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DIGITAL AND OPEN INNOVATION IN THE AUTOMOTIVE INDUSTRY

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This document offers an initial discussion on features of the digital transformation process of the automotive industry. Delegates are invited to comment and provide further information on such processes regarding the automotive and/or other sectors. Delegates are also invited to propose firm, industry and technology case studies that can shed light on changing business models for innovation.

The document contributes to the work of the TIP Digital and Open Innovation Project [DSTI/STP/TIP(2017)2], particularly on the strand of work focusing on analysing the impacts of digitalisation on innovation processes and business models across sectors. The work is part of a number of activities conducted across the OECD that inform the Going Digital project.

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DIGITAL AND OPEN INNOVATION IN THE AUTOMOTIVE INDUSTRY

Executive Summary

1. The digital transformation has not only changed production processes, but also the very business model of the automotive industry. The industry is shifting from mechanical-based manufacturing to a software-based service industry. Automated driving applications, connected infotainment systems, services provided by “connected” cars, the emergence of car-sharing services and the possibilities to collect personal data are major drivers of change of traditional business models of car manufacturers. Car sales are no longer the exclusive source of revenue as “on-board” services, exploitation of personal data and car-sharing models offer new income streams.

2. These changes shape the innovation imperative of car producers as they face competition from leaders of digital technologies. Their objective is to develop competitive innovations by combining software-based capabilities with expertise in car production. In response, car manufacturers compete for top talent, invest in retraining and build organisational structures that emulate the flexibility of dynamic start-ups.

3. The digital transformation also has direct impacts on innovation processes that offer opportunities if adequate adjustments are undertaken. First, much shorter product development cycles for software, an increasingly important component of new cars, introduce a short product innovation cycle to the much longer physical car development cycle. Second, connected cars allow involving consumers in mass product trials at much larger scale than is possible for trials of the physical car. If well exploited, such feedback can result in co-development of new cars.

4. The new context also leads big automotive firms to engage in innovation beyond their own boundaries. Rationales for doing so include gathering different competences and digital assets, jointly engaging in the development of platforms and standards as well as pooling costs and risks in innovation investments. Car producers have engaged in a number of partnerships with other companies and universities as well as acquired digital start-ups for these reasons.

5. These changes are relevant for innovation policy. The increased importance of collaboration with other firms and industries, for instance, may suggest policies that promote collaboration are more important than before. Similarly, increased role for start-ups to help develop and test disruptive innovations may require new emphasis on support to entrepreneurship. The rapidity of change challenges defining platforms and standards, both of which play a central role in the digital economy.

6. While this preliminary study has focused on the car industry, many of the issues that it raised might be generic, extending to other sectors. The TIP project aims to provide a more in-depth analysis of changes in the business models for innovation and in innovation practices across industries, including service sectors. Delegates are invited to propose case studies of firms, industries and technologies to inform the project.

