Why incumbents and entrants need each other:

The road to autonomous vehicles

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Summary

The emergence of autonomous vehicle(AV) technology, as well as other technologies associated with the *"Fourth Industrial Revolution",* opens up opportunities for entrant firms to challenge incumbent firms and implies a transition in the way societal functions are currently fulfilled. Such *sociotechnical transitions* require radical changes in dominant technologies but also in institutional elements, such as user practices, standards, rules, norms, cultural beliefs, and expectations. However, scholars that have studied incumbents and entrants in the face of radical change have predominantly focused on determinants of successful performance and not on how incumbent and entrant firms influence sociotechnical transitions by their actions. Also, there has been a propensity to explain the outcome, instead of focusing on the process within unfolding transitions. This thesis fills these gaps by focusing on firm agency together with the endogenous processes of a sociotechnical transition, leading to the research question of: '*how do incumbent and entrant firms differ in their contribution to technological and institutional change within the sociotechnical transition towards autonomous vehicles?'*. Four incumbent and four entrant firms are studied over the period 2009-2016, with a focus on the state of California in the USA. This thesis uses three types of qualitative data, i.e. a media analysis, secondary data, and stakeholder interviews, to distill an extensive overview of the shift towards autonomous vehicles. The main finding is that the transition towards autonomous vehicles has undergone an acceleration as a result of differing, but complementary and synergetic contributions of both incumbent and entrant firms to technological and institutional change. Specifically, *incumbent* firms have been paramount in progressing AV *technology* gradually for the past two decades. But by undermining current cultural-cognitive beliefs and norms regarding vehicles and by expressing bold technological expectations, a new powerful, influential *entrant* sparked essential *institutional* change. In turn though, incumbents started adopting these institutional strategies and technological expectations themselves. Moreover, incumbents and entrants started working together in developing AV technology. In conclusion, this thesis shows that incumbents and entrants need each other to instigate technological and institutional change required for a sociotechnical transition.

Content

*"As the joke goes,
if Microsoft made a car,
it would have to pull over regularly
to reboot itself."*

– Financial Post
January 23, 2013

1. Introduction

It is not a matter of *if* but only a question of *when* autonomous vehicles (AVs) will hit the road (Mosquet et al., 2015). Autonomous vehicle technology refers to a control system within a vehicle that takes over executive driving tasks and the monitoring of the driving environment from a human driver in some, and ultimately all, driving situations. Multiple estimates of consultancies and vehicle manufacturers say AVs will hit the road en masse somewhere between 2020 and 2030 (Automotive Technology Research, 2014; Gao, Hensley, & Zielke, 2014; Martin, n.d.; Morgan Stanley, 2015). Protagonists perceive AVs to improve traffic flows, be safer, cleaner (through efficient driving behavior and electric vehicles), and to enhance productivity and social inclusion (The Netherlands EU Presidency, 2016). Conversely, skeptics see a less rosy future: traffic flows could worsen due to cheaper car use and zero-occupancy vehicles, and if neither ride sharing nor electrification takes off this transition might not turn out so positive (Barcham, 2014; Chase, 2016)

The shift towards automation and artificial intelligence is also happening outside of the automobile industry; it is recognized to be part of the *"Fourth Industrial Revolution"* (Kagermann, 2013; Mosquet, 2015; Schwab, 2016). This revolution is characterized by the emergence of cyber-physical systems[1] that include numerous emerging technologies, such as artificial intelligence, robotics, the *"Internet of Things"*, nanotechnology, energy storage, and quantum computing (Schwab, 2016). These emerging technologies bring about two things. First, it opens opportunities for new entrant firms to challenge incumbent firms with these technologies. Second, the way societal functions are currently fulfilled will change drastically as a result of these emerging technologies, in academia referred to as a *"sociotechnical transition"* (Geels, 2002).

However, sociotechnical transitions do not happen easily due to the lock-in of current sociotechnical configurations (Cohen, 2012; Unruh, 2000). Sociotechnical configurations are namely stable – *and inert* – through a dominant technology that is interdependent and co-evolves with coherent institutional elements, e.g. certain user practices, standards, rules, norms, cultural beliefs, expectations (Geels, 2002, 2014; Penna & Geels, 2014; Smith & Raven, 2012). Within this stable configuration there is room for gradual technological and institutional change, but for a transition to occur radical technological and institutional change is required (Geels & Schot, 2007).

Actors, such as incumbent and entrant firms, play a mediating role regarding the co-evolution of technology and institutions and influence the transition process (Fuenfschilling & Truffer, 2016). Incumbent firms are tied to the established technology and embedded within in the dominant institutional environment while entrants are not. Therefore, incumbents and entrants may have different contributions to radical technological and institutional change within a sociotechnical transition. These differing contributions may both play a crucial, complementary, and synergetic role in a sociotechnical transition.

Yet, scholars that have studied incumbents and entrants in the face of radical or disruptive technological change have not researched this. Instead there has been a propensity towards explaining