacDuffie, 2013). Consequently, the activity perimeter of incumbent carmakers (“*who can do what*”) is significantly reduced, leading to an equally significant drop in their revenues (“*who gets what*”).

Three major arguments can be put forward in favor of this hypothesis: (1) the heavy and continuous trend towards de-verticalization and outsourcing of the automobile industry during the 20th century (Fourcade and Midler, 2005, 2004; Sako, 2003; Sako and Murray, 1999) which has led suppliers to produce between 70 and 75% of the value of a vehicle, (2) the superior modularity of electric drive trains (Christensen, 2011; Fuchs et al., 2013; Luccarelli et al., 2013) compared to thermal drive trains which favors an outsourcing, and (3) the ability of electric drive train specialists, thanks to greater series effects and specialization effect, to achieve production cost and quality levels that are much more efficient than those of manufacturers.

However, this movement is not yet visible for at least two reasons. Firstly, Fine’s work is inspired by the electronics industry, where the dynamics of change of the main components make it possible to reshape manufacturing processes at the speed of Moore's law. Fine (2009) does claim that the same phenomena are also occurring in highly capital-intensive sectors such as the automotive industry, but at a slower pace. As noted, the EV case is a good place to explore whether this slower pace is enough to alter the double helix hypothesis as applied to the automotive industry, i.e. that it is making a transition from highly integral to highly modular product architecture. Auto manufacturers certainly have strong incentives to incorporate EV changes in dominant design within their existing production systems. Confronted with the massive conversion of their internal combustion engine plants, the strategic choice to manufacture high-voltage battery systems or electric propulsion systems in-house makes it possible to cushion the impact of electrification on employment in a context where strategy of massive layoffs, combined with massive outsourcing of supplies, would be difficult to justify or achieve given social and political opposition.

Secondly, since the revival of BEVs some ten years ago, many improvements have been made to high-voltage battery systems, such as reducing the use of rare raw materials or increasing the capacity of stored energy, as in Renault's ZOE, where this capacity has been

doubled while maintaining the same mass and volume characteristics. However, all these improvements have been achieved within the dominant design of liquid lithium-ion technology, and the phenomenon of very frequent and exponential technology performance improvements that made Intel's success possible has not yet been observed in the case of high-voltage batteries. To date, the statement from Schlachter (2013) “*there is no Moore’s Law for battery improvement*” is still valid.

What could be the winning "Intel inside" strategy for suppliers of batteries (hardware) or engine management systems software to destabilize the automotive industry? Tier 1 suppliers of engine management systems, have successfully won acceptance from some OEMs of their software solution for ICEV power management, even though this function is thought to be at the heart of a car manufacturer's DNA. Given that a battery power management system has a major impact on the performance of an EV, whether in terms of range, maximum speed, charging speed or overall energy efficiency, we could imagine that the supplier of an “EV Operating System” whose performance is superior to the software developed by the OEMs could gain considerable leverage if their EV-OS became a de facto industry standard.

3.5.3. Description of the disruption dynamic

What the two previous dynamics have uncovered is that electrification of vehicles doesn’t appear to threaten the resilience of carmakers and their dominant role. But, both *status quo* and *redistribution* dynamics have a strong intrinsic limitation, since they simply do not consider one of the main lessons learned from past experiences with the introduction of EVs on the market: “*They revealed the necessity to enlarge the scope and radicalism of the innovation step to a deep redesign of the vehicle, a renewal of the classical business model and development of valuable mobility services targeted to specific customers*” (Midler and Beaume, 2010b, p. 148). Consequently, we introduce a *disruption* dynamic spurred by the development of new high-value and innovative mobility services, i.e. Mobility as a Service (MaaS), driving the emergence of a new business model supported by the development of innovative Connected, Autonomous, Shared, Electric vehicles (CASE).

We choose to illustrate the Mobility as a Service concept (MaaS)⁴⁰ through the example of a mobility operator managing a fleet of versatile (adapted to the requirement of customers) robotaxis, i.e. connected, electric and fully autonomous vehicles (which can also be shared).

⁴⁰ We present the MaaS scenario to illustrate what could be a future disruption affecting this industry. We are aware that, at this stage, CASE's innovations are not yet sufficiently developed, either separately or together, to give a clear vision of what the future of MaaS will be

The division of activity, along the full value chain, is completely shaken: carmakers, as other incumbent actors (car adapters, Tier X suppliers, ...), deliver some intermediate products to a mobility operator. Then, the mobility operator combines them with some complementary products / services (for instance a self-driving package) which may come from outside the automotive industry, to build the mobility offer for the final customer. Even more fundamentally vis-à-vis systemic disruption, the distribution and sale perimeters are not anymore driven by carmakers but by the mobility operator who provides the mobility offer to the final customer.

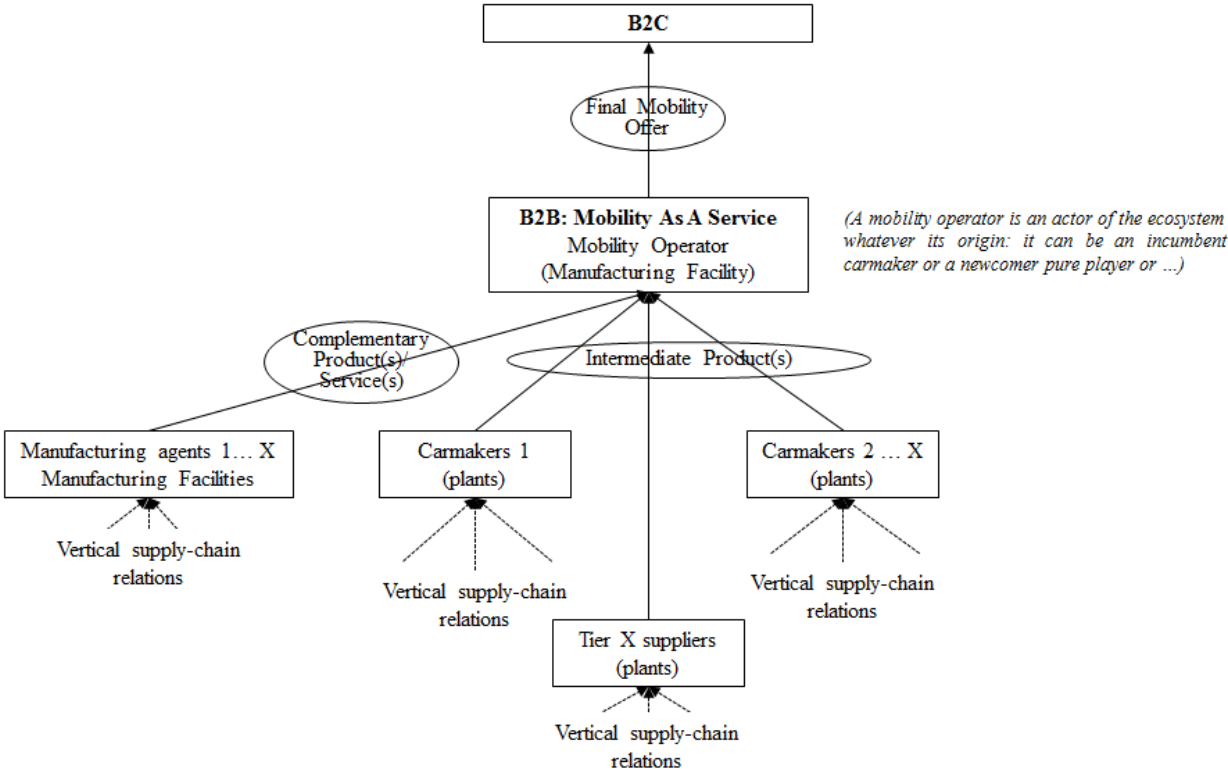


Figure 11: Illustration of the disruptive scenario in case of MaaS – management of a robotaxis fleet.

Adapted by the authors from the definition of an “Ecosystem-based Value System” (Jacobides et al., 2018).

This new division of activity, also drives a new distribution of revenue related to the production of the different subsets of the final product, namely the intermediate product(s) made by carmaker(s), Tier X suppliers and the complementary product(s) made by the complementing agent(s); but, and even more important, it also impacts the distribution and sales sides of the industry. The multiple assembly operations between intermediate product(s) and the complementary product(s) / service(s) to provide the end customer with the mobility offer pave the way to recurrent revenues for actors producing the mobility service, namely the mobility operators.

This hypothesis is not a pure act of imagination, insofar as the management of robotaxis fleets is very much what two powerful mobility operators, Waymo (subsidiary of Alphabet-Google) and Cruise (subsidiary of GM and Honda) are setting up. To do so, they have both set up their own manufacturing capabilities in Detroit, where they transform mass-produced vehicles (Chevrolet Bolt for Cruise, Chrysler Pacific or JLR I-Pace for Waymo) into robotaxis by integrating all the autonomous driving hardware and software they have developed and validated.

As for versatile robotaxis, many carmakers (Daimler, Toyota, Renault, NEVS) are already proposing concepts of vehicles while Tier 1 suppliers (Continental, ZF, Panasonic) are proposing concepts of electrified, autonomous and connected platforms (sometimes named as skateboards⁴¹). The on-demand marriage between such a skateboard and a transportation cell (of persons, goods, services, etc.), realized by a mobility operator in its own hubs would have a much bigger impact on the production system of vehicles than the current production of BEVs as we have observed it.

3.6. Conclusion and future research issues

We will now take stock of the assertion about the resilience of the automotive industry, specifically in the case of electrification of vehicles (Jacobides et al., 2006; Jacobides and MacDuffie, 2013), to consider the extent to which it merits reconsideration.

Our empirical study, the first to be carried out on such a scale and scope, shows that, to date, the resilience of the industry has been confirmed. We view the current situation as the result of a *status quo* dynamic that has three main advantages for incumbent carmakers: (1) mitigating the risks and minimizing the costs of the transition to electrification; (2) absorption of electrification technologies in the dominant design of the product and industry architecture; and (3) enabling the longest possible utilization of existing manufacturing assets and thus their share of activity ("*who can do what*") in the industry.

This observation of stability confirms, to date, the arguments from the strategy literature about how and why automotive incumbents can persist in a central role in their industry's architecture. But what can we say about the future? We present two different hypotheses on the future dynamics of this industry. By applying the first one, based upon the *double helix* model (Fine and Whitney, 1996; Fine, 2009), we ask whether the shift in dominant design

⁴¹ <https://www.forbes.com/sites/alanohnsman/2020/05/20/a-bottom-up-approach-to-cheaper-next-gen-electric-vehicles/#41dcab3f4267>

towards electric drive trains, a more modular product architecture than internal combustion engines, could shift power to the specialized suppliers who produce high voltage battery and electric propulsion systems (hardware and software), to the detriment of incumbent automakers. Within the persistent hierarchical industry architecture of the EV value chain, could the shift in dominant design create a *redistribution* dynamic in which the activity perimeter of incumbent carmakers (“*who can do what*”) is significantly reduced, leading to an equally significant drop in their revenues (“*who gets what*”). We speculate about whether power management system software (a so-called EV-OS) that becomes a *de facto* standard could drive such a *redistribution* dynamic, noting the mixed evidence in the “make” vs. “buy” trends for this software at the present time. Nonetheless, we conclude that there is no visible sign on the horizon of a “battery-maker inside” strategy that would, for example, allow a battery maker to take control of the EV value chain.

Overall, therefore, we conclude that the electrification of vehicles alone doesn’t appear to threaten the resilience of automakers and their dominant role in the EV value chain⁴². Consequently, we wonder whether the combination of innovations affecting mobility, including Connected, Autonomous, Shared, Electric vehicles (CASE), moving towards an ecosystem of Mobility-as-a-Service (MaaS), could pose such a threat. This broadens the field of analysis to other economic, social, and political factors which, according in a cascading, systemic effect, could combine with the current technological breakthrough of electrification to cause a more radical destabilization of the industry.

We took the example of a mobility operator, managing a fleet of versatile, autonomous electric robotaxis, to represent an example of MaaS. This, in our view, could lead to a completely different distribution of activity and value, largely in favor of the new player, because this service provider would almost fully capture the relationship with the customer and all the benefits that go with it. This is a perfect example of a *disruption* dynamic leading to a strong and deep destabilization of the automotive industry because it could reduce car manufacturers to a role of commodity supplier supplying to the specifications of a mobility operator that would then occupy the system integrator role at the top of the hierarchical industry architecture. Or, in an evolution towards a mobility ecosystem, we could see the dynamics of

⁴² We take note (mid-2020) of the extraordinary increase in Tesla’s recent market valuations. We don’t see Tesla’s successes as evidence that new outside entrants to the EV market are going to displace automotive incumbents – rather that Tesla, impressively, is joining the ranks of auto OEMs as a strong competitor that has mastered all the capabilities (R&D, product development, supply chain management, manufacturing, sales and distribution) required.

platform-based competition that are now so familiar from digital exchange platforms. The examples of Waymo and Cruise who are attempting to launch just such mobility operator activity with fleets of autonomous, electric robotaxis show that this hypothesis is not just an act of the imagination⁴³.

In summary, we set out to identify theoretical frameworks that could help identify and analyze the potential reinforcement or destabilization of the architecture of the automotive industry. Our empirical analysis confirmed that the initial strategic analysis, positing a persistent role for automotive OEM incumbents as system integrators and validators of quality and safety, is still relevant. Put differently, electrification is a technological innovation that changes the dominant design (aka product architecture) and yet can be absorbed effectively by industry incumbents.

We also conclude that combining the CASE set of innovations, each of which have different social and economic as well as technological ramifications, could lead to much more disruption of the industry architecture and the dynamics of competition, precisely because the combination increases the systemic multi-dimensionality of disruption. Using the example of a mobility operator of a fleet of electric and autonomous robotaxis, we hypothesize that a sociotechnical transition framework is more valuable to understand the potential for more disruptive systemic innovation in a mobility ecosystem (or systems). We are currently applying such a framework in a research program involving global benchmarking on mobility service innovations, broadly construed, to evaluate 1) the performance of the innovation with respect to multiple economic and non-economic metrics; 2) the configuration of ecosystem actors involved in the innovation; and 3) the extent of the collective learning gained as these actors work together to realize the innovation. We hope that the research will shed light on the questions raised above, namely “what are the consequences of a change in the dominant design of mobility services?”

Lastly, on the managerial and socio-economic level, the empirical study of the electric vehicle value chain shows how automakers have used the existing dominant design of a vehicle

⁴³ Tesla, of course, via the pronouncements of CEO Elon Musk, promises to be an innovator in all of the CASE innovations, including Level 5 autonomy and the potential for peer-to-peer car-sharing by Tesla owners as a way to gain greater value from an expensive and often little-used asset. Whether Musk’s predictions are found to be credible and influential has varied over time. The extraordinary rise in Tesla’s valuations in the first half of 2020 show that, at this moment, the market is believing that Tesla will lead the way in systemic disruption of the mobility ecosystem. While admiring Tesla’s accomplishments, we are doubtful that it would be able to maintain a monopoly – or even dominant – position in the variety of mobility ecosystems found around the world – but we do expect it to be an important player and potential acquisition target for the foreseeable future

to integrate, by the means of electrification, an architectural innovation that many assumed would create systemic disruption. Automakers continue to demonstrate: their capabilities at designing and coordinating the production of integral architecture vehicles (Fujimoto, 2017 ; MacDuffie, 2013); their design agility linked to the continuous integration of evolving component technologies (Wells and Nieuwenhuis, 2012); and the persistence of their operational routines (Zirpoli and Camuffo, 2009). An overarching enabler of automakers' ongoing dominant role is their ability (at least to date) to exploit and sustain the powerful business model – amply supported by social, economic, and institutional embeddedness -- that has supported this industry for over a century.

This research has some inherent limitations in the scope of the empirical study. The real surge in the numbers of EVs produced by global players will take place in the next 5-10 years; the next stage of innovations both in electrification but also the rest of CASE (Connected, Autonomous, Shared) also lies in the future and is not yet fully observable; and, with the exception of Tesla, we haven't yet seen the full development of new entrants – whether in BEVs or electric autonomous robotaxis – that will display the full potential of systemic disruption of the mobility ecosystem. Thus, we will need to return to the opening question of this paper in five or ten years to be able to provide a more definitive analysis and set of conclusions – and we plan to do so!

3.7. Annexes

3.7.1. BMW study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
I3	Leipzig (Germany)	No	No	https://www.bmwgroup-plants.com/en/produktion/bmw-i.html
Mini Electric	Oxford (England)	Yes	Yes	https://www.bmwgroup-plants.com/en.html

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	Samsung SDI, CATL	https://www.bmwgroup.com/.../bmwgroup_com/ir/downloads/en/2019/tech-workshop20191120/191120_BMW_Group_TechWS_Battery_Cell_Technology_final.pdf https://www.press.bmwgroup.com/global/article/detail/T0302864EN/bmw-group-forges-ahead-with-e-mobility-and-secures-long-term-battery-cell-needs-%E2%80%93-total-order-volume-of-more-than-10-billion-euros-awarded
Module	Make		
Battery system	Make		

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make	highly integrated electric drive component Landshut plant (Germany)	https://www.bmwgroup.com/.../bmwgroup_com/ir/downloads/en/2019/gb/190321_22_BPK&AIK_Rahmenprogramm.pdf https://www.bmwgroup.com/en/company/bmw-group-news/artikel/Interview-Juraschek.html https://www.bmwgroup-plants.com/landshut/en/our-plant.html (read plant brochure)
transmission	Make		
Power control	?		

3.7.2. BYD Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Make		http://www.byd.com/en/InnovationByd.html (select automotive innovation)
Module	Make		
Battery system	Make		

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make		http://www.byd.com/en/InnovationByd.html (select automotive innovation)
transmission	Make		
Power control	Make		

3.7.3. Daimler Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
Smart ForFour ED	Novo Mesto Slovenia	Yes	Yes	https://group.renault.com/en/our-company/locations/novo-mesto-revoz-plant/
EQC (X)	Bremen, Rastatt, Sindelfingen Germany Hambach France Tuscaloosa USA	Yes	Yes	https://www.daimler.com/investors/reports-news/financial-news/20190507-eqc.html https://www.daimler.com/innovation/case/connectivity/eq-locations.html

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	SK Innovation, LG Chem, CATL (Reuters)	https://www.daimler.com/innovation/case/electric/battery-cells.html https://www.reuters.com/article/us-daimler-batteries/daimler-to-buy-23-billion-of-battery-cells-for-electric-car-drive-idUSKBN10A00G
Module	Make		
Battery system	Make		

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make	Electronic powertrain	https://www.daimler.com/career/about-us/locations/location-detail-page-5048.html
transmission	Make	(eATS)	https://www.greencarcongress.com/2019/12/201912123-mbu.html
Power control	?	Untertürkheim plant (Germany)	

3.7.4. FCA Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
New 500 BEV	Mirafiori (Italy)	Yes	Yes	https://www.fcagroup.com/enUS/media_center/fca_press_release/2018/november/Pages/meeting_between_FCA_and_trade_unions_in_turin.aspx
New Jeep BEV	Detroit (USA)	Yes	Yes	https://www.fcagroup.com/en-us/media_center/fca_press_release/2019/february/pages/fca_to_expand_production_capacity_in_michigan.aspx

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy		http://www.media.fcaemea.com/em-en/corporate-communications/press/new-battery-hub-at-mirafiori-speeds-fca-electric-product-plans
Module	Make or Buy		
Battery system	Make		

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make	In house ????	https://careers.fcagroup.com/job/10193895/electric-motor-design-engineer-auburn-hills-mi/
transmission	Make		
Power control	?		

3.7.5. Ford Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
Next generation BEV	Flat Rock Assembly plant (Michigan USA)	Yes	Yes	
All electric performance SUV	Cuautitlan (Mexico)	Yes	Yes	

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	LG Chem in USA (1)	(1) https://www.evspecifications.com/en/news/01402da (2) https://media.ford.com/content/fordmedia/fna/us/en/news/2020/06/10/ford-volkswagen-sign-agreements-for-joint-projects.html
Module	Make	USA (1)	
Module	Ally	EU (2)	
Battery system	Make	USA (1)	
Battery system	Ally	EU (2)	

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make		
transmission	Make		
Power control	Buy	?	

3.7.6. GM Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
Bolt / New BEV	Orion Assembly plant (Michigan USA)	Yes	Yes	
Electric Cadillac				
All electric trucks and SUV	Detroit-Hamtramck (Michigan USA)	Yes	Yes	https://plants.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2020/jan/0127-dham.html

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	LG CHEM (USA), CATL (China, autonews)	http://autonews.gasgoo.com/new_energy/70015117.html https://media.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2019/dec/1205-lgchem.html
Module	Make		https://www.gm.com/our-stories/commitment/ev-battery-modular-technology.html
Battery system	Make		

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make		https://www.gm.com/our-stories/commitment/ev-battery-modular-technology.html
transmission	Make		
Power control	?		

3.7.7. Honda Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	CATL (China)	https://plants.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2018/jun/0607-gm-honda-battery-cell.html https://global.honda/newsroom/news/2020/c200403eng.html
Module	Ally	GM (North America)	
	Make	China	
Battery system	Ally	GM (North America)	
	Make	China	

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make		
transmission	Make		
Power control	?		

3.7.8. Hyundai Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
Hyundai Ioniq electric	Ulsan (Korea)	Y	Y mixed with ICEVs and other electrified versions	https://en.wikipedia.org/wiki/Hyundai_Ioniq
Hyundai Kona Electric	Ulsan (Korea) Nošovice (Czech Republic)			https://insideevs.com/news/401471/hyundai-kona-electric-production-czechia/
Kia Soul EV	Gwangju (Korea)			https://press.kia.com/eu/en/home/media-resouces/press-releases/2014/14_06_12_37---start-of-production-soul-ev-exports.html
Kia E-Niro	Hwaseong (Korea)			https://en.wikipedia.org/wiki/Kia_Niro

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	SK Innovation, LG CHEM	https://english.nna.jp/articles/3568
Module	Make		https://www.reuters.com/article/us-autos-batteries-factbox/factbox-the-worlds-biggest-electric-vehicle-battery-makers-idUSKBN1Y02JG
Battery system	Make		

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make		https://press.kia.com/eu/en/home/media-resouces/press-releases/2020/Plan_S.html
transmission	Make		
Power control	?		

3.7.9. Nissan Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
New LEAF	Oppama Japan Sunderland GB Smyrna (TE USA)	Y	Y mixed with ICEVs	https://uk.nissannews.com/en-GB/releases/release-426204014-production-of-new-nissan-leaf-to-begin-in-us-and-uk
E-NV 200	Barcelona Spain			https://reports.nissan-global.com/EN/?p=15206

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	CATL	https://www.envision-aesc.com/en/aboutus.html
Module	Buy	CATL	http://autonews.gasgoo.com/new_energy/70014684.html
Battery system	Buy	Envision (used to be AESC)	
	Make		

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make		
transmission	Make		
Power control	?		

3.7.10. PSA Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
e-208	Trnava Slovakia	Y	Y mixed with ICEVs version Common Modular Platform	https://www.fsok.sk/actualites/n/news/lusine-automobile-de-groupe-psa-slovakia-a-trnava-lance-la-production-dune-nouvelle-generation-du.html https://media.groupe-psa.com/en/cmp-new-modular-multi-energy-platform-groupe-psa?idotok=6d24cbbb230
DS3 crossback New Opel SUV	Poissy France			https://media.groupe-psa.com/fr/1%E2%80%99usine-de-poissy-va-produire-un-v%C3%A9hicule-additionnel
Electric version Opel Astra	Russelsheim Germany		Y mixed with ICEVs version EMP2 platform (electrified version)	EMP2 platform, https://media.groupe-psa.com/en/next-generation-opel-astra-will-be-built-russelsheim-0

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	LG Chem, CATL, Future: ACC (Automotive Cell Company)	https://europe.autonews.com/automakers/psa-will-produce-batteries-slovakia-spain https://www.usinenouvelle.com/article/apres-la-slovaquie-psa-assemblera-ses-batteries-a-vigo-et-ailleurs.N854900
Module	Make		https://www.saftbatteries.com/press-releases/launch-pilot-plant-manufacture-european-batteries-electric-vehicles
Battery system	Make		

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Ally	JV Nidec Leroy-Somer	https://media.groupe-psa.com/en/tr%C3%A9mery-plant-france%E2%80%99s-grand-est-region-forefront-groupe-psa%E2%80%99s-energy-transition
transmission	Make	Assembly in Tremery plant France	
Power control	?		

3.7.11. Renault Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
Twizy	Busan Korea	N	N	Quadricycle with a fully dedicated process (tubular body assembled by welding beads + anti corrosion protection, final assembly, all body trim parts are in plastic)
Kangoo 2 ZE	Maubeuge France	Y	Y mixed with ICEVs versions	Kangoo ZE – dossier de presse 03 octobre 2011
ZOE	Flins France	Y	Y mixed with Clio IV (now stopped) and Nissan Micra	Renault ZOE – dossier de presse 26 février 2013
Renault City K-ZE	China	Y	Y	Own information from the authors
Twingo ZE	Novo Mesto Slovenia	Y	Y mixed with ICEVs versions	https://fr.media.groupe.renault.com/actualites/nouvelle-renault-twingo-z-e-plus-que-jamais-la-reine-de-la-ville-1054-e3532.html (access to press kit)

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	CATL, LG CHEM	http://autonews.gasgoo.com/new_energy/70014684.html https://www.large.net/news/73u43nm.html
Module	Buy		
Battery system	Make		
	Buy	Lishen (China)	Own information from the authors

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make	Electric Drive train Cleon plant France	https://group.renault.com/en/our-company/locations/cleon-plant-2/
transmission	Make		
Power control	Make assembly		

3.7.12. Tesla Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
All models	Freemont CA USA	Y	Y	
Model 3 Model Y (mid 2020 ?)	Shanghai China	Y	Y	https://www.theguardian.com/technology/2019/dec/30/tesla-delivers-first-china-made-cars-from-shanghai-factory https://www.tesla.com/presskit#gigafactory

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	Panasonic, LG Chem and CATL (Reuters)	https://www.tesla.com/presskit?redirect=no#gigafactory https://www.reuters.com/article/us-tesla-catl-battery-electric/chinas-catl-signs-battery-supply-agreement-with-tesla-idUSKBN1ZX02D
Module	Make	MegaFactory (Nevada USA)	
Battery system	Make	for Model3 Gigafactory China	

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make	MegaFactory (Nevada USA)	https://www.tesla.com/presskit?redirect=no#gigafactory
transmission	Make	for Model3	
Power control	?	Gigafactory China	

3.7.13. Toyota Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
BEV	China			https://global.toyota/en/newsroom/corporate/28419929.html?_ga=2.255734984.139220130.1586790836-620925945.1586790836

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Ally	CATL, Panasonic, BYD	https://global.toyota/en/newsroom/corporate/28913488.html?_ga=2.103398848.1971602286.1583074634-1551232268.1583074634
Module	Ally		https://global.toyota/en/newsroom/corporate/28913709.html?_ga=2.128702156.1971602286.1583074634-1551232268.1583074634
Battery system	Ally		https://global.toyota/en/newsroom/corporate/31477926.html?_ga=2.235991489.1971602286.1583074634-1551232268.1583074634

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Ally	BYD	https://global.toyota/en/newsroom/corporate/30977776.html?_ga=2.131340623.1971602286.1583074634-1551232268.1583074634
transmission	Make		https://global.toyota/en/newsroom/corporate/28913709.html?_ga=2.128702156.1971602286.1583074634-1551232268.1583074634
Power control	Ally	DENSO	https://global.toyota/en/newsroom/corporate/28913709.html?_ga=2.128702156.1971602286.1583074634-1551232268.1583074634

3.7.14. VW Study case

Battery Electric Vehicle production system				
Vehicle	Assembly plant	Use of standard assembly process	Process modification according to ICEV dominant design	Sources
E-Golf	Wolfsburg (Germany)	Y	Y mixed with ICEVs	
E-Up	Bratislava (Slovakia)	Y	Y mixed with ICEVs	
Audi e-Tron	Brussels (Belgium)	Y	Y mixed with ICEVs at launch	https://www.volkswagenag.com/en/news/stories/2017/06/e-factory.html
ID on MEB	Zwickau (Germany)	Y	Y	https://www.volkswagenag.com/en/news/stories/2019/04/charged-up.html

Battery system value chain			
	Strategy	Supplier(s)	Sources
Cell	Buy	CATL, LG Chem, Samsung SDI, SK Innovation, NorthVolt	https://www.volkswagenag.com/en/news/2018/11/volkswagen-nominates-further-battery-cell-supplier.html https://www.volkswagenag.com/en/news/2019/06/VW_Group_Northvolt.html
Module	Make		https://www.volkswagenag.com/en/group/e-mobility.html
Battery system	Make		

Electric drivetrain value chain			
	Strategy	Supplier(s)	Sources
e-motor	Make	Győr plant Hungaria	https://www.volkswagenag.com/en/news/stories/2018/09/electric-motor-now-in-series-production-in-gyoer.html https://www.volkswagen-newsroom.com/en/stories/from-springs-and-dampers-to-rotors-and-stators-5177
transmission	Make		
Power control	?		

4. ESSAY 2: Automobile industry, towards an electric autonomous mobility service industry? A sociotechnical transition-based approach

Abstract

Due to many technological and non-technological factors, both internal and external to the industry, the automotive sector is currently undergoing a deep transition towards Connected, Autonomous, Shared and Electric mobility.

Is this transition oriented toward a single new dominant design of mobility services? Will the resilience of the architecture of the automotive industry be sufficient to absorb the effects of the transition to mobility services?

Building on the Socio-Technical Transition paradigm, the Multi-Level Perspective framework and a theoretical characterization of mobility services, we explore these two questions through an empirical study based on 10 mobility emblematic initiatives in the USA, Europe and China. Theoretically, this paper opens up a new space of application of the Socio-Technical Transition paradigm to ongoing transformation and proposes a Multi-Level Perspective based framework to study the automotive sector transition. In addition, this paper suggests that linking Multi-Level Perspective and project learning field could help a better understanding of the roles of the different actors involved in a transition.

On the managerial and socioeconomic level, by characterizing three different ideal types: *the mobility service added to product ideal type*, *the robotaxi ideal type* and *the territorialized open mobility platform ideal type*, it demonstrates that there is no « one best way » in vehicle-based mobility services. It also questions the resilience of the automotive industry by describing the possible roles of carmakers, mobility operators and public authorities in shaping its future architecture.

Keywords: industry architecture, sociotechnical transition, multi-level perspective, electromobility, automobile sector, public authority

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4.1. Introduction

Due to societal and environmental constraints imposed by public authorities, the evolution of transport demand towards mobility services and, last but not least, the massive introduction of communication and automation technologies in the driving experience, the automotive industry is currently undergoing a major transition. As many technological and non-technological factors, both internal and external to a strongly resilient industry are involved, we state that the use of the Socio Technical Transition (STT) paradigm and the Multi-Level Perspective (MLP) framework is relevant to study this transition. It enables to widen the scope of study and leads to explore, beyond the current resilience of the automotive industry, the potential conditions for its future destabilization.

While the study of this transition is addressed by many researchers, public and professional reports, we point out two critical remaining questions. The first one is the potential trajectory targets of such transition. *“Are these automobile mobility trajectories oriented toward a single dominant design of mobility services?” “Is there a « one best way » in vehicle-based mobility services?”* The second one is the potential impact of such transition on the architecture of the auto industry. Some recent research has demonstrated the capacity of this sector in absorbing the major change from Internal Combustion Engine (ICE) to electric powertrain without disrupting the existing industrial architecture. We therefore ask ourselves: *“Will the resilience of the architecture of the automotive industry be sufficient to absorb the effects of the transition to mobility services?”*

To answer these questions, we conduct an empirical study based on the analysis of ten innovative mobility experiences in the USA, Europe and China. We use an analytical framework built on a Multi-Level Perspective approach (MLP) and make two hypotheses about the ongoing transition. Firstly, social actors that concretely activate the "external" and "internal" forces at work in this transition are (1) the carmakers, as incumbent major actors in the dynamics of the sector, (2) the mobility operators, (3) the Tech firms that provide the technologies supporting the new mobility services, (4) the public authorities, who regulate and prescribe transport, and (5) major construction companies that often finance and operate major infrastructure works in Public Private Partnerships. Secondly, as far as the trajectory of the specific dynamics of automobile industry architecture is concerned, we hypothesize that it could evolve from the traditional B2C or B2B (fleet) business model for production and sale of vehicles to a new model sale of mobility services.

To characterize the changes induced by this transition of the automotive industry, we introduce a specific framework based on the definition of the design space of an innovative mobility service (Mobility as a Service, MaaS). It enables to describe a mobility initiative, in all its characteristics necessary for its operation, as well as to measure the direction and intensity of the changes that its implementation entails

Therefore, this paper is organized as follows: in Section 1, we introduce the factors contributing to the ongoing transition. In Section 2, we summarize the main arguments supporting the assertion of the resilience of the automotive industry, and then discuss the relevance of the STT paradigm and MLP framework in answering our research question. Accordingly, section 3 presents the analytical frameworks of the empirical study, based upon STT paradigm and MLP framework as well as a design space for MaaS initiatives. Section 4 presents the design of our research while Section 5 introduces the ten innovative mobility service initiatives, focusing on the role of the key actors we identified. On the basis of this empirical evidence, we develop, in section 6, three ideal types that the ongoing transition in the automotive industry could produce. We analyze the role of car manufacturers, mobility operators and public authorities in their development. The conclusion section draws the implications of these findings for both academic and managerial purposes and proposes perspectives for future researches.

This paper, which addresses one of the key industrial transitions of the beginning of the twenty-first century, makes four main contributions:

1. It shows how the STT paradigm and the MLP analytical framework can be applied to analyze emerging transitions and how they allow apprehending their current trajectories. It articulates the theoretical frameworks of STT and the more recent frameworks of project-based organizational learning management. This allows for a more precise apprehension of the capacities for dynamic evolution of the transitions that the initiatives studied have revealed.
2. This implementation of the STT paradigm makes it possible to broaden the field of study and to question the influence of multiple factors, other than purely technological ones, on the future of the architecture of the automobile industry. As such, it makes it possible to complete and extend the stream of research, about the resilience of the automobile industry, proposed by some authors (Jacobides et al., 2016; Jacobides and MacDuffie, 2013; MacDuffie and Fujimoto, 2010; Wells and Nieuwenhuis, 2012).

3. Based on the cases studied, we characterize three different MaaS ideal types (Weber, 1978) to which the current transition could lead (i) *mobility service added to product*, (ii) *robotaxi* and (iii) *territorialized open mobility platform* and so demonstrates that there is no “*one best way*” in vehicle-based mobility services.
4. We characterize the new ecosystem architectures behind those three different ideal types focusing on the roles of carmakers, mobility operators and public authorities. Therefore, we point out some conditions which could pave the way to a disruption of the long-lasting architecture of the automotive industry.