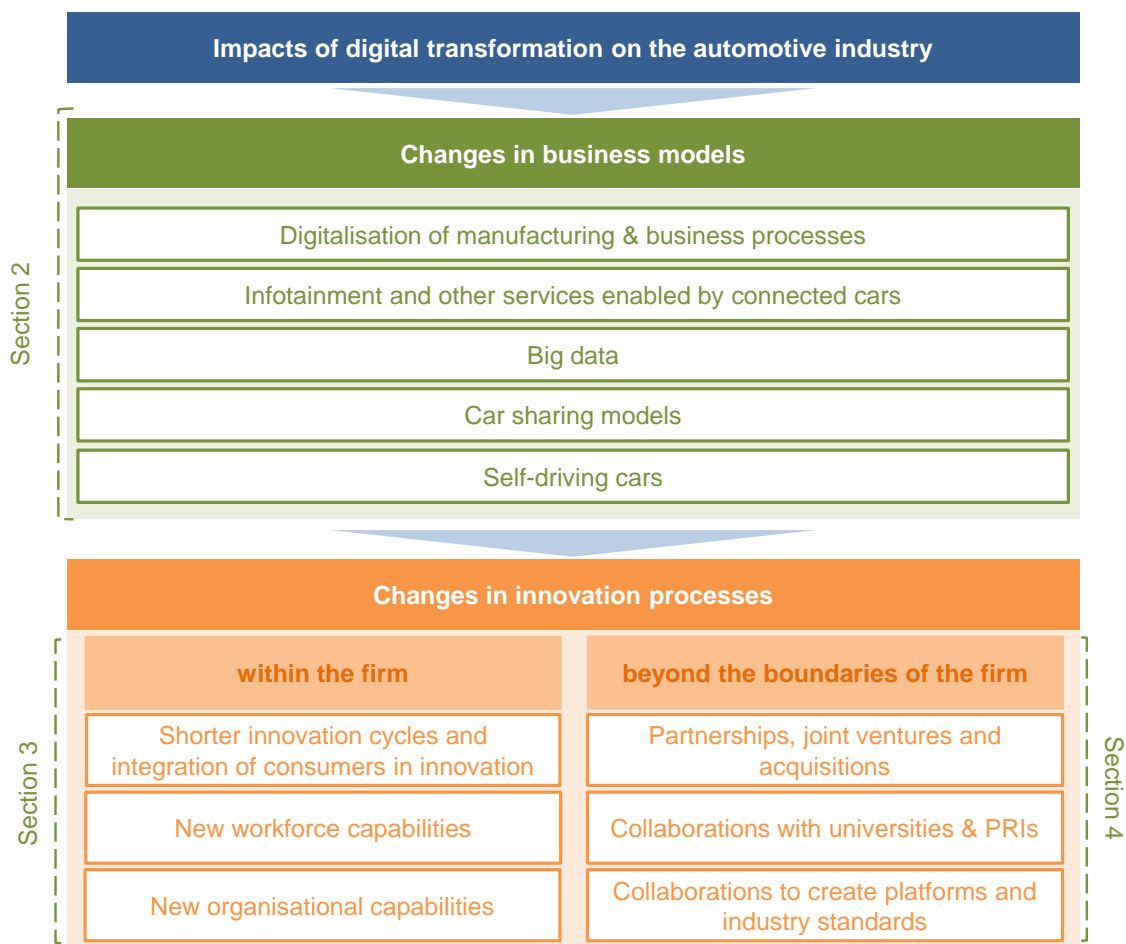
1. Introduction

7. Digital technologies change societies and the way economies operate, and increasingly change established industries and their ways of conducting innovation activities. The quick development of new digital technologies of large potential, such as advances in Artificial Intelligence (AI) and the Internet of Things (IoT), illustrate the speed of change. Innovation is at the heart of those changes, both as digital technologies generate new opportunities for innovations and as these technologies changes the business models of industries, affecting the incentives to innovate and the direction taken by these innovation activities.

8. The automotive industry is, for several reasons, an excellent case example to illustrate the significance of this digital transformation for innovation. First, this is a highly innovative sector. With an investment of around USD 117 billion in R&D in 2013, the automotive industry accounts for a high share of total private R&D expenditures worldwide. The patent filings of the automotive industry have been ranked third (behind the telecommunications industry, and the computing and peripherals industry) (Thomson Reuters, 2015). Second, the sector is a major (direct or indirect) employer in many countries. The 14 major global car producers alone had a workforce of 2.8 million in 2014 (see Annex 1). Third, the digital transformation has led to fundamental changes for car producers' business models.

9. This document discusses changes to the business models of large car manufacturers and implications for innovation within and beyond the boundaries of the firm (Figure 1).

Figure 1. Overview of the themes of the document



10. The remainder of the document is structured as follows: Section 2 discusses the changes that digitalisation brought to the business model of different businesses in the automotive industry. Section 3 briefly describes how these changes have affected the ways firms operate and innovate internally, while section 4 discusses open innovation models adopted by the industry in order to respond to the new challenges. The final section outlines possible implications for innovation policy.

2. The digital transition and supply side changes to traditional business models of the automotive industry

11. This section provides an overview of supply side to the business models of traditional car producers such as Volkswagen, General Motors and Toyota have changed with the digital transformation. Business models define a company's revenue streams (static aspect), as well as future development concepts including innovation strategies (dynamic aspect) (Bieger and Reinhold, 2011; Staehler, 2002). The business model of traditional car producers was based on core competencies in the development, production and distribution of mechanically highly sophisticated cars with internal combustion engines. With the digital transformation, the revenue streams of the automotive industry are expanding and diversifying as new on-demand mobility services and connectivity-driven services emerge. These are also recurring sources of revenues (in contrast with one-time car sales). However, the digital transformation of the automotive industry differs from services industries in that its main product remains a physical product, although the revenue from physical production component is diminishing with the growing importance of more service-based attributes of products.

12. The changes discussed add to changing demands for transportation that also change the car industry, such as, for instance, less demand from younger generation to own cars as well as growing demand for sustainable modes of transportation that also affect business models of the car industry. They are important to complement how business models of the car industry are changing.

2.1. New manufacturing and business processes: towards more efficiency

13. Software-based technology started changing the automotive industry in the 1960s with the introduction of simple robotics at General Motors: robots performed simple motion cycles such as pick-and-place operations (i.e. picking up an item and placing it at a different location). About 20 years later, car production relied on integrated computers that enabled machines to take over multiple manufacturing operations (Groover, 2007). Siemens and General Electric among others developed automation software for the industry. The development of smart factories that integrate Artificial Intelligence and the Internet of Things point to further opportunities to increase the efficiency of production processes.

14. Shortly after, car producers also started to use more advanced software application systems for business processes (e.g. digital resource planning) provided by third parties, such as SAP (a software manufacturer with headquarters in Germany). These software solutions brought significant efficiency gains and facilitated the spread of global production networks, as real-time information about, for instance, inventories and the arrival of car components was more easily compiled and transferred across the value chain (Nieuwenhuis and Wells, 2015).

2.2. New infotainment and other services enabled by connected cars

15. Digital technologies have progressively allowed for the introduction of on-board services. This started in the beginning of the 2000s, with the introduction of vehicle telematics, such as on-board navigation systems (VDA, 2015). Initially, such services represented no more than an add-on to cars. Since then, the scope of functionalities offered by infotainment systems (i.e. systems that provide on-demand information and entertainment services) has increased, becoming a more important factor in consumers'

decision of purchasing a car. Car models of Tesla (a company specialised in producing electric cars, with headquarters in the United States) already have more advanced infotainment systems with touch-screens and integrated web-browsers (Tesla, 2017). At the Consumer Electronics Show (CES) 2017 in Las Vegas, automotive companies described automobiles as “third space” between home and workplace (Techradar, 2017) where personal profiles of drivers allow to automatically adjust individual settings – from the position of the driver seat to the music preferences. For instance, vehicle temperature could be adjusted to the body temperature, or the music playlist to the measured heart rate while driving. The market for on-demand consumption of music, movies and other information and entertainment sources in cars is estimated to gain a value of USD 65 billion by 2025 (WEF, 2016).

16. The integration of automatic payment in application systems of cars opens another potential source of future revenues. Cars with integrated payment systems will be able to pay automatically for all kinds of costs related to driving (e.g. fuel, street charges, etc.) and other types of purchases done “on-board” (Center for Automotive Research, 2014).

17. The most important driver of enhanced services is connected vehicles, which are vehicles that can generate data from the physical world via sensor technology, receive and process data, as well as connect to other cars and devices. The prototype of the Toyota Prius model in 2009 was the first car that established a 4G mobile network connection and access cloud services (IOT Evolution, 2009). Tesla’s Model S, released in 2012, also connects sensor technology to the car and is able to send and receive information from Tesla (Tesla, 2017).

18. The personalisation of services could be even more targeted if connectivity involves pooling personal data across different digital activities of customers. Alphabet and Apple have developed interfaces between their smartphone application systems and automotive infotainment systems (Android Auto and Apple’s Carplay). Volkswagen has already tested exchange of information between vehicles and smart phones, which allows, for example, to check vehicle temperature and other information regarding the vehicle status remotely, and also to operate smart home applications (e.g. temperature control) directly from the car via the on-board system (Volkswagen Magazine, 2017). It is easy to see how these developments would result in improved products for the end consumer but also how pooling personal data needs to be done in a way that ensures privacy concerns are addressed.

2.3. Big data

19. Connected cars do not only allow for the provision of new services to consumers but also allow gathering data that are of value to third parties (such as insurance companies and sellers of consumer products), introducing two-sided market structures as the user of the car is no longer the only potential client. The type of data that can be collected includes real time technical vehicle information (e.g. status and performance of components and parts), driving-related data (e.g. route chosen, the types of vehicle used, information on traffic) and personal consumer data (e.g. behavioural data, health data).

20. Examples include the following: Vehicle insurance companies would be interested in real-time data on driving behaviour of insured individuals (such as the frequency of car use and compliance with speed limits) to assess the risks of being involved in an accident and subsequently calculate personalised premiums rates (i.e. insurance prices). Real-time information on the location of vehicles is also relevant to private companies in different sectors (e.g. to identify best placements for advertisements, particularly if such data are linked to personal information) (Hanelt et al, 2015). Such information also facilitates regulating car traffic.

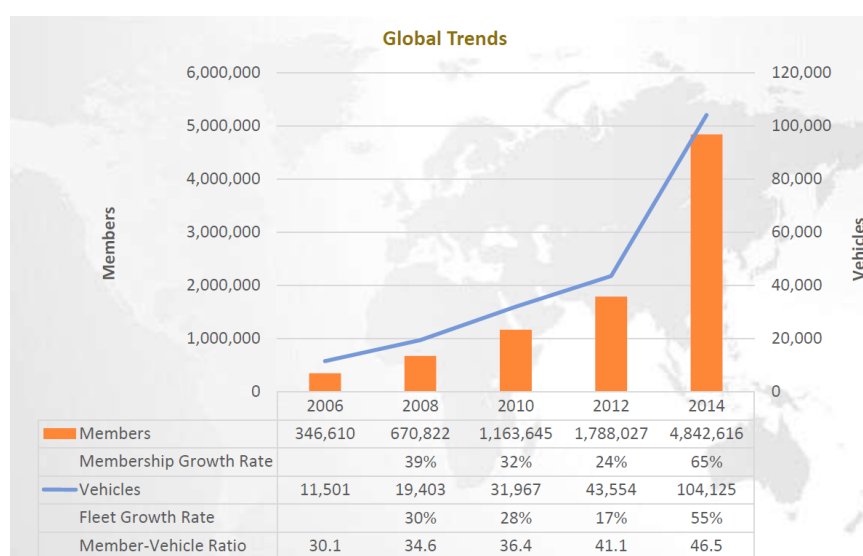
2.4. Car sharing models

21. With the digital transformation, car-sharing models offer consumers a more attractive alternative to car-ownership than was the case in the past. The mobile application introduced by Uber has shown the potential of digital technology to operate mobility services based on their potentially to give in-time information on the demand and supply of transportation services. This has led car producers to respond by proposing car-sharing services, in which a company provides the car-fleet. This differentiates it from peer-to-peer car rental, which refers to the process whereby car owners rent their cars to other individuals for short periods of time. It also differs from traditional concepts of car rental, as the pick-up and returning points of car sharing vehicles are not limited to a few locations, such as airports or offices of car rental companies.

22. Car rental services are gaining with the digital transformation because of the following: The Mobile technologies make car sharing much more convenient for users. Members of Zipcar for example can locate available vehicles. Multimodal integration will enable users to combine car sharing with different transportation means (e.g. metro, train, bike sharing) to get from location A to B via one-click payment or integrated pricing packages. Some cities, including Gothenburg in Sweden and Helsinki in Finland, already run pilot programs for such applications in order to improve urban mobility (Box 1) (WEF, 2016; MaaS, 2017). Finally, car-sharing models are also a response to the success of peer-to-peer car rental services that are facilitated by digital technologies.