These results should be of interest to operational actors in the public and private domains and contribute to the numerous current academic works on the transition of the automotive industry.

Our research is part of a cooperative research program conducted at the Management Research Center / I³ of Ecole Polytechnique and, is supported by the Institute for Sustainable Mobility⁴⁴, created by the Renault foundation, as well as the Cai Yuanpei research program⁴⁵.

4.2. The automotive industry, on the move towards an industry of connected, autonomous, shared and electrified mobility services?

Several authors have argued that the automotive industry is particularly resilient and that carmakers have the means to keep control of the industry (Jacobides et al., 2016; Jacobides and MacDuffie, 2013; MacDuffie and Fujimoto, 2010; Wells and Nieuwenhuis, 2012). The prediction that vehicle electrification will not change this sustainable situation (Jacobides et al., 2006; Jacobides and MacDuffie, 2013) is coming true because OEMs have relied on their strong and ancient core technology (ICE) to integrate the technological components of electrification all things being equal. However, we argue that electrification is the first step in the transition underway in the automotive industry and that other factors, technological and also environmental, legal, societal and economic, will influence its evolution. This assertion is based on numerous academic works, reports from public bodies or authorities and consulting firms, which all converge on the orientation and radicality of the ongoing transformation.

⁴⁴ Institute for Sustainable Mobility is a multidisciplinary platform dedicated to research on the future of transport and mobility solutions <https://group.renault.com/en/news-on-air/news/sustainable-mobility-institute-5-years-in-5-questions-2/>

⁴⁵ Cai Yuanpei is a program supporting cooperative research between academic teams from France and China.

The “Smart Mobility and services, expert group report”, made at the request of the European Commission⁴⁶, summarizes that the automotive mobility is on the verge of profound changes. Under the influence of multiple factors, there is a rebalancing of individual car mobility in favor of more efficient and sustainable collective or shared mobility. All these moves are facilitated by *technological breakthroughs* that cover a wide area, many of which are outside the automotive industry core competencies. Far beyond the electrification technologies, it encompasses connectivity, autonomous driving (AD) as well as digital technologies (AI, big data, etc.).

In line with the need to act against global warming and to reduce the level of air pollution, environmental regulations are a crucial driver of this transition. The International Energy Agency⁴⁷ summarizes that the regulations currently adopted by the major automotive markets encompass the deployment of vehicle-level requirements, such as zero-emission vehicle mandates (12% by 2020 in China), maximum CO₂ and pollutant emission thresholds (in Europe, 95 gCO₂ /km in 2021) or fuel economy standards; they also include tax incentives for vehicle purchasers and subsidies for the manufacturers. While public regulations, at national or supranational level, are well identified as a force acting on the automotive industry, it is also necessary to consider actions to regulate urban and peri-urban transport at local level. As commuting causes a high level of pollution or congestion, local authorities have already taken decisions such as congestion pricing (London, Stockholm, Milan for some examples), restricting or even banning the circulation of ICEVs (Burch and Gilchrist, 2018) and/or granting advantages to owners of EVs in urban centers (Oslo or Beijing for instance). It confirms that *public regulations* have a strong influence on the future of the automotive industry, and also underlines the *growing role of local authorities*; the latter will become even more important under the impact of galloping urbanization since, according to the United Nations⁷, 68% of the population is expected to live in cities in 2050, up from 55% in 2018, that will add 2.5 billion to the world’s urban population by 2050.

Urbanization is also contributing to changes in the relationship of people to the car: instead of a personal, flexible and accessible means of transport, the car is increasingly seen as a useless object that causes more trouble than it provides satisfaction. The relationship to the car is also influenced by *societal and new consumer trends*; if the need of mobility is still there, it is

⁴⁶ EUR KI-02-17-940-EN-N Smart Mobility and services - European Commission - europa.eu

⁴⁷ Global EV Outlook 2019 - <https://www.iea.org/reports/global-ev-outlook-2019>

strongly impacted by the evolution of consumer attitudes from ownership of goods to the use of a service⁴⁸.

These new societal and consumer trends facilitate the rise of mobility services and drive an *evolution of the systems of actors* involved in automotive mobility. The leading ride hailing companies were created at the beginning of the previous decade (e.g. Uber in 2009, Lyft and Didi Chuxing in 2012), and they have since been joined by numerous competitors. McKinsey⁴⁹ points out that many newcomers, not only carmakers, equipment manufacturers, but also technology players and start-ups, will launch fleets between 2019 and 2022. Cruise (a subsidiary of GM and Honda) and Waymo (a subsidiary of Alphabet-Google), two among these new competitors, have the ambition and the means, both technological and financial, to develop autonomous robotaxis services on a global scale. The simultaneous convergence of four major technologies, i.e. electrification, connectivity, autonomous driving and digitalization, makes it possible to improve the profitability of the service by eliminating the highest recurring cost item, that of driver remuneration. These newcomers have a clear ambition, explicitly summed up by D.Ammann, the CEO of Cruise when he states that the aim of the company is to replace the car by a safer and more affordable transportation system⁵⁰.

On the automotive industry side, while some car manufacturers are positioning themselves as suppliers of vehicles for mobility operators such as Fiat Chrysler Automobiles (FCA) and Jaguar Land-Rover (JLR) with Waymo, others are taking the plunge and positioning themselves resolutely as mobility service operators. This drives a *shift of the manufacturers' product and market strategies* from sales of vehicles (and some added services) to sales of mobility services. This recent and dramatic change in the strategy of car manufacturers is manifested in numerous different ways:

- *operating mobility services*, such as BMW, Daimler, Ford, GM, Hyundai/Kia, Nissan, PSA and Renault who already operate electric vehicle sharing services,
- *Strategic orientations* as A.Toyoda, President of Toyota announced at CES 2018 that "*It's my goal to transition Toyota from an automobile company to a mobility company*",

⁴⁸ <https://www.rolandberger.com/en/Media/Autonomous-driving-and-alternative-mobility-services-compel-the-automotive-indus.html>

⁴⁹ <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/change-vehicles-how-robo-taxis-and-shuttles-will-reinvent-mobility>

⁵⁰ <https://medium.com/cruise/we-need-to-move-beyond-the-car-ad065eb800e3>

- *Massive investments* when Volkswagen announced that it will invest more than 34 billion Euros by 2022 to develop electric mobility, autonomous driving, digital connectivity and new mobility services,
- *Alliances* as, in June 2019, the Renault group and Nissan announced an exclusive agreement with Waymo to explore driverless mobility services,
- *Reorganization* with Daimler, in 2019, by creating three legally independent joint stock companies to operate its main activities: (1) vehicles and vans, (2) trucks and finally (3) **mobility** and finance.

Therefore, the conditions that could destabilize the automotive sector seem credible: under the dual influence of recent technological developments and societal issues: new electric, autonomous, connected and shared mobility offers are pushing for the transformation of the business model from the sale of vehicles in B2C or B2B to that of the sale of mobility services.

If the conditions for a potential destabilization are met, this leaves a very wide field of possibilities regarding the precise orientation of this dynamic as well as the impact on the architecture of the industry. If the notions of "Electric, Autonomous, Connected and Shared Vehicle" appear in all the speeches of car manufacturers (CASE for Daimler and Toyota) or the prospective studies of international consulting firms (ACES for McKinsey), the concept still carries multiple ambiguities: is it a "ride hailing" strategy (Uber, Didi)? Or is it car sharing (Autolib, Free2Move)? Is it Peer to Peer or via a service offered by an operator? Or, is it simply the application of the more traditional strategy of carmakers, namely an evolution from driving aids towards autonomous driving functions for high end vehicles?

4.3. Literature review, identifying a framework to study the automotive industry transition

4.3.1. A resilience hypothesis of the current industry architecture supported by strategic theories

Many scholars (Abernathy and Utterback, 1978; Bower and Christensen, 1995; Henderson and Clark, 1990; Porter, 1985a; Teece, 1986) have studied the impact of the introduction of major technological changes on established companies and the consequences for their respective industries. Building on two types of technological innovation, namely *incremental* and *radical* innovation as well as by the means of multiple "a posteriori" analysis to what happened within different industries, they have identified different patterns of innovation and explained how their introduction have led to build or destroy a dominant design, put established

firms in difficulty, allow new companies to enter the market, or cause the failure of incumbent firms or even a complete reorganization of an industry.

The concept of industry architecture is also part of the theoretical framework that needs to be mobilized which Jacobides et al. (2006, p. 1205) synthesize as follows: “*Thus, industry architectures provide two templates, each comprising a set of rules: (1) a template defining value creation and division of labor, i.e. who can do what (2) a template defining value appropriation and division of surplus, or revenue, i.e. who gets what*”. The consolidation of a dominant design contributes greatly to shaping the architecture of an industry, and indeed dominant design and industrial architecture are highly interdependent and mutually reinforcing (Abernathy and Utterback, 1978; Jacobides, 2006; Tushman and Anderson, 1986).

Building on these theories, several authors have argued that the automotive industry is particularly resilient and that carmakers have the means to keep control of the industry as they (1) act as system integrators, (2) are at the top of a hierarchical value chain that they control, (3) master the relationship with the end customer and (4) have the capacity to guarantee quality and compliance with regulations relating to safety and health issues (Jacobides et al., 2016; Jacobides and MacDuffie, 2013; MacDuffie and Fujimoto, 2010; Wells and Nieuwenhuis, 2012).

The resilience of the automotive industry, under the impact of electrification, is confirmed by Dijk et al. (2016, p. 77) as they state: « ... *our analysis suggests that the disruptive niche of full-electric mobility is currently insufficient to displace the ICE regime* ». Beyond this observation of current stability, two other theoretical frameworks make it possible to formulate different hypotheses on the future dynamics of this industry.

By applying the *double helix* model (Fine and Whitney, 1996; Fine, 2009), we could assume that electric traction specialist suppliers produce high voltage battery and electric propulsion systems in the detriment of carmakers. As relevant as it may be, the application of this theoretical framework would “only” lead to a reorganization of the industry: it would induce significant changes in the division of activities and in the distribution of income while maintaining the hierarchical architecture of the vehicle production value chain, as it can already be observed in the case of "large" modules (seats, cockpit, etc.).

The other theoretical current of interest to explore our research question is that of socio-technological transitions (STT) that we now introduce.

4.3.2. The paradigm of Socio-Technical Transitions

The sociology of technology stream of research considers that a technology only has an impact if it fulfils a function within a society, and thus is part of a social system or organization; building on the finding that a technology is a "*configuration that works*" (Rip and Kemp, 1998), which means that it fulfils a function that makes sense for society, Geels (2002) infers that the functions of society are fulfilled by *sociotechnical configurations*. These latter are the grouping of heterogeneous elements, being technical, but also regulatory, organizational, financial, etc., whose combination allows the realization of a function necessary to the functioning of the society. Their stability is the result of the links between the heterogeneous elements that make it up, which are produced, thanks to organizational and cognitive routines, by the actors of the said system who are aligned and coordinated with each other; as these routines also exist at the technological level, they contribute to forming a "*technological regime*" (Nelson and Winter, 1982; Rip and Kemp, 1998). Actors of a regime are either technological ones, such as engineers, firms, suppliers, universities, etc. and non-technological ones, e.g. users, policy makers or special interest groups, Non-Governmental Organization, etc. (Geels, 2006).

Continuing to exploit the concept of "*technological regime*", and (1) highlighting the fact that such a regime leads to the implementation of a "*technology trajectory*" as a result of concerted actions by all the technological actors and (2) that these actions are also influenced by all the non-technological actors in the regime, Geels (2002) concludes that it is more appropriate to adopt the term "*sociotechnical regime*". A *sociotechnical transition* is then described as a move from one "*sociotechnical regime*" to another one, which does not occur spontaneously in an established regime, since the latter is based on a logic of lock-in and path dependency that favors incremental changes (Geels, 2010; Geels and Schot, 2007). In contrast to the strategic paradigm, where major changes in the system are linked to competition between actors around the deployment of technological substitution, a STT is a multi-actors process, which takes into consideration multiple interactions and cooperation between technological and non-technological actors (Geels, 2006; Geels and Schot, 2010).

These key notions, and all the rich literature about the STT paradigm, bring two strong principles, particularly relevant, to address our research question: (1) significant transitions of an industry can only occur when a combination of external and internal factors come together (Geels and Kemp, 2000; Kemp, 1994; Rip and Kemp, 1998; Schot et al., 1994; Van den Ende and Kemp, 1999) and (2) the dynamics of technology is only one of them (Dijk et al., 2016; Geels, 2006; Marletto, 2014; Van Bree et al., 2010). Thus, Smith et al. (2005, p. 1494) stress

that, in order to explore the causes of a transition, it is necessary to focus on the governance of all the external and internal factors affecting a regime, by analyzing : “(1) *the shifting of selection pressures bearing on the regime*, (2) *the coordination of resources available inside and outside the regime to adapt to these pressures*”.

The Multi-Level Perspective (MLP) provides an useful framework for understanding system changes and transitions, as it understands transitions as the result of alignments between multi-level developments, and considers radical changes and stability both inside and outside of a regime; therefore, this naturally applies to the study of STT, which are multi-dimensional phenomena (Geels, 2020, 2010, 2006; Geels and Schot, 2007). The use of the MLP framework makes it possible to describe the dynamic of sociotechnical change as a movement unfolding on three analytical and interacting levels (Kemp et al., 1998; Rip and Kemp, 1998). At the macro level, it is within a "*sociotechnical landscape*" that non-technological influencing factors are located, being economic, cultural, social, regulatory, etc.; at this level, developments are generally quite slow in view of the actors and energies that need to be mobilized. At the meso level, there is a set of *sociotechnical regimes*, each representative of a function in society, such as transport, communication, food, etc.; each of these regimes has its own characteristics and, through alignment and coordination between its constituent players, ensures the gradual development of the technologies necessary for its smooth operation (Geels, 2002). Finally, at the micro level, there are the *niches of innovation* which, being isolated from the sociotechnical regime while sharing the same type of structure, offer a more favorable context for the emergence of radical innovations and their eventual subsequent growth (Geels and Schot, 2007; Hoogma et al., 2002; Kemp et al., 1998, 2001).

Concerning how a change happens to come, Geels and Schot have (1) summarized that there is not a single cause of evolution but the convergence of multiple processes, (2) described more precisely the interactions between each of the three levels of a MLP framework as well as over time, and (3) explained the mechanisms implemented within a socio-technical regime, including those leading to the construction of a dominant design (see Geels and Schot, 2007, p. 401 for a description of Multi Level Perspectives on transitions).

Lastly, Geels and Schot (2007) have proposed a typology of transition pathways based on different multi-level interactions; combining two criteria, namely timing and nature and interactions, and considering the type of external landscape pressure (Suarez and Oliva, 2005), as well as the presence and the force of radical niche-innovations, they have introduced five patterns of transition pathways: *reproduction, transformation, de-alignment and realignment*,

technological substitution and reconfiguration. We will use this conceptual framework to characterize the different types of transitions that our empirical study might reveal.

In addition, there is a long tradition of examining major industrial transitions, including that of the automotive industry, in light of the STT paradigm and the MLP framework. Andersen and Markard (2020) investigated the importance of multi-technology interaction in transitions, which is particularly relevant as our study addresses the application of electrification, autonomous driving and connectivity technologies to vehicles. The MLP framework has already been used to study the on-going transition to decarbonization (Moradi and Vagnoni, 2018; Rogge et al., 2020), the impact of autonomous driving on business model (Fritschy and Spinler, 2019) or of its integration into the system of urban mobility (Marletto, 2019). On their side, Wells et al. wonder whether automobility-as-a-service (AaaS) is disruptive to the incumbent automotive companies (2020). As they state that “*Automobility-as-a-service (AaaS) is narrower than MaaS*” (2020, p. XX), their study is of great interest as it can be seen as an intermediate milestone in the wider transition we aim to observe. Lastly, from a theoretical viewpoint, Geels (2020) has continued to develop the Multi-Level Perspectives theoretical micro-foundations.

4.4. Analytical frameworks to study the electromobility transition

4.4.1. A global MLP framework for electromobility study

We define the sociotechnical configuration of the automotive industry by considering some previous contributions (Dijk et al., 2016; Geels, 2002; Van Bree et al., 2010) and elaborating on our own analysis of the factors which will influence the transformation of the automotive industry. Therefore, we identify six broad categories, to which we associate the actors that activate them:

- *Regulation*, which has a major influence in the current transition towards electrification and can be activated by supranational, national but also local public authorities,
- *Social trends and customer usage and values* which support the deeply rooted cultural, social status that makes the automobile the preferred means of individual mobility,
- *Infrastructure* such as roads, expressways, traffic management system or charging networks that can be activated by public authorities and/or private companies (construction companies, expressway operator, charging network operator, etc.),
- *Technology*, which involves carmakers, tier X suppliers and tech companies acting in CASE and digitalization fields,

- *Industry architecture*, which encompasses all the actors of the automotive value chain (carmakers, tier X suppliers, retail and maintenance / repairation networks),
- *Product and market strategy*, the classic B2C and B2B sales of multipurpose vehicles (and some added services) as one of the major levers of action for carmakers.

At the landscape level, we consider this is an *avalanche* type change (Geels and Schot, 2007; Suarez and Oliva, 2005), as the regime has to face the simultaneous and cumulative pressure of three high intensity changes: climate change, increasing urbanization and changing consumption patterns. Similarly, the emergence of MaaS, which is one of the possible responses to these societal changes, can only take place if there is a simultaneous convergence of four major technologies, at high levels of frequency, amplitude, speed and scope, namely electrification, connectivity, autonomous driving and digitalization. This convergence, similar to that of tectonic plates, adds a new typology of change to the one used, which will be referred to as an *earthquake* type of change in this paper, see representation below.

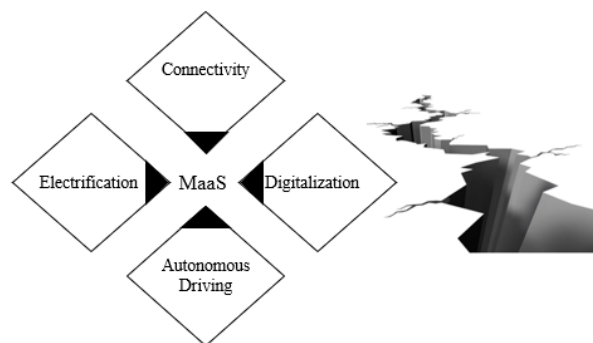


Figure 12: Earthquake typology of change, proposal from the authors of this paper

Consequently, we propose an MLP framework to study the transition towards electromobility as presented in figure below.

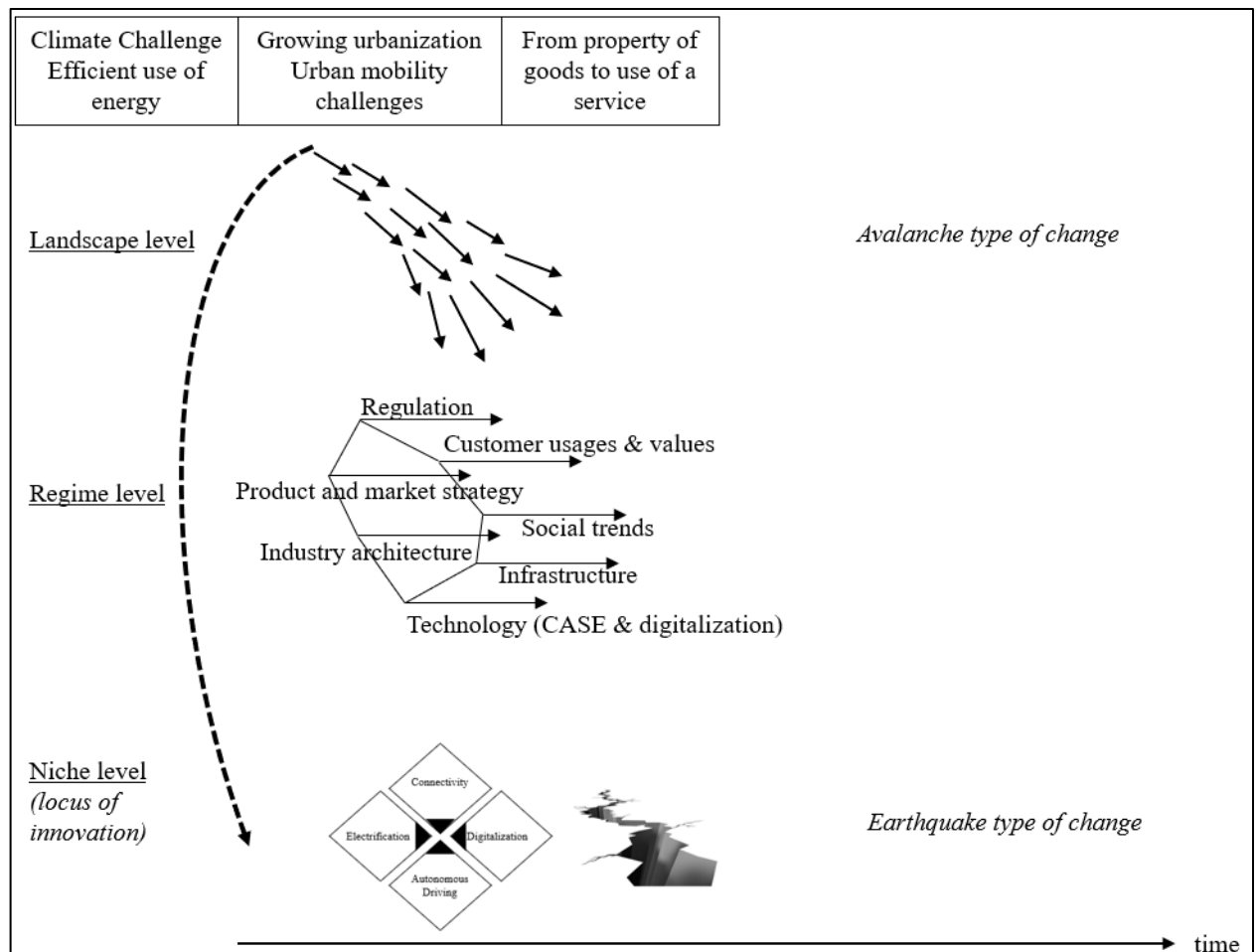


Figure 13: An MLP framework to study Electromobility

Adapted from (Geels and Schot, 2007, p. 401)

4.4.2. A framework for specifying the direction and intensity of the automotive industry transition to mobility services

Studying a transition empirically implies being able to characterize precisely the reality of the introduced changes, namely its meaning as well as its intensity. In this case, we have to assess how the cases studied may or may not be a next step in the transition of the industry from the traditional B2C or B2B (fleet) business model for production and sale of vehicles to a model of an automobile mobility services industry. The concept of product-related service has a long history in the automotive industry: it is therefore necessary to characterize more precisely how current innovations in this field differ from this long tradition of integrating service into the dominant design of the industry's products.

Building on servuction literature (Eiglier and Langeard, 1987) and design theory (Hatchuel and Weil, 2008), Lenfle and Midler (2009a) have proposed an analytical framework to characterize the design space of a service innovation. This framework has been adapted by the authors to characterize the design space of MaaS in six integrated domains: (1) Specifying the

mobility service; (2) Designing vehicle to MaaS; (3) Designing an Autonomous Vehicle (AV) enabling infrastructure; (4) Designing backend fleet operating system; (5) Designing frontend mobility system; (6) Defining the stake-holders contract relation.

A specific MaaS solution can be characterized by the definition of each of these variables. Analyzing the cases on the basis of this grid will make it possible to empirically measure the disruption introduced by the experiments in progress, taking as a reference the concept of “*service added to the product*” (Verstrepen et al., 1999).

4.5. Research design

4.5.1. Designing an international research

The research we present is part of a large-scale study of new automotive mobility initiatives, exploring a variety of cases in various countries and involving many industries and institutions as we argue that:

1. The actors' space considered involves carmakers and all stakeholder industries: transport operators, technology or service providers, digital companies as well as territorial public operators who play a key role in the design of current mobility experiences.
2. The "playground" for this learning of new mobilities is global. The "triad" of USA, Europe and Japan, which traditionally set the pace and direction of innovation in the sector, is now being contested by Asian countries, especially China, because of the size of their markets and the dynamism of their automobile industry, and also because of political initiatives giving a large place to ambitious experiments in the field of transport.

Building on previous collaborations, and considering the global playground of new mobilities, we gather an international research community around this research covering north American, European and Asian regions.

The year 2019 was clearly devoted to develop a common understanding of the issues to tackle. We formalized these issues and converged towards a shared questionnaire to frame the cases in a comprehensive way. Before the COVID19 crisis, interviews with some companies involved in the new mobility initiatives have been carried out at the end of 2019 in Europe and China as well as early 2020 in Europe.

4.5.2. Theoretical sampling

The MaaS challenge is an emerging trend as players began to move during the past five years, and the challenge is planned to deliver a stable value proposition and business model within the next 10-15 years.

Firstly, we draw on one of the most robust social science findings on technological change, which assumes that there is no technological determinism, but only learning determinisms (Midler and Charue-Duboc, 1994) or, in the language of economists, path irreversibility (Dosi, 1982). It is therefore by studying and comparing the various experiments in progress, by studying their meaning and by evaluating their performance in leading, more or less rapidly, to operational realities that we will shed light on the uncertainties of possible destabilization scenarios.

As the MaaS transition has a too short history to allow us to study stabilized configurations through a statistical sampling, we chose to have a *theoretical sampling* (Eisenhardt and Graebner, 2007), seeking a range of very heterogeneous management situations, in order to build a comprehensive picture of the management challenges and organizational configurations.

4.5.3. Case definition

Previous surveys about automotive took various units of analysis. Surveys about manufacturing took a factory as a relevant unit of analysis, comparing the relative performance of practices around the world (Krafcik, 1988). Surveys about new product development (Clark and Fujimoto, 1991) took the vehicle as a unit of analysis, comparing the performance of various players in the world towards the development of new cars. Studies about innovation management (Maniak et al., 2014a) took embedded technologies or innovative features as a unit of analysis, showing the variety of practices notably in advanced engineering.

For this research, given the systemic characteristic of innovations (von Pechmann et al., 2015), we define a case as an “*innovative MaaS initiative*”. Generally, such initiatives involve various players, and as we cannot investigate every player from every initiative, we chose to focus on a key player to provide information about the whole MaaS initiative. This key actor is selected for his influential role in the ongoing transition and may or may not be the project owner of the initiative.

To date, we have been studying fourteen cases and we exploit, here, the results of ten of them which are at different levels of maturity (concept formulation, development, field experimentation and operation) and have been developed and/or operated in the USA, Europe

and China. These case studies have been selected as they are fully representative of the MLP framework we introduced and are summarized in the table below.

Study case	Project owner	Key player selected	Headquarter Region	Maturity of the offer	Type of offer	Data collection process	
						Questionnaire	Second sources
1	National public / private institute dedicated to sustainable mobility	Same actor	Europe	Concept formulation	Shared express transportation	Yes	No
2	City public authority	Technology firm	China	Development	Automated shuttle	Yes	No
3	Carmaker	Carmaker	Europe	Concept formulation	Autonomous urban mobility	Yes	No
4	Local public authority	Technology firm	China	Development	Automated logistics operation in private area	Yes	No
5	Mobility operator	Same actor	USA	Operation	Autonomous ride-hailing	No	Yes
6	City Public authority	Carmaker	Europe	Field experiments	First / Last mile autonomous transport of persons	Yes	Yes
7	Mobility operator	Same actor	USA	Field experiments	Autonomous ride-hailing	No	Yes
8	Carmaker	Same actor	Europe	Field experiments	Autonomous ride-hailing	Yes	Yes
9	Logistics operator	Technology firm	China	Operation	Sales and installation of autonomous driving packages in vehicles	Yes	No
10	Carmaker	Carmaker	China	Operation	Sales of car and added services	Yes	Yes

Table 20: The ten selected cases

4.5.4. Analytical Framework and methodology

We use the questionnaire, based upon the design space of MaaS, to characterize and compare the studied cases on the following dimensions:

1. The *nature of the experiment* defined through the six main variables of the design space, that will show us how innovative the experience is, compared to manufacturers' current offers of services added to the vehicle,
2. The *ecosystem involved*, which is a direct output of the questionnaire, its leadership organization with a focus on the role of carmakers, mobility operators and public authorities.

For eight of the ten cases, the information is obtained directly through interviews, lasting between two or three hours, in presence of different members of the international research team. The interviewees are the executives of the companies or institutions involved in these new initiatives, and / or operational staff, such as those in charge of projects under development. The data collected has been reviewed by the interviewees.

In the other two cases (USA cases), only information from second sources was used.

4.6. Results presentation

4.6.1. Ten initiatives in a nutshell

Study case 1 aims to solve the problems of saturation of public transport, generally congestion problems when commuting between suburbs and city center. The proposed solution consists of setting up rapid transit lanes open to electric vehicles (buses, shuttles, taxis or even private cars), equipped with the software and hardware (level 3-4 of AD⁵¹) allowing them to be handled by an automated control system which secures the entrances and exits of the rapid transit lanes and ensures a high flow of passengers. A European consortium of carmakers, digital, construction and infrastructure companies, to be joined by mobility operators, technology providers, etc., is in charge, under the leadership of a public/private research institute, of the development phase leading to experiments in the field.

Study case 2 is a typical example of an automated electric shuttle for person transportation (AD level 4); under the leadership of a City authority, the shuttle is developed by a carmaker and transformed into an autonomous vehicle by a very recently created Chinese technology company.

Study case 3 is a very innovative concept of autonomous urban mobility, involving versatile electric robotaxis (AD level 5) which aims at moving persons, goods, and also bring services

⁵¹ All Autonomous Driving (AD) levels cited in this section refer to SAE definition (SAE, 2019)

where people are (service mover). Urban governance of all these different types of mobility should reduce the number of vehicles needed and thus reduce pollution and congestion. This concept is under study by a carmaker and jointly developed with a city public authority to define the mobility governance rules.

Study case 4 addresses a problem of logistics transportation (AD level 4) in a port area; it involves special electric vehicles, dedicated to this specific mission and developed by a special vehicle maker, while the AD package is developed by a very recently created Chinese technology company. The project owner is the port operator, a listed company with majority owned by the state.

In *study case 5*, the targeted MaaS solution is a ride-hailing service involving an electric robotaxi with AD level 5 that operates without any interaction with the road infrastructure or any traffic management system; the electric vehicles are supplied by carmakers while the mobility operator performs the adaptation to autonomous driving in its own factory. The case is already in operation with paying customers, while for obvious reasons of safety and security, safety officers are still present in vehicles; it is also operated in a fully driverless mode for some early testers in a restricted area. It is developed and operated by a subsidiary of an American giant technology company.

Study case 6 proposes a solution to deal with the problem of transporting people on the first / last mile, between a train station and different residential or activity areas. It is developed under the leadership of an urban public authority, operated by a transport company. The carmaker provides an electric robotaxi with AD level 4 capability, requiring exchanges with land-based driving decision support systems in a few specific cases such as roundabouts.

Study case 7 is very similar to study case 5, the main difference being that it is developed and operated by a subsidiary of two global carmakers (and other shareholders); the vehicle used for the first experimentation and operation phases is produced by one of the carmakers and adapted to autonomous driving. The mobility operator has presented, at the beginning of this year, a dedicated robotaxi jointly developed by its two shareholders.

Study case 8 is another example of ride-hailing service involving an electric robotaxi with AD level 4 and interactions with some dedicated road infrastructures. The case is in a situation of field's experimentation and the service is operated by a carmaker.

Study case 9 addresses a very recently created Chinese technology company who provides a logistics operator with an AD level 4 package integrated in existing trucks, operational on routes learnt in advance by the system, which means there is no connection between the vehicle

and any road infrastructure or traffic management system; a safety officer is present in the vehicle to deal with any possible system failure.

Study case 10 concerns a Chinese carmaker, newcomer to the automotive industry, which recently launched two high-end electric SUVs with AD level 2, equipped with in-car navigation and entertainment systems. In order to capture new value beyond the traditional business scope of a carmaker, the company has developed numerous mobility services (recharging, repair, maintenance, etc.) and "multi-service personal application" type services (social networking, entertainment, merchandising, leisure, travel, etc.); it also offers a P2P carsharing service reserved to the owners its vehicles.

The summary of these different cases, accordingly to the MaaS design space we introduced, is provided in the table below.

Study case	Designing the mobility service	Designing Vehicle to MaaS	Designing an AV enabling infrastructure	Designing Backend AV fleet operating system	Designing Frontend mobility system	Designing the stakeholders' contract
1	Express shared public and private transportation (AD levels 3- 4)	Open to bus, shuttle, taxis, personal cars (EVs) equipped of appropriate hardware/software package	Control system to secure (fast) lane inserts and exits and to ensure a high passenger flow	Hub management, fleet supervision and control, Customer Relation Management (CRM)	B2C CRM, inter platforms communication (B2B)	Depending upon territory policy and strategy
2	Autonomous transportation of person (AD level 4)	Dedicated electric shuttle	Road perception system	Hub management, fleet supervision and control	B2C CRM	On-demand pricing
3	Autonomous urban mobility: persons, goods, service mover (AD level 5)	Versatile electric robotaxi	City governance of all vehicles	Hub management, fleet supervision and control, CRM	B2C CRM, inter platforms communication (B2B)	On-demand pricing?
4	Autonomous logistics (special usages) (AD level 4)	Dedicated electric special vehicles	Connection to infrastructure of operating area	Hub management, fleet supervision and control	Internal company system	Operation contract
5	Autonomous ride-hailing (AD level 5)	Dedicated electric robotaxi, adapted from mass produced EV	Stand-alone vehicle (no connection with infrastructure or traffic management)	Hub management, fleet supervision and control, CRM	B2C CRM	On-demand pricing
6	Autonomous ride-hailing (AD level 4), first / last mile transportation of person	Dedicated electric robotaxi, adapted from mass produced EV	V2 Infrastructure (crossroad management)	Hub management,	inter platforms communication (B2B)	On-demand pricing
7	Autonomous ride-hailing (AD level 5)	Dedicated electric robotaxi, adapted from mass produced EV Presentation of a pure robotaxi	Stand-alone vehicle (no connection with infrastructure or traffic management)	Hub management, fleet supervision and control, CRM	B2C CRM	On-demand pricing
8	Autonomous ride-hailing (AD level 5)	Dedicated EV	V2 Infrastructure (crossroad management)	Hub management, fleet supervision and control, CRM	B2C CRM	On-demand pricing
9	Logistics service (AD level 4)	Dedicated Logistics trucks, EV?	Stand-alone vehicle (no connection with infrastructure or traffic management)	Off line control	Internal company system	Operation contract
10	Sales of high-end vehicles and added services (AD level 2)	Multipurpose EV	Stand-alone vehicle	Charging, repair and maintenance network - Network of third-party service providers	B2C CRM	Annual fees

Table 21 : Summary of the ten study cases

4.6.2. Characterizing the orientation and radicality of the innovations

To characterize the orientation and radicality of the innovative changes proposed by each case study, we focus on the nature of the experience (How does an initiative introduce changes and how can they be characterized in our mobility services design space?) and the ecosystem involved (Is the car manufacturer still the central company?).