23. Car sharing was originally started with a few mobility start-ups, such as Zipcar in the US in 2000, which provided urban car-fleets for members. Figure 2 shows the rapid expansion of this market worldwide between 2006 and 2014. Most car-rental companies and carmakers have progressively entered the market and offer alternative car sharing solutions – some of them via joint ventures. For example, in 2011 BMW and Sixt, a multinational car rental company, jointly launched *DriveNow*, which has reached almost 1 million users in 2017. Other examples include *Multicity* by Citroen, Daimler's *Car2Go*, Volkswagens' *MOIA*, and Fords's *GoDrive*.

Figure 2. Growth of car-sharing business worldwide, 2006-2014



Source: Shaheen and Cohen (2016).

24. Car sharing marks an important departure from existing business models, requiring a new set of services, including maintenance services and charging infrastructures for electric vehicles. In the case of

car sharing services, car producers no longer sell the vehicles to customers but rather keep them in their books as fixed assets and must write them down in value over the product lifecycle, as they do it with machines in manufacturing plants. Therefore, machine failure constitutes a new risk for providers. To minimize these risks, carmakers start to implement effective fleet management that maximizes utilization of vehicles by customers and decreases the possibility of machine failure.

25. If successful, new forms of competitive advantages and brand power can be generated by high service qualities; new possibilities to acquire knowledge for other business fields (e.g. about vehicle performance or consumer preferences) can be enabled via data collection and analysis of vehicle fleets and customers' mobility patterns. Mobility business models offer new revenue sources with potentially high profit margins and open new consumer segments.

Box 1. Mobility as a Service (MaaS)

Mobility as a Service (MaaS) is a concept for multi-modal mobility that aims to integrate different passenger transportation means in one platform. Currently, Helsinki is testing a pilot program on MaaS in which a private company, MaaS Global, provides an urban mobility platform for its customers. Users can combine public transport, taxis, car-sharing and other means with one-click-payment from their mobile phones or by purchasing a monthly based package.

For consumers this combination of many different assets of transportation companies will increase options for transportation improving the quality of the services (regarding convenience, time and cost). This is achieved as consumers receive more comprehensive information about different offers and providers is higher with MaaS. Furthermore, by using the app, travelling in Helsinki will become more convenient as it can be organised and purchased via one single smartphone application (MaaS Global, 2017).

2.5. From automated driving to self-driving cars

26. Self-driving cars mark another development with implications for the business model of car manufacturers. With automated driving,¹ software systems that use artificial intelligence (AI) will become a central component of the car of the future, reducing further the contribution of technical capabilities that allow for the physical production of cars.

27. Currently, all new car models offer automated driving support, in that they take over parts of the vehicle motion control and support the driver with certain tasks such as parking and lane- and speed-keeping –but the driver is still in charge of driving (VDA, 2015).

28. At full driving automation, cars drive independently and react to their environment without intervention of the driver. Such systems are currently tested in pilot projects (Center for Automotive Research, 2017). Alphabet, a multinational conglomerate of companies that includes Google, was one of the first players to start a project on self-driving cars in 2009 building on its competences in algorithms, AI and mapping. In 2016, Alphabet created of a new subsidiary for self-driving cars named Waymo. The objective is to establish a platform for self-driving cars, in which Waymo would provide the automated driving system and collaborate with carmakers who would develop the physical vehicles behind it. Chrysler and Toyota (Lexus) are so far the first automobile companies that have joined this platform. Chrysler and Alphabet have already created a self-driving minivan (Waymo, 2017). Other companies are also in the race to introduce the first mass produced self-driving car, including BMW (in collaboration with Intel, Mobileye and Delphi), Ford and GM. Uber is also investing in autonomous driving software to enter

¹ Automated driving refers to cars that are equipped with advanced automated driving systems (ADS), which integrate sensor technology, software algorithms, and hardware and control motions of the car.

new profitable segments in the future, such as autonomous delivery and autonomous taxi services. To that end, Uber acquired Microsoft's former mapping division (Business Insider, 2015).

3. Changes to innovation within the firm

29. The digital transformation has also changed innovation processes; both directly, as new product components and processes involve different ways for innovation, and indirectly, as changing business models require adapting the capabilities of the workforce and of organisations.

3.1. Opportunities of the digital transformation for innovation processes

3.1.1. Software innovations introduce an additional quicker innovation cycle

30. Software innovations constitute an increasingly important type of innovation for car manufacturers in the context of new business models (particularly infotainment and other services and automated and self-driving cars as discussed above).

31. The different nature of the product (software) introduces also a different innovation cycle to that of the physical car. The software development cycle is short and to some extent continuous in that today's software updates are frequent and often used to not only fix bugs but also to offer new functionalities. New versions are released frequently and improvements constitute a major after-sales service (PWC, 2016a). This contrasts with car development activities that generally are set out in 2-5 year product development cycles.

32. With the introduction of its Model S in 2012, Tesla (an innovation-based manufacturer of electric cars, headquartered in Silicon Valley, USA) was the first company to produce a car that could receive software updates similarly to connected digital computers (Wired, 2014). This offers the possibility of introducing add-ons to the same car, breaking up the physical car development cycle with the development cycle of its increasingly important software component. It also raises serious security issues.