Considering these two dimensions, case 10 consisting in a high-end electrified multi-purpose family vehicle, is not an escape from the dominant design as the vehicle is (i) produced according to a mass production process, (ii) sold on a B2C commercial model and (iii) the OEM plays the role of the focal firm. Even though the vehicles are complemented by an innovative offer of multiple digital services and if the car manufacturer offers access to a P2P car-sharing service, we are close to the concept of “*service added to the product*” (Verstrepen et al., 1999).

We identify a first group of cases, namely 1, 2, 3, and 4 which share the same characteristics, as in terms of *nature of experiment*, (1) the development of the solution is spread over many variables of the mobility system and (2) the *ecosystem* involves both many different industries and public authorities. In these initiatives, the vehicle is one enabler, among others, of the mobility system, which cannot be operated without: lane control and traffic management systems, as in case 1; city mobility governance rules, as in cases 2 and 3; or detailed operation rules, as in case 4. In addition, the actor in charge of operating the service has to manage a fleet of vehicles and ensure their capacity of operation through cleaning, maintenance, repair, battery charging activities operated in hubs. The involved ecosystem is wide, the most emblematic case probably being case 1 and, in most of them, needs cooperation between public and private actors to deliver the service. In these cases, a carmaker, when involved, is no longer the focal actor of the ecosystem and the product, a vehicle, is only a catalyst, among others, of the capacity to operate the system; therefore, these cases go far beyond the traditional B2C or B2B business models of the automotive industry.

In the second group (5,6, 7 and 8), the solution is *product-centric*, a robotaxi, under the strong management of a *platform leader* (M.A. Cusumano and Gawer, 2002), the mobility operator. The vehicle, here, concentrates most of the operational complexity of the proposed system; as a level 5 AD stand-alone⁵² robotaxi, it is expected to operate in a wide range of weather, geographical and driving conditions without any communication with its environment, which implies that the entire control system is on board. This level of complexity is much higher

⁵² Even if some debarked sensors may be use in some specific occasions in cases 6 and 8

than that of Advanced Driver Assistance Systems (ADAS), which most car manufacturers have already deployed in their vehicle ranges. In cases 5, 7, the mobility operator is leading the development project and plays the role of a platform leader since all the critical competencies to develop and operate a ride-hailing system have been integrated inside the company; in cases 6, 8 where the car manufacturers have concluded certain cooperation agreements with technology companies, it is nevertheless true that the carmakers also play the same role. As in addition, the mobility operator must also manage a fleet and hubs, as explained for the previous cases, these cases correspond to a real breakthrough innovation in terms of the product, the service and of the make perimeter and involved players, which go far beyond the traditional B2C or B2B business models of the automotive industry.

4.6.3. Characterizing the role of the social actors activating the transition

Carmakers, four different roles for three different business models

In case 10, the OEM plays the role of the focal firm in a classical B2C business model.

In cases 7, 8 the carmaker is also playing the role of a mobility operator; by doing so, companies widely extend their make perimeter as they deal with hubs and fleet management issues as well as a new type of relationship with the final customer, namely managing the assignment of a mobility mean according to a given customer requirement. Here, we are still in a B2C business model, but much more engaging than the traditional model.

In cases 1, 2, 4, 5, 6, 9, vehicle manufacturers (cars, trucks, shuttles, special vehicles) provide an electric vehicle as part of a mobility solution and, almost always (except in case 6), this vehicle is adapted by a third party to provide the level of AD necessary to perform the service. It paves the way to a B2B business model where carmakers, focusing on their initial core business and competencies, provide vehicles to mobility operators or fleet managers to name but a few possibilities.

Case 3 is interesting because the car manufacturer concerned, in cooperation with an urban authority, designs an innovative mobility service that cannot be provided by the usual transport solutions; at the same time, it designs new types of versatile vehicles that would meet these new mobility needs and the service it could then operate or not.

Mobility operator, the capacity to disturb the architecture of the automotive industry

In case 1, the mobility operator will be one of the possible users of this system as private individuals with their own vehicle. It will have to implement, on its fleet of vehicles, the technical solutions allowing access to the service and its service offer will be integrated in the

overall mobility offer. This is more the role of a provider of means of transport than a mobility operator in its own right or under public service delegation.

While in cases 2, 6 and 9 they (will) operate in conventional mode under a public service delegation, in cases 5, 7 and 8 they fully exploit, by themselves, the ride-hailing service based on the use of robotaxi vehicles, and the latter is the most interesting in the context of our study. Indeed, it could lead to the destabilization of the architecture of the automotive industry by the appropriation, by mobility operators, of two of the fundamental assets of carmakers. When a mobility operator is also a carmaker (cases 7 and 8), it uses its own products, adapted or specifically developed, such as robotaxis. But if the mobility operator comes from another industry (technology company in case 5), it usually buys or uses cars from external car manufacturers and adapt them with his own autonomous driving systems: he thus deprives the manufacturer of his role of integrator of the final product. The second asset is the mastery of the relationship with the final customer: with the widespread use of mobility services in parallel with galloping urbanization, customers may become accustomed to a specific MaaS because of the quality of the service, regardless of the company that produces the vehicle.

Local and territorial authorities, the power to shape future mobility

Apart in case 10, where public authorities are not involved at all in this initiative (P2P carsharing and multiple services provider) as it is an extension of the current dominant design, they usually play or will play a key role in the initiatives we have observed.

In cases 1 and 3, which are at very upstream stages, public authorities have the capacity of shaping the future of electromobility. Indeed, in case 1, because of the collective impact of such a project in terms of mobility (cost for passengers and the community, passenger flows at peak times, control of public investment, etc.), it can be expected that a public authority will quickly take over the steering of this project; similarly, in case 3, an autonomous urban mobility solution aimed at pooling versatile means to optimize and fluidify car traffic, which implies strong political and social choices, can only be piloted by a public authority.

In cases 2, 4, and 6, which are more advanced (development and field experiment phases), public authorities play a classical role of project owner and manage different B2B contracts with suppliers. However, all these cases concern more sustainable (case 2), efficient (case 4) and people-centric (case 6) uses of mobility; in this sense, they foreshadow many new mobility needs that public authorities may have to consider in the future.

In all the other cases (5,7, 8 and 9), the public players, in the territories concerned, even if they are obviously involved in the global mobility project, are more akin to experimental field

suppliers to test a solution that will then be proposed, by the mobility operator, to other local authorities, according to an already packaged formula. Although they currently play a less influential role in these cases, we can assume that, when these initiatives are extended to other territories, their requirements in terms of the overall efficiency of mobility services as well as local operating conditions will require changes to the offer initially designed by the mobility operator.

Construction companies, potential key players in Public-Private-Partnership infrastructure projects.

In particular, in cases 1, 3 and 4, construction companies seem to be powerful facilitators and co-contributors, with the public authorities, of the transition. First, they have a direct and important contribution to the success of the projects to which they contribute because the infrastructure embodies key technical and functional components of the system. Second, they certainly can contribute to ensure lineages and economies of scale beyond local innovations.

Technology companies, the ones without whom nothing would happen

With respect to technology companies, our cases confirm that they are the key enablers of these initiatives, either by providing or integrating autonomous driving sets (components or full package, onboard and/or debarked), or by providing digital platforms for customer relationship management or the aggregation of multiple services. We can characterize that they play three main roles in the undergoing transition; firstly, in cases 1, 3, 6, 7, 8 and 10, they play a traditional role as suppliers, even if it is about innovative autonomous driving packages or digital platforms. What is more interesting for the future of the automotive industry is when they co-design a mobility solution (in cases 2, 4 and 9) or act as a mobility operator (case 5).

4.7. Discussion: what could happen?

4.7.1. The transition of auto industry to an electric, autonomous connected and shared mobility: Towards three possible MaaS models?

The ten cases studied show the diversity of current attempts to innovate with respect to the dominant model of automobile mobility, i.e. the driver owning a vehicle purchased from a carmaker. The cases reveal evidently different levels of maturity of the initiatives, but more interesting, significant orientations of the trajectories taken, due to different configurations in the variables of the service design space that are activated, and the actors that are at the forefront of these initiatives.

At this stage, our empirical analysis does not allow us to conclude that the transition is towards a future "*one best way*" of the dominant MaaS model, which would be to future car mobility what the dominant model of OEMs is. Conversely, the analysis of our panel leads us to propose 3 different possible ideal types as targets for the transition trajectories outlined in the cases studied: (1) *Mobility service added to product*, (2) *Robotaxi* and (3) *Territorialized open mobility platform*.

(1) *The mobility service added to product ideal type*. Long known in the automotive industry, the strategy of *service added to a vehicle* (Verstrepen et al., 1999) makes it possible to continue selling vehicles on a B2C basis. What is innovative, here, is the addition of a new mobility service capability to the vehicle through the use of new technologies, as particularly illustrated by the P2P car sharing service described in case n°10 or by the initiative from Tesla evoked by E.Musk⁵³. In this type, *carmakers* have integrated new technologies into the dominant technological design and, therefore, enhanced their *technology* portfolio; they have maintained the *industry architecture* by extending the value chain management to third parties operating different services, and continued to sell mass-produced multi-purpose vehicles to individual and fleet customers accordingly to their *product and market strategy*. In this case, the role of the automobile as the preferred means of personal travel has only been marginally questioned. Consequently, as the make domain of the carmaker is maintained, we consider that this ideal type doesn't contribute, to date, to the destabilization of the industry; however, it can be imagined as a first step to more profound changes.

(2) *The robotaxi ideal type*. This type takes over from the ride-hailing model at Uber or the car-sharing model at Autolib by offering a fleet of automated vehicles that supports the service; it is illustrated by cases 5, 6, 7 and 8. Here, the operator of the mobility system becomes the platform leader of the ecosystem by operating the different functions of the transport system: specifier of vehicles, owner and manager of the fleet, manager of the hubs, manager of customer relations. As the cases show that this key role of robotaxi fleet operator can be occupied by actors who occupied different roles before the transition such as carmakers (cases 5 and 8), public transport operators (case 7), technological firm (case 6), it paves the way to two very different situations for carmakers. In cases 5 and 8, carmakers keep, in their make domain, the role of integrator and the relation with the end customer, even if the latter is fairly different from the existing B2C model of sales of vehicles and added services. In cases 6 and 7, the

⁵³ in Q4 2019 Financial Results, Q&A webcast - <https://ir.tesla.com/events-and-presentations>

carmakers may lose the role of final integrator of the product (as FCA and JLR in the cooperation with Waymo) and, for sure, lose the mastery of the relationship with the end customer, whom we consider as one of their main assets.

(3) *The territorialized open mobility platform ideal type.* This ideal type is part of an economic model of public-private partnership oriented towards solving collective mobility problems specific to certain territories: in our study, case 1 addresses the need for commuting to and from work, while case 3 addresses urban problems that cannot be solved by traditional public transport. Case 4, 6 and 9 address other specific local problems of transportation or logistics and are very representative of future mobility needs. Here, the implementation of the mobility solution is much more distributed, with the infrastructure providing open standards allowing a variety of actors to contribute to the development and operation of the system. Without any doubt, the local or territorial public authorities co-lead the ecosystem, as project owners collaborating with solution providers to deliver a mobility system.

In terms of influence on the industry, the carmakers lose, for sure, part of the role of final integrator of the vehicle as the hardware and software package enabling access to the service is part of the mobility open platform. If the inclusivity of the mobility system allows private owners of cars to use it, then carmakers may maintain a significant B2C business in parallel.

We agree with Wells and al. when they state that AaaS is not a threat to the automotive industry as “*It may allow the perpetuation of the automotive industry and of mass automobility, and thereby assist the industry in resisting transformative change*” (2020, p. 8). Indeed, “*mobility service added to product*” and (some implementations of) “*territorialized open mobility platform*” ideal types may leave some room for carmakers to run a significant B2C business. But the services they have studied don’t activate two key levers of transformation we have pointed out, i.e. depriving the carmaker (i) of his role of integrator of the final product and (ii) of the mastery of the relationship with the end user. This is exactly what could happen in the “*robotaxi*” and (some implementations of) “*territorialized open mobility platform*” ideal types.

4.7.2. Making the transition happen: the role of the key players towards ideal types

As our case study has allowed us to formalize three ideal types as potential targets, we now seek to understand (i) what levers of action each actor can activate for the transition to one of these targets and (ii) which type of transition pathway is activated (Geels and Schot, 2007). To do this, we will analyze how each actor can manage the governance of the transition (Smith et al., 2005, p. 1494). In addition, we will complete the MLP theoretical framework by mobilizing

project learning theories to help us understand how each actor can manage forces to direct the current dynamics towards a given ideal type.

Five categories of actors appear to be as key enablers of the initiatives studied, namely car manufacturers, transport operators, public authorities, infrastructure operators and technology companies, whose role in the learning trajectories leading to the three ideal types we have identified are now discussed.

Concerning the *mobility service added to product ideal type*, carmakers manage this transition by (i) producing vehicles compliant with the regulations addressing global warming and the level of air pollution, and (ii) selecting the specific market of high-end customers fond of novelty and high technology. They will push this trajectory as a natural extension of their current strategy of developing sophisticated driving aids, and of trying to increase their revenue through increasingly sophisticated services of which they hope to capture a significant part of the value. They have an interest in such a trajectory and are in a position as platform leaders (M.A. Cusumano and Gawer, 2002) to integrate the necessary components. This move is pretty similar to the one leading to the appropriation of electrification by the industry and is of *reconfiguration* type (Geels and Schot, 2007). In case 10, the carmaker is clearly developing a planned project lineage strategy (Kock and Gemünden, 2019; Maniak and Midler, 2014; Midler, 2013) oriented towards mobility services, from the very foundation of the company.

In the *robotaxi ideal type*, a strong capacity for negotiation, with the public authorities, to change the regulations to allow operation in public areas and the extension of the service is required, whatever the player. Three key players appear to be at the forefront in the cases studied: carmakers, transport operators and technology companies. As far as the coordination of resources, each actor has a different score to play. As they know how to run the business, incumbent mobility operators turn out to be the most natural candidate: they can manage B2B relationships with vehicle makers, are very skilled with hubs and fleets management and, most of them have stepped into the use of digital platforms for managing the customer relation. In addition, they are used to cooperate with local or territorial public authorities and can aggregate robotaxis with their usual solutions of mass transportation. On their side, with strong and appropriate co-operation activities, carmakers can build on two strengths: (i) they are able to develop, new vehicles according to the new requirements of mobility services, and (ii) they can use their brand image and long experience in customer relations to introduce new services. But, they face a main drawback: taken separately, electrification, connectivity, autonomous driving and digitalization of the industry are, by themselves, fairly complicated, and moving forward

in parallel towards new mobility service is a very complex issue which requires a huge amount of resource. It perfectly illustrates “*the importance of multi-technology interaction within and across sectors*” (Andersen and Markard, 2020, p. 1) in a transition of the magnitude that the automotive industry is actually undergoing. This is where technology companies gain a significant advantage since, as summarized by J.Krafcik, CEO Waymo⁵⁴, they have built trajectories for the deployment of disruptive innovations by capitalizing on learning from successive projects encompassing both technological developments and user experiments. By doing so, they combine project lineage strategy (Kock and Gemünden, 2019; Maniak and Midler, 2014; Midler, 2013) and the role of experimentations in the emergence phase (Ben Mahmoud-Jouini and Charue-Duboc, 2017). Lastly, the ability to finance costly projects over such a long period of time is an important resource that not all actors seem to share at the same level and which could be discriminatory in their respective trajectories. This difference in financing capacity has much more to do with the intrinsic strengths of the firm or the confidence placed in it by the financial markets than with its own nature. In terms of transition pathway, *technological substitution* (Geels and Schot, 2007) is undoubtedly the first step involved in the move towards this ideal type as a robotaxi is in direct competition with a multipurpose vehicle and could overcome it. If mobility services do indeed take precedence over individual mobility, it could be followed by a *de-alignment* of the regime of the automotive industry, i.e. a destabilization of its architecture. As far as *re-alignment*, we can hypothesize two different paths (i) a contraction of the current regime where carmakers would be reduced to the role of commodity suppliers for mobility operators leading the dominant regime of mobility services or, (ii) an extension of the current regime where carmakers would also play the role of mobility operators.

Concerning the *territorialized open mobility platform model*, working cooperatively with public authorities is the main capacity required to manage the pressure on the regime. Construction companies are here key players as (i) they have long been the privileged interlocutors of the territorial authorities to build and operate local infrastructures and (ii) they provide the necessary financing for such infrastructure within the framework of Public Private Partnerships. Mobility operators, who have a strong competence to co-operate transport systems with local authorities are also natural key players. The car manufacturers will certainly favor “vehicle centric” solution such as the service added model and the robotaxi model, because (i)

⁵⁴ <https://blog.waymo.com/2019/09/waymo-iaa-frankfurt-2019.html>

they can mostly maintain their historical dominant design and (ii) they do not have the skills to manage cooperatively these deployments of mobility systems with public authorities, due to their B2C business culture; we also make the latter comment about technology companies. As the strong territorialization of experiences and their contingent character to the context and to local actors, constitute many barriers to their large scale deployment, we are typically in a learning strategy from one project to another (Lenfle and Loch, 2010) where mobility operators and construction companies are probably the most skilled actors to ensure lineages and economies of scale beyond local innovations. Could the public authorities in charge of transport become the leader of the platform dynamics? On the one side, Maniak and Marccochia (2018), have shown the importance of public innovation support programs in order to bring about the emergence of innovations in mobility, which are conducive to experimentation. On the other side, the strong investment of territorial public actors, a guarantee of local sustainability, will not be found in other contexts. Finally, the deployment of this model can probably only be achieved through a combination of local experimentations and leadership from a higher level of public authority(ies), capable of placing local initiatives in a more global plan at the national or international level. This is what countries, such as China and France, are trying to do at different levels and according to different mechanisms, through incentive plans for the deployment of complementary experiences and the pooling and generalization of their teaching. This ideal type is just emerging and its impact on the automotive industry is not yet visible; however, considering galloping urbanization and the influence of local public authorities on urban mobility services, we hypothesize that next steps could be *technological substitution* and *de alignment* of the regime (Geels and Schot, 2007).

4.8. Conclusion and future research

The current dynamics of the automotive sector demonstrate one of the major industrial transitions of the beginning of the 21st century. The scale of this transition, which many reports describe as a shift from a model of selling vehicle products to end customers to the Connected, Autonomous, Shared and Electrified (CASE) mobility services offer, can be measured by the generalization of the strategies of automotive groups as major new entrants from the digital world, and the associated importance of investment in the development and experimentation of related innovations. This transition is the result of a combination of technological, regulatory, economic and social factors, both within and outside the industry.

This paper focuses on two questions that remain unanswered today: (i) Is this transition oriented toward a single new dominant design of mobility services? (ii) Will the resilience of

the architecture of the automotive industry be sufficient to absorb the effects of the transition to mobility services?

Combining STT paradigm, MLP analytical framework, and a theoretical definition of the design variables of a mobility service, we conduct an empirical study about ten initiatives of innovative mobility; this latter focuses on the role of carmakers, mobility operators and public authorities in the deployment of these new services as well as their respective impact on the future architecture of the automotive industry.

Concerning our first research question, the results of our empirical study allow us to characterize three significantly different MaaS ideal types (Weber, 1978) to which the current transition could lead (i) *mobility service added to product*, (ii) *robotaxi* and (iii) *territorialized open mobility platform*, demonstrating that there is no “*one best way*” in vehicle-based mobility services but a diversity of possible configurations that could be built through differentiated learning trajectories.

Concerning our second research question, we characterize the new ecosystem architectures behind those three different ideal types focusing on the roles of carmakers, mobility operators and public authorities. We understand the interplay of actors at work in collective learning processes that progressively shape transitions. We show that the trajectory towards the first target is a natural extension of manufacturers' strategies, that the second target is part of a more marked breakthrough, and that it is supported by a platform logic driven by clearly identified leaders, whether they were at the origin carmakers, mobility operators or technology companies. Finally, the third is a collective learning process in a more heterogeneous ecosystem, less coordinated by an obvious focal actor, who would be able to easily organize the scale up of local experimentations. We have shown that public authorities could possibly play this role of aggregators of territorial initiatives, provided that local public action is effectively combined with national or international programs promoting the transfer and capitalization of experiences. As such, our results also complete and extend the stream of research, about the resilience of the automobile industry, proposed by some authors (Jacobides et al., 2016; Jacobides and MacDuffie, 2013; MacDuffie and Fujimoto, 2010; Wells and Nieuwenhuis, 2012).

Considering these results, the article makes the following contributions.

On a theoretical viewpoint, it shows how the STT paradigm and the MLP analytical framework can be applied to build an empirical analytical apparatus capable of shedding light on an emerging transition through the study of experiment initiatives. As it articulates them and

the more recent frameworks of project-based organizational learning management, it allows for a more precise apprehension of the capacities for dynamic evolution and the role of the different actors in the transitions that the initiatives studied have revealed. Thus, we could empirically measure the disruption introduced by the experiments in progress, differentiate the orientations within the studied cases and construct on these empirical evidence potential precise targets for the transition. These developments complete the concepts proposed by Geels and Schot (2007) to characterize the transition pathways from the studied niche experiments towards these potential targets. We introduced a new type of radical niche-innovation description, the *earthquake* type, namely a simultaneous convergence of four (in this case) major technologies, at high levels of frequency, amplitude, speed and range that we hope to be helpful for other studies.

As for managerial contributions, our characterization of the three ideal types widen the range of possibilities, beyond the trend, too often observed, of the fascination for a one best way extrapolated from the most advanced and mediatized experiences, here the robotaxi. On the other hand, it shows the potentialities and risks of the current emergences for the different actors in the field of automotive mobility. Our analysis of the actors at work in the various associated ecosystems clarifies, for the professionals involved, whether private or public, the stakes of the initiatives in progress and the role they can play in the implementation of the learning trajectories that will extend them.

This article exploits the theoretical construction phase and the first part of the empirical analysis of the current research. The continuation of the empirical investigation beyond the ten cases already studied will make it possible to give a more quantitative dimension on the importance of the different trajectories described, as well as on their distribution in different geographical and institutional contexts, whether these are directed economies such as China or contexts dominated by large market players such as the USA.

5. ESSAY 3: Systemic innovation and project learning: from firm to ecosystem learning capability

Abstract

Projects are important learning vehicles for companies. But in the context of systemic innovations, a single firm cannot be considered as the sole locus of learning processes since it requires the coordination of various actors within a large and differentiated ecosystem. This paper addresses the little-studied issue of project-based learning at the ecosystem level associated with systemic innovation.

After defining our theoretical framework, we test it through a comparative cases study of innovative mobility as a service (MaaS) initiatives.

We confirm the importance of the project's experiences in ecosystem learning context. We compare how financial, technical, systemic and performance risks are mitigated along the learning trajectory. We characterize key players of the project to project learning processes in this ecosystem context.

Theoretically, this article opens up a new space for the analysis of project-based learning processes at the ecosystem level; it connects the project management stream to literature on systemic innovation and ecosystems. On the managerial and socioeconomic level, it sheds light on one of the major contemporary industry transitions.

Keywords: project learning, systemic innovation, ecosystems, automobile industry, multi case methodology.

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STATUS OF THE PAPER: UNDER REVIEW PROCESS

5.1. Introduction

Projects are important learning vehicles for organizational learning. The field of project management has analyzed the processes that underpin such learning capacity: how vanguard innovation projects can create new knowledge about markets or technologies for a company, how project-to-project and project-to-permanent organization learning processes can deploy and sustain such learning over time through lineage management.

These researches analyze situations where project-based learning processes are operated and more or less managed within a leading (usually large and global) company. But the literature on innovation and strategy has underlined the importance of the concept of "systemic innovations" in our contemporary economies. In systemic innovations, it is clear that a single firm cannot be considered as the sole locus of learning processes as it requires the coordination of various learning processes within a large differentiated ecosystem and an application context involving various actors. What are the processes that drive project learning processes in such a context of systemic innovation?

This paper explores this research gap in a typical systemic innovation context, the field of innovative automotive mobility services, namely Mobility as a Service or MaaS (MaaS-Alliance, n.d.). On the supply side, this field of innovation involves differentiated actors, such as carmakers, IT service providers, private and public infrastructure managers. On the demand side, they come from private car customers but also from public transport authorities.

We develop a theoretical framework to analyze these contexts of systemic innovation in a methodology based on multiple cases. This framework characterizes the ecosystem (supply and stakeholder sides) associated with systemic innovation. It proposes a metric to characterize the complexity risk associated with the systemic dimension of innovation. It complements the traditional dimensions of technological maturity and financial risk associated with the innovation effort. We explore how the systemic nature of innovations is compatible with the inter-project firm centric learning processes identified in the literature. We propose the concept of "*ecosystem learning capability*" to characterize the effectiveness of the context of systemic innovation in terms of collective learning.

The application to mobility as a service domain confirms the importance of experimentation projects in the learning trajectory of an industry. It sheds light on the importance of considering the learning capability of the ecosystem beyond the enterprise level. The comparison of cases

in different contexts shows the importance of local and national territories on these ecosystem capabilities.

For academics, the contribution is to broaden the scope of analysis from project-based organizational learning processes of the enterprise to ecosystem learning processes. For business leaders and public authorities, it underlines the importance of coordinating efforts to manage such important transitions as the trend in mobility services.

This communication is organized in five sections. In Section 1, we present the context of the ongoing transition in the automotive industry from a product-oriented B2C internal combustion engine context to an electric, connected and autonomous mobility service context. In Section 2, we develop our theoretical framework that articulates systemic innovation and notions of ecosystem to project-based flow while Section 3 introduces the design of research and methodology.

In section 4, we present three cases studied through our analytical grid, which allows us to build the empirical evidence we exploit in section 5 to present (1) the importance of project scope for the ecosystem learning process and (2) how our theoretical model can help to assess learning capacities in differentiated project contexts. The conclusion draws the implications of these findings for both academic and managerial purposes and proposes perspectives for future researches.

5.2. Context: the automotive mobility momentum, 2020-2035 the end of a century automobile paradigm

The automotive industry is currently undergoing a major transition under the conjunction of four societal trends.

The first, in response to the risks of climate change, implies policies to limit CO₂ emissions. Incentive policies in favor of clean energy are old, but regulations are evolving from encouraging electric power to banning combustion engines (Burch and Gilchrist, 2018). The challenge, set by the States to achieve carbon neutrality by 2050, which, given the length of time the car fleet is used, means a total ban on the sale of new internal combustion cars by 2035. As an example, the industry has 15 years to go from 2% to 100% of electrical sales in Europe!

Secondly, the problematic nature of traffic in large metropolises, which will worsen in the future with the urban concentration of populations and the trend towards remoteness from places of residence and work as a result of the rising cost of housing in urban centers.

Thirdly, there is a behavioral change from purchasing proprietary products to consuming service experiences. The evolution of car mobility, with the spectacular development of operators such as Uber or Lyft, particularly among young urban dwellers who, in previous decades, had been car owners, is striking.

The fourth contextual element is the development of digital technologies that enable the implementation of these services. These technologies enable complex services such as "ride hailing" to be organized with a large fleet of vehicles, and allow easy and personalized access to them through applications on smartphones. The robotaxi is the horizon for the development of mobility services (Accenture, 2019; McKinsey, 2019) as it combines the exploitation of digital technologies with the ongoing development of automated vehicle driving.

Altogether, they drive the major and rapid dynamics of large automotive companies towards electric, connected, shared and autonomous mobility services (for some examples, Daimler, n.d.; General Motors, 2019; Toyota Motor Corporation Official Global Website, 2018). Numerous statements and reports attest to the unprecedented innovation effort associated with the implementation of these dynamics which, when unprepared, currently lead to the absorption of the least prepared by companies that have built the capacity to cope with them.

Moreover, these industrial dynamics are taking place in a competitive context marked by two evolutions disrupting the structure of the sector established for decades: the irruption of new entrants from high tech sectors and the end of the domination of companies located in mature markets: USA, Europe, Japan.

The traditional automotive industry is organized in a hierarchical chain of command. Manufacturers (or OEMs), final assemblers and distributors are the dominant players, controlling a value chain also hierarchically organized, from Tier 1 suppliers, who deliver global and complex modules or functions, to Tier X-level suppliers who deliver elementary components and raw materials. This competitive context is destabilized by the importance of technology industries necessary for the automation of vehicles as well as by service operators. Alphabet, with its subsidiary Waymo, is today the most advanced player in the field of robotaxis, while the ride hailing operator Uber has embarked on an ambitious innovation strategy in the domain. In both cases, actors, outside the traditional automotive environment, are setting the pace of the transition: this is obviously a major change from the innovation dynamics of previous decades.

The other disruption in the competitive situation of the auto sector is the end of the domination of mature market (Europe, Japan and US) as sole locus for automotive innovation. Till the 2000's, Asian markets and, specifically the Chinese one, are leading in term of sales volumes. In the field of Li Ion batteries used by EVs, China is now in the lead thanks to its industrial policy, while in the field of Tech companies, Baidu, Tencent and Alibaba compare favorably with the GAFA and Didi is the Chinese equivalent of Uber. At the same time, the stricter standards for vehicle emissions, both at the national level and in large, heavily polluted cities, are forcing automobile companies to develop cars polluting less. The innovation playground for green, connected and autonomous mobility is then a global one, where competitive advantages car lay in the specific regulation or resource of a given region or country.

The management of these dynamics is at the origin of transformations in innovation processes within automotive companies. Midler et al., (2019) analyzed, under the name of ambidextrous program management, these transformations that call into question the management of project portfolios implemented in the 1990s and 2000s. But what has just been a developed show that the management of these dynamics takes place at a much broader level than that of an automobile company, even if it is global. The example of Waymo shows that a company completely outside the sector can even become a leader in transformation. It is therefore important, in order to understand the dynamics at work, to broaden the scope of analysis beyond companies that were once dominant, such as regions that once shaped the industry's trajectory. It is this double shift in analysis angle that we are doing in this paper.

5.3. Literature review, research question and theoretical framework

a. Project learning

The role of projects in organizational learning has long been studied by the academic field of project management. This learning function has been highlighted on the one hand within the project itself, especially when its focus is particularly innovative and uncertain. Lockheed has developed a specific tradition of managing its riskiest projects, the "skunk projects" (Jenkins, 2001). Frederiksen and Davies (2008) proposed the concept of "vanguard projects" to describe such adventurous projects and their role in entrepreneurship. Lenfle (2008) characterized the more general concept of exploration projects and showed the differences. Beyond project-based internal learning, the research also showed the processes by which permanent organizations learn from the projects they conduct. Brady and Davis (2004) thus proposed a general

framework for the relationship between learning in projects and the learning of the permanent organizations that carry them out. Loch and Lenfle (2010) proposed several configurations of permanent organization learning through projects, either by organizing competition and selection within a portfolio, or by organizing learning from one project to another according to the logic of the pivot of start-ups, or by combining the different approaches. Soderlund and Tell (2011, 2009) have studied the capability of a firm to organize project based learning on a global scale. Maniak and Midler (2014; 2013) characterized, under the concept of project lineage management, the organizational modalities organizing learning within a succession of projects while Kock and Gemunden (2019) have explained several lineage management configurations. Several authors have also emphasized the importance of projects as a learning vector for the permanent organizations that carry them out.

b. Systemic innovation

The work described above focuses on learning perimeters that concern the same company, the one that initiates and carries out the projects from which it will then draw lessons. But many contemporary innovations go beyond the boundaries of a single company, or even a single industrial sector. The concept of systemic innovation introduced by (Teece, 1996) refers to breaks that companies deploy over a wide range of components, activities and players, well beyond the product they manufacture. We will use, in this paper, the definition proposed in (Maniak et al., 2014a; Midler and von Pechmann, 2019; von Pechmann et al., 2015) as they define them as transitions that bring together four characteristics: (i) their level of radicalism in the rupture introduced; (ii) the extent and heterogeneity of the perimeter of players they mobilize; (iii) the large scale of the projects; (iv) the speed of the expected transitions.

For this type of innovation, the right scope for analyzing learning processes is no longer the company but the business ecosystem that collectively deploys the (systemic) innovation. *What does project-based learning mean when the organizational scope to define innovation strategy and capabilities is no longer a single firm but an ecosystem?*

c. Ecosystems

In their recent literature review on the ecosystem notion, Jacobides et al., (2018) identify three broad groups of ecosystems: a “business ecosystem” stream, centered on a firm and its environment as a community of share fate as a whole; an “innovation ecosystem” stream, focused around a particular innovation or new value proposition while « platform stream » focuses on a specific class of technologies and the interdependence between them. These three

currents share basic notions, those of complementarity (Teece, 2018b) and co-specialization: the actors in the ecosystem develop different and non-generic offers (i.e. they cannot be obtained in a simple way by the market) which, taken in isolation, have less value (or no value at all) than if they were offered simultaneously. They then propose the following definition encompassing the three streams: “*an ecosystem is a set of actors with varying degrees of multilateral, non-generic complementarities that are not fully hierarchically controlled*” (Jacobides et al. p2264 2018).

The central issues of this stream are then notably that of the conditions and management of the alignment of this co-specialization.

According to the currents quoted, the authors adopt different names and visions to describe the capacity of an economic actor to lead the others in this alignment. In the first trend, this alignment is not necessarily "managed". It is a common good that the various players will seek to maintain, and which may result from the action of an ecosystem manager or hub or keystone firm, but also from the action of regulators or from a specific feature of the environment in which the ecosystem is deployed (regulation, access to a shared common resource, etc.). We keep from this stream the importance of the ecosystem dependency from the context where it is embedded. In the second case, it is the firm that develops the "focal innovation" and organizes the upstream coordination of the design processes and downstream of the processes for implementing the offer (Adner, 2017). It is the platform leader (platform leadership or platform sponsor) that has defined the architecture of the offer, in particular its modularity (Baldwin and Clark, 2000) and the conditions of access to products that are complementary to it (opening of the platform) (for IT domain, Cusumano and Gawer, 2002; Jacobides et al., 2016 for the automotive industry).

The literature on systemic innovations is closely related to the second stream we have cited. The deployment of innovation takes place simultaneously with the rise of the associated supply ecosystem. One of the key questions is that of the emergence phase of these innovations.

Indeed, when the innovation has reached a certain stage of deployment, when its architecture has stabilized on a configuration that offers sufficient value to end customers, the alignment mechanisms become relatively simple. The case of iPhone applications is an archetypal example of this. Apple offers the developer a "tool kit" to easily develop applications on the iPhone, which is paid for by selling the applications and the value of the iPhone is increased for the end customers (two-sided market place). These mechanisms are based on the existence of a large installed base of I Phones.