3.1.2. Integration of consumer and user data in innovation

33. Digital technologies also allow collecting data on customer experience to feed into the innovation processes. A number of carmakers have already engaged in pilot programmes that aim to reproduce the successful model of software producers, who release beta versions to test user expectations and track user behaviour regarding products that are already on the market, so as to identify software errors and areas where software improvements are needed.

34. Pilot programmes include, for instance, *Multicity* by Citroen, Daimler's *Car2Go*, BMW's *DriveNow*, Volkswagens' *MOIA*, and Fords's *GoDrive* – all of which are car-sharing brands of carmakers. Their services are currently not profitable for car manufacturers, but function rather as pioneering activities to understand consumer preferences and needs regarding car sharing by generating and evaluating user data (Nieuwenhuis and Wells, 2015). This has the objective of shaping the car-sharing business model jointly with consumers

35. In the case of autonomous driving, Tesla installed a "public beta" of its AutoPilot software in more than 70 000 vehicles, collecting in this way data from consumers testing the software at large scale, with the advantage of testing its robustness to different traffic scenarios (Tesla, 2017). Tesla's strategy CEO Elon Musk sees this strategy as an important component to the quick development of self-driving vehicles (The Guardian, 2016). Test consumer safety however needs to be weighed against the advantages from widespread testing.

3.2. New workforce capabilities: Reskilling and recruitment efforts

36. With the digital transformation, car producers require a workforce with new digital competencies but also other competencies to operate new business models. First, to connect their traditional competencies primarily in mechanical and electrical engineering with skills in software engineering and in major digital technology trends (e.g. big data analytics, cloud computing, AI, IoT) (WEF, 2016). Second, competences in providing on-demand services, in managing customer-relationships in innovation processes and car sharing business arrangements are also part of the new skills requirements.

37. Many companies have engaged in efforts to build a workforce with those required skills. This has involved retraining of the workforce. Retraining, however, has its limitations where entirely new skills sets are needed as they require long-term training. Consequently, efforts have been deployed in recruiting “digital talent”. As the demand for such talent is substantial across the economy, car manufacturers have developed different methods to recruit skills. GM, for example, has established an internal database for the collection of talent data from labour force platforms such as LinkedIn (Automotive News, 2017a). Others, such as Audi, have intensified partnerships with universities and sponsored research and doctoral projects to access these talent pools (Automotive News, 2017a).

38. Beyond individual capabilities, digital talent alone has proven insufficient to allow car producers to adjust to new business models, unless organisational structures and processes are also adjusted to allow for adequate innovation responses to fundamental changes of the digital transformation (Egon Zehnder, 2017).

3.3. New needs for organisational capabilities

39. Three core aspects of organisational structures are arguably critical in a context of wide-ranging business model changes that require the ability to undertake possibly important changes compared to past ways of operating and to do so quickly in view of a more rapid rate of technical change. These are the adoption of: 1) agile structures and processes; 2) defined human-machine interfaces; and 3) collaborative networks with external players.

40. First, there is a debate about the impact of static and hierarchic structures that may inhibit car producers’ ability to react quickly to changes. Reasons are long processes required to obtain approval in complex hierarchies and possibly fewer cross-departmental collaborations. For example, instead of working in fixed structures, employees may carry out processes and tasks in horizontally connected, independent teams. This can increase the speed and flexibility of operating these tasks (Gerald et al, 2016). Daimler AG introduced such changes by introducing “swarm organisation management techniques” in 2016. The stated objective is to enable more rapid development in emerging critical mobility fields (e.g. connected cars, autonomous driving, shared mobility and electric drive systems). Employees in the swarm organisation are not integrated in strict hierarchies and have more opportunities to interact with others outside of their own unit (in the case of Daimler the levels were reduced from 6 to 2) (Handelsblatt, 2016).

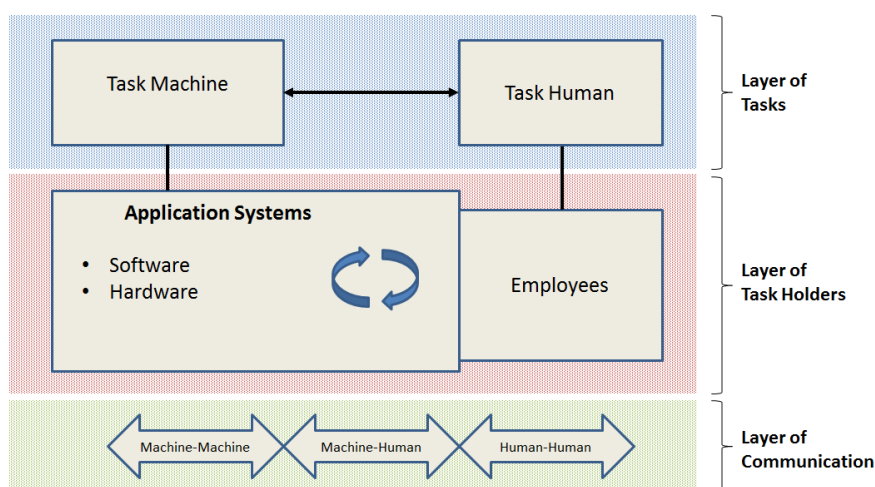
41. Volkswagen also founded a new brand, MOIA, to develop its business independently in a flexible “start-up alike” organisation of no more than 50 people while benefiting from Volkswagen knowledge, infrastructure and financial power. Furthermore, MOIA aims to acquire further mobility start-ups and attract young entrepreneurs who will bring in external input while remaining in their flexible start-up environment (MOIA, 2017).