But how do these "win-win" dynamics between complementary products engage when the reputation and market power of the focal offer is not assured? Who takes (or take) the risk of the initial investment? And how does (do) he (they) train potential complementors in these adventurous investments? Here we typically come up against "chicken and egg" problems: partners have to be attracted to create joint value, but this attraction is far from obvious because potential value cannot be proven in this emerging phase of the process.

The analysis of these phenomena of emergence of these systemic innovations and the associated nascent ecosystems has led to research work in strategy and innovation. Ben Mahmoud-Jouini and Charue-Duboc (2017), studying the case of hydrogen based energy engines, show the importance of demonstration projects in generating knowledge and reducing uncertainty among actors of the nascent ecosystem. These projects involve all the actors necessary to deliver and operate a complete solution. These experiments mobilize customers by using innovation in real conditions; they constitute a common knowledge base for the partners in the experiment they constitute a common knowledge base for the partners in the experiment. Marcocchia and Maniak (2019; 2018) have identified the role played by public authorities in mobilizing various actors in innovation support programs. Public calls for tenders open up opportunities to set up "proto-ecosystems" which will then be able to mobilize collectively on common innovation strategies, even if the specific objective targeted by the call for tenders is not itself a success, through a mechanism of redeployment of resources (Hannah et al., 2016). This importance of public policy in the emergence of an ecosystem is typical of contextual based characteristic that was identified above.

Strategic literature emphasizes the role managing the "bottlenecks" that prevent the scaling up of systemic innovation in the emerging phase. Baldwin (2015, p7) defines bottleneck as a critical part of a technical system that has no - or very poor - alternatives at the present time. Bottlenecks have the dual properties that (1) it is necessary to the functioning of the whole and (2) there is no good way around it (Adner and Kapoor, 2010).

In order to overcome the bottlenecks, a first strategy is that of integration, that creates competitive relations with the other actors of the ecosystem in order to create entry barrier by capturing the bottleneck value. Colfer and Baldwin (2010), Fine (2010) show that innovations initially developed as integral architectures in integrated companies, before being transformed into modular platform architectures and deployed across a broad ecosystem. Hannah and Eisenhardt (2018) identify two other strategies: one is to simultaneously compete and cooperate with complements to resolve the bottleneck, while the other is to fully cooperate with ecosystem

complements to manage bottlenecks. Last but not least, a third strategy is to bypass the bottleneck by changing the problematic component within the global system and providing a simpler but less valuable solution (« minimum viable product ») to market (Adner, 2006). This strategy emphasizes the lead time performance to real market experimentation.

Of course, each strategy has different kind of risks. Integration strategy is financially costly. Cooperative strategy generates what we will call a systemic risk, because of the uncertainties in the interdependencies created within the ecosystem. And bottleneck bypassing creates generally a quality or performance risk. *How the ecosystem project is mitigating these different risks within its learning track?*

d) Theoretical framework

From this literature review, we draw the following theoretical issues to study our research question:

- The right scope of analysis for studying systemic innovation is the related ecosystem that is involved in the innovation process.
- The emergence of a nascent ecosystem is strongly context dependent. Regulation, passed business history, specific shared resources... can stimulate or on the contrary forbid the necessary alignment of business actors on a common systemic innovation strategy.
- Ecosystems related to a systemic innovation are a non-strictly hierarchically organized network of firms that provide complementary offers/competencies. Nevertheless, some firms play a dominant role, as platform or ecosystem leader or focal firm.
- Project plays a central role in the learning process of an ecosystem, both to build the relations between the complementors and design the first systemic solution.
- Taking the intra-project learning issue in systemic innovation project, managing the scaling-up of a systemic innovation creates « chicken and eggs » problems that are connected to the risks associated to the bottlenecks that exist along the learning trajectory. The management of bottlenecks is a key process that implies a fine tune tradeoff between four types of risks: technological risk, financial risk, systemic risk and performance risk.
- Taking the project to project learning issue in systemic innovation context, is the issue of lineage management, piloted by a company, still practicable? If so, under what conditions? If not, how can learning between different projects take place?

Therefore, our analytical framework to tackle our research question in our case-based research is summarized below:

- We will first characterize the specificity of the systemic innovation case in terms of nature of mobility transition and performances targeted;
- We will characterize the project ecosystem involved in term of firms involved and structure of leadership;
- We will analyze the main bottleneck issues that challenges the learning track and the related risks that are assumed by members of the ecosystem;
- We will analyze the project to project learning processes: which actors manage such learnings and how?
- Finally, such analysis will permit to set the basis of an ecosystem learning capability notion that we test on the comparison of our case studies.

5.4. Methodology

5.4.1. Choice of the industry

As the main issue is “how do players align in the context of nascent ecosystems and emerging systemic innovations”, we chose the automotive industry as an emblematic industry.

First, the product itself becomes a systemic innovation. It has been considered as a self-standing product for a century, but the ever-increasing connection of the product (to digital networks, to the energy grid, to people, to other services) makes it part of a system which goes far beyond the product. Infrastructures, regulation, suppliers, complementors, public authorities, have to align to deliver ever more connected products, which have to work together into a seamless mobility experience.

Second, as said before, the industry itself has been entering into a paradigm shift from a product-centric approach to a service-centric approach (MaaS), with new and strong environmental and social constraints: new mobility has to provide less congestion within the cities, deliver more value to the customer than a pure automobile, and provide neutral or positive externalities towards environment.

Third, the automotive industry has proved in history to have a powerful ripple effect in the deployment of new management practices, whether it is first in its experimentation or whether it adopts it after other sectors.

Therefore, we face here a perfect case to study how players align within this paradigm and systemic context.

5.4.2. Theoretical sampling

The MaaS challenge is an emerging trend. Players began to move towards MaaS during the past five or maybe ten years, and the challenge is planned to deliver a stable value proposition and business model within the next 15 years. So we do not have enough history to study stabilized configurations through a statistical sampling. We face players, which take part to various systemic initiatives and orient their investment in very various ways.

So instead of a statistical sampling we chose to have a *theoretical sampling* (Eisenhardt and Graebner, 2007), seeking a range of very heterogeneous management situations, in order to build a comprehensive picture of the management challenges and organizational configurations.

In order to capture this diversity, and given the importance of the local context and regulation policies in MaaS deployment, we had to “think worldwide” and engage into an international research process.

5.4.3. Designing an international research

Exploring various cases in various countries is not easy. Research teams have their own industry network, which often are located in their home country. Building on previous collaborations, we build an international research community around this research covering American, European and Asian regions. Our counterparts (1) have proved to be cutting-edge researchers in the field of innovation management and (2) have a local industry network in the context of MaaS. We formalized the roles of each research team within the global research initiative.

Research question was relatively easy to share among the network, since every country was facing the same paradigm shift. What was trickier was to align on common issues to track among the various MaaS initiatives that we wanted to include within the theoretical sampling, since every research team was influenced by its own research perspective and industry background.

The year 2019 was clearly devoted to develop such a common understanding of the issues to tackle. We formalized these issues and converged together towards a share questionnaire to frame the cases in a common way. This questionnaire was translated in various languages (Chinese, Japanese, French) and each research team is in charge of deploying the questionnaire within its own country / area, always accompanied by one the authors.

5.4.4. Case definition

Previous surveys about automotive took various units of analysis. Surveys about manufacturing took a factory as a relevant unit of analysis, comparing the relative performance of practices around the world. Surveys about new product development (Clark and Fujimoto, 1991) took the product (a vehicle) as a unit of analysis, comparing the performance of various players in the world towards the development of new cars. Studies about innovation management (Maniak et al., 2014a) took embedded technologies as a unit of analysis, showing the variety of practices notably in advanced engineering.

For this research, given the systemic characteristic of innovations, we define a “case” as *MaaS initiative encompassing various players*. Since we cannot investigate every player from every initiative, we chose to investigate the platform / ecosystem leader (M.A. Cusumano and Gawer, 2002) to provide information about the whole MaaS initiative.

Three out of six cases are presented, that reflect the variety of innovation targets sought, the identity of the ecosystems involved and the contexts in which they are located.

The table below synthesizes the study cases we have selected for this paper.

Study case	Ecosystem leader	Headquarter Region	Maturity of the offer	Type of offer	Data collection process	
					Questionnaire	Second sources
1	Technology firm and logistic operator	China	Operation	Sales and installation of autonomous driving packages in vehicles	Yes	Yes
2	Mobility operator	USA	Field experiments	Autonomous ride-hailing	No	Yes
3	National institute dedicated to sustainable mobility	Europe	Concept formulation	Shared express transportation	Yes	No

Table 22: The three selected cases

5.4.5. Framework

How to frame the management issues for a MaaS initiative?

The first challenge is to define the *design spaces*. Building on servuction literature and design theory, Lenfle and Midler (2009a) have proposed an analytical framework to characterize the design space of a service innovation. This framework has been adapted by the authors to characterize the design space of MaaS in six integrated domains: (1) Specifying the mobility service; (2) Designing vehicle to MaaS; (3) Designing an AV enabling infrastructure; (4) Designing backend fleet operating system; (5) Designing frontend mobility system; (6) Defining the customer contract relation. A specific MaaS solution can be characterized by the definition of each of these variables.

The second challenge is to define *relevant management variables*. So, on each of the above cited domain, we asked questions about (1) Strategy: what is the target of the initiative (2) Organization: how do the focal firm and the main other players organize internally to face the initiative (3) Project management: how players structured the project, with loose or strong “heavyweight” management (4) Ecosystem management: what are the governance principles ruling the ecosystem involved in the initiative.

We adopt this framework to compare the MaaS solutions proposed in our different study cases.

5.5. Preliminary results on 3 projects

Study case 1 addresses a very recently created Chinese technology company who provides logistics operators with autonomous driving packages implemented in two different use cases. The first is the installation of ADAS (ADvanced Assistance System) in vehicles to improve

operational efficiency, while the other is a level 4 Autonomous Driving⁵⁵ (AD) package, operational on routes learnt in advance by the system; in the latter, a safety officer is present in the vehicle to deal with any possible system failure. We summarize the characteristics of the MaaS solution of Case 1 in the table below:

Design variables	Designing the mobility service	Designing Vehicle to MaaS	Designing an AV enabling infrastructure	Designing Backend AV fleet operating system	Designing Frontend mobility system	Designing the customer contract
Case One	- Logistics operation	- Technological bricks and platform for AD (level 2 and 4)	- No required road or traffic infrastructure, the vehicle is operating with its own embarked resources	- Off line analysis of missions' records (use case 2)	- Unknown	- B2B - Probably on demand pricing?

Table 23: Study case 1 MaaS solution

In study case 2, the targeted MaaS solution is a robotized Ride-hailing service. The case is in a very advanced situation of field's experimentation since its level 5 AD ride-hailing service is already in operation with paying customers, while for obvious reasons of safety and security, safety officers are still present in vehicles; it is also operated in a fully driverless mode for some early testers in a restricted area.

⁵⁵ All autonomous driving levels cited in this section refer to SAE definition (SAE, 2019)

We summarize the Maas solution of this offer in the table below:

Design variables	Designing the mobility service	Designing Vehicle to MaaS	Designing an AV enabling infrastructure	Designing Backend AV fleet operating system	Designing Frontend mobility system	Designing the customer contract
Case 2	Autonomous ride-hailing (AD level 5)	<ul style="list-style-type: none"> - Embarked level 5 AD package - Integration of level 5 AD package in vehicles provided by global players 	<ul style="list-style-type: none"> - No required road or traffic infrastructure, the vehicle is operating with its own embarked resources 	<ul style="list-style-type: none"> - Manufacturing plant - Hub management - Fleet management and supervision - Customer relation management 	<ul style="list-style-type: none"> - Mono-modal App 	<ul style="list-style-type: none"> - B2C - On demand pricing

Table 24: Study case 2 MaaS solution

Study case 3 has just finished its concept formulation phase and enters the development and validation phase leading to field experiments. The basic idea behind the project is to develop a sustainable and shared express transport system offering a passenger throughput worthy of rail transport while maintaining a low user cost very close to that of a private vehicle.

To do this, the proposed solution consists of (gradually) setting up fast transport lanes open to buses, shuttles, taxis or even private cars, as long as these vehicles are pure EVs, equipped with the software and hardware package allowing them to be considered by the automated system which controls the flow of vehicles in the reserved lane; the main functions of the control system are to secure lane inserts and exits as well as to ensure a high passenger flow.

Hubs, distributed along the expressways, allow passengers to reach the vehicles best suited to their transport needs, whether public or private transport, the latter allowing the implementation of peer to peer (P2P) solutions.

We summarize the targeted MaaS solution in the table below:

Design variables	Designing the mobility service	Designing Vehicle to MaaS	Designing an AV enabling infrastructure	Designing Backend AV fleet operating system	Designing Frontend mobility system	Designing the customer contract
Case 3	<ul style="list-style-type: none"> - Energy management service - Individual or collective mobility service - Could be extended to goods 	<ul style="list-style-type: none"> - BEV - Level 4 AD designed accordingly to the system requirements - Connectivity to the fast lane monitoring system - Open to any versatile vehicle complying with fast lane management system 	<ul style="list-style-type: none"> - Hubs including charging facilities - Road infrastructure - Traffic management 	<ul style="list-style-type: none"> Hub management - Fleet management - Fast lane management system - Supervision for mobility operators 	<ul style="list-style-type: none"> - Apps for final customer - Inter platform management system for the different stakeholders 	<ul style="list-style-type: none"> - B2C, B2B2C - Probably on demand pricing for final users

Table 25: Study case 3 MaaS solution

5.5.1. Characterizing the mobility solution ambition

The three cases show different approaches to translate the unclear overall concept of mobility services into concrete solutions. In cases 1 and 2, the performance of the solution is ensured by the technology embedded in the vehicle, while in case 3, mobility autonomy is achieved by external control of the vehicle supported by the functions provided by the infrastructure.

The cases present contrasting ambitions, both in terms of the level and the performance to be achieved.

In terms of level of ambition, case 1 relies on existing technologies to improve the logistics of operators on a given fixed route. The second case, on the other hand, aims to achieve complete vehicle autonomy, without any limitation of territory or mission. Case 3 is somewhere in between, building a performance progression combining existing solutions and then improving them with the contribution of new technologies to automate traffic flows.

In terms of performance orientation, case 2, using a robot taxi, aims at improving individual transport. Case 3, on the contrary, aims at solving public transport problems, typically

congestion problems when moving from the suburbs to the city center when public transport is already saturated.

5.5.2. Characterizing the ecosystem composition and structure

In this section, we analyze the ecosystem involved in the three MaaS projects in terms of actor involved and playing roles.

In case 1, the ecosystem provides a dual leadership with the logistics operator as client and the technology company as solution provider in a B2B alliance relation. In addition, there is technical cooperation between the technology company and the truck manufacturer, chosen by the operator, to install the AD packages and validate their operation in logistics trucks.

In case 2, the leading company of the ecosystem is a very powerful high-tech firm which develops the complete hardware and software AD package as a stand-alone solution, meaning no interaction with road infrastructure or any traffic management system. It has developed a strong ecosystem with many key actors of the automotive industry; it sources vehicles to be adapted from global carmakers and Tier 1 suppliers provide some of the key components necessary to make the level AD 5 package operating. In complement, its manufacturing plant, where sourced vehicles are adapted to self-driving function, has been designed and installed through a partnership with a top-level engineering company of the automotive industry. In order to develop its business, the company has signed numerous partnership agreements with various companies and public transportation authorities to operate an autonomous first- or last-mile transportation service allowing customers of these companies or travelers from underserved areas to easily access their final destination. As far as digitalization business is concerned, the company is strongly supported by its parent company.

Without any doubt, this company is leading the development project, plays the role of a focal firm since all the critical competencies to develop and operate a fully autonomous ride-hailing system have been integrated inside the company.

In case 3, the team in charge of the concept formulation brings together major skills as it is composed of two OEMs, one construction company, one IS/IT solution developer and is coordinated by a public / private research technical institute dedicated to sustainable mobility. Far more interesting is the forecasted composition of the team in charge of the development: in complement of the different industries or institutes already cited, it is necessary to integrate Tier X suppliers (embarked AD package), technology companies (components for embarked AD and debarked fast line management), public and / or private transportation operators,

expressways concessionaires or operators and, last but not least, public authorities. As the main values of this mobility concept are more collective (sustainability, low transport costs, high passenger throughput, reuse or potential adaptation of existing assets such as urban or suburban expressways) than individual, it can be assumed that the lead partner for such a project would probably be a public authority (or a consortium of public authorities all bound by the same objectives), strongly supported by private / public technical institute(s).

Here again, the cases present a variety of configurations. In cases 1 and 3, the projects involve both a project owner component, which is responsible for formulating the request, and an engineering contractor component, which is responsible for designing the solution. In case 2, the project is clearly dominated by a dominant prime contractor proposing the solution and operating the service in innovation-push logic.

5.5.3. Characterizing the internal learning process of the project: mitigating the technical, financial, systemic and performance risks in bottleneck management

Case 1 shows a very pragmatic learning track which avoids technical difficulties by simplifying the mobility mission: one road, fixed stops, one operator in the truck which can take care of problems that the assistance cannot handle. The learning trajectory pursued by the technology provider aims to gradually vary and complicate routes as well as address new demands, based on requests of different project owners. Technological and financial risks are therefore minimized here.

The systemic risk is also minimized, since the vehicle adaptation is implemented as plug-ins on existing trucks while the absence of any communication with road or traffic infrastructure combined with the presence of a safety officer have enabled a quick go-to-market of the offer. On the other hand, the performance ambition of the targeted solutions remains modest and we can ask ourselves whether or not these current steps will promote the transition to fully automated vehicles.

In case 2, the ultimate promise of a stand-alone ride hailing is very ambitious. The technical risk is significant and is located mainly on the vehicle side where the level 5AD package has to demonstrate its operability and safety in many various situations of road traffic but also in hard conditions of weather or luminosity, to cite a few examples. Similarly, the financial risk is major, with the operator assuming most of the engineering and equipment investment involved in the experiment. In terms of overall cost, the long ten-year journey of the learning process with many different stages of prototyping and associated experimentation as well as the

potentially high cost of the complete AD package suggest a relatively long return on investment, once the service can be marketed for widespread distribution. Conversely, the systemic risk is minimal, because the solution is an autonomous vehicle independent of the infrastructure resources and the company closely controls the relationship with the complementors, thanks to the purchase contracts (vehicles, components, etc.) that it establishes with them.

In case 3, the technological complexity is not so great on the vehicle side and can be considered as an enabler; it can be limited to level AD 4 since the expressway monitoring system limits the use of automation at the entrance and exit of the lane as well as flow control once inserted in the lane and there is no need to operate autonomously outside the expressway network. As a corollary, it can be assumed that the complexity of the fast lane monitoring system could be very high. In terms of global cost, the vehicle side is mostly an enabler while the infrastructure side could be highly costly depending upon the capacity of reusing or modifying, at “low cost”, existing assets. Moreover, the success of such a project seems difficult to conceive without a strong financial and political investment by local or territorial authorities.

The system complexity is, on the contrary, high due to the numerous and different stakeholders, the integration of different technologies coming from industries not used to work together, the uncertainty related to the capacity of the business model to provide sufficient revenues for all the actors. On the other side, as we assume that public authority(ies) would lead such projects we expect that they would enable an easy obtention of the permit(s) for field experiments and operations.

5.5.4. Characterizing the project to project learning in ecosystem project context

With regard to learning between different projects, *Case 1* shows how AD technology logistic provider and operator, operates learning between different experimental projects, mobilizing very different ecosystems, but within the same territory context. Here, we are typically in a learning strategy from one project to another as Loch and Lenfle (2010) have characterized it.

In case 2, the dominant player is clearly developing a planned project lineage strategy (Kock Gemunden, 2019) oriented towards robotic ride hailing. He clearly can drive the ecosystem learning through his platform leadership capability as described by Cusumano and Gawer (2002). This strategy was initiated by the company ten years ago, which has since made massive investments. This massive commitment of resources allows the leading company to develop a learning strategy implementing several parallel projects that explore different

ecosystem configurations in a relatively independent way that combines selectionism and project to project learning.

Case 3 is not yet advanced enough to address the issue of inter-project learning. Let us simply note that at present it proposes a general and abstract mass transit solution, which must be embodied in a specific concrete territory. It is therefore important to note that the territorial public authorities are a key player in the initiative. The issue of scaling up is therefore much more complex here than when the initiative is led by a powerful global platform leader. Indeed, each time the mobility service is deployed in a new territory, its specifications have to be redefined and renegotiated with new and different local actors.4.5. Characterizing the ecosystem learning capability

The three cases we have studied in this paper are at very different levels of maturity.

In *case 1*, it is part of a relatively recent history (the company was created in 2017) but the mobility technology solution is already in real operation in two different situations, and is already programmed for new applications. Learning therefore takes place through the pursuit of a succession of modestly ambitious targets that are reached each time.

Case 2 is being experimented in real-life situations and on a large scale, as part of a massive, proactive strategy, some ten years in the making. The target is very ambitious and it should be noted that the company has announced deadlines for reaching this target, which have so far been postponed several times.

Case 3 is at the concept definition stage, and is looking for a testing ground to embody and test itself; we can assume that the testing stage of the complete solution will be long-lasting.

5.6. Discussion

We highlight five main lessons from the analysis of these cases in relation to our research question: the role of projects in the emergence of systemic innovations as well as of new ecosystems; internal learning in systemic innovation projects; project-to-project learning; the role of the context in which these projects take place.

5.6.1. Projects as key playground for systemic innovation and nascent ecosystems

The cases studied confirm the importance of projects as playground for the emergence of systemic innovations (Ben Mahmoud-Jouini, Charue-Duboc, 2017, Marcocchia & Maniak 2018). Indeed, these innovations imply a double learning process: that of the content of the project itself and that of the cooperation between the differentiated heterogenous participants.

The project, by proposing an operational space for the commitment of a concrete cooperation on the one hand, and by limiting the risks of these commitments by the limited perimeter in the duration and in the objectives, constitutes a space favorable to encourage such learning; this role corresponds exactly to the "temporary trading zone" function analyzed by Lenfle and Söderlund (2019).

5.6.2. Ecosystem identity and innovation orientation

In case 2, the ecosystem is clearly controlled by the driving automation solution provider, according to a platform leader configuration (M.A. Cusumano and Gawer, 2002). The focal company invests massively, contracts with companies to complement the solution, and drives the learning process. The public players in the territories concerned are more like experimental field providers to test a solution that will then be proposed to other territorial authorities, according to a formula that is already packaged. The strategic model is therefore the capture, by this platform leader, of a significant part of the profit generated by the solution B2B2C.

In case 1, the technology provider is involved in a quite traditional B2B project relationship between a project owner who defines his requirements and a prime contractor who develops a solution accordingly.

In case 3, as the benefit is more of a collective business-to-territory (B2T) type and, due to the very important place of road infrastructure development or modification, it seems obvious that territorial authorities would play a major leadership role in the ecosystem.

5.6.3. Managing the inside project learning: risk strategy and leadership in the ecosystem

The three cases present contrasting configurations for the management of the four risk categories we have defined.

Case 1, a typical of a start-up strategy, is based on a relatively short time horizon, minimizing financial and technological risks in order to quickly arrive at "minimum viable solutions" that are truly marketable and exploitable. The systemic risk is low, because the projects progress in a "bowling alley" logic (Moore, 1991; Moore and Fabis, 1995) where the supplier develops B2B solutions specifically for each client. On the other hand, the performance risk remains high, in face of more ambitious players who would be capable, in the long term, of imposing a more accomplished autonomy solution that would impose itself as a global standard.

Case 2, on the other hand, sets itself a particularly ambitious and distant target solution (fully automated robotaxis), even if it means having to deal with degraded and costly transitional solutions. By the strength of its leadership and of its ambitious performance targets, the focal company frees itself from systemic risk by imposing its solutions on the complementors. This is a typical platform leader strategy, common in the digital field, where "winner take all"; we will discuss later on whether this strategy is valid in the field of mobility characterized by important contingencies of the territorial context.

Case 3 presents an intermediate strategy in successive stages, based on a hybridization of existing concepts (peer to peer carpooling and reserved lanes for public transport) to gradually develop, thanks to the contribution of on-board and off-board technologies, a more efficient mode of public transport than existing solutions. While the technological risk is minimized, the financial risk, which could be very high on the infrastructure side, is gradually shared between the players supplying vehicles and infrastructure. On the other hand, the systemic risk is maximal here, since it is a question of coordinating learning trajectories from universes as different as the automobile, infrastructure and public transit systems.

5.6.4. Systemic innovation and project to project learning

The project management stream has identified several learning processes for firms mobilizing projects: lineage management, selectionism in differentiated project portfolios, but are they compatible with the systemic nature of the innovations explored in the project?

In case 1, the ecosystem configuration is, a priori, less favorable to inter-projects learning, due to the succession of clients and projects which do not have the same mission orientations. Here, the technology provider has to ensure the inter-projects learning, at the level of functional and technological building blocks, by adapting standardized technological elements to differentiated missions.

As this a bowling alley logic (Moore, 1991; Moore and Fabis, 1995), the difficulty of this strategy is precisely to organize this compromise between standardization of technological bricks and custom design of offers in order to satisfy each customer's different expectations.

Case 3 seems to be the case where the specificity of the territorial context is the strongest, and therefore the least favorable to easy inter-project learning.

Beyond the power of the (global) leader companies to impose their learning track to the ecosystem, and although most of the companies involved in these projects have a global dimension, the learning trajectories we have forecasted in these cases take place in specific

territories: USA, China or Europe. We find here the characteristic of context dependence that has been highlighted by the literature on ecosystems: alignment is also linked to territorial specificities that create constraints and common challenges for the actors and thus help to explain the alignment of their strategies with the projects. These are regulations on mobility such as forms of housing and transport use.

Will project-based learning trajectories remain encapsulated in local and territorial logics, which would mean that the systemic logic would remain dominant? Conversely, will new transport solutions be imposed at the end of this learning process as new global standards, just as the automobile product has been able to establish itself globally, albeit by diversifying? Our research is certainly not intended to answer these questions, but to stimulate future research in this direction.

5.6.5. Systemic innovation and project learning efficiency: public authorities as systemic innovation project learning leaders?

If the direction of the trajectory is probably marked by the identity of the territories, so is the speed of learning. The Chinese case presented here shows an exceptional performance in reducing the effective time to market of innovative mobility solutions by a start-up created in 2017. Similarly, the US case shows a situation where it is possible to experiment with autonomous transport technologies that are still experimental in nature, on a large scale and over time.

These two contexts, although obviously profoundly different, share two characteristics that favor the speed of learning about disruptive innovation. On the one hand, the ease of raising significant funds (whether private in the USA or public in China) to support ambitious disruptive innovation promises; on the other, regulatory authorities that are permissive with regard to experimentation in real-life situations. The European case is certainly in a context of regulation that is less permissive to innovation.

The other important role of national public authorities is to help the scale-up of the systemic innovation. Indeed, they can organize cross learning of local experiments and expand their application scope through national regulation roadmaps that could align the innovation dynamics beyond the local territorial specificities. In this sense, public authorities can be seen as public platform leaders. As the strategic literature is mainly focused on the role of private firms as platform leaders (Cusumano Gawer, 2002), this opens space for new researches on the role of public platform leadership management.

Obviously, these three cases cannot serve as proof for a theory on the capacity of a socio-political context to stimulate or favor systemic innovations such as new mobility systems. But this provides an incentive for further research at this broader policy level.

5.7. Conclusion

The literature on project management has highlighted the importance of projects in corporate learning. One of the characteristics of contemporary innovation strategies is to be located beyond the perimeter of a single company, at the level of an ecosystem of companies. Those companies offer differentiated and complementary contributions that together constitute the innovation value for end customers. It is systemic innovations of which the microelectronics and IT sector is emblematic. Learning must therefore take place not only within a company, but be coordinated across all companies involved in the ecosystem. The purpose of the research presented in this paper is to analyze the role of projects as a vector of learning in this context of systemic innovation led by an ecosystem.

We have studied this research question on the empirical case of new mobility services, an emblematic context of systemic innovations mobilizing actors from various sectors: car manufacturers, digital companies, transport operators, infrastructure managers and territorial public authorities. We have adopted a multi-case analysis methodology that allows us to compare different initiatives and ecosystem contexts. We have built an analytical framework allowing to characterize (i) the more or less systemic nature of the innovations studied, (ii) the perimeter and structure of the ecosystem involved, (iii) the way in which learning takes place within the project on the uncertainties of the offer in the field of technical maturity, financial constraints, systemic uncertainty and the ambition of the performance target, and (iv) the possibilities and modalities of learning between several successive projects.

The study of three cases confirmed the importance of the project as a vehicle for learning from the nascent ecosystem, since it provides both the opportunity for mutual knowledge between actors from different contexts and for confronting the uncertainties of the targeted innovation. It shows the importance of the composition and structure of the ecosystem on the orientation and choices made in the collective learning trajectory within the project, as well as on the possibilities of implementing learning strategies through successive projects. Finally, the comparison of American, European and Chinese cases shows that these eco-systemic learnings are dependent on the characteristics of the national context, which, on the one hand, more or less stimulate the alignment of actors' strategies with innovation perspectives and, on the other

hand, more or less favor the possibilities of experimentation necessary for learning about systemic innovations.

Theoretically, this communication opens up a new space for the analysis of project-based learning processes at the ecosystem level. It connects the project management stream to literature on systemic innovation (in the field of innovation) and ecosystems (in the field of strategy). The management literature has focused on the role of private firms to coordinate ecosystem dynamics through the platform leadership theory (Cusumano, Gawer 2002). For systemic innovation context, this article emphasized the importance of public regulation in the capacity to (i) stimulate the emergence of innovative ecosystems by giving ground to innovative experiments and (ii) facilitate the project to project learning through consolidating and disseminating the experiments results by public transport regulation roadmaps. It opens to new research efforts on the role of public management as important capability within systemic innovation project learning processes.

On the managerial and socioeconomic level, it sheds light on one of the major contemporary industry transitions. For managers, it emphasizes the importance of collective strategies to sustain the development of such systemic innovations and illustrates various possible configuration that connect the target of the initiative and the characteristics of the ecosystem involved. For public authorities, the article shows the importance of a strong involvement in ongoing initiatives as a Public Platform leadership position. In order, on the one hand, to stimulate et drive the ecosystem learning towards targets relevant to collective territorial issues and, on the other hand, to stimulate the scaling up of local embedded experiences whose lessons might not be disseminated without integration into an overall plan.

This communication has two limitations. Firstly, it only reports on the first phase of research that will continue over the next two years; secondly, the proposals made in this communication on inter-project learning are, at this stage, conjectures and hypotheses that have yet to be validated. The continuation of this study, will make it possible to overcome these limitations. Secondly, the research question on project-based ecosystem learning is obviously not specific to the context of automotive mobility, which is studied here. A confrontation with other contexts would certainly be fruitful.

6. ESSAY 4: How do servitization impact on project management? Some examples from the emergence of MaaS

Abstract:

While innovative services are becoming more and more important in terms of product ownership, little research has been conducted on the link between innovative project management and a company's servitization strategy. This paper addresses this issue on the emblematic case of the transition of vehicle product innovation to Mobility as a Service offers.

After setting up an analytical apparatus that describes innovative initiatives of mobility services and enables a structured analysis of the projects that contribute to their development, we conduct an empirical study on three contrasting examples of MaaS initiatives.

Consequently, we introduce a new typology of services strategy, based upon the intrusiveness of the innovative service development within the product development. With this perspective, we differentiate “*product-centric added services*”, “*product-centric service enabler*” and “*product enabler of service-centric offer*”. We also exhibit that the transition from product to service drives a transition from managing a product lifecycle to a service lifecycle which has major impacts in terms of managing an innovative project.

Keywords: servitization, product service system, articulation product-service in development, project management, innovation.

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STATUS OF THE PAPER: WORKING PAPER

6.1. Introduction

The situation about the galloping development of services is quite well summarized by Deloitte: “*Customers don’t simply buy products anymore and are increasingly looking to pay for the services they provide*”⁵⁶. This phenomenon has recently accelerated with the advent of the internet and the spread of digital technologies that make the collection, transfer and analysis of data easier and faster. It paves the way for many services such as pay per use offers for end users and, for companies, for manufacturing, maintenance, logistics etc. as a service.

This move from products to services is consistent with the forecast produced by Vandermerwe and Rada when they introduced the concept of *servitization*: “*Swept up by the forces of deregulation, technology, globalization and fierce competitive pressure, both service companies and manufacturers are moving more dramatically into services*” (1988, p. 315).

When developing a “ ... ‘bundles’ of customer-focused combinations of goods, services, support, self-service and knowledge” (Vandermerwe and Rada, 1988, p. 314), the articulation between the development of the product and of the service has a first order impact on the management of the project. Whether the service is simply added to the product, or whether it is deeply embedded in the product, or indeed whether the product is deeply embedded in the service, will influence the nature and organization of all design activities. In addition, as customers are co-producers of the services (Eiglier and Langeard, 1987; Grönroos, 1990; Lenfle and Midler, 2009a), the direct consequence of the service centrality of an innovation is that it is the customer's experience that must be validated. The latter, being integrated in a specific context and for a specific customer use, requires specific processes, procedures and tools that generally go far beyond what companies apply for the validation of their products.

The aim of this work is, thus, to analyze how the transition from products to services impacts the management of innovative projects. This leads to the introduction of a research question: “*How does servitization impact on the management of product-oriented innovation projects?*” to which we answer by analyzing the results of an empirical study devoted to the impacts of the emergence of Mobility as a Service (MaaS) on the management of innovative projects.

The purpose of this question is to guide the research work as the literature on servitization is abundant but mainly focused on strategy and marketing perspectives. In addition, our

⁵⁶ <https://www2.deloitte.com/ch/en/pages/consumer-industrial-products/articles/transitioning-from-products-to-services-to-fuel-growth.html>

literature review exhibits that, if the transition from products to services has been studied, the papers dedicated to these issues have mainly identified challenges in company organization and related network organization while the impact on project management has been less studied. On the other hand, the literature on the management of innovative projects is mainly focused on the management of product projects, whether in a mono or multi-project context. This paper, which aims to fill the research gap highlighted by our initial questioning, is structured as follows.

Section 1 reviews the existing literature on servitization and its relation to innovation strategy and processes. The servitization literature analysis shows that product and service offers are more than often coupled, within a variety of possible articulations. We also summarize some papers dealing with the impact of servitization on innovation development projects, coming from the automotive industry, as this industry has a long and strong tradition of innovation. The analysis of the literature on the management of product-oriented innovation projects allows us to know the state of the art on the process of integrating innovations into the management process of such projects; it also provides us with a reference against which to position the impacts of servitization. Finally, by focusing on innovative service design and project literature, we build an analytical framework to characterize the design perimeter of an innovative service offer using six major variables. This allows us to precise our research question as follows: what are the impacts of the articulation between the product and the service, as revealed through the activation of the service major design variables and the relationships between them, on the management of an innovative mono-project?