42. Similarly, for the development of electric vehicles (i-Series) and car-sharing services, BMW established separate business units that are functionally detached from the company’s organisational

structure. Although these units use the company's established logistic and manufacturing channels, they develop their business independently, similarly to start-up organisation (NTT Innovation Institute, 2015).

43. Second, in addition to becoming more agile, the integration of new digital technologies within firms' organisational structures (e.g. cloud computing, big data analytics, AI, etc.) results in increasing applications of machines in manufacturing and business processes. While car manufacturers have already faced the challenge of optimizing the interaction between employees and digital technologies since the 1980s (with the automation of many tasks), it is important to ensure that the interfaces between the labour force and machines are appropriately defined and communicated with wider applications of technologies.

Figure 3. Information system of an enterprise



Source: Adapted from Ferstl and Sinz (2012)

44. Third, additional organisational adjustments may be needed to engage successfully in innovation activities that involve others, which is becoming an indispensable practise for car producers to develop digital business models (see section 4). This includes setting up interfaces for collaboration and building specific units that manage and engage in collaborations. Toyota for example has created *Toyota Next*, an open innovation platform to foster collaborations with start-ups, university teams and companies for the development of future mobility services. Most car manufacturers have also established incubator programmes to foster knowledge exchange and collaborative innovation with start-ups. Some examples are Ford (Techstars Mobility², which also has support from other businesses) and PSA (PSA unboxed³).

4. Innovation beyond the boundaries of the firm

4.1. Rationales for engaging in innovation activities with others

45. Firms in the automotive industry have several incentives to collaborate with other actors (e.g. firms within the automotive sector and in other sectors, universities, PRIs) for innovation and participate in innovation networks. One reason is to have access to a broad range of assets and competences: Innovation in the automotive industry has traditionally involved car manufacturers and their suppliers, who conducted innovation activities internally. The complexity and fast pace of new digital developments and the

² <http://www.techstars.com/programs/mobility-program/>.

³ <https://unboxed.globalpsa.com/>.

emergence of new business models requires a broad range of competences and assets in order to remain competitive. These go beyond the competences and assets of any single player. In some cases, firms may decide to internalise capabilities, others may decide to acquire them. Acquisitions have been a much observed phenomenon in the digital economy with large prizes paid for small start-ups (referred to often as unicorns).

46. Firms may also decide to jointly engage in joint projects where the investment costs and risks are large for a single company, as is often the case of investments in new digital technologies. Pooling efforts may allow reducing individual risk by sharing the costs. This, of course, comes at the cost of potentially having to share the benefits if successful. Consequently, firms may have an incentive to leave partnerships when they see opportunities to develop innovations that can succeed in the market.

47. Another more strategic reason is the advantage of participating in the establishment of platforms and standards: The digital transformation of business models creates new markets with high revenue potential. If companies do not participate in early stages, they might not be able to enter them in the future. Specifically, there may be advantages of teaming up to be part of the creators of industry-wide standards that can guarantee key positions in the new market.

4.2. Partnerships, joint ventures and acquisitions

48. Common forms of collaboration among firms are partnerships and joint ventures in which firms share infrastructures, investments or assets to reach a joint objective. For example, in 2016 BMW started a partnership with Intel and Mobileye (an Israeli high-tech company that develops vision-based advanced driver-assistance systems, which was acquired by Intel in March 2017). Delphi, an automotive parts manufacturing company headquartered in the UK, joined the partnership in 2017. The partnering companies plan to develop an autonomous driving platform that is expected to deliver 40 pilot cars by the end of 2017 (AutoServiceWorld, 2017). Similarly, Mercedes announced in 2017 a strategic partnership with the automotive supply company Bosch to develop autonomous driving systems (Automotive News, 2017b).

49. Collaboration of car manufacturers with digital start-ups have also become more important as start-ups can function as “digital accelerators” as they often enjoy greater flexibility in developing new disruptive technologies (McKinsey, 2016a). Start-ups have natural incentives to collaborate with large players to access finance, technology and customers. For example, Volkswagen recently started a strategic partnership with the mobility start-up Gett, a company that provides an application that allows to book transportation and logistics services, by investing USD 300 million. In 2017, Ford announced its USD 1 billion investment in Argo AI, a technology start-up with major competences in robotics and artificial intelligence software. By becoming the major shareholder of Argo AI, Ford aims to accelerate the development of autonomous driving cars with close collaborations and the combination of skills and technology assets (Forbes, 2017).

50. Car producers have also started strategic partnerships with consultancy firms to intensify collaborations on the development of new competences. Ford for instance partnered up with Pivotal Labs, a software consulting firm based in San Francisco that is specialized on programming in engineering fields (Automotive News, 2017a).

51. Digital business model trends are currently driving merger and acquisition (M&A) activities of automotive companies (PWC, 2016b). Tech-start-ups, in addition of providing digital technologies and a skilled workforce, may also bring in dynamic organisational structures. Often such acquisitions are considered strategic to be able to remain competitive in new emerging markets. For example, autonomous driving is expected to soon account for large revenue streams in the market. In this context, the German car

manufacturers BMW, Mercedes and Audi, jointly acquired Nokia's mapping service *Here* to gain mapping capabilities (Forbes, 2016).

4.3. Collaboration with universities and PRIs

52. Collaborations with universities and research institutes can play a major role in the development of new competences for carmakers, and lead to important knowledge transfers from science to industry.

53. In Europe, various collaborations between car manufacturers, such as Volkswagen, and the German Fraunhofer Institutes (a German research organisation for applied science) have been established in the past years to carry out research projects in diverse technological areas (Fraunhofer Fokus, 2014). Toyota's Research Institute has also established academic partnerships around the world. Toyota Research Institute, which oversees various research activities for the company in computer science, artificial intelligence and material science among others, fosters Toyota's innovation activities regarding future mobility concepts. In 2015, the institute invested USD 50 million in research collaboration with Stanford University and the Massachusetts Institute of Technology (MIT). The collaborations focus in particular on machine autonomy (in MIT laboratories) and human-robot interactions (in Stanford laboratories) (Toyota Research Institute, 2017).

4.4. Collaborations to create platforms and industry standards

54. The interest in providing industry platforms and industry standards is another reason why firms have more incentives to innovate with others. In the context of the digital transformation, platforms play an important role and a number of standards need to be created. Firms may innovate with others to participate in the development of industry platforms, which provide a subsystem or a product component to which complementary product and software components can be added, to become leaders of such platforms. An example for an industry platform in the field of connected cars is the Open Automotive Alliance (OOA), which was founded by Alphabet in 2014. It includes several carmakers, including Audi, GM, Honda and Hyundai, and technology companies, such as Sony or NVidia. Together with its partners, Alphabet developed the infotainment system software Android Auto that allows connecting Android smartphones functionalities to the dashboard of cars. Apple's CarPlay is the equivalent for iPhones.

55. Another example of the trend towards open innovation is the opening of Tesla's patents since 2014, which allow competitors to use them free of charge. Tesla has established the most advanced battery and electric charging infrastructure in the world. So far, car-manufacturers have all build on distinct battery solutions without a common interface. With the use of Tesla's patents by competitors, the battery and charging technology could become industry-standard and facilitate the establishment of a common supply base. With its Gigafactory (for battery production) and highly advanced charging infrastructure of power-supply stations, Tesla could create an e-mobility platform and become the most advanced battery and charging infrastructure provider in the world (Forbes, 2014). At the same time, all participants would benefit from economies of scale, which would lead to heavy decreases in costs. Furthermore, consumers-attention and acceptance for electro-mobility would increase enormously and stimulate a high market growth. However, a problem for many competitors would represent the potentially monopolistic position of Tesla as a battery provider, which would certainly cause high dependencies.

5. Implications for innovation policy and next steps for the TIP project

5.1. Some perspectives on implications for innovation policy

56. The impacts of the digital transformation for innovation in the car manufacturing industry point to possible implications for innovation policy. This includes, for example, the following:

57. Ensuring collaborations among firms and with research institutions and dynamic start-ups may be more important than before the digital transformation. One major reason is that a wider capability mix is needed. This may include collaboration with foreign-based entities. Policies that ensure dynamic start-ups may also be more important as start-ups may act as incubators of new disruptive ideas industry can implement once successfully tested.

58. Policy instruments also need to take into account the rapid and disruptive changes car manufacturers have experienced and consequently need to ensure support programmes take into account new actors engage in the industry. Policies need to be sufficiently flexible to take into account changing market dynamics and technology developments.

59. The development of new platforms, standards and key technologies also needs to be reconsidered in the context of the digital transformation. The contributions of new platforms and standards towards better products (e.g. platforms that allow the transfer of personal information across several devices allow for more personalised services) and enable innovation (as, for instance, innovations in mobile apps that build on the Android operating system). They need to evaluate these benefits against two sources of risk that may stifle innovation: i) lock-in to inferior technologies in a period of rapid change and ii) strong market power rather than contestable markets for core technologies that are part of platforms and standards, resulting in winner-take-all market dynamics.

5.2. Next steps for TIP work

60. The questions to be addressed by the TIP activity on the conditions of innovation in different sectors include:

1. What open innovation models have been developed in different sectors? Have platforms attracted more firms and individuals to the innovation process? Are there trade-offs between the benefits of collaboration in innovation and the gains from competition?
2. In what ways are business models changing with digital innovations and how are these changes affecting innovation ecosystems? What role are platforms playing? What are the implications for different actors, including large firms, SMEs, and start-ups?
3. What are the core skills and capacities businesses need for a successful digital transition? In what ways are public research institutions supporting the new requirements for innovation?

61. Answering these questions with regard to the car industry requires conducting additional analysis of changes in opportunities for different industry actors including the industry's SMEs, the different upstream and downstream suppliers. The changes in demand away from car ownership and towards more sustainable modes of transportation also affect business models of the industry. Work conducted by the International Transport Forum analyses the changing models for transportation complementing the preliminary discussion of this document, which aimed at providing a first discussion on changing innovation practices of the car industry. Further detail on the capabilities at organisational level needed to compete and on changing market dynamics would also be important to complement the initial discussion. Complementary statistical analysis would allow tracing evolving patterns of collaboration in innovation across sectors, the speed of change and factors that facilitate or challenge adoption as well as to assess innovative performance outcomes.