Section 2 is devoted to methodology. First of all, we explain the choice of the automotive industry as an emblematic example of the transition from a product innovation strategy to a mobility services innovation strategy. Then, we present our case-based methodology and explain how and why we selected the cases we are studying in our empirical study. Finally, we introduce the analytical apparatus and the study process used to describe the cases and identify the impacts of the innovative service on the management of the project.

Section 3 presents the results of this empirical study. It shows that (1) the scope of the projects as well as the ecosystem involved in the projects are significantly broadened, that the nature of the relation between product and service at design level has a direct impact (2) on the nature and organization of design and validation activities and (3) on the governance of the project.

In section 4, we discuss these results answer our research question and contribute, in the field of project management, to advancing knowledge on the implications of the shift from product-centric to service-centric innovation. We propose a typology of different configurations of the coupling between product and service project.

We conclude by summarizing the contributions and limitations of this study and making suggestions for future research.

This paper brings a novel contribution to the project management research stream first of all because it focuses on a little-explored issue so far: the impact of an innovative servitization strategy on the management of product-oriented innovation projects. In addition, the empirical study, which supports our research, addresses one of the most disruptive transitions in industry and society, namely the emergence of MaaS and its impact on the automotive industry. The detailed study of innovative mobility initiatives, both in terms of the methodology used and the results obtained, makes an original contribution, per se, to the study of the management of innovative projects. First, we confirm the importance of the PSS categories and of the theoretical framework we introduced to analyze the impacts of a service innovation on the management of product-oriented innovation projects. Secondly, we introduce a new typology of services strategy, based upon the intrusiveness of the innovative service development within the product development. With this perspective, we differentiate “*product-centric added services*”, “*product-centric service enabler*” and “*product enabler of service-centric offer*”. We also exhibit that the transition from product to service drives a transition from managing a product lifecycle to a service lifecycle which has major impacts in terms of managing an innovative project.

6.2. Literature review, servitization and innovation processes

6.2.1. Coupling product and services

More than thirty years ago, Vandermerwe and Rada introduced the concept of servitization “*Modern corporations are increasingly offering fuller market packages or ‘bundles’ of customer-focused combinations of goods, services, support, self-service and knowledge*” (1988, p. 314). As services are beginning to dominate, this movement is termed the “*servitization*” of business which Vandermerwe and Rada are careful to differentiate from “... “*servicing*” where a good is repaired or maintained by the manufacturer...” (1988, p. 315). It is also different to

that of “*servuction*”, coined by Eiglier and Langeard (1987), who conceptualized the act of producing a new service⁵⁷.

On their side, Goedkoop et al. introduced the concept of Product-Service System (PSS)⁵⁸ that they describe as “*The combination of products and services can exceed the traditional functionality of products, in terms of quality and cost performance*” (1999, p. 11).

Some authors consider that the name PSS has taken over from the name servitization (Kryvinska et al., 2014; Mahut et al., 2017; Pawar et al., 2009) while Baines et al. (2009, 2007) consider that the concept of servitization encompasses this of PSS. On our side, we continue to use, in this paper, the historical term of servitization and our literature review has considered papers addressing both concepts as they are both relevant for our study⁵⁹.

While many authors have compiled some definitions of servitization and PSS (Baines et al., 2007; Cheng and Johansen, 2016; Kryvinska et al., 2014; Mahut et al., 2017), we particularly retain this one: “*A PSS is an integrated bundle of products and services potentially interacting with a network, which aims at creating customer utility and generating value*” (Mahut et al., 2017, p. 2107). In fact, the notion of network is particularly interesting in the hypothesis that the empirical study, which supports our research, would highlight systemic innovations; indeed, for these, the presence of complementors of a solution is an essential condition of success (Teece, 1986). This reference, to the notion of network, echoes studies that show that, under the influence of the servitization process, companies are pushed to position or reposition itself in the industry's value system (Cheng and Johansen, 2016; Huikkola et al., 2020; Rabetino and Kohtamäki, 2013).

Many reasons have been put forward to explain what the interests of undertaking a transition from products to services are. Among them, we can cite a way to differentiate or customize the offers (Baines et al., 2007; Kryvinska et al., 2014; Tukker, 2004; Verstrepen et al., 1999), an improvement of the financial situation and competitiveness of a company (Kryvinska et al., 2014; Oliva and Kallenberg, 2003; Vandermerwe and Rada, 1988), the ability to withstand market dilution for the company's traditional products (Baines et al., 2007; Kryvinska et al.,

⁵⁷ As the action of producing a product is called production, they proposed to name the production of a service “*servuction*”.

⁵⁸ The concept of PSS is often identified as contributing to sustainable production; this point is not developed in this paper as is not the main focus of our study.

⁵⁹ A much broader review of the different streams of research related to servitization can be found in (Lightfoot et al., 2013)

2014; Verstrepen et al., 1999) and the capacity to satisfy customers and gain their loyalty (Oliva and Kallenberg, 2003; Tukker, 2004; Vandermerwe and Rada, 1988; Verstrepen et al., 1999).

On the other hand, some barriers have also been identified such as an absence of willingness from executives (Oliva and Kallenberg, 2003; Vandermerwe and Rada, 1988) as they don't believe in the potential or service or consider it is out of their usual scope of business. A specific obstacle attracts our attention: the non-proprietary nature of the product used to support the implementation of the service (Baines et al., 2007; Mahut et al., 2017).

The necessity to change the organization of the company is another challenge as Oliva and Kallenberg (2003, p. 170) state that “... *most challenges seem to be in the organizational change domain ...*” and point out the necessity for a company to broaden the scope “... *to adopt horizontal service delivery structures when moving into operational services.*” (2003, p. 171). However this challenge may even be higher as this internal evolution within a company may not be sufficient to ensure the success of a transition to a service offering, as it often requires cooperation with other companies to acquire the skills, resources and capabilities needed to make it happen (Pawar et al., 2009; Rabetino and Kohtamäki, 2013). Some more recent papers also develop knowledge and recommendations about the organizational changes required to drive such a transition (Baines et al., 2017; Rabetino et al., 2017) when Adrodegari and Saccani propose a maturity model to assess the position of a company in its journey to servitization (2020).

Elaborating on an initial identification of three main categories of PSS (leading to a total of 8 when subcategories are included) realized by Tukker (2004, p. 248), many authors (Baines et al., 2007; Kryvinska et al., 2014; Kuo et al., 2010; Mahut et al., 2017) have completed definition of PSS categories. These different contributions can be summarized as set out in the table below and we have added some general examples.

Category of PSS	Broad description	General examples
Product Oriented Services	Core activity remains sales of a product, results in a transfer of ownership PSS offering allows the integration of extra service Companies are motivated to minimize costs for a long-lasting product	Traditional B2B or B2C business model of companies including sales and completed by pre-sales services (financing, insurance ...) and after-sales services (repair, maintenance...) For end-users: cars, white goods, etc... For companies: production facilities
Use Oriented Services	The core activity is not the sale of a product which is owned by the service provider Requires a new business model Companies are motivated to maximize the use of a product to meet demand Value created depends highly on the capacity of the service network to deliver the service	All Pay per use offers for both end users and companies All product leasing, renting, sharing offers Peer 2 Peer product sharing
Result oriented Services	The contract between the consumer and the provider relies on a result and the product is not a matter to the consumer The product is now replaced by a substituting service	Public transportation (From A to B at the minimum cost) Navigation system (from A to B in the shortest time) Services APPLications on a smartphone for end users Manufacturing, maintenance, logistics, ... as a service for companies

Table 26 : Summary of main categories of PSS

Compilation by the authors of contributions from (Baines et al., 2007; Kryvinska et al., 2014; Kuo et al., 2010; Mahut et al., 2017; Tukker, 2004)

6.2.2. Impact of servitization on product-oriented innovation project management

When we focus on the topic of the impact of servitization on innovation development projects, we observe that significant contributions from the literature come from empirical studies carried out on the automotive industry. This is not surprising because (i) product-oriented innovation processes have been for a long time a central capability for automotive firms and (ii) the orientation of innovation strategy as a value and competitive driver has been heavily growing in the past twenty years. And indeed, carmakers have, for a long time, developed different types of services. But when considering the innovation development issue, such service developments are far from similar.

Verstrepen et al., (1999) explained how car manufacturers develop services that take place after the initial sales transaction, such as the installation of additional equipment, maintenance or repair of the vehicle, quality control, etc. They highlighted that services are increasingly adding value to carmakers and that this trend is likely to continue as “*Servitization in general, and a strong focus on service after sales in particular, are powerful ways for European car manufacturers to differentiate their products, improve customer loyalty, generate extra business and defend financial margins*” (1999, p. 543). This type of service innovation is not

very intrusive in the product development process as it is developed through complementary after-sales design. The product-service articulation in design we have described is a case of product-oriented services that we name “*Service added to product*” and whose impact on project management is very limited.

But aiming to create more valuable services sometimes imposes introducing specific components within the initial vehicle development. In his longitudinal analysis of the connecting car concept, Midler (2002) explains how the car radio, initially installed through a heavy aftersales operation, was gradually incorporated, in the 1980’s and 1990’s, as an integral component of the vehicle design process. As a result, the process of coordinating car radio and vehicle designs has changed significantly, moving from an act of purchasing the off-the-shelf solution from suppliers for after-sale installation to a process of co-development (Lenfle and Midler, 2008). These projects, which are of product-oriented services type, belong to the category of product-service articulation that we will name as “*innovating service related product innovation*” which imposes a co-development process between the OEM and related suppliers.

Analyzing a pioneer embarked telematics innovation, Lenfle and Midler (2003) focus on the impact of an innovative service on the car development process. While “*Project management for products has been structured in such a way as to uncouple the elimination of major uncertainties (i.e. the role of advanced engineering) from the development of projects relying on a solid knowledge base that has been developed in strategic areas of expertise.*” (2003, p. 152), they point out that “*The user learning process and the exploration of technical solutions must occur simultaneously*” (2003, p. 148). As a matter of facts, in this type of projects, a continuous acquisition of expertise on technology, customers’ usages, regulation, etc. is both necessary and deeply embedded in the development process. Since then, the improvements and the spread of digital technologies have developed as key issues in most OEMs’ agenda and strategy. The use of a platform approach to leverage the value of digitalization (Cenamor et al., 2017) is a continuation of the more general movement to platformization in the automotive product (Cusumano and Nobeoka, 1998) and to building an innovative featuring capability (Maniak et al., 2014a). Innovative services are supported by embarked modules that are first matured in the advanced engineering phase of the design process then “plugged” on the platform during the vehicle development phase. We have exhibited a new product-service articulation that we will call in this paper “*dedicated product*

to service innovation” combining upstream advanced engineering activities and the continuous acquisition of expertise in the field of the innovative service.

The last two product-service articulations confirm the statement made by Galera-Zarco et al. about the specific industry of project-based firms as they state: “A growing inclusion of services in all phases of the project has been observed ...” (2014, p. 336).

Lastly, we discuss the relationship between the PSS typology introduced by Tukker (2004) and these three types of service-product articulation. Without any doubt, as the *Service added to product* product-service articulation is a pure continuation of the existing business model of the automotive industry, it belongs to the Product-oriented typology we have described as being the current one of the automotive industry. For the other two, as they are fueled by the introduction of new digital and communication technologies in the vehicle, and benefit from a more service-centric coordination between the product and the service during the development phases, they pave the way for the development of new services, of which we provide a few examples. For instance, it enables Use-Oriented services, such as pay per use infotainment, and Result-oriented services such as navigation (from A to B at the lowest cost, in the shortest time...) or emergency alert (an emergency center is alerted and ready to intervene in less than X minutes).

We summarize the three different types of service-product articulation we have uncovered, their respective impact of product development process as well as the PSS category they belong to in the table below.

Type of product-service articulation	Impact on product development process	PSS Category
Service added to product	Very limited	Product-oriented services
Innovating service related product innovation	Co-development with suppliers	Pave the way to Use-Oriented and Result-oriented services
Dedicated product to service innovation	Upstream advanced engineering activities and continuous acquisition of expertise in the field of the innovative service	

Table 27: Summary of current types of service-product articulation

6.2.3. Management of a product-oriented innovation project

Contemporary innovation strategies are characterized by processes that organize the management of several projects within a company.

These concepts of multi-project management have been widely developed and discussed in the context of product-oriented innovation. But to our knowledge, they are not (yet) applied to contexts of servitization, although this seems particularly relevant.

However, in order to better focus on product-service articulation, we will only study the impacts of servitization in a mono-project context.

For the automotive industry, Beaume et al., stating that after “*the empowerment and routinization of product activities in the 1990s*”, (2009, p. 167), companies now deal with “... *applying innovative features within a regular stream of products and platforms*” (2009, p. 166). Consequently, they introduce an Innovation Life Cycle (2009) which aims at describing the introduction of an innovative features in the development of a product-oriented project and encompasses four main phases:

1. Exploration of an innovative feature for future deployment,
2. Contextualization, adaptation of a specific feature to a given vehicle
3. Development of the feature within the vehicle development process,
4. Deployment, i.e. capitalization and roll-out on other products,

As we limit our study to a mono-project context, we replace the last step of deployment by mass production and take as a reference the process described below.

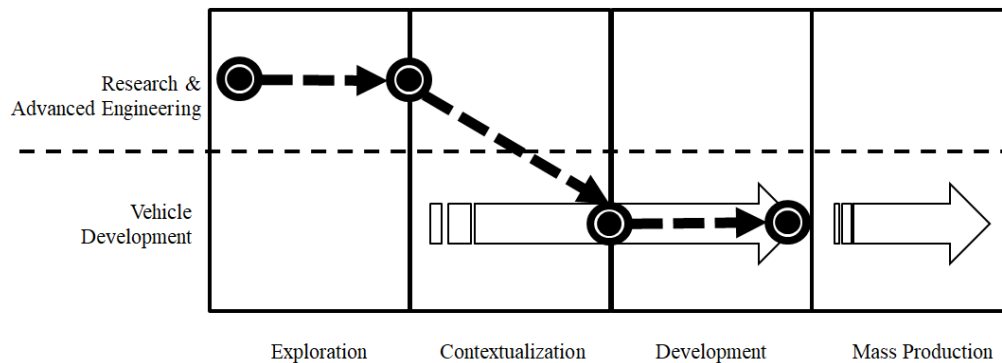


Figure 14: Innovation Life Cycle in a mono project context

Adapted from Beaume et al. (2009)

This Innovation Life Cycle in a mono project context encompasses all the three types of product service articulation we have exhibited in our literature review as (1) *Service added to product* has no impact on this process, (2) *Innovating service related product innovation* imposes the necessity of co-development with suppliers within the development phase and (3) *Dedicated product to service innovation* can be considered as an emblematic example of its application.

6.2.4. Characterization of service vs product design domain

Building on servuction literature (Eiglier and Langeard, 1987) and design theory (Hatchuel and Weil, 2008), Lenfle and Midler (2009a) have proposed an analytical framework to characterize the design space of a service innovation. They identify six design variables that

must be activated in order to design a new service, which we present using the example of services that can be used on a smartphone.

1. The definition of the service of course, i.e., an app on a smartphone,
2. The product that sustains the service, namely the smartphone handset in our example,
3. The infrastructure related to the usage of the product, such as telecommunication systems and servers' infrastructures here,
4. The back-office functions that operate and maintain the service including development and maintenance teams, third-party service providers, ...
5. The front-office that the customer can operate to implement the service, i.e. the store which enables to download the APP on the smartphone,
6. The contracts and value streams that define the economic and legal relations between the different actors in the offer system and customers.

Such a characterization demonstrates that the scope of design of an innovative service offer is much broader than that of the product that supports it. Of course, in general, not all variables are activated at the same time in an innovative service. For example, the incessant generation of innovations in smartphones relies on the stability of telecommunications infrastructures and the contractual relationships established between operators, customers and manufacturers.

By combining this service design framework and the categories of PSS, we can anticipate the importance of the type of servitization on the broadening and increasing complexity of the innovation process.

Product-oriented services need of course design effort to define and develop the new service, to make it accessible by customer (frontend user interface) and to deliver and maintain it though a back-office service capability. But the product, infrastructure and economic model structure generally remain unchanged. To take up some of the examples cited in the automotive sector, financing and after-sales services do not require a significant effort to adapt the product or mobility infrastructure and are easily integrated into the traditional B2C sales model.

Use oriented services definitely changes the economic and legal relations between the service offer system and the customer, introducing the operator responsibility as critical. Back office and frontend interface are also deeply impacted while the product and infrastructure remain, in first analysis, unchanged

Result oriented services activate mostly all the variables, adapting the product to fit to service performance ambitions.

Table 2 below summarizes this discussion. A "+" sign indicates that a design variable is activated to a significant extent for a type of PSS, while a "-" sign indicates that it is activated to a lesser extent.

Design variable PSS category	Service definition	Supporting product	Enabling infrastructure	Backoffice	Frontend user interface	Economic and legal contracts
Product Oriented Services	+	-	-	+	+	-
Use Oriented Services	+	-	-	+	+	+
Result oriented Services	+	+	+	+	+	+

Table 28: Impact of a PSS type on the activation of the variables of a service

This framework will be useful to identify what are the key design variables activated by a service and analyze how the interactions between them impact the management of the project.

In conclusion, this literature review supports our research by emphasizing the following key points:

1. Most of literature about servitization deals with companies' strategy, marketing issues as well as the impact of the transition from product to service on the organization of a firm or its (re) position inside the value chain. On another hand, the impact of servitization on the management of product-oriented innovation has been less studied.
2. On its side, the literature on the management of innovative projects is mainly focused on the management of product projects, whether in a mono or multi-project context.
3. The identification of three categories of PSS shows that there is a variety of configuration in articulating product and service in the innovation strategy of the firm.
4. The state of the art on how to integrate innovations into the management process of such projects provides us with a reference against which to position the impacts of servitization. To date, this reference process encompasses all of the services exhibited in our literature review.
5. We have identified, in the literature, a theoretical framework which allows us to characterize, in terms of design perimeter, the impact of a service innovation versus a product innovation.

6.3. Methodology

In this section, we firstly explain why the transition of auto industry to MaaS is a good candidate to analyze the impact of servitization on innovation project management. Then we introduce how we have selected the study cases which support our empirical study and what is our analytic protocol to implement the cases analysis.

6.3.1. The transition of auto industry to MaaS: an emblematic case of product centric to service centric innovation management

According to Accenture's forecasts⁶⁰, revenues from mobility services are expected to reach nearly €1.2 trillion in 2030, even exceeding those from the classic B2C offer of carmakers! The predicted disappearance of the traditional B2C business model, that has underpinned the automotive industry for decades, the potential development of cheaper, more efficient and sustainable mobility⁶¹ as well as the forecast of very high revenues are enough to explain why carmakers and leaders in the digital economy are looking to Mobility as a Service (MaaS) as the "next big thing".

And, indeed, we are far away from the time when carmakers developed complementary service activities that only came into play after the product had been sold (Verstrepen et al., 1999)! The recent period has been characterized by a major change in carmakers' strategy and many of them now openly declare that they are refocusing on becoming *mobility* companies. For instance, Akio Toyoda, president of Toyota Motor Corporation, declared: "*It's my goal to transition Toyota from an automobile company to a mobility company ...*"⁶² while BMW and Daimler have pooled their mobility services to create a new global player providing *sustainable urban mobility* for customers⁶³.

This rise of autonomous vehicles may take advantage of PSS that have been classified into the use-oriented and result-oriented categories as these two last ones can be focused on pay per use, car leasing, renting, and sharing instead of the traditional ownership model.

But, for all that, do these new services offer an escape from the dominant product-oriented design of the automobile defined as (1) a multi-purpose family vehicle, (2) a B2C business

⁶⁰ <https://www.accenture.com/us-en/insight-mobility-automotive-ecosystem>

⁶¹ <https://maas-alliance.eu/homepage/what-is-maas/>

⁶² <https://global.toyota/en/newsroom/corporate/20566886.html>

⁶³ <https://media.daimler.com/marsMediaSite/en/instance/ko/BMW-Group-and-Daimler-AG-invest-more-than-1-billion-in-joint-mobility-services-provider.xhtml?oid=42597429>

model, (3) a mass manufacturing process and (4) an industrial architecture with the carmaker as the focal firm at the top of a hierarchical supply chain?

We can observe that the currently most widespread mobility services, namely ride-hailing as proposed by Uber or Lyft in western countries or Didi in China, have little intrusion on the design of the automotive product. They belong to the Use-oriented service category, changing the business model of traditional car mobility by introducing a service operator who manages the front office application and a driver who takes care of the driving and maintenance of his / her vehicle. But the vehicle itself and the B2C sales model from manufacturers to drivers are not questioned.

The situation is obviously different for autonomous robotaxis, which require a radical change in the transport vector. Indeed, the B2C owner-driver sales business model is transformed into a B2B2C model where the robotaxis fleet operator acquires a fleet of vehicles for which it takes charge of all front-office and back-office functions to deliver a mobility service to the end-user customer.

Hence, it confirms that (1) servitization can pave the way to some escape route from the industry dominant design and (2) there is some interest of studying real cases to highlight the effective impact of mobility service innovations on product-oriented design projects.

6.3.2. A case study methodology

The challenge of MaaS is an emerging trend for which we do not have a sufficient history to take, by statistical sampling, representative cases of stabilized configurations. As a result, a cooperative research plan dedicated to study innovative mobility initiatives around the world has been launched. It involves university teams with expertise in the automotive industry which cover the main markets, i.e. USA, Europe, Asia and China. This program is under the responsibility of senior researchers from the Centre Recherche en Gestion (CRG) at Ecole Polytechnique and the authors of these papers are participating to this research program; consequently, they have access to the cases which are studied and have selected three cases out of fourteen studied initiatives.

The aim of this selection is not to be representative of the overall population of cases (the sample is far too small to claim any representativeness of the general transition underway), but to illustrate the diversity of concrete achievements behind the generic term of mobility services.

As a matter of fact, these cases present contrasted characteristics, considering the product-service articulation. The first one is typical of service added to product strategy. The other two

are more of result-oriented services type, but with different design variables activated: change in the product for the second, change in the infrastructure for the third.

The empirical data for this paper was collected from January 2019 to October 2019. According to Yin’s recommendations (2009b) we selected one case study (MaaS) and used multiple cases, i.e. different carmakers, as part of the same study with the intention of covering various MaaS situations. Each carmaker under study - including subsidiaries – is characterized by its seniority in the industry (incumbent or newcomer), the region of the world where it is headquartered as well as the maturity and type of the project or offer (accordingly to the case). Although each characteristic is understandable in itself, we precise that maturity refers to different degrees of development, namely concept formulation, demonstrator, prototype, field experiments (Mahmoud-Jouini et al., 2013) to which we add operation.

We focused on three contrasting case studies where we strengthened the evidences (Yin, 2009b) by obtaining additional information either through a series of semi-structured interviews with sources directly involved in the projects or through the analysis of secondary sources; regardless of the method used to gain additional knowledge, we always used the same analytical framework, described in next sub section, to characterize the project of mobility service initiative.

For the first case study, we were able to combine the two approaches, while the second is based solely on the analysis of secondary sources; finally, for the third case study, still in the early stages of development, we had the opportunity to conduct interviews even though no information is publicly available. Finally, we precise that all the information gathered during the interviews is the subject of a non-disclosure agreement signed with the company.

The table below synthesizes the study cases we have selected.

Study case	Newcomer or Incumbent	Headquarter Region	Maturity of the offer	Type of offer	Data collection process	
					Questionnaire	Second sources
1	Newcomer	China	Operation	Sales of vehicles, usage of multi-service personal APP	Yes	Yes
2	Incumbent	Europe	Concept formulation	Shared express transportation	Yes	No
3	Newcomer	USA	Field experiments	Autonomous ride-hailing	No	Yes

Table 29 : Summary of the selected study cases

6.3.3. A framework to describe the mobility service initiatives

The analytical framework for service design characterization introduced by Lenfle and Midler (2009a), has been completed and adapted by the authors to characterize the design space

of MaaS in six integrated domains: (1) Designing the mobility service (2) Designing vehicle to MaaS, (3) Designing an enabling infrastructure, (4) Designing backend fleet operating system, (5) Designing frontend mobility system, (6) Defining the customer contract relation; each design domain is characterized by design variables enabling a precise description of the considered MaaS initiative as detailed below.

Design domains	Designing the mobility service	Designing Vehicle to MaaS	Designing an enabling infrastructure	Designing Backend fleet operating system	Designing Frontend mobility system	Designing the customer contract
Design variables	<ul style="list-style-type: none"> - Energy management service - Mobility service - Multi-service personal APP (in complement to energy and mobility scopes) - Operating zone - Routing - etc. 	<ul style="list-style-type: none"> - Vehicle Fuel - Autonomous Driving vehicle feature - Autonomous Driving level⁶⁴ - Connectivity - Adaptability 	<p>Main enablers such as hub or manufacturing facilities, charging network, road infrastructure, etc.</p>	<p>Main functions such as hub or manufacturing management, fleet management and supervision, third parties' services, etc.</p>	<p>Customer Relation Management including website, community of users, Apps, etc.</p>	<ul style="list-style-type: none"> - Business model - Customer Contract Purpose - Payment

Table 30 : The six domains of MaaS design space

Answering our research question needs to discuss the articulation between the development of the product and of the service as it has a first order impact on the management of the project. Whether the service is simply added to the product, or whether it is deeply embedded in the product, or indeed whether the product is deeply embedded in the service, will influence the nature and organization of all design and validation activities.

In order to address these questions, we need to analyze, for each study case:

1. The category of PSS (Tukker, 2004), i.e. product-oriented, use-oriented or result-oriented to which the mobility initiative belongs to,
2. What design variables are activated,
3. At which stage of the development process they are activated,
4. What are the relations between the different variables which are activated.

⁶⁴ All Autonomous Driving (AD) levels cited in this paper refer to SAE definition (SAE, 2019)

Consequently, our analysis framework is based upon the MaaS design space we introduced, completed by one set of questions addressing the category of PSS and the key variables activated by the service.

6.4. Results presentation

6.4.1. Three cases in a nutshell

This section, devoted to the presentation of cases “in a nutshell”, is structured, per case study. First, we briefly describe what the MaaS project is about and characterize the service variables. Then, we define the category of PSS (Tukker, 2004) it belongs to and using the analytical framework we defined, we summarize the design variables which are activated. We also briefly introduce the platform strategy chosen by the project leader.

Study Case 1 (SC1)

This Chinese automaker, newcomer to the automotive industry, has recently launched two high-performance, premium SUVs that are pure EVs, namely Battery Electric Vehicle (BEV), and offer level 2 Autonomous Driving (AD). Each vehicle is equipped with a high-level navigation and in-vehicle entertainment system, while a (mainly) free premium service including different solutions for repair, maintenance, etc. is included in the offer. The scope of the services is very wide as it encompasses (1) a mobile service of battery charging (concretely a van equipped with batteries which moves where the vehicle is to recharge its battery), (2) a battery charging service by the means of a network of battery swap stations, (3) a peer to peer (P2P) car-sharing reserved to the owners of the cars, and (4), far beyond the field of mobility, many services such as social networking, entertainment, merchandising, leisure, travel, etc., which we have grouped together under the term “Multi-Service Personal” APP (MSP-APP).

The company is also developing a network of high-end customers through a website, a user community and access to various locations and activities dedicated to their sole benefit. The characterization of the mobility service is summarized below.

Design domains	Designing the mobility service	Designing Vehicle to MaaS	Designing an enabling infrastructure	Designing Backend fleet operating system	Designing Frontend mobility system	Designing the customer contract
Solutions	<ul style="list-style-type: none"> - Battery charging services (swapping station and mobile power) -P2P car sharing - Multi-service personal APP 	<ul style="list-style-type: none"> - BEV - Level 2 AD - Connectivity: through the embarked system and the App - Multipurpose vehicle 	<ul style="list-style-type: none"> - Charging network 	<ul style="list-style-type: none"> -Manufacturing management -Mobility services management (charging, maintenance, etc..) and supervision - Inter platforms management systems with services providers. 	<ul style="list-style-type: none"> - Website -Community of users - Apps - Dedicated places and activities dedicated to sole users 	<ul style="list-style-type: none"> - B2C - Sale of vehicle and use of the MSP-APP - Upfront payment for the sale of the vehicle, yearly fixed fees for the use of the APP

Table 31 : Study case 1 service characterization

As core activity remains sales of a product, enhanced by the integration of multiple services encompassing mobility and MSP-APP, and that the ownership is transferred to the user / driver of the car, SC1 belongs to the Product Oriented Services category of PSS.

As far as the key variables which are activated, the vehicle is a very important one as it the product sold by the carmaker and it supports the offer of all the services. These latter cannot exist if there are no back-end functions supporting the operation of the numerous services and no front-end enabling the access to these services.

We point out that the carmaker has the full ability and capacity to act as a focal player managing a value chain that extends, far beyond the classical automotive industry, into the world of digitization. It is a perfect example of a *product platform* strategy defined as “*Put simply, a product is largely proprietary and under one company’s control ...*” by Gawer and Cusumano (2008, p. 68). In other words, the carmaker has made the choice of a closed platform strategy.

Study Case 2 (SC2)

Study case 2 has just finished its concept formulation phase and enters the development and validation phase leading to field experiments. The project is about Shared Express Transportation System whose basic idea is to develop a sustainable and shared transport system offering a passenger throughput worthy of rail transport while maintaining a low user cost very close to that of a private vehicle.

To do this, the proposed solution consists of (gradually) setting up fast transport lanes open to buses, shuttles, taxis or even private cars, as long as these vehicles are pure EVs with the

longitudinal and lateral driving control functions required by the system⁶⁵ and equipped with the software and hardware package allowing them to be considered by the automated control system. The main functions of the control system are to secure lane entrances and exits as well as to ensure a high flow of vehicles (and consequently passengers) thanks to an overall speed control on the traffic lanes.

Hubs, distributed along the expressways, allow passengers to reach the vehicles best suited to their transport needs, whether public or private transport, the latter allowing the implementation of P2P solutions. The characterization of the mobility service is summarized below.

Design domains	Designing the mobility service	Designing Vehicle to MaaS	Designing an AV enabling infrastructure	Designing Backend AV fleet operating system	Designing Frontend mobility system	Designing the customer contract
Solution	<ul style="list-style-type: none"> - Energy management service - Individual or collective mobility service - Could be extended to transportation of goods 	<ul style="list-style-type: none"> - BEV - Level 3- 4 AD designed accordingly to the system requirements - Connectivity to the fast lane monitoring system - Open to any versatile vehicle complying with fast lane management system 	<ul style="list-style-type: none"> - Multimodal transport hub - Road infrastructure - Traffic management 	<ul style="list-style-type: none"> - Hub management - Fast lane management system - Fleet supervision for mobility operators being part of the initiative 	<ul style="list-style-type: none"> - Apps for final customer - Inter platform management system for the different stakeholders 	<ul style="list-style-type: none"> - B2T2C - Probably on demand pricing for final users

Table 32: Study case 2 service characterization

In SC2, the consumer will adopt the service if it is efficient, accessible and affordable: it is the result that matters! As it is not the product (i.e., the means of transportation) that is chosen by the consumer, SC2 belongs to the result-oriented service category of PSS. Therefore, this case study shows a loophole in the dominant conception of servitization in the automotive industry, which is still mainly in the category of product-oriented services.

As a matter of facts, the main values of this mobility concept are collective (sustainability, low transport costs, high passenger throughput, reuse or potential adaptation of existing assets such as urban or suburban expressways, etc.), that focuses the development on infrastructure,

⁶⁵ The level of requirements for automated driving control functions evolves with the increasing maturity of the system

back-office functions for operations and front-office functions for the communication with the end user. In this project, a vehicle, which can be of very varied types (bus, shuttle, personal car ...) is one enabler, among others, of the service. As we are in a very early phase of the project and the platform strategy is not yet defined, we assume that the project manager will choose an *industry platform* strategy defined as: “...an industry platform is a foundation technology or service that is essential for a broader, interdependent ecosystem of businesses.” (Gawer and Cusumano, 2008, p. 68). This choice would be consistent with the ambition and inclusiveness of the project as well as with the heterogeneous ecosystem that is necessary to develop and operate it.

Study Case 3 (SC3)

Study case 3 is actually in the field experiments’ phase of an autonomous ride-hailing offer involving a pure electric AD level 5 robotaxi developed as a stand-alone solution, meaning without any interaction with road infrastructure or any traffic management system. A mass production manufacturing plant is dedicated to the production of the robotaxi, while at the same time, high power charging network is under deployment and the ride-hailing system (back-office and front-office features) is also part of the on-going field experiment. The characterization of the mobility service is summarized below.

Design domains	Designing the mobility service	Designing Vehicle to MaaS	Designing an AV enabling infrastructure	Designing Backend AV fleet operating system	Designing Frontend mobility system	Designing the customer contract
Solutions	- Charging network - Autonomous ride-hailing service operating on demand in open public area	- BEV - Level 5AD - Connectivity: vehicle to fleet management and supervision - Dedicated purpose vehicle		- Charging network - Hub Management - Robotaxis production management - Fleet management and supervision,	Mono modal App	- B2C - Use of mobility service - On-demand pricing

Table 33: Study Case 3 service characterization

What is the PSS category of this initiative? As in the previous case, it is a result-oriented one as the customer wants to be transported from point A to point B and it also presents an escape from the dominant design of servitization in the automotive industry.

There are three key variables activated here: (i) the vehicle, an electric robotaxi with AD level 5 functions, and (ii) the back-office functions i.e. hubs ensuring maintenance, battery charging, etc. that are of first order to guarantee the quality and the availability of the service

and (iii), the APP, which enables communication between the service operator and end-user customers, very similar to that already used in existing ride-hailing services. The mobility operator, in charge of developing the system and operating the service, is a highly verticalized company that has the capacity to define its own solutions, impose them to its suppliers and complementors as well as to successfully achieve the integration of the complete system. As in SC1, this is another example of a *product platform* strategy (Gawer and Cusumano, 2008, p. 68).

6.4.2. How does it impact the nature of the relation between product and service at design level?

Here, based on the characterization of mobility services, we explain at which stage of the development process the design variables are activated and what are the relationships between the different variables that are activated.

In SC1, we consider the four different services we introduced: (1) mobile battery charging service, (2) battery swapping service, (3) P2P car sharing and (4) MSP-APP.

As far as mobile battery charging is concerned, this is a classic after-sales service where there is no relationship between the product and the service at the design level because the mobile service reuses the on-board charging system originally designed for the static charging service. This is a typical example of the “*Service added to product*” service-product articulation introduced in our literature review.

The battery swap service requires extensive design activities, which, without going into detail, concern (1) the vehicle, which must include equipment for easy and safe mechanical and electrical disassembly/assembly of the battery pack, (2) the battery pack, which must be interchangeable, and (3) a disassembly/assembly facility capable of operating safely, quickly and reliably on a wide variety of vehicle and battery pack geometries. This is undoubtedly a very complex design activity requiring a robust co-development between the car manufacturer, the battery supplier and the facility manufacturer. In this service, the key variable activated is the product which drives the development of specific back-end facilities and operation. The front-office function, allowing the localization of a battery exchange station near the vehicle and navigation to it, is quite loosely linked to the design of the vehicle even if one of its key inputs is the state of charge of the battery.

The P2P car sharing service requires a front office function enabling two car owners to organize under what conditions the car sharing is going to happen. But this service is strongly

enabled by the product as explained in the following example. One of the key issues in car-sharing is how to provide secure access to the vehicle if the car owner is not present; similarly, when the user returns the vehicle, how to ensure that the vehicle is then only accessible to the owner. Here again, without going into detail, this requires designing access and car start-up functions that only work under perfectly controlled conditions, guaranteeing that the person who wishes to use the vehicle actually has the right to do so.

For the front-end function of all the services which are provided (including MSP-APP), the carmaker has adopted a platformization strategy for leveraging the impact of digitalization (Cenamor et al., 2017) and also takes advantage of featuring capabilities (Maniak et al., 2014a). By doing so, it successfully achieves to “...*uncouple the elimination of major uncertainties (i.e. the role of advanced engineering) from the development of projects ...*” (Lenfle and Midler, 2003, p. 152) and, consequently, product functions and front-end applications’ roadmaps are loosely linked.

The project, analyzed in SC2, which deals with shared express transportation is, without a doubt, service-oriented. As far as the vehicle is concerned, two main categories of functions are required to provide the service. Firstly, the automated longitudinal and lateral driving functions are developed by the car manufacturer, if only to increase its classic B2C offer. But, the functions allowing access to, use of and exit from the service are part of the open mobility platform which is designed to provide the greatest possible access to many types of vehicles. Considering the service in its target operating phase, with all necessary functions activated, the operation of the service is very intrusive in the vehicle operation since the shared transportation system takes control of the vehicle's longitudinal and lateral driving functions as well as its speed. The vehicle manufacturer has to integrate, in its design, the interface functions that allow the vehicle to be granted the capacity to participate in the shared transportation system. This leads to co-development between the vehicle manufacturer and the transportation system leader during the development phase.

In SC3, the proposed automatized ride-hailing service doesn't exist if the vehicle doesn't exist. Indeed, the robotaxi concentrates all the disruptive technologies enabling the service since there is no link between the vehicle and the road infrastructure or the traffic management system. The product is the true enabler of the service and it is the progression in vehicle design that determines whether or not the service can be deployed at a later date. The design of the mono-modal APP, quite similar to what already exists in ride-hailing services already on the market, since it is a question of proposing available robotaxis to customers whereas the current

systems propose available cars with driver, can be designed quite independently from the vehicle⁶⁶.

Lastly, services from the different SCs share some characteristics related to the mode of coordination to be implemented as the following two examples show. A service may contain multiple layers that need to be coordinated to work together: this is the example of SC2 where a vehicle, equipped with its on-board autonomous driving system, needs to communicate with expressway traffic management components and a lane monitoring system. A service may also need to link technical and non-technical components in order to operate: an example is the interface allowing a customer to select his route in SC3, which requires exchanges between the customer application in the front office and the management application of the possible types of route in the back office. Whether it involves coordination between multiple layers or between technical and non-technical components, this requires control actions involving many players outside the core competencies of the automotive industry. In an unknown area of investigation, if this coordination is not present or is poorly managed by the project manager, regardless of its origin and the nature of the platform (i.e. product or industry), it can lead to significant additional costs or delays in the development of the service and the vehicle.

6.4.3. What is the impact on product validation?

In SC1, the mobile battery charging is a classic after-sales service which can be validated independently from the vehicle as well as the services which are provided through MSP-APP.

Exactly as the battery exchange service requires in-depth design activities, it also requires a comprehensive validation plan for the complete swapping process involving the vehicle, the battery pack, the swapping facility and the swapping station. The validation of the front-office function is more related to vehicle positioning, navigation and user interface and is not very tightly linked to the validation of the swapping process.

While most of the front-office function of the P2P car sharing service can be validated independently from the vehicle, two of them, namely the vehicle access and start-up, have to be jointly validated with the product.

⁶⁶ This is in fact what happened with the applications proposed by Uber or Lyft, even if it is, here, necessary to replace a communication interface with a driver using an application on his / her smartphone by a communication interface with the robotaxi, which is made possible thanks to the communication capabilities of the latter

SC2 and 3 belong to the result-oriented type which means that the customers are co-producers of the services (Eiglier and Langeard, 1987; Grönroos, 1990; Lenfle and Midler, 2009a). It implies that what has to be validated is no more the product but the customer experience of the service, which is embedded in a specific territorial context and a specific customer usage. Consequently, the technical maturity of the PSS offer, i.e. the maturity of “*A PSS is an integrated bundle of products and services ...*” (Mahut et al., 2017, p. 2107) is totally linked to many and varied contexts such as geographical, meteorological, traffic situations, etc.

Consequently, a product, part of a PSS offer, can no longer be evaluated alone: the classical logic, included in the Vee development model⁶⁷, of progressive and integrative validation, from the component level to the complete product level, on test benches or environments representative of uses, no longer works. This implies multiplying the number and nature of validation activities, both digital and physical, far beyond what is required for a conventional or even an ADvanced Assistance System (ADAS)-equipped vehicle, and accordingly to the service requirements.

Secondly, up to now, a new type of vehicle is placed on the market after the vehicle manufacturer has carried out two major operations: an internal validation process to check that the vehicle meets the regulatory requirements and performance criteria that the manufacturer has set itself, and a demonstration, vis-à-vis the approval authorities, of its compliance with the regulatory requirements in force. The service centricity of an innovation implies revisiting these two processes, since the vehicle must then be validated and approved under the real conditions of its use, i.e. on the premises of its operation and in the presence of real customers. It thus implies two major changes: (1) in addition to functional validations carried out on test benches or circuits by automotive professionals, there must also be phases of experimentation and learning on real-life terrain with real users, and (2) the validation domain is no longer just that of tracks representative of typical driving conditions, but also that of the territory concerned with its topology, weather conditions, traffic rules, driving practices, etc. It means that the industry has to switch from a logic of compliance to requirements, issued from regulations, to a logic of certification, completely correlated to a context of use, as known in the aeronautics

⁶⁷ The Vee model is mainly used in system engineering and we retain here the definition made by Midler and Lenfle: “...the “V cycle” model which organizes design activities along two dimensions: the vertical axis, from the global functional vision to the detailed technical definition; the horizontal axis, which marks the progression from the specification of the objective to the definition of the solution and its validation”. Adapted and translated by the authors from (Midler and Lenfle, 2008).

or pharmaceutical industries. In concrete terms, a new certification stage must be added to the process that a vehicle manufacturer must undertake before marketing a new type of vehicle intended for these innovative mobility initiatives. This development, which is profoundly intrusive on the organization of automotive engineering divisions, will obviously take time to be implemented.

6.4.4. What is the impact on the governance of project?

In SC1, the carmaker keeps the capacity of a focal actor managing an extended value chain within a *product platform* strategy (Gawer and Cusumano, 2008).

SC2 exhibits a *platform industry* strategy (Gawer and Cusumano, 2008) within a heterogenous ecosystem composed of many actors from different industries (automotive, transport, construction to cite but a few) whose contribution are necessary to make the service happen. In this context, the carmaker is no longer in a position to exercise the traditional practices of controlling a product-centric innovation project, whether in terms of product definition or management of the project's overall economic loop.

SC3 also presents a *product platform* strategy (Gawer and Cusumano, 2008) and the focal company acts as platform leader with a platform leader (M. A. Cusumano and Gawer, 2002) having the capacity to define its own solutions, impose them to the complementors and to successfully achieve the integration of the complete system.

6.5. Discussion

Firstly, we point out first that our literature review, which led us to note the existence of three main categories of PSS, has allowed us to formulate a basic hypothesis: the emergence of servitization paves the way to escape from the classic model(s) of product-oriented service(s) in force in the automotive industry. This hypothesis is confirmed by SCs 2 and 3 and, consequently, our empirical study, although it has some limitations that will be discussed later in the paper, can support, with its results, the development of an answer to our research question.

In SC1, which is a product-oriented service, we propose to name the product-service articulation as “*product-centric added services*”. It is founded on the “*Service added to product*” type exhibited in our literature review but the linkage between the product and the service at development level is much deeper. In fact, the operation of the service requires a specific design of the product, associated to dedicated validation plans, as shown by the examples of the battery exchange and P2P car sharing functions.

In SC3 the service is deeply rooted in the product and in SC2, it is the product that is deeply rooted in the service, therefore the impacts regarding the development of product-oriented innovation projects are definitely different from what is the current situation of a product-oriented service.

SC2 exhibits a pattern of product-service articulation we name as: “*Product enabler of service centric offer*”, which is characterized by the fact that the product specifications include, of course, the fundamentals of the product to meet market expectations but also the functions that will enable the service to achieve its performance objectives.

SC3 offers a very contrasted situation as the product is the key enabler of the service which exists only because the product exists. This is another pattern of product-service articulation that we name as “*Product centric service enabler*”.

In addition, SC2 and SC3 exhibit some similar impacts on the articulation between the product and the service in development phase. Firstly, in the upstream phase, one of the main results in determining the interest and attractiveness of the (future) service is the selection of the application case: it must both provide an efficient mobility offer and be "easily" accessible in terms of complexity and investment. This selection requires new engineering capabilities, totally unknown to the automotive industry: “*Mobility service engineering*”. Such a capability has three components. Firstly, the ability to collect and analyze a huge amount of data on mobility uses and needs in order to identify a potential and efficient mobility service; secondly, to have powerful simulation tools in order to qualify and quantify the mobility offer (how many vehicles, on which routes, which schedule, how many hubs, etc.). While these elements may seem close to what is the current engineering activity of a "traditional" mobility operator, the multimodal dimension of Maas as well as an inclusive design of the transport system, such as, for example, first/last kilometer transport, make the problem much more complex to solve than the dimensioning of a bus line. Finally, it also requires to be able to bring together, from this upstream phase, a multi-disciplinary team (OEMs, construction companies, mobility operators, expressway concessionaires, public authorities, etc.) capable of building a robust project and assessing its implementation and operating costs. Undoubtedly, this last element is highly innovative compared to the current engineering activity of mobility operators. In validation phases, we summarize three key points: (1) the product can't be validated independently from the service, (2) the contingency of the service to the territory which makes validation deeply embedded in a context and (3) the introduction of a certification activity. Finally, we also stress that the project manager must ensure strong coordination that goes far beyond the usual

framework of the automotive industry to cover the entire scope of the service throughout the project.

In terms of project governance, SC1 and SC3 present very similar schemes based on a *product platform* strategy with a central actor who alone provides project governance, whether it is a carmaker at the top of an extended value chain in SC1 or a platform leader in SC3. SC2 scheme is totally different as it is an *industry platform* strategy encompassing, in a heterogenous ecosystem, many actors coming from different industries.

Our results are summarized in the table below “Summary of impacts of servitization on the management of product-oriented innovation projects, the case of Maas emergence”.

Study Case	PSS category	Service	Impact of the articulation between product and service on				
			Design activities		Validation activities		Project governance
1	Product Oriented Service	Mobile charging	Very loose relation between product and service in both design and validation activities				Product platform strategy The carmaker is the focal actor managing a value chain widely extended to the world of digitalization
		Battery swap	Very complex design activity requiring a robust co-development (carmaker, battery supplier and facility manufacturer) in development phase	Very limited as APPs development takes benefit of Platform digitalization Platformization in the automotive product and Innovative featuring capability	Independent validation plan for the complete swapping process	The front-end application can be validated relatively independently of the product	
		P2P car sharing	Product development activity in development phase		Dedicated product / usage validation plan Some functions of the front-end application (vehicle access and start-up) have to be jointly validated with the product		
		MSP-APP	Similar to featuring activities		None in a mono project context - elimination of major uncertainties in upstream phases		
2	Result Oriented Service	Shared Express Transportation System	The definition of the service is very intrusive on the design of the vehicle as the interface vehicle ↔ service is not specified anymore by the carmaker	Same comment as above about the design of APPs Introduction of a new engineering discipline “Engineering of mobility service” The project leader must ensure a strong coordination far beyond the usual scope of the automotive industry	As customers are co producers of the service, the product (i.e. the interface vehicle ↔ service in SC2, the robotaxi in SC3) can’t be validated independently from the service Strong territorialization of mobility services drive the embeddedness of validation plans in the specific context Certification activity of the mobility service	Industry platform strategy Heterogenous ecosystem composed of many actors from different industries The carmaker is no longer in a position to exercise the traditional practices of controlling a product-centric innovation project, whether in terms of product definition or management of the project's overall economic loop.	
3	Result Oriented Service	Robotized ride-hailing (robotaxi)	Development of the product drives the development of the service			Product platform strategy The mobility operator is the focal actor and acts as a platform leader	

Table 34: Summary of impacts of servitization on the management of product-oriented innovation projects, the case of MaaS emergence

What are the impacts of these product-service articulations on the Innovation Life Cycle in a mono project context that we took as a reference for the management of product-oriented innovation projects?

We can say that the innovation life cycle in a mono-project context encompasses the services outlined in SC1. This is not the case for SC2 and SC3, which are results-oriented service-type innovations, a departure from the industry dominant design.

In the exploration phase, we have already pointed out the necessity to properly select an application case presenting sufficient interest and attractiveness which leads to the development of a new engineering discipline, i.e. “*Mobility service engineering*”. In both exploration and contextualization phases, the deployment of « *complete solution experiments*” (Ben Mahmoud-Jouini and Charue-Duboc, 2017) is mandatory to learn about the capacity of (1) the supply system to produce the solution and (2) the demand system to evaluate and use it. It also contributes to the definition of more robust specification of the mobility service. In the development phases, both design and validation are impacted. We already pointed out the impacts in the design phase for SC2 and SC3, but we introduce here the fact that the product is not finished when it leaves the factory. As a consequence of the co-production of the service by the customers and the contingency of the service to the territory, implementation of the service, in the field, may lead to new requirements from customers or to adaptation of the product. In other words, the marketing of the service will strongly impact the product in its very design.

In the validation phase, the primary concern is to avoid what is related by Midler and Lenfle in a paper dealing with the launching of a telematics service: “*First, at the technical level, the tests performed before service marketing were not adequate to deal with all the uncertainties*” (2009b, p. 162). Although we have already commented on the fact that the product can no longer be validated independently of the service and that the validation plan must be linked to a territory, we would like to stress here the importance of the certification activity, which is very similar to the one already implemented in the aeronautics industry. It is not enough to meet regulatory requirements to market a product, as in the European Union where there is agreement on common specifications and validation procedures, it is a complete and territorially integrated certification procedure that must be put in place. The best reference is that of an aircraft pilot who, in addition to his / her qualifications authorizing him / her to fly, must be certified for a given airport. Consequently, the launching of a service, even in a mono-project context, will require as many certification’s loops as targeted territories.

6.6. Conclusive remarks

In this paper, we bridge the innovation project management and servitization literatures to study closely what is the impact of servitization on the management of product-oriented projects. While in the discussion section, we have focused primarily on conclusions drawn directly from our case studies and applicable to the automotive industry, our intention here is to draw more general conclusions applicable to the impact of the transition from product to services on the management of product-oriented innovation projects.

Firstly, the three categories of PSS exhibited by Tukker (2004) are very useful for analyzing a service and identifying its positioning in relation to industry practices. In our case, categories use-oriented and result-oriented lead to breakthrough innovations in relation to the dominant design of the industry.

Secondly, the framework we use to describe a service, adapted from Lenfle and Midler (2009a), enables to characterize its scope, the variables which are activated and the relations between them. Consequently, it makes it possible to describe the articulation between the product and the service as well as its consequences in terms of design and validation. It enables to characterize different kinds of innovation management in project triggered by the different types of transition from product centric strategy to service centric strategy. This leads to a new typology of innovation management in project based upon the intrusiveness of the innovative service development within the new product development. With this perspective, we differentiate “*product-centric added services*”, “*product-centric service enabler*” and “*product enabler of service centric offer*”.

The comparison with the innovation life cycle, adapted from Beaume et al. (2009) to a mono-project context exhibits, that the switch from product to service also drives a switch from product life cycle management to service cycle management. The consequences, in terms of project management are as follows: (1) the importance of « *complete solution experiments*” (Ben Mahmoud-Jouini and Charue-Duboc, 2017) in upstream phases to better describe the service and the conditions of its acceptance by end-user customers, (2) the necessity to introduce new engineering discipline(s), certainly highly dependent from an industry, in order to have the capability to quickly assess the interest and feasibility of a new service, (3) the necessity to introduce numerous design loops to deal with the marketing of the service and its impacts on the product in its very design, (4) the necessary adaptation of the validation process as a consequence of the joint validation of product and service, and lastly, (5) the need for an

industry to go beyond a logic of product homologation, in relation to a regulation, to a logic of certification, in the sense of the aeronautics industry practices. The implementation of the matter is a very cumbersome and time-consuming process for the engineering departments of automotive companies.

At the practitioner level, SC1 demonstrates that it is possible for a carmaker to enter deliberately and boldly the world of services, both innovative mobility services (battery swap, P2P carsharing reserved for company car owners) and people-focused services (MSP-APP) while remaining in the traditional dominant design of the automotive industry. If we generalize this observation to other industries, an incumbent can realize a significant journey from product to service, even inside the scope of the Product-oriented service category, as long as it remains in a closed product architecture.

This paper has some limitations. First, the small sample size, although acceptable for empirical and theoretical exploration, is an obvious limitation for a generalization of the proposed concepts; this is all the truer as the emergence of MaaS is ongoing and exploratory, making it difficult to assess the evolution of the model. Secondly, we have not covered all the fundamental aspects of project management. In particular, while we have briefly discussed project governance, we have not addressed the impact in terms of project organization: how the identity and relationships between the actors involved are influenced by the service dimension? The emergence of a new type of design ecosystem was barely mentioned, as the project studied in SC2 is at too early a stage for the study to lead to significant conclusions. Similarly, neither the impacts on the project performance objective nor those on the risks' management have been addressed. Finally, in order to facilitate the understanding of the impacts, induced by the transition from product to service, on project management, we limited our study to a mono project context which is no longer the current context of most industries.

But, thanks to the theoretical and empirical interests of the subject, this paper also opens up a variety of perspectives. The first one consists to exploit more results coming from the ongoing benchmark of MaaS initiatives to extend this first approach to a more systematic and quantitative multi-case analysis. Having shown that radical innovations in mobility services make the traditional logic of automotive product development obsolete, it might be interesting to study what responses the industry is providing. In particular, the study of carmakers' learning strategies or the analysis of the organization of development within the ecosystem of the innovation project would allow a better understanding of the impacts of a service-centric

strategy; in this respect, a bridging with the fields of ambidextrous organization and of open innovation should be useful.

In addition, one of the most interesting perspective is probably provided by the presentation, by Cruise, of a product, Origin, designed to service: « *It's not an improvement on the car. It's what you'd build if there were no cars. It's not a product you buy; it's an experience you share* »⁶⁸.

Analyzing the project lineage capability (Maniak and Midler, 2014; Midler, 2013) of this company, which starts from an adaptation of a mass product, namely Chevrolet Bolt, and ends up with a product designed for service, is likely to contribute to the understanding of the mechanisms of transition from product to service and their impacts of the management of innovative projects.

⁶⁸ <https://www.getcruise.com/>

7. ESSAY 5: Are Chinese regulations shaping the worldwide EVs industry?

Abstract

While the objective of carbon neutrality by 2050 is forcing the automotive industry to make a major transition, we wonder whether there are models for the co-evolution of public regulations and company strategies likely to give a competitive advantage to the actors involved.

Based upon the Triple Embeddedness Framework and dynamics of institutional learnings, we address this question through an empirical comparison of the relationships between policy makers and the automotive industry in China and Europe.

We conclude that the Chinese configuration, because of its impact on the global automotive industry, its better articulation between environmental and industrial policies and its greater agility, is more suited to carry out the necessary transformations and thus succeed in the imperial enterprise explicit in the plan "Made in China 2025".

Keywords: EV, NEV, emissions regulations, China, Europe, co-evolution, automotive industry, TEF

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7.1. Introduction

The objective of carbon neutrality by 2050, resulting from the Paris Agreement adopted in 2015⁶⁹, imposes a major transition on the automotive industry, from a dominant technological model based on internal combustion engines towards electrification of vehicles. This is a systemic transition, which requires impressive investments and mobilizes, within an ecosystem, many actors with complementary and co-specialized offers: carmakers, using a variety of vehicle strategies, namely battery electric vehicles (BEV), rechargeable hybrids, hydrogen fuel cells, and also suppliers of energy, of high-voltage battery systems or charging systems. The public nature of the environmental externalities as well as the radicality and scale of this transition mean that it cannot be analyzed as a classic game of competitive corporate strategies in a market economy. In addition, while the automotive industry is a major contributor to carbon emissions, e.g. around 12% for cars in European countries⁷⁰, it is also one of the main sources of employment and wealth in the countries where it operates. Therefore, what is at stake here is not only an environmental transition but also an industrial transition in which public regulatory authorities play a leading role because, "*Industrial policy is, as the definition indicates, a government intervention or policy*" (Spring et al., 2017).

The importance of public institutions in the formation of competitiveness of firms in a given sector has long been emphasized, particularly in the work of Chandler (1990) and Porter on the "*competitive advantages of nations*" (1990) and in the regulatory movement (Boyer and Freyssenet, 2000). Numerous studies, aimed at understanding the Japanese domination of the 1980s in consumer electronics and automotive industries, have highlighted the links between "*Toyotism*" (Coriat, 1991) or "*the J Firm*" (Aoki, 1988) and the Japanese economic and social institutions. In the pharmaceutical industry, biotechnologies and the field of New Information and Communication Technologies (NICT), it is rather the American ultra-domination, enabled by the model of the "start-up nation" favored by public authorities, that has sometimes led to proposing the adoption, in Europe, of institutions similar to those to which American firms are backing their supremacy (Bélis-Bergouignan et al., 2014).

Nelson introduced the concept of "co-evolution" of institutions, enterprises and industries, and stressed the importance of this relationship in the emergence phases of new technological

⁶⁹ <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement>

⁷⁰ https://ec.europa.eu/clima/policies/transport/vehicles/cars_en

cycles, where innovation could destabilize established situations (1993). More recently, Geels' work (2014) on the Triple Embeddedness Framework (TEF) and the concepts developed to capture the dynamics of "institutional learning" (Johnson, 2010), provide more precise analytical tools to capture this interaction between institutional frameworks and firm strategies.

Are there models of co-evolution of public regulations and firms' strategies that are likely to confer a competitive advantage in this major transition of the automotive industry towards carbon-free mobility?

To study the impact of public authorities on the efficiency of the conversion of the traditional auto sector into carbon-free mobility, we have decided to conduct a comparison between Europe and China for two main reasons. First, over the last decade, the 'triad' of the US, Europe and Japan, which traditionally sets the pace and direction of innovation in the sector, has been displaced in favor of China, which has become the world's largest auto market and the primary outlet for many global players, particularly European ones. Second, Europe and China both have adopted environmental policies that are very ambitious although different in the way they translate their objectives into regulations for the automotive sector.

What is the impact of these differences between European and Chinese regulations on the transition towards carbon-free mobility? More precisely, we want to understand: *are Chinese regulations shaping the worldwide Electric vehicles (EV) industry directly or indirectly? Or, compared to the European context, "are Chinese regulations capable of conferring on the Chinese players and/or the players present in China a comparative advantage such that the world standard is, de facto, Chinese?"*

To conduct this study, in Section 1, we will first describe the conceptual framework we have adopted to analyze the institutional configurations of the study subject. We will use the Triple Embeddedness Framework (TEF Geels, 2014) as well as the concepts developed to capture the dynamics of "institutional learning" (Johnson, 2010). Indeed, in a transition process such as the one the automotive industry is going through, it is important to be able to capture the way in which the regulation/strategy pair of firms evolves during the transition deployment. Next, after defining our methodology in Section 2, we will reconstruct the characteristics of the European (Section 3) and Chinese (Section 4) configurations and the transformations that marked them with the turning point around 2015. In Section 5, we will present and discuss the main differences between the European and Chinese governance regulations. Lastly, we will then defend in a concluding section (Section 6) the reasons why we think the Chinese

configuration is better able to carry out the transformations in question and thus to succeed in the imperial enterprise explicit in the statement of the Made in China 2025 plan. Indeed, as reminded by Kendall (2018), New Energy Vehicle (NEV) policies, aligned with “*Made in China 2025*”, also aim to transform Chinese carmakers in “... *innovation leaders that shape industry*”.

This paper, which addresses one of the key questions of this special issue, namely the influence of public policy on the performance of innovation of the automotive industry in the challenge of reducing CO₂ emissions from mobility, makes five main contributions:

1. We propose an original approach that combines recent and proven theories to analyze this interaction, such as Geels' TEF framework and institutional learning theory (Mantzavinos et al., 2009) as well as a longitudinal approach of European and Chinese regulations, the latter having been little studied until now. This framework allows us to understand how these public regulations have evolved, and which actors have been dominant in this evolution.
2. Given the importance of the Chinese auto market for global manufacturers, especially for EVs, the effects of environmental regulations on this perimeter have a major knock-on effect for the whole sector and well beyond China. Consequently, our study highlights that what is currently happening in China is shaping one of the major transitions of the automotive industry. As this industry is one of the main sources of employment and wealth in the countries in which it operates, this ongoing transition has a major impact on the global economy.
3. Our comparison shows how differences in regulatory approaches between Europe and China produce very different industrial dynamics. In western countries, the legislator focuses mainly on the effect of carbon reduction measures, and let the market and the competitive game of firms take care of the impacts induced by technological options on other value criteria of offers. Conversely, the study of the Chinese regulations shows that environmental and industrial policies are strongly linked. Chinese policy makers, because they define prescriptive scenarios that are more precise in their scope and broader in their field of action, have a greater capacity to structure the innovation strategies of companies in the sector, leading, in the medium term, to a better coordinated industrial dynamic between the players.
4. We also identify policy making philosophy differences regarding the business visibility given to firms. The philosophy of European regulation is to introduce stability over a

relatively long period of time in order to limit uncertainty for players in the supply system. Conversely, Chinese regulation is much more pragmatic, experimental and agile, which adapts more quickly to the effects induced by its previous decisions and the consequent market reactions. This philosophy, which combines advanced planning and rapid learning capacity, two hitherto antagonistic characteristics, is more in line with the precepts of innovation management that are widely accepted in the business world: the ability to quickly mobilize relevant groups on clearly identified, value-generating targets, even if it means stopping just as quickly ("fail fast") when obstacles that were not initially foreseeable show up or, on the contrary, adapting when new opportunities appear in the learning trajectory.

5. Empirically, we conclude that Chinese regulations have a much greater impact on the global EV industry than European ones for three main reasons: (i) the Chinese EV market was, prior to the current economic crisis, the largest in terms of volume and stock, has experienced the most dynamic growth and is likely to remain so after the current economic crisis. (ii) As the Chinese government, through the use of subsidy allocation policies, influences the nature and the pace of NEVs' performance improvements, it clearly shapes the industry at the national level. And, (iii) as the majority of global OEMs already produces or will produce EVs in China, either for the local market or for export, it is a very important part of future global EV production that could be shaped by Chinese regulations.

These results, based on a highly operational study of the conditions of the ongoing environmental and industrial transition to carbon free mobility, should be of interest to actors both in the public and private sectors and contribute to the current academic works on environmental and industrial policies.

7.2. Literature review, building a theoretical framework to study governance of regulations

The co-evolution's perspective

The empirical question we are dealing with refers to the question of co-evolution as posed by Nelson in his paper entitled "*The Co-evolution of Technology, Industrial Structure, and Supporting Institutions*" (1994). His intention was « *to link two broad bodies of appreciative evolutionary theoretic writing. The first proposes that a new technology develops along a relatively standard track from the time it is born, to its maturity, and that firm and industry structure 'coevolves' with the technology. The other is concerned with the development of*

institutions in response to changing economic conditions, incentives, and pressures ». He showed that the junction between the concerns of the economics of technology and the more traditional concerns of the industrial organization had been made by works such as those of Gort and Klepper (1982). In fact, authors from both currents have tried to grasp how a "dominant design", a "paradigm" or a technological "regime" erects barriers to entry in the industry concerned. Symmetrically, Nelson underlines that, in the exploratory phase, « *there are no particular advantages to incumbency* » so much « *with the market less fragmented and more predictable, firms try to exploit latent economies of scale, and advances in process technology both reflect and enforce this* » (Nelson, 1994, p. 53)

Linking these results with empirical work on organizational learning, according to Nelson, firms, in the context of a stabilized dominant design, must learn how to make well a limited number of products by knowing how to better structure their production processes, marketing, distribution, etc. In contrast, « *this suggests that established firms may have considerable difficulty in adjusting, in gaining control of needed different capabilities, when important new technologies that have the potential to replace prevailing ones come into being* » (Nelson, 1994, p. 54). It is in order to understand both these difficulties and the possible overcoming of them that the question of institutions needs to be examined to envisage how public policies could help deal with the transition we study.

More specifically, Nelson calls the penultimate part of his article on co-evolution « *Economic Growth and the Formation of Comparative Advantage at a Sectoral Level* » and thus comes very close to the problematic of this paper as he writes: « *Regarding the determinants of comparative advantage when an industry is new, the technology cycle story calls attention to the fact that countries clearly differ in the ease with which new firms can form and get funding and in the degree to which markets are open to new sources of supply. They also differ in the speed with which universities are able to adopt new sciences, in how adaptable legal structures are to changing demands put on them by new technologies, in how supportive public sector programs are of the new as contrasted with protective of the old, etc.* » (p.59).

The Triple Embeddedness Framework

Geels builds on Nelson's perspective and adds that it is then useful to broaden the perspective from considering only the relations between science and industry or training and industry: « *The reorientation of incumbent industries towards radical innovations that address grand challenges will require pressures from consumers, policymakers, civil society, and*

social movements. The accumulation of such pressures may stimulate incumbent firms to overcome lock-in mechanisms and reorient towards more radical innovations.» (2014, p. 261). As suggested by Dosi and Marengo (2007, p. 291), he emphasizes the importance of 'visions of the world' underlying the institutional configurations. He thus joins Pettigrew, who considers that *“In that intellectual space there are many big questions about the leadership, change, and performance of the modern corporation in its institutional field and its relationships with the State which have barely been addressed”* (2012, p. 1325). In order to better occupy this research gap, Geels proposes to mobilize three main categories of contributions: those of evolutionary theory, those of sociological "neo-institutionalism" and those of economic sociology. This is what he synthesizes in the concept of the Triple Embeddedness Framework (TEF).

Acknowledging the achievements of evolutionary theory and its integration of institutional issues, Geels lists a series of contributions that have underlined the difficulty in finding a place for questions of meaning, interpretation, and intentionality. He attributes this deficiency to the links between evolutionism and behaviorism which, as noted by Gavetti et Levinthal (2004, p.1314) *« is relatively silent on the issues of how alternatives are to be evaluated or issues of cognition more generally »*. They add *« The result is a view in which deliberation and strategic choice are relegated to a modest corner »*.

To make progress in this direction, we must be able to grasp the non-market logics that structure them. They refer to a political dimension that is struggling to find its place in evolutionary theory even though firms play a much more active role in it than it manages to recognize. It is for this reason that recourse to the work of neo-institutional theory is essential. Indeed, from the 1980s onwards, authors such as Di Maggio and Powell (1983) proposed that firms operate in organizational fields that are not only populated by firms, since they also include a number of other organizations that make up their "institutional environment" and exert a significant influence on their performance. Because they are aware of this, firms are not only competing at the commercial or technological level, they are also competing at the institutional level. As Powell points out, the terms of this competition differ from those prevailing in the merchant field since, as he writes: *“in institutional environments, organizations compete for social fitness rather than economic efficiency”* (Powell, 1991, p. 184). Thus at the institutional level of competition, the usual criterion of “efficiency” is replaced by the social criterion of “legitimacy”, explained by Suchman as *« appropriate within some socially constructed system of norms, values, beliefs and definitions »* (1995, p. 574). Geels emphasizes that this social criterion and the way in which it is applied is not purely

exogenous, since the firms are involved in the development of the standards in question: « *firms-in-industries not only adapt to institutional pressures, but also respond strategically to shape them* » (2014, p. 265).

Borrowing both from the sociology of Fligstein (1996) for whom states constitute markets by defining property rights or taxation and from Lindblom who considers that « *if the market system is a dance, the state provides the dance floor and the orchestra* » (2001, p. 42), Geels retains from economic sociology the fundamental idea that the relationship between firms and institutions is bi-directional: « *firms and industries use power and politics to shape formal institutions to their advantage* » (2014, p. 265).

In a case like the one we are dealing with, the TEF, proposed by Geels, places the industrial regime, and the renegotiations to which it is subjected, at the crossroads of two environments, one economic and the other socio-political. Indeed, firms are just as active in one as in the other, since the technologies, skills, identities, norms and regulations that structure these regimes fall within both spheres. It is because these elements are strategic, both to preserve a regime and to make it evolve, that firms seek to influence them.

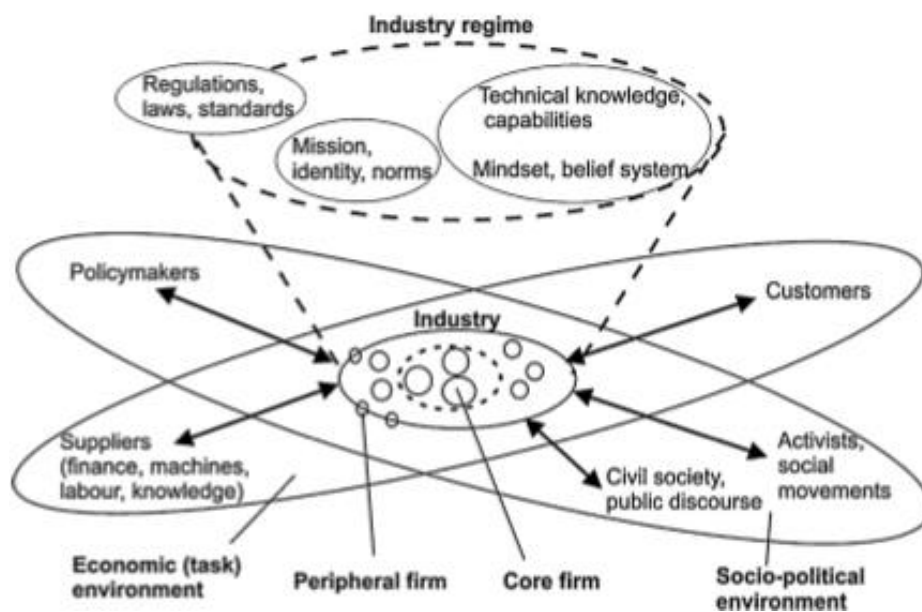


Figure 15: Triple Embeddedness Framework

(Geels, 2014, p. 266)

Institutional Learning

The object of our research is basically the comparison of the institutional and industrial dynamics that characterize the respective trajectories of the European and Chinese automotive industries faced with the management of the ecological transition. Fundamentally, the cycle to

be managed refers to a sequence of institutionalization-deinstitutionalization-reinstitutionalization (Jullien and Smith, 2012) which aims at re-structuring the industry and re-founding the associated "sectoral system" of innovation and the corresponding learning processes. The issue here is the politically determined redefinition of "industrial regime" that intersects economic environments, structured as spaces of interaction between producers, suppliers and customers, and socio-political environments, structured as spaces of interaction between policy makers, firms and civil society.

By definition, the aim of this re-institutionalization is both to meet the requirements of decarbonation and to preserve or strengthen the competitiveness of the industries concerned as well as their assets and the number of jobs they offer. As a process, this re-institutionalization is subject to great uncertainty and leads to significant conflicts. Therefore, the policy makers, at the initiative of the move, find themselves in a key position with regard to the "regime" that is taking shape and the capacity it seems to have - and which must be constantly evaluated - to become sustainable regarding the constraints associated to economic environment as well as socio-political one. It is to shed light on the process thus conceived that we intend to study in the European and Chinese configurations that the concept of institutional learning deserves to be mobilized. It is a question here of identifying the forms of adaptation and - possibly reorientation - of the standards defined and/or the aid provided according to the evaluation of the changes obtained in the economic and socio-political environment.

Johnson sums up the question for our purpose quite well when he writes: "Institutions have a strong impact on technical change. However, partly as a consequence of technical change they shape, a tension between technology and institutions and a pressure for institutional change is often provoked. At the same time institutions are normally quite rigid and not change easily. The capability of national economies to cope with this problem, i.e. to **learn about, adapt and change their institutional frameworks – to engage in ‘institutional learning’** – is important for the development of their international competitiveness." (2010, p. 23).

Thus conceived, the question of institutional learning in our case is that of evaluating the respective capacities of the European and Chinese systems to design new "dance floors" (Lindblom, 2001) then to rearrange them until they appear to structure interactions such that the learning gained is judged satisfactory - in Simon's sense (1957) - in the economic sphere as well as in the socio-political sphere. In this perspective, taking up Douglas's (1987) contributions, Johnson stresses the respective capacities of national systems to accept or even promote "forgetting" technological options explored in order to better resolve the tension

between the necessary stability of institutions and the need to make them evolve and encourage the emergence of major innovations and the structuring of new industries or, re-institutionalized industries. As we shall show, this is the key to understanding the unequal capacity of the European and Chinese systems to effectively reorganize the new dance floors that they offer - or impose - on industrial players.

7.3. Methodology, characterizing the dynamics of regulation

7.3.1. A relevant TEF instantiation to support our study

The TEF framework is primarily influenced by empirical work that has looked at processes of structuring and restructuring of industries observable in market economies. For these reasons, and because, for more than 100 years, very large automotive firms have played a major role in industrial economies, understanding, how they seek to structure the economic and the socio-political environments to build a most favorable context for development, is the perspective favored by most research. What we are looking at, in this paper, is somewhat different because it is then a question of understanding (i) how regulations are constructed so that companies can develop their activities and (ii) how these companies ally with or influence other companies or stakeholders, such as policy-makers, to make this happen.

In order to understand how the transition from ICE vehicles to electric vehicles will or will not change this state of affairs both in China and in Europe, we will use the instantiation of TEF shown in the figure below.

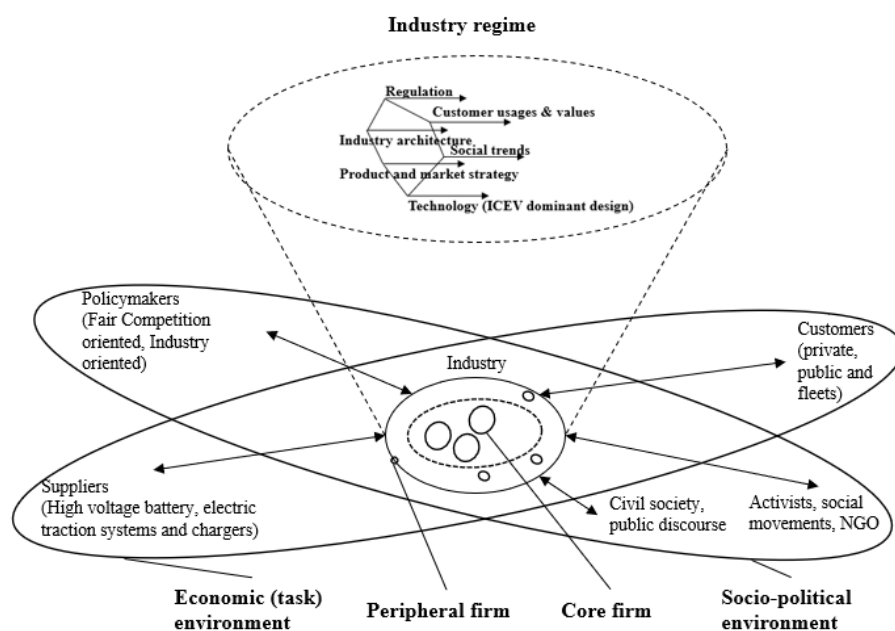


Figure 16: Relevant TEF instantiation for our research
 adapted by the authors from Geels (2014, p. 266)

To describe the industry regime, we consider six broad categories of factors which will influence its transformation, and we associate, with each factor, the actors that activate it:

- *Regulation*, the trigger for the transition we are studying in this paper which is activated by public legislator;
- *Social trends and customer usage and values* which support the deeply rooted cultural, social status that makes the automobile the preferred means of individual mobility;
- *Infrastructure* such as roads, expressways, traffic management system or charging networks that can be activated by public authorities and/or private companies (construction companies, expressway operator, charging network operator, etc.);
- *Technology*, which is the trigger for object of the transition we are studying in this paper, activated by both incumbent OEMs and new suppliers or technology companies,
- *Industry architecture*, which encompasses all the actors of the automotive value chain (carmakers, tier X suppliers, retail and maintenance / repairation networks);
- *Product and market strategy*, the classic B2C and B2B sales of multipurpose vehicles (and some added services) as one of the major levers activated by carmakers.

As far as **policy-makers** are concerned, even if they all share the same objective of reducing GHGs and pollutants, we consider two main categories with a different orientation: (i) "*industry-oriented*" whose aim is to develop an efficient and competitive industry while at the same time contribute to the reduction of emissions and (ii) "*fair competition-oriented*" whose credo is to set emission targets and be technologically neutral so as not to create market distortions. We focus on the suppliers most involved and crucial in this transition, namely those of high-voltage batteries, electric propulsion and charging systems, while considering that customers include private car owners, corporate fleets and public fleets to broadly cover the entire market targeted by EVs.

7.3.2. Empirical field of study

Being close to "*empirically grounded research questions*" (Browning and de Treville, 2018), this paper is based on a longitudinal study of European and Chinese environmental regulations over the last decades. On the European side, we have examined the "classic" regulations addressing CO2 and pollutants emissions. As a comprehensive work has already been done by some authors (for some examples, Chen and Midler, 2016; Gong et al., 2013; Yuan et al., 2015; Zhang and Bai, 2017) to identify and analyze all the regulations promulgated by the Chinese State Council to support the uptake of the NEV market and, as our research

intention is to analyze the institutional learning capacities of the Chinese State Council, we have focused our analysis on the regulations published, separately or jointly, by the so-called “four ministries”. The “four ministries” encompass the National Development and Reform Commission (NDRC), the Ministry of Science and Technology (MOST), the Ministry of Industry and Information (MIIT) and the Ministry of Finance (MOF), and are the key institutions deploying the strategic plans decided by the State Council in this matter. This set of regulations is of particular interest because it covers many operational aspects of the development of New Energy Vehicles (NEV), such as battery system and vehicle performance characteristics, battery manufacturers' catalogs, subsidy regulations, approval of new NEV manufacturing projects, etc.

7.3.3. Data collection

First, we precise that our study only addresses passenger cars. For all observations, we refer to second source data whose origins are indicated below for each case.

7.3.3.1. Study of European EVs' regulations

We use different data sources, the first one being the different portals of the European Commission (EC) providing access to vehicle emission regulations:

- For CO₂: https://ec.europa.eu/clima/policies/transport/vehicles/cars_en.
- For road vehicles air emission: <https://ec.europa.eu/environment/air/sources/road.htm>.

We also consider technical briefs or statements made by the Association des Constructeurs Européens d'Automobiles⁷¹ (ACEA) which shed light on the relationships between policy makers and the industry.

Whenever necessary, we provide a full reference and access to the appropriate document (regulation, report, etc.) to which we refer directly in the text or by means of footnotes.

7.3.3.2. Study of Chinese EVs' regulations

In their paper dedicated to the emergence of environmental technologies in China, Lanckriet and Ruet (2019) explain how the Chinese State Council has shaped new complete industry sectors. They show that central government has transformed its "natural upstream advantage" (i.e. global monopoly of rare earths production) into a "downstream built

⁷¹ European Automotive Manufacturers Association

advantage" over technologies allowing the emergence of complete industrial sectors. To do so, the Chinese State Council has developed a scientific policy of technological integration and an industrial policy to attract the technologies chosen by the regime. It has also installed a close management of the domestic market and relied on economic diplomacy to build a global competitive advantage. Keeping in mind this industry sector strategy, as it is an important clue to understand the Chinese governance of environmental regulations, we now focus on the development of NEVs. As already mentioned, we have focused our analysis on the regulations published, separately or jointly, by the so-call "four ministries".

Among these, we select regulations dealing with the construction of the NEV industry, subsidies and those defining performance characteristics for the placing on the market of vehicles which are highly representative of the constant adaptation of the Chinese State Council in favor of the NEV scale-up.

As 2009 is a turning point in the development of NEVs, we decided that our longitudinal study of China's NEVs regulations begins in 2009 and, is, momentarily, stopped at the end of June 2019. Consistently with the government's long term strategy of placing BEVs at the priority (Chen and Midler, 2016; Cheng and Tong, 2017; Yuan et al., 2015), in our search of documents, we have been focusing on keywords such as "new energy vehicle", "pure electric passenger car" and "power battery" and we end up with a total of seventy regulations.

Among those, seven policies dealing with the use of subsidies related to battery system and vehicle performance requirements have been identified (full references of which are provided in Appendices 7.8.1.) while six have been selected addressing the construction of the power battery industry (full references of which are provided in Appendices 7.8.2.).

7.4. European regulations, driven by achieving strong reductions of emissions' levels

7.4.1. Description of emission regulations and their dynamics over time

The earliest history relates to air pollutants for which the first regulation, i.e. Euro1, was promulgated in the early 1990s. While a new regulation was issued approximately every four to five years until Euro4, there have been six successive stages from Euro5a to Euro6d between 2011 and 2021. Nowadays, emissions of particulate matter (PM) including mass and the

number of particles since Euro5a, nitrogen oxides (NO_x), unburnt hydrocarbons (HC) and carbon monoxide (CO) are subject to regulations that have become much stricter over time⁷².

Following the European Commission's endorsement in 1993 of the conclusions of the United Nations Framework Convention on Climate Change, and while the voluntary approach by manufacturers had not produced the expected results, CO₂ reduction targets were proposed at the end of 2007⁷³. By 2020, the European Commission had set a 30% reduction target for greenhouse gas emissions compared to 1990 levels and made a firm independent commitment to reduce them by at least 20%.

The first operational implementation is provided by regulation 443/2009/EC in 2009 which, considering an average emission value of 158.7 g in 2007, defines an average threshold of 130g of CO₂/km in 2015 for 100% of the fleet sold by each manufacturer. These policies have certain efficiency as the 2017 average emission was 118.5 g CO₂/km which corresponds to a reduction of roughly 25% in ten years. The EC continues to boldly adopt stricter CO₂ emission regulations with a new target set at 95 g CO₂/km from 2021 onwards, 40% less than in 2007, and a tremendous increase of penalty applied in case of exceedance⁷⁴. It also provides incentives to the industry to support the transition by means of super credits for vehicles with extremely low emissions (below 50 g CO₂/km) and a 7 g CO₂/km extra credit for implementing innovative technologies reducing emissions in use (European Commission, 2016).

This legislative package favors battery-powered electric vehicles, which produce neither CO₂ nor pollutants linked to the operation of the engine, whereas hybrid engine vehicles, even if they contribute to the reduction of CO₂, emit pollutants in non-100% electric operation. Continuing to promote the transition from ICEVs to cleaner vehicles, the EC proposes that the average CO₂ emissions will have to be 30% lower in 2030 than in 2021⁷⁵. In response to this proposal, the ACEA (2018) has raised a "chicken and egg" readiness issue (EVs offer versus e-mobility ecosystem availability) and proposed the implementation of a conditionality mechanism considering a targeted adaptation to actual market adoption and availability of recharging infrastructure, measured by 2025 during the mid-term review.

⁷² <https://ec.europa.eu/environment/air/sources/road.htm>

⁷³ Full text available: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52007PC0856>

⁷⁴ For example, an overrun of 3 grams for a fleet of 1 million vehicles would result in a penalty of €285 million instead of €45 million with the previous rules

⁷⁵ https://ec.europa.eu/transport/modes/road/news/2017-11-08-driving-clean-mobility_en

The existence, mainly for NOx emissions from diesel vehicles, of a significant discrepancy between road vehicle emissions and the regulatory compliance results published by certification laboratories when qualifying a new type of vehicle was known by the EC since a report issued by the Joint Research Center in 2011⁷⁶. Shortly afterwards, public opinion and non-governmental organizations (NGOs), on the basis of studies showing the same type of discrepancy for PM and their effects on health, have begun to call for measures to reduce their presence in the air. Finally, the Volkswagen emissions scandal, unveiled in 2015, has also urged the necessity to apply more relevant and efficient qualification procedures for a new type of vehicle.

Consequently, the EC has promulgated two new regulations to fix these issues:

1. Worldwide harmonized Light vehicles Test Procedures (2017/1151/EC - WLTP), applicable since January 2018 for new cars, aims to provide more realistic situations of usage versus the previous test procedure⁷⁷,
2. Real-Driving Emissions test procedure (2018/1832/EC - RDE), applicable for all vehicles complying with Euro 6d-TEMP standards or higher, complements the laboratory procedure to verify that NOx emission and Particle Number (PN) levels remain below reasonable limits even under real driving conditions.

7.4.2.A fair competition-oriented governance of regulation

Previous works characterizing the ‘European Government of Industries’ (Jullien and Smith, 2014) showed that this governance is structurally incomplete because EU’s competences are (i) shared with states and (ii) distributed between different Directorate General (DG) whose mandates are strictly defined. For these reasons, this governance is handicapped when it would be useful to ‘politicize’ industrial problems to change the ‘visions of the world’ underlying the institutional configurations (Dosi and Marengo, 2007). Conversely, industrial questions are technicized (rather than politicized) and their ambitions are, for this reason, fundamentally limited. As far as our question, DG CLIMA promulgates regulations addressing CO2 emissions, DG environment deals with reduction of pollutants emissions while DG GROW has the difficult mission to reconcile both economic development and environmental protection: *“Providing 13.8 million jobs, the automotive industry is a key EU employer. Due to its strong*

⁷⁶ Full text available at <https://publications.jrc.ec.europa.eu/repository/handle/JRC62639>

⁷⁷ New European Driving Cycle (NEDC), directive 70/220/CEE – See (ACEA, n.d.) for an easy to read comparison between the two procedures

economic links to many other industrial sectors, it has an important multiplier effect in the economy. At the same time, road transport emissions continue to represent a main source of air pollution. The aim of the EU's policy in the automotive sector is to establish an internal market for vehicles, ensure a high level of environmental protection and safety, strengthen competitiveness, and provide a stable level playing field for the industry”⁷⁸.

Consequently, the philosophy of European regulation, driven by a strong sense of compromise, is to work over time to introduce stability and limit uncertainty for industry players. The setting of the Euro5 and Euro6 emission limits in 715/2007/EC for application dates between 2011 and 2021 or the proposal of 2020 target and commitment for CO2 reduction, both as early as 2007, provide a striking example of this method of governance.

This philosophy is also reflected in the shared governance of emissions regulations as the automotive industry, represented by ACEA, is, since 1993 (Directive 93/59/EEC), recognized as one of the stakeholders contributing to it (Akpinar, 2017; Klebaner, 2018). This way of functioning is quite compliant with the western attitude towards advanced technology development where the legislator usually sets “...*efficiency standards to meet energy and environmental goals, but allow the competition to determine the rate at which improved technologies are deployed*” (Howell et al., 2014, p. 17).

This leads to a European configuration where policymakers are mainly **fair competition oriented**. On their side, manufacturers are influential in the socio-political and economic spheres. They fully master the industry dominant design, possess the bargain power vis-a-vis their suppliers and are in a position to exert significant influence on their consumers in order to support the development of their skills and maintain very high barriers to entry.

However, under the **growing influence** of public opinion, NGOs and the considerable impact of the Volkswagen scandal, 2015 is a pivotal point in the EC strategy that has contributed to the cascade of successive pollutant regulations between 2018 and 2021 which has put a strong pressure on the automotive industry both in terms of schedule and cost.

One step further, the EC's proposition, in 2017, to accelerate the transition to cleaner vehicles (i.e. BEVs) provokes a strong reaction from the ACEA which denounces it as an intrusion against citizens' interests as it limits access to technological innovations (ACEA, 2019a). What the carmakers criticize here is nothing more and nothing less than the

⁷⁸ https://ec.europa.eu/growth/sectors/automotive/policy-strategy_en

abandonment of the doctrine of technological neutrality by the policymakers. This **growing tension** between the EC and ACEA is also apparent in a thinly veiled criticism of an EC strategy which forces manufacturers to put cleaner vehicles on the market without the conditions, allowing their mass deployment, having been met (ACEA, 2019b).

Finally, the divergence of views among manufacturers within ACEA, between, on the one hand, the major promoters of electrification (Renault as a first mover and German OEMs who are now investing heavily in the EV industry, especially in China), and, on the other hand, other players with a more critical stance, make it increasingly difficult to reach a consensus within ACEA. This opposition produces a **fragile consensus** within ACEA which weakens its position vis-à-vis the policymakers and the public opinion.

Urbanization, societal trends and new consumption patterns are changing people's relationship to the car, leading to **disinterest**. Indeed, the car is moving from being a personal, flexible and accessible means of transport to a not so useful object that causes more problems than it provides satisfaction.

In about five years, the well-established regime of the car industry in Europe has been undermined to some (limited) extent, OEMs have been weakened even though they retain a strong influence on the policy-makers and over their value chain.

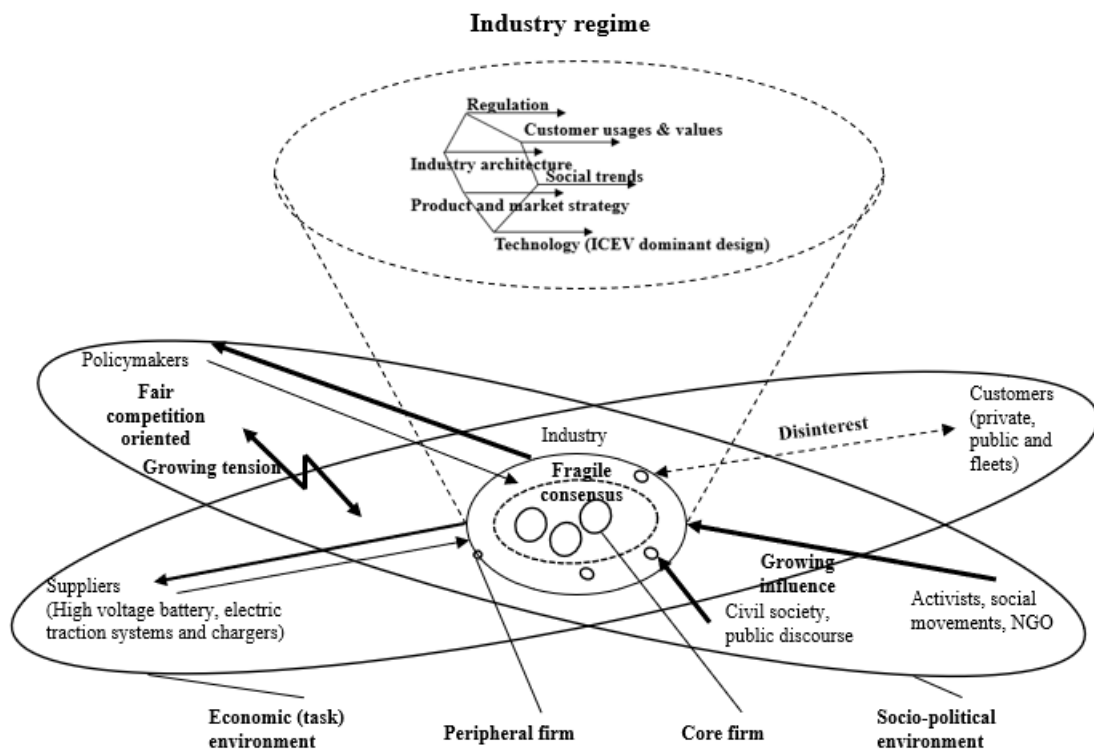


Figure 17: European context
TEF concept adapted by the authors from Geels (2014, p. 266)

7.5. Chinese NEV regulations, constant adaptation towards the growth of the market

In one decade, China has become a major player in the automotive industry as the biggest producer of cars (2009), the largest market in volume (2013) but also the largest producer of pollutants and carbon dioxide (CO₂) due to transport (2012).

The fact that motor vehicle exhaust emissions are the main causes of air pollution, as well as the willingness to develop a strong automotive industry and to reduce oil dependence have urged the Chinese government, to promote a NEV industry; NEVs use non-fossil fuel⁷⁹ and include, among others, Battery Electric Vehicles, Plug-In Hybrid Electric Vehicles (PHEV) and Fuel Cell Vehicles (FCV)⁸⁰.

While the first target, announced in 2009, of 500,000 EVs by 2011 had not been met (Chen and Midler, 2016; Howell et al., 2014; Kendall, 2018), the Chinese State Council had set very high ambitions for its NEV industry⁸¹, with combined production and sales of more than 5 million EVs between 2012 and 2020 and an intermediate stage of 0.5 million EVs and pure hybrids in 2015. Consequently, the Chinese State Council has undertaken an intense legislative effort to support the growth of the NEV market and, among the main policies promulgated, are the Corporate Fuel Average Consumption (CAFC), aiming at a decrease of 40% in ten years, or the New Electric Vehicle mandate which came into force on April 1, 2018 (ICCT, 2018). The latter imposes NEV credit targets as 10% of the conventional passenger vehicle market in 2019 and 12% in 2020 for any carmaker with over 30 000 vehicles manufactured locally or imported yearly

Indeed, before the effects of the global economic crisis that started at the end of 2019, the Chinese EV market was the largest in volume, had the most dynamic growth and, at the end of 2018, the stock was about half of the target set by the State Council for 2020 (between 2.3 million vehicles EV-Volumes, n.d.; and 2.6 million W. Li et al., 2019).

⁷⁹ The authors recognize that the use of non-fossil fuels for vehicles is an important first step towards achieving the decarbonization targets set by the Paris Agreements (2015); they also acknowledge that the maximum benefit is achieved by the total reduction of CO₂ emissions over the full life cycle of the vehicle. However, this last point is not the subject of this paper.

⁸⁰ http://www.nea.gov.cn/2012-07/10/c_131705726.htm

⁸¹ Energy Conservation and New Energy Vehicle Industry Development Plan (2012-2020)

http://www.gov.cn/zwqk/2012-07/09/content_2179032.htm

7.5.1. Description of EV regulations and their dynamics over time

The first salient point concerning all 70 regulations that we selected among those issued by the "four ministries" concerns their promulgation dynamics: as shown in the figure below, the number of regulations per year is quite low until 2013 with a real uptake in 2014 and a quite high level since then (except 2019 which is not totally significant since we stop in June) as more than 60% of them have been promulgated in less than five years.

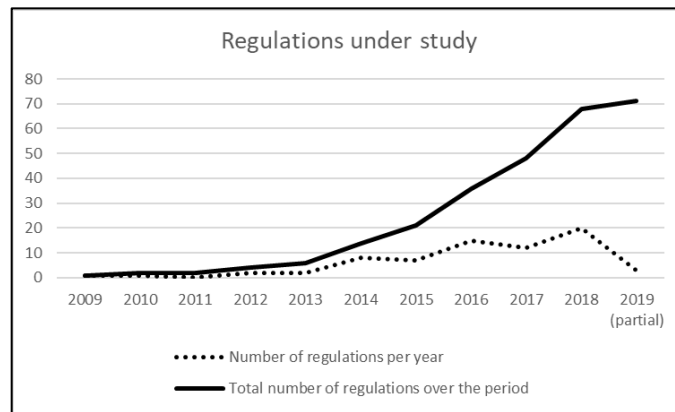


Figure 18: Number of regulations under study

Among these, seven deal with the calculation of subsidies related to battery system and vehicle performance requirements. The principle is as follows: any vehicle with a value above the threshold for a given criterion is eligible for a subsidy. While initially the amount of a subsidy was a fixed value, later in the document we will explain that it is now calculated using value multipliers that change the amount of the subsidy.

These policies have been promulgated regularly and constantly since 2010: when there was one policy issued in 2010, there is one policy issued each year between 2014 and 2019 and the last two being quite close to each other: the forthcoming end of subsidies, initially expected in 2020, was probably one of the causes of this haste!

In terms of calculation of subsidy, each value above the threshold for a given criterion allows the allocation of a subsidy; as there are many criteria, the vehicle global subsidy is calculated with a quite complex formula combining the contributions of each criterion⁸².

The content of these policies as well as their increase in number and severity over time are summarized in table 1 below.

⁸² See an example in ICCT report "CHINA ANNOUNCED 2019 SUBSIDIES FOR NEW ENERGY VEHICLES" June 2019 page 3, accessible at <https://theicct.org/publications/china-announced-2019-subsidies-new-energy-vehicles>

Energy Efficiency (100 km power consumption Y in KW/H)	M ≤ 1000kg				Y ≤ 0,014M + 0,5		Y ≤ 0,0126M + 0,45	
	1000kg <M ≤ 1600kg				Y ≤ 0,012M + 2,5		Y ≤ 0,0108M + 2,25	
	M > 1600kg				Y ≤ 0,005M + 13,7		Y ≤ 0,0045M + 12,33	
Battery system Performance	Power battery density (WH/kg)				≥ 90	≥ 95	≥ 105	≥ 125
Vehicle Performance criteria	Vehicle maximum speed (KM/H)			≥ 100	≥ 100 (during ≥ 30mn)			
	Vehicle driving range (KM)		≥ 80	≥ 100			≥ 150	≥ 250
Battery	Battery size (KWH)	≥ 15						
Regulations	Date of issue	31/05/10	01/08/14	22/4/15	29/12/16	26/12/17	12/02/18	26/03/2019
	Title	Notice on Piloting Pilots for Private Purchase of New Energy Vehicles - Public Finance Project [2010] No.230	Announcement on exemption of new energy vehicle purchase tax - Announcement No. 53 of 2014	Notice of the four departments on the financial support policy for the promotion and application of new energy vehicles in 2016- 2020	Notice on Adjusting the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles	Announcement of the four departments (MOF, Administration of Taxation, MIIT, MOST) on the exemption of new energy vehicle purchase tax	Notice of the Four Ministries (MOF, MIIT, MOST, NDRC) on Adjusting and Perfecting the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles	New energy vehicle promotion subsidy program and product technical requirements
	Ministry	MIIT, NDRC	MIIT	MOF, MIIT, MOST, NDRC	MIIT	MOF, Administration of Taxation, MIIT, MOST	MOF, MIIT, MOST, NDRC	MOF, MIIT, MOST, NDRC

Table 35: Battery system performance criteria and Vehicle performance criteria for subsidy obtention

First, we can note a significant increase in the scope covered by these policies. The very first Chinese regulation on NEV, published in 2010, simply requested a minimum energy capacity for a BEV battery: it had to be at least 15 Kilowatts Hours (KWH) which, at the time, offered less than 100 km range and was consistent with the weakness of the Chinese automotive industry at this time. Today, they encompass vehicle performance (maximum speed and minimum range), battery density as well as vehicle energy efficiency and address both customer requirements and the need to structure and advance the NEV design.

Secondly, there has been a tremendous and fast tightening of regulatory thresholds enabling the allocation of subsidy. Referring to table 1, the vehicle driving range has been multiplied by 3 in 5 years (starting from a very low base compared to the western state of art at the time). Similarly, the power battery density has been increased by 36% in 3 years, and, much more impacting on the vehicle design, the global energy consumption requirement has been tightened over 10% in 2 years.

The final, and probably most important comment, as we study the potential influence of Chinese regulations on the global EV industry, relates to the vehicle energy efficiency criterion. It naturally requires the optimization of the entire electric traction system (high-voltage battery and electric drive) and the reduction of all electrical loads that have a negative impact on the traction capacity of the battery.

But, mobilizing much more deeply the traditional core knowledge of the automotive industry, it also requires a significant improvement in aerodynamics and a reduction in vehicle mass. In other words, by imposing a global vehicle optimization, this policy demonstrates a very high level of intrusiveness into the dominant design of the automotive industry.

As clearly stated by the “four ministries”⁸³, “*The subsidy is for consumers.*” Accordingly, the most common idea about the influence of subsidies on the uptake of the NEV market deals with the concepts of supporting sales by ad-hoc incentives (W. Li et al., 2019).

But, as 2020 is expected to mark an important milestone in the development of the NEVs’ industry, the major objective of the Chinese government is to place this industry in the best possible technological and economic position in this short-term perspective and for its future. Consequently, three important roles of subsidies have been highlighted in the literature to

⁸³ “Notice of the four departments on the financial support policy for the promotion and application of new energy vehicles in 2016-2020” – File accessible at <https://policy.asiapacificenergy.org/node/3018>

support this objective: (i) subsidies also determine technological orientation (Cheng and Tong, 2017; W. Li et al., 2019), (ii) H.Li et al. (2019) argue that tightening subsidy criteria, year after year, leads to improved performance of NEVs and (iii) Zhang and Bai (2017) point out that the central government is phasing out subsidies to avoid the risk of "subsidy dependency" that would lead to poor quality products, low standards or overcapacity.

Our longitudinal study provides a very good example of this strategy. As BEVs have been confirmed as the strategic priority, the power battery density criterion, which has a direct impact on autonomy and therefore on customer satisfaction, has been the subject of a rapid increase in performance requirements, further reinforced by the policy of awarding the subsidy as shown in the figure below. The strategy behind these regulations has a double effect: how to make NEVs more attractive for the customers by suppressing one of the main burdens of EVs (range anxiety) and making them cheaper as far as the carmaker can achieve a subsidy with a multiplier value⁸⁴ of 1 or even higher.

From the industry's point of view, this is a strong incentive to achieve higher quality and standards since the 2019 threshold for a subsidy with a multiplier value of 1 is nothing but the result achieved by the Renault ZOE ZE50 put on the market mid-2019!

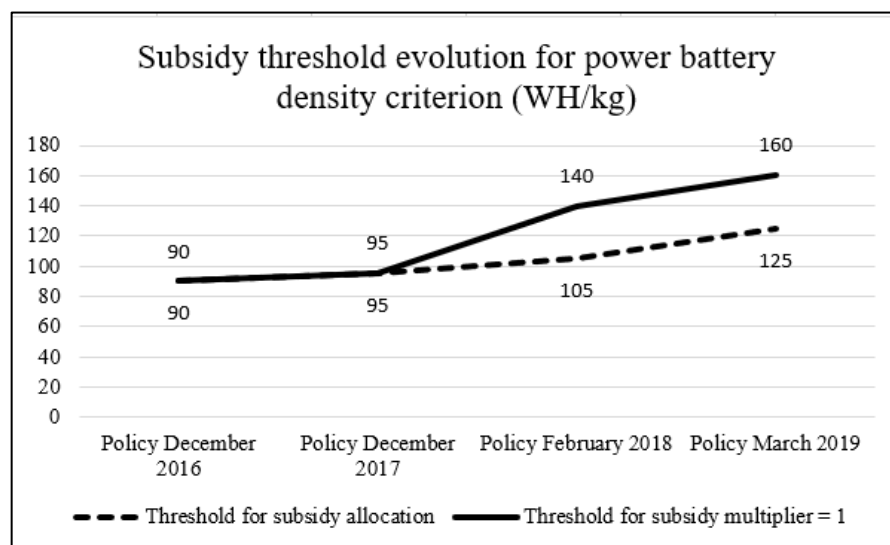


Figure 19: Subsidy threshold evolution for power battery density criterion

⁸⁴ For a given criterion, the subsidy multiplier enables to adapt the value of the subsidy to the performance provided by the OEM. Generally, less than 1 when the performance achieved is equal to the sales threshold, it can be significantly greater than 1 if the performance is much better than the **global** industry standard

In order to make this happens, the Chinese State Council had been issuing many regulations to develop the power battery industry (refer to Appendices 8.2.). In March 2015, considering that “*At present, China's automotive power battery industry has such outstanding problems as the number of production enterprises and the uneven technical level*”, the regulation “*Announcement of Automobile Power Battery Industry Standard Conditions*” has been issued to set robust and long-term foundations to this industry. Between November 2015 and January 2017, four catalogues of electric battery companies were published, defining the list of the only companies authorized to produce as they meet the requirements of the directive issued in March 2015. The obligation to source high-voltage battery systems from these companies for the manufacture of NEV in China was lifted in 2019.

In conclusion, a NEV to be price-competitive in the market must seek the highest possible multiplier value for each performance criterion. To achieve this, the manufacturer must constantly seek to improve the performance of both the high-voltage battery system and the vehicle. This strategy clearly pushes the improvement of vehicles on the market and the selection of the most performant carmakers.

7.5.2. A regulation governance to develop an industry sector

Both the overall production trajectory of regulations and the more focused analyses done by us show a diachronic dynamic in the deployment of the Chinese NEV industry. The first phase, between 2009 and 2014-2015, very similar to the process of emergence of environmental technologies in China (Lanckriet and Ruet, 2019), aims to create, almost from scratch, a complete industrial sector. Indeed, the scope is very wide as it encompasses mining and refining of raw material, production of the high-voltage battery and electric propulsion systems, as well as BEVs and charging facilities. The second, still in progress, fully aligned with the Made in China 2025 strategy, has the real ambition to make Chinese NEVs not only competitive against ICEVs, but also against EVs proposed by foreign players in China and out of China. This is a typical example of an **industry-oriented** policymaking strategy as introduced in our methodology section.

Although the market system has been gradually introduced in China since the 1980s, the Chinese central government continues to exercise a fundamental role in planning the development of its defined strategic industries, including the automotive industry (Chen et al., 2018; Chen and Midler, 2016; Cheng and Tong, 2017; Liu and Kokko, 2013; Yuan et al., 2015; Zhang and Bai, 2017): **directiveness** is the first characteristic to emerge from our study. It is

well illustrated by the choice of a technology, namely BEV, the imposition of criteria for subsidy allocation and the pace of improvement of these criteria. Subsidies, because they are the instruments for making these choices effective for the industry and for customers, are at the service of this directiveness.

To be effective, directiveness must also be intrusive, and the Chinese State Council has also demonstrated that it can be intrusive to the automotive industry. Indeed, many regulations affecting EV design but also the dominant design of ICEVs, such as the vehicle energy consumption criterion, have been promulgated.

The combination of directiveness and **intrusiveness** supports the upgrading of the Chinese automotive industry. The requirements about power battery density or vehicle energy efficiency are of most importance in the current context of the automotive industry. They push the Chinese carmakers, who are strong competitors in open modular architecture products (Baldwin and Clark, 1997b; M.A. Cusumano and Gawer, 2002; Fujimoto, 2017; Iansiti and Levien, 2004), to compete with global players who, having strong coordination capabilities in design and manufacturing, are more competitive with relatively integral architectures which are necessary to design and constantly improve high-performance vehicles such as EVs.

The last and not least characteristic of the Chinese State Council in developing this industry is **agility**, which is favored by a long tradition of trial-and-error approach (Ruet, 2016). There is agility when switching, thanks to the subtle use of subsidies, from hybrids to BEVs and, eventually fuel cell technologies later on; agility also when it comes to forcing the development of the NEV industry, imposing supply choices on high-voltage battery systems and then lifting them to allow global players a chance to contribute to the expansion of the EV market in China.

Given a weaker role of civil society or other movements in this industry, the fact that there is a large pool of customers who are still first-time buyers as well as the overwhelming role of the Chinese State Council in this transition, we summarize the situation in the TEF shown below.

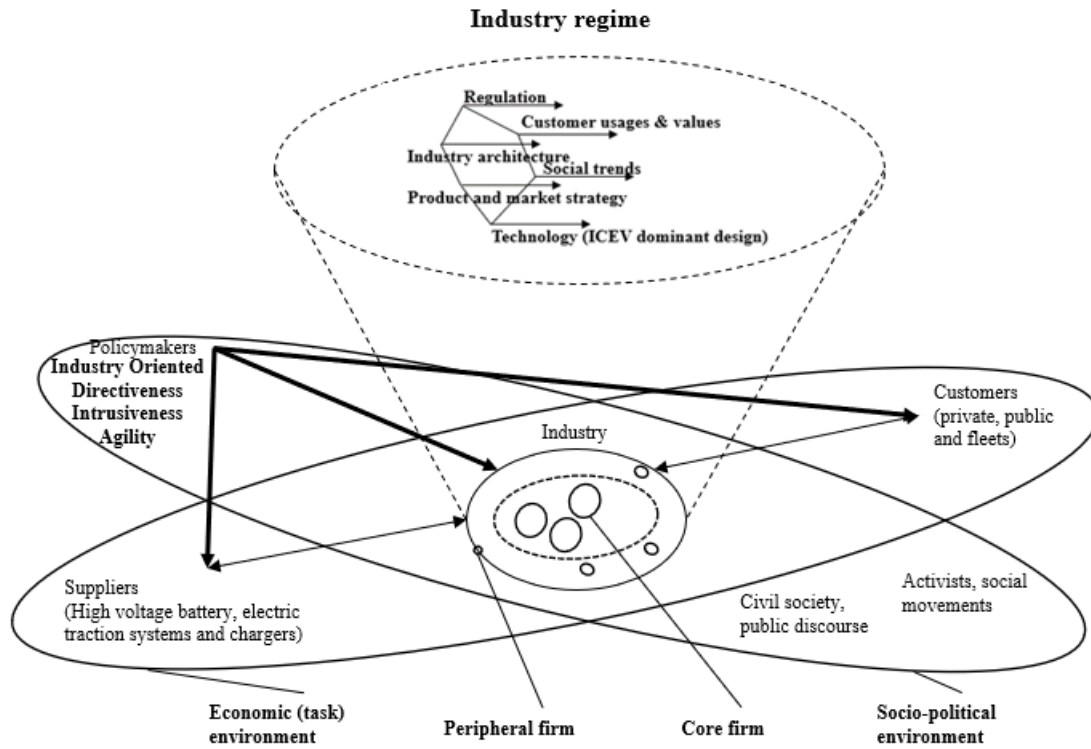


Figure 20: Chinese context

TEF concept adapted by the authors from Geels (2014, p. 266)

7.6. Discussion

There are three main categories of differences, summarized in the table below, in the way in which the European Commission and the Chinese Government deploy environmental regulations.

	European Commission	Chinese State Council
Scope of regulation	<ul style="list-style-type: none"> • <u>Vehicle side</u>: Thresholds for CO₂ and pollutants emissions • <u>Industry side</u>: carmakers have to comply to regulations 	<ul style="list-style-type: none"> • <u>Vehicle side</u>: CAFC, NEV mandate and performance' criteria for subsidy allocation • <u>Industry side</u>: development of a new industry sector
Governance of regulation	<ul style="list-style-type: none"> • Fair competition-oriented policy makers • Long tradition of technology neutrality, co-governance and trade-offs • 2015 pivot drives growing tension between policymakers and ACEA • Weakened but still influent carmakers 	<ul style="list-style-type: none"> • Industry-oriented policy makers • Strong position of policy makers • Directiveness and intrusiveness reinforced by the 2015 pivot • Carmakers are not in a position of arguing on technological choices
Adaptability	<ul style="list-style-type: none"> • Great inertia in the definition of regulations induced by a high degree of organizational and political complexity 	<ul style="list-style-type: none"> • Agility favored by a long tradition of trial-and-error approach

Table 36: Comparison of European and Chinese governance of environmental regulations

Firstly, the scope covered by Chinese regulations, both in terms of vehicles and industry, is much wider than that covered by European regulations. At the vehicle level, the European Commission, being **fair competition-oriented**, has promulgated regulations addressing CO₂ and pollutant emission thresholds. If quite similarly, the Chinese State Council has promulgated the CAFC and the NEV mandate, it has also set performance criteria for allocating subsidies. As these latter relate not only to the design of the electric traction system but also to the overall design of the vehicle, this shows a much greater intrusiveness of the Chinese legislator in the technological perimeters to which the regulations apply. As Chinese policymakers are **industry-oriented**, they have the ambition to build, almost from scratch, a complete industry sector from raw materials to vehicles. European legislators are lagging behind Chinese

legislators in this area and their recent initiatives, such as the European Battery Alliance⁸⁵, are not sufficient to (quickly) bridge this gap.

Second, if Europe and China have both implemented a pivotal strategy around 2015, it was for very different reasons and, above all, with very different methods of regulations' governance. In Europe, it has been triggered by the discrepancy between road emission and certification procedures results for pollutants emissions and accelerated by the Volkswagen scandal. It has led the EC to deviate from the doctrine of **technology neutrality**, undermined the long-term strategy of **co-governance and trade-offs** (Akpinar, 2017; Klebaner, 2018), and set up a **growing tension** between policy makers and industry, represented by ACEA. The strategy Made in China 2025, decided by the State council, has accelerated the convergence towards BEVs with enhanced performances and favored the emergence of a new industry in the scope of environmental technologies in China (Lanckriet and Ruet, 2019). It is enabled by the overwhelming role of the State Council which doesn't face public opinion of NGOs hostile to its intention or an industry in capacity of arguing on technological choices. Therefore, the Chinese central government has demonstrated **directiveness** to drive the development of the NEVs industry in its own way. It has been acting as a central planner and has applied a philosophy of regulation that was previously found in the West, for example in the major post-war development programs. It is made possible by a combined level of directiveness and **intrusiveness** which is characteristic of the Chinese economy.

Thirdly, the philosophy of the EC, which has to cope with a high degree of organizational and political complexity, is to introduce stability over a relatively long period of time in order to limit uncertainty for players in the supply system. Conversely, Chinese regulation is much more **agile** and adapts more quickly to the effects induced by its previous decisions. In addition to the examples provided in this paper, one of the very recent regulation issued by the "four ministries", in April 2020, which states that "*Based on comprehensive technical progress, scale effect and other factors, the Chinese government will extend the implementation period of the new energy vehicle promotion and application of financial subsidy policy until the end of 2022*"⁸⁶ is another demonstration to this capacity of adaptation. This decision was taken to continue to support market development in a context where the end of subsidies was probably

⁸⁵ https://ec.europa.eu/growth/industry/policy/european-battery-alliance_en

⁸⁶ http://www.gov.cn/zhengce/zhengceku/2020-04/23/content_5505502.htm

coming too quickly to guarantee the sustainable upgrading of manufacturers and where the COVID19 crisis has increased this level of risk.

7.7. Conclusion

While the objective of carbon neutrality by 2050 is forcing the automotive industry to make a major transition, we wonder whether there are models for the co-evolution of public regulations and company strategies likely to give a competitive advantage to the actors involved.

On the theoretical side, our original approach combines recent and proven theories to analyze this interaction, such as Geels' TEF framework and institutional learning theory (Mantzavinos et al., 2009) as well as a longitudinal approach of European and Chinese regulations, the latter having been little studied until now. This framework allows us to understand the dominant philosophy of both environmental public regulations, why and how they have evolved, and which actors have been dominant in this evolution.

Our analysis reveals two regulatory philosophies that are both ambitious in their objective of reducing CO₂ and pollutants emissions, but contrasting in their mode of action. In western countries, fair-competition oriented policymakers mainly aim at reducing CO₂ and pollutants emissions, and let the market and the competitive game of firms take care of the impacts induced by technological options on the dynamic of the industry. Conversely, Chinese policymakers not only set performance criteria, but, being industry-oriented, also support their achievement and the overall progress of the industry through the use of subsidies focusing on the key priorities: environmental and industrial policies are strongly linked. The long tradition of construction of complete industry sector, almost from scratch, has a greater capacity to structure the innovation strategies of companies in the sector, leading, in the medium term, to a better coordinated industrial dynamic between the players. It is made possible by a combined level of directiveness and intrusiveness which is characteristic of the Chinese economy.

The other notable difference between the two modes of regulation is their ability to evolve in the uncertain context of the technological innovations that are involved in the current transitions. European policymakers, relying on a strong tradition of co-governance and trade-offs with the industry, as well as limited by a high degree of organizational and political complexity, exhibit a great inertia in the definition of regulations. On the contrary, the Chinese State Council demonstrates a much greater agility and a faster rate of learning: Chinese policymakers, taking benefit of trial-and-error approach, don't hesitate to pivot as quickly as

needed to achieve their targets. By doing so, they demonstrate a faster rate of learning. This philosophy, which combines advanced planning and rapid learning capacity, two hitherto antagonistic characteristics, is more in line with the precepts of innovation management that are widely accepted in the business world: the ability to quickly mobilize relevant groups on clearly identified, value-generating targets, even if it means stopping just as quickly ("fail fast") when obstacles that were not initially foreseeable or, on the contrary, adapting when new opportunities appear in the learning trajectory.

Empirically, we conclude that Chinese regulations have a much greater impact on the global EV industry than European ones. China can thus succeed in the imperial enterprise explicit in the "Made in China 2025" plan, for three main reasons: (i) the Chinese EV market was, prior to the current economic crisis, the largest in terms of volume and stock, has experienced the most dynamic growth and is likely to remain so after the current economic crisis. (ii) As the Chinese government, through the use of subsidy allocation policies, influences the nature and the pace of NEVs' performance improvements, it clearly shapes the industry at the national level. And, (iii) as the majority of global OEMs already produces or will produce EVs in China, either for the local market or for export, it is a very important part of future global EV production that could be shaped by Chinese regulations.

Given the importance of the Chinese market for global manufacturers, especially for EVs, the effects of environmental regulations on this perimeter have a major knock-on effect for the whole sector and well beyond China. Consequently, our study highlights one of the major transitions of an industry which, because it is one of the main sources of employment and wealth in the countries in which it operates, has a major impact on the global economy. These results should be of interest to operational actors in the public and private domains and contribute to the numerous current academic works on environmental policies.

7.8. Appendices

7.8.2. List of policies addressing the allocation of subsidies related to battery system and vehicle performances

Date	Institution	Policy Title	WEB Sources
2010, May 31 st	MIIT, NDRC	Notice on Piloting Pilots for Private Purchase of New Energy Vehicles - Public Finance Project [2010] No.230	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c3757144/content.html http://zfxgk.ndrc.gov.cn/web/iteminfo.jsp?id=1038
2014, August 1 st	MIIT	Notice of the four departments (MOF, MIIT, MOST, NDRC) on the financial support policy for the promotion and application of new energy vehicles in 2016-2020	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757016/c3764314/content.html
2015, April 22 nd	MOF, MIIT, MOST, NDRC	Notice of the four departments on the financial support policy for the promotion and application of new energy vehicles in 2016-2020	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n4509627/c4511776/content.html
2016, December 29 th	MIIT	Notice on Adjusting the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c5449722/content.html
2017, December 26 th	MOF, Administration of Taxation, MIIT, MOST	Announcement of the four departments (MOF, Administration of Taxation, MIIT, MOST) on the exemption of new energy vehicle purchase tax	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n4509607/c5990438/content.html
2018, February 12 th	MOF, MIIT, MOST, NDRC	Notice of the Four Ministries (MOF, MIIT, MOST, NDRC) on Adjusting and Perfecting the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c6064786/content.html
2019, March 26 th	MOF, MIIT, MOST, NDRC	New energy vehicle promotion subsidy program and product technical requirements	http://m.mof.gov.cn/zcfb/201903/t20190326_3204190.htm

7.8.3. List of policies addressing the construction of the NEV industry

Date	Institution	Policy Title	WEB Sources
2015, March 24 th	MIIT	Announcement of "Automobile Power Battery Industry Standard Conditions"	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n4509627/c4511776/content.html
2015, November 11 th	MIIT	Catalogue of power battery enterprises	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n4509607/c4511345/content.html
2016, January 20 th	MIIT	Catalogue of power battery enterprises (2 nd batch)	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n4509607/c5363261/content.html
2016, April 29 th	MIIT	Catalogue of power battery enterprises (3 rd batch)	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n4509607/c4754149/content.html
2016, July 7 th	MIIT	Catalogue of power battery enterprises (4 th batch)	http://www.miit.gov.cn/n1146295/n1652858/n1652930/n4509607/c5137938/content.html
2017, June 28 th	NDRC	Foreign Investment Industrial Guidance Catalogue (Revised 2017), Decree No. 4 of 2017	http://zfxgk.ndrc.gov.cn/web/iteminfo.jsp?id=2808

8. GENERAL CONCLUSION

Before synthesizing the empirical, theoretical and practical results brought by this thesis, I can already affirm that it focuses on one of the most important industrial transitions of the beginning of the 21st century. The current results show that the automotive industry is currently experiencing a singular moment in its history and support the hypothesis of an avalanche of converging causalities leading to the destabilization of its historical architecture. And that, in accordance with the theory of transitions, it is the modes of regulation between these different factors or, using notions from the field of innovation project management, the modes of collective learning about these different variables, that will play a decisive role in these potential destabilizations.

The theoretical path also presents an original capacity to widen an initial field centered on the relation between technology and industrial dynamics to a multi factors approach, technological but also societal, to identify and analyze the conditions which can influence the stabilization or destabilization of the architecture of an industry. This capacity, to bring together several fields of research of strategy, economy and management, will be the subject of specific analysis and appropriate learnings in a concluding chapter of this thesis.

8.1. Empirical results

The research activities, carried out within the framework of this thesis, lead to seven major empirical conclusions:

1. The empirical study, carried out on the electric traction value chain, allows a large-scale validation of the resilience hypothesis of the historic architecture of the automotive industry to the rise of electrification. The scope of the study, both in terms of the number and diversity of the manufacturers observed and the units of analysis used, makes it possible to present, to date, solid conclusions for the world's leading manufacturers concerned by this possible destabilization of the industry. The study also demonstrates that carmakers have taken advantage of the dominant design to integrate an electric motor instead of an internal combustion engine "everything equal besides" (which is much easier to say in this paper than it is to do on mass-produced vehicles!) and introduce electrification through an architectural innovation.
2. The empirical study, conducted on Chinese regulations applying to the development of NEVs, both products and the associated industry, shows that the regulatory actor guiding the dynamics of the sector is changing sides and paradigm: (1) whereas it was

the Western world that guided the "progress" of the automobile, it is now China that dictates the trajectory and forces Western industry to adapt; and (2) whereas Western regulation focused on limiting nuisance and left the market to regulate performance, Chinese regulation is intrusive on performance itself. Beyond the significant consequences of these findings for global automobile manufacturers, these results show, according to STT theory, that one of the important factors in the stability of the existing automobile system, namely public regulation of the industry, is changing significantly.

3. Beyond the empirical study about Chinese NEVs, the case studies carried out show the importance of regulation, or more broadly of public authorities, at supranational (e.g. Europe), national but also regional and local levels in this transition. While regulatory impulses at supranational and national levels are one of the most powerful triggers in the current transition to electrification, regional and local decisions on transport policies will be the drivers of the transition to electromobility. From the decisions already taken to restrict or even prohibit the circulation of internal combustion vehicles and/or to grant advantages to owners of electric vehicles in urban centers to future investment decisions in modes of transport that must effectively combine collective (economy, high passenger flows at peak hours, return of urban space to inhabitants, etc.) and individual (comfort, safety, health, etc.) values, public actors have, more than any other actor, the capacity to shape tomorrow's mobility.
4. The case studies lend credibility to the scenario of a destabilization, in a second phase, of the organization of the automobile industry, caused by the transition to electromobility. This possible destabilization would be the conjunction of the emergence of several radical technologies, including electrification, connectivity, automated driving and digital technologies, and societal changes such as the fight against global warming, growing urbanization and changes in consumer behavior with regard to property and mobility. More concretely, it could be the consequence of the introduction of a new product offer (a versatile and electric robotaxi), the deployment of a new business model (the sale of mobility services), and the appearance, downstream of the value chain, of a new type of actor (a mobility operator) with the ability to capture the customer relationship to its sole benefit.
5. Building on the analytical framework of mobility services, the case studies show the variety of nature and direction of current initiatives. There is no history already written for the future of the autonomous vehicle, but a diversity of approaches as the analysis

of the ten cases leads to propose 3 different possible ideal types as targets for the transition trajectories: *Mobility service added to product*; *Robotaxi*; *Territorialized open mobility platform*. Each of them has different orientation towards either individual values such as individualization of services and comfort, or more collective values such as peak hour transport flows on major routes to give a few examples.

6. These same studies also emphasize the key character of the governance of the transition of socio-technical regimes and, in particular, the governance of learning about the dynamics of the various initiatives underway. Will the learnings acquired in managing systemic innovation projects as a leader of an ecosystem allow car manufacturers to maintain control of an automotive industry extended to mobility services? Or will the new entrants in mobility, with their more systemic approach and their mastery of new digital technologies and the associated ecosystem, take control of customer relations at the expense of car manufacturers?
7. Lastly, the cases study makes it possible to question the role of key players, namely, carmakers, mobility operators, public authorities, construction companies and technology companies, towards the three ideal types which have been identified. Carmakers, who are the incumbent major actors in the dynamics of the sector, will certainly favor “vehicle centric” solution such as the *mobility service added to product* and the *robotaxi* ideal types, because they can mostly maintain their historical dominant design. Incumbent mobility operators turn out to be the most natural candidate: they can manage B2B relationships with vehicle makers, are very skilled with hubs and fleets management and, most of them have stepped into the use of digital platforms for managing the customer relation. In addition, they are used to cooperate with local or territorial public authorities and can aggregate robotaxis with their usual solutions of mass transportation. They have the capacity to destabilize the current architecture of the automotive industry as they can capture both the final assembly operation of the vehicle and the relationship with the final customer. Could the public authorities become the leader of the platform dynamics and destabilize the current architecture of the automotive industry? They can support programs in order to bring about the emergence of innovations in mobility and can decide to fund investment projects to support development and operation. They can initialize a strong move, but as, deployment of this model can probably only be achieved through a combination of local experimentations and leadership from a higher level of public authority(ies), capable of

placing local initiatives in a more global plan at the national or international level. Construction companies have long been the privileged interlocutors of the territorial authorities to (i) build and operate local infrastructures and (ii) provide the necessary financing for such infrastructure within the framework of Public Private Partnerships. Consequently, they can strongly influence a future destabilization of the automotive industry if they co-lead, with public authorities, the roll-out of innovative mobility services. Lastly, technology companies can have an influence on the future of the automotive industry if they also play the role of mobility operator.

8.2. Theoretical contributions

From a theoretical point of view, this thesis makes interesting contributions in the following areas:

1. The theories of the relationship between technological change and industry dynamics as well as the conditions leading to the stability of an industry are confirmed by the empirical study of the electric traction value chain. Similarly, the conditions of application are specified, since this shows the limits of this approach when technological change is not the major factor of evolution.
2. The second is to have built, based on the STT paradigm, an empirical analytical apparatus capable of shedding light on the emerging transitions in the field of automotive mobility. It was necessary to build a framework to characterize the direction or targets of the transition which was done through the mobilization of the literature on service design and the ecosystems of the actors. This allowed to empirically measure the disruption introduced by the experiments in progress, to differentiate the orientations within ten studied cases and construct on these empirical evidences three different innovative mobility services ideal types: (i) *mobility service added to product*, (ii) *robotaxi* and (iii) *territorialized open mobility platform*.
3. The interest of using the theoretical framework of sociotechnical transitions to deal with mobility is, in continuity with other studies already carried out, confirmed; in practice, this thesis illustrates the relevance of combining the analysis of external pressure factors and the resources deployed by an industry to understand its evolutionary dynamics. Finally, it helps to clarify the principles of governance of such a transition by highlighting the importance of collective learning mechanisms within ecosystems.

4. Elaborating on the image of the markets system as a dance (Lindblom, 2001), this thesis provides empirical data to demonstrate that the Chinese State Council has a unique and strong pre-eminence over dancers while the European Commission manages to build a dance floor and an orchestra that both allow all former dancers (the historic carmakers) to still be part of the show. From a theoretical point of view, it demonstrates the major role of the learning capacity of an institution (here, the Chinese State Council) in shaping the future of markets and an industry.
5. The automotive case study helps to highlight generic models for a company's servicing strategy: (1) "*product centric added services*" when the service offer complements a product offer without any real intrusion on the product, (2) "*product enabler of service centric offer*" when the project is service-centric and the product (vehicle) is one of the catalysts for its operation, and (3) "*product centric service enabler*" when the development of breakthrough technologies, embedded in the product (vehicle), is the main catalyst for the operation of the service. For vehicle manufacturers faced with the last two cases, these are typical situations of ambidextrous management, as they involve projects that are heterogeneous in nature and in terms of time horizon compared with traditional range development projects.
6. The case studies have also confirmed the importance of the project as a vehicle for learning about a nascent ecosystem, since it offers both the possibility of mutual knowledge between actors from different contexts and the possibility of pooling the management of uncertainties in targeted innovation. The thesis thus shows the importance of the composition and structure of the ecosystem on the orientation and choices made in the collective learning trajectory within the project; it also helps to show the interest of implementing learning strategies through successive projects. Finally, it raises the question of the actors involved in the steering of this learning: the leading company of the platform when it exists in the ecosystem configuration, but also the regulatory body of territorialized mobility.

8.3. Managerial Contributions

Among the lessons of this thesis that could have an application in practice in companies, these seem to be major for the automotive industry, while of course being transposable to other industries:

1. Firstly, the need to develop new coordination capacities well beyond the traditional automotive industry; as electromobility projects may require coordination between multiple layers or between technical and non-technical components, this requires additional coordination with many players outside the core competencies of the automotive industry. Similarly, the design space including the 6 pillars of a MaaS should be integrated into the concurrent engineering logic of vehicles developed for mobility services.
2. The need to create and develop a new engineering discipline, totally unknown to the industry, and not only to the automotive industry, namely "mobility service engineering" whose functions are to (1) identify, qualify and quantify a need for mobility, (2) quantify the resources needed to put this service into operation, (3) conduct multidisciplinary upstream studies to build a robust project and evaluate its implementation and operating costs.
3. As a direct consequence of the centrality of innovation on service, it is no longer a product that needs to be validated, but the service experience for the customer that is part of a specific territorial context and a specific use. This implies an in-depth review of the internal validation and approval processes of car manufacturers, as well as the implementation of a complementary, complex and costly activity: certification in the sense of what is already applied by the aeronautics or pharmaceutical industries. This is a very significant development for the engineering departments of automotive companies and will certainly take time to be effectively implemented.
4. The empirical study, conducted on Chinese regulations concerning the NEV industry, shows an increasing tightening of the criteria necessary for placing a vehicle on the market, which requires (1) to further strengthen the design and integration capacities of carmakers and (2) to modify the criteria for assessing the performance of a vehicle, by increasing the weight of energy performance. In particular, the existence of an overall energy performance criterion, at vehicle level, could profoundly change the design choices of global manufacturers.
5. Finally, a comparison of the American, European and Chinese cases shows that ecosystem learning depends on the characteristics of the national context, which, on the one hand, more or less stimulates the alignment of actors' strategies with innovation prospects and, on the other hand, more or less favors the possibilities of experimentation necessary for learning about systemic innovations.

8.4. The dialectic of empirical questioning and theoretical frameworks

What does this itinerary tell us about the interactive research approach? A few elements of answer on the formulation of the research question, the choice of the theoretical framework and the contribution of the productions to the dynamics of the fields mobilized are proposed here. While these elements shed light on the approach used, they also indicate that there is still a long way to go to continue the study of the major transformation of an industry that is more than a century old and whose future has never been so closely linked to the major societal, economic and industrial choices of its time.

How to formulate research questions? This itinerary is driven by a twofold empirical curiosity: on the one hand, the observation of the momentum of the automotive industry, characterized by major breaks and, on the other hand, the questioning of the future trajectory of the sector. Interactive research finds its sources of questioning in socially important issues. The transformation of this curiosity into a research question has taken place through the choice of theoretical frameworks that formulate more precise and limited questions and offer solid analytical apparatus to investigate these questions. This transformation was achieved in two ways: first, through the operability of the survey, i.e. the way in which questions were precisely formulated and ready to be studied. It is also that of the socialization of research in a scientific community: how to be part of a "conversation" with colleagues, confronting the questions that interest them, giving oneself the possibility of publishing in journals defined by scientific fields, etc.

Why change the theoretical framework? The itinerary described shows an evolution and composition of the theoretical frameworks mobilized: strategic management, STT and MLP, design, project management. The dialectic described shows how a theoretical framework alone cannot exhaust an empirical interrogation. For example, the initial research question on the impact of technological breakthroughs on the transformation of the architecture of the automobile industry did not specify a horizon for considering breakthroughs or the scope of variables to be considered to answer them. The framework of the strategic analysis provided us with a precise but limited answer: all things being equal, the scale up of the breakthrough that electromobility constitutes will not succeed in destabilizing the current automotive system. But in real life, things are not all equal. The current momentum in the automotive sector is indeed characterized by a diversity of many disruptions: electromobility, but also the shift of the dominant markets of the triad towards Asia, changes in consumer behavior, the irruption of

powerful players in the digital world in a previously closed sector. Hence the mobilization of other theoretical approaches, including the STT framework, which focuses precisely on the question of the composition of the factors of transformation of an industrial regime. This framework has made it possible to structure the broadening of the scope of analysis, to construct a theoretical question that is both closer to empirical questioning and based on robust methods.

But while this framework allows for the forces at work in transitions to be considered, it says nothing about how the system will integrate these forces in order to transform itself, nor about the direction this transition will take, and therefore the impact for the different actors in the system. We must then turn to the theoretical management frameworks that aim precisely to understand these dynamic processes: design theory, organizational learning and the management of innovation projects. Design theory has provided a framework to characterize the space in which this collective design process will take place: the space of innovative electromobility services. This theory thus provides a cartography for analyzing empirical situations not in relation to what exists in the present, but what could potentially exist. The questionnaire grid of the benchmark is the operationalization of this reversal of the approach of confronting the empirical observables constituted by the cases studied, not with respect to the past (which was done by confronting the productive systems based on the internal combustion engine with those based on electric drive) but with the potential concepts of electric and autonomous mobility services. This approach made it possible to characterize three different concepts, which may be potential targets of the trajectories initiated in the initiatives studied.

The question of the management of these trajectories and the role of the actors operating them remains. This question is addressed by organizational learning theories, and more specifically those concerned with projects (because projects are the elementary links in these trajectories) and the organisation of collective learning in firms and ecosystems (management of lineages, steering of platform dynamics).

What is the contribution of the interactive approach to the theoretical fields mobilized? While it seems natural that this research approach contributes to the understanding of the socio-economic problems that stimulate it, the question of its contribution to the advancement of the theoretical fields that it mobilizes is a priori less obvious. We will insist here on two contributions. The first is the testing of the relevance of the theory used, an unavoidable question in management: what does theory produce as an answer to a question with a high socio-economic stake? The second is the organization of the debate between different theoretical currents. The call for the virtues of multidisciplinary is obviously not new. So is the

abstract discussion of various theoretical fields in the chapters analyzing the literature of academic works. The path that has been followed goes further, by confronting, on the same field of application, the contributions and limits of different explanatory frameworks, finally demonstrating their complementarities and the possible articulations between them.

8.5. Limitations

Finally, this thesis also has limitations. First of all, empirical studies assessing the stability of the architecture of the automotive industry have all focused on global manufacturers, which presents a certain logic for a study with the ambition of studying the transition of an industry whose regime has been established for several decades; however, a study focused on the Chinese automotive industry and observing, in particular, the emergence of the NEV industry, would allow testing the empirical, theoretical and practical results and contributions in a context where the historical role of manufacturers is not so predominant.

Case studies of concrete New Mobility projects, involving interviews with executives and operational actors from a wide range of companies in the automotive, technology or transport services industries as well as research institutions or public actors were, in the terrible context of the coronavirus that hit the world in 2020, reduced to work carried out at the end of 2019 or a few second-source studies that could be carried out in 2020. The fourteen or so cases studied make it possible to propose conclusions that will have to be challenged as soon as health, social and economic conditions allow this study to be resumed with respect for individuals, companies and institutions.

The theoretical framework of the socio-technical transition was used and showed its effectiveness in studying this transition; the importance of the principles of governance of a transition was confirmed and enriched by highlighting the importance of collective modes of learning about the different factors of a transition and how they can play a decisive role in potential destabilization of the regime. On the other hand, there has been no exploitation of the proposed analytical frameworks or the cases studied to contribute to the study of the theoretical underpinnings that support this theoretical framework.

Finally, this thesis is fully dedicated to the automotive industry and the deep transition it is currently undergoing. The capacity to extend the empirical, theoretical and managerial results and contributions to other industries, in a wide sense, remains to be demonstrated.

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Titre : Rupture technologique et dynamique d'une industrie, la transition vers l'électromobilité

Mots clés : électromobilité, innovation systémique, transition industrielle, apprentissage d'écosystème

Résumé : Des réglementations strictes obligent les constructeurs à investir massivement dans la production de véhicules électriques. L'électrification est une innovation systémique et sa massification devrait perturber la conception dominante des véhicules. *"Cette perturbation pourrait-elle déstabiliser durablement l'architecture d'une industrie considérée comme très résiliente ?"*

Une étude empirique de la chaîne de valeur de la traction électrique, confirme, à ce jour, la résilience de cette industrie dont les constructeurs automobiles restent l'acteur central et que l'électrification seule ne suffit pas à déstabiliser. Mais les innovations technologiques, les nouveaux défis sociétaux, les nouveaux acteurs puissants de la mobilité influencent l'avenir de cette industrie. *"Cette combinaison de facteurs internes et externes à l'industrie pourrait-elle favoriser une dynamique de rupture ?"* En analysant 10 cas de services de mobilité innovants au niveau mondial, cette thèse identifie 3 types idéaux : *"service de mobilité ajouté au produit"*, *"robotaxi"*, *"plateforme ouverte de mobilité territorialisée"*.

Si le premier est une extension naturelle de l'activité des constructeurs, les deux derniers ont le potentiel de déstabiliser cette industrie.

Une comparaison, entre la Chine et l'Europe, de la gouvernance des réglementations environnementales, indique que la Chine est en situation d'imposer désormais ses normes dans le monde entier grâce à une capacité de planification alliant directivité, intrusion et agilité.

Théoriquement, cette thèse confirme les théories stratégiques et l'utilisation du paradigme de la STT pour étudier les transitions dans cette industrie. Elle contribue aux domaines de la gestion de l'innovation et de la servitisation en proposant un espace de conception pour le développement des services de mobilité et confirme que le projet est un important vecteur d'apprentissage dans un écosystème naissant. Elle soutient l'hypothèse d'une avalanche de causalités convergentes conduisant à la déstabilisation de l'architecture historique de l'industrie automobile et que les modes de régulation entre ces différents facteurs vont façonner ces déstabilisations potentielles.

Title: Technological breakthrough and dynamics of an industry, the transition towards electromobility case

Keywords: electromobility, systemic innovation, industrial transition, ecosystem learning

Abstract: Strict regulations force global players to invest heavily in the production of electric vehicles. Electrification is a systemic innovation whose massification should disrupt the vehicle dominant design. *"Could this disruption durably destabilize the industrial architecture of a sector, considered as very resilient?"*

An empirical study on the electric traction value chain, confirms, to date, the resilience of this industry as carmakers remain the focal actor: electrification alone is not enough to destabilize this industry!

But, technological innovations, new societal challenges, new powerful players in the mobility market influence the future of this industry.

"Could this combination of factors internal and external to the industry facilitate a disruptive dynamic?"

By analyzing 10 case studies of innovative mobility services worldwide, this thesis identifies 3 ideal types: *"mobility service added to product"*, *"robotaxi"*, *"territorialized open mobility platform"*. If the first one is a natural extension of

the carmakers' business, the last two have the potential to destabilize the automotive industry.

An empirical comparison, between China and Europe, of the governance of environmental regulations, states that China is now in capacity to impose its standards worldwide through a planning capacity combining directiveness, intrusiveness and agility.

Theoretically, it confirms strategic theories and the interest of building upon the STT paradigm to shed light on transitions in this industry. It contributes to innovation management and servitization fields by proposing a design space for the development of mobility services and confirms that project is an important learning vector in a nascent ecosystem. This thesis supports the hypothesis of an avalanche of converging causalities leading to the destabilization of the historical architecture of the automotive industry. In accordance with the theory of transitions, the modes of regulation between these different factors will shape these potential destabilizations.