62. Beyond the car industry, other sectors need reviewing to understand similarities and differences in impacts, in order to identify implications for innovation policy. Interesting examples include services, ranging from creative industry to the retail sector. In the financial industry, electronically placed orders via mobile apps and the internet have replaced traditional ways of investing in stocks. FinTech start-ups i.e.

start-ups that offer new technological applications for the financial sector, are rapidly growing. In the marketing and advertising industry, many marketing instruments used during the past decade are considered outdated with the different opportunities to “reach” customers on social media platforms compared to traditional media.

63. Delegates are invited to propose case studies that would cover the experiences of firms, industry or technologies. Studies on the impacts of widely adopted digital technologies (or of the potential of widespread adoption) across sectors would also be interesting. Industry or companies may also volunteer to offer perspectives on their own research. Ideally, case studies would reflect the experiences of both smaller and larger companies and focus on selected manufacturing and services industries. Quantitative studies on how IT adoption affected firm innovative performance would also be interesting to describe changes in different actors in the economy.

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ANNEX 1: BASIC CHARACTERISTICS OF MAJOR CAR MANUFACTURERS

The global automotive industry has 14 car producers that build their own cars and between them had USD 1.7 trillion sales (in 2015), employed 2.8 million people and owned 58 brands. Table 1 provides basic statistics to characterise these major car manufacturing companies. In terms of revenues, Volkswagen AG and Toyota Motor Corporation are the top leaders of the industry. The entire industry is much larger as many other firms and industries contribute directly or indirectly to the production and commercialization of cars – both in the upstream and downstream parts of the value chain.⁴

Table A1. Major car producers, 2015

Company name	Brands	Annual car sales (in thousand)	Annual car production (in thousand)	Number of employees (end of FSY2015)	Annual revenues (USD billion)	Country of origin/ headquarter
Volkswagen AG	Volkswagen, Audi, SEAT, SKODA, Bentley, Bugatti, Lamborghini, Porsche, Ducati, MAN, Scania	10 009	10 017	610 076	276	Germany
Toyota Motor Corp.	Toyota, Hino, Lexus, Ranz, Daihatsu	8 971	8 929	348 877	266	Japan
Hyundai Motor Company	Hyundai, KIA Motors	4 843	4 948	112 072	103	Korea
General Motors Company (GM)	Chevrolet, Buick, GMC, Cadillac, Holden, HSV, Opel, Vauxhall, Wuling, Baojun, Jie Fang, Ravon	9 958	-	215 000	152	United States
Honda Motor	Honda	4 206	-	203 902	94	Japan
Nissan Motor Corporation	Nissan, Infiniti, Datsun	5 318	-	151 710	111	Japan
Ford Motor Company	Ford, Lincoln	6 635	6 674	199 000	141	US

⁴ The upstream part of the automotive industry comprises various suppliers of manufacturing and services out of industries such as the chemical industry, the metal industry and other natural resource industries; the transportation and logistics sector; as well as the automotive sector itself. The downstream part of the automotive value chain comprises services such as car financing, distribution, sales, car rental, insurance and MRO (maintenance, repair and overhaul).

Suzuki Motor Corp.	Suzuki	2 702	3 043	45 000	25	Japan
Groupe PSA	Peugot, Citroën, DS Automobiles	2 972	-	184 000	45	France
Groupe Renault	Renault, Dacia	2 800	2 800	120 000	56	France
BMW AG	BMW, Mini, Rolls-Royce	2 247	2 278	122 244	111	Germany
FCA Group	Fiat, Chrysler, Alfa Romeo, Dodge, Jeep, Lancia, Ram Trucks, Abarth, Maserati	4 700	-	234 000	138	France
Daimler AG	Mercedes-Benz, Maybach, Smart	2 853	-	284 000	193	Germany
Tesla Motors	Tesla	50	50	13 000	4	US

Note: Data based on annual reports for Fiscal Year 2015. The starting/ending month of Fiscal Year (FY) varies from company to company. Currencies have been converted into US-Dollars using PPP conversion rates of 2015. Due to high annual growth rates and several acquisitions, numbers of Tesla Motors have significantly increased since FY 2015.

Source: Daimler: Annual Report 2015, Daimler: Corporate Presentation FY 2015, FCA: 2015 Annual Report, Ford Motor Company 2015 Annual Report, General Motors Company: 2015 Annual Report, Honda: Annual Report 2015, Hyundai Motor Company: Annual Report 2015, Hyundai Company Website (<http://worldwide.hyundai.com/WW/Main/index.html>), Nissan Motor Corporation: Annual Report 2015, PSA: 2015 Annual Results, Groupe Renault: 2015 Annual Report, Suzuki Motor Corporation: Annual Report 2015, Toyota Motor Corporation: Financial Summary FY 2015, Toyota Company Website (<http://www.toyota-global.com/>), Volkswagen: Annual Report 2015, Tesla Annual Report 2015 (http://ir.tesla.com/secfiling.cfm?filingid=1564590-16-13195&cik=#TSLA-10K_20151231_HTM_ITEM_8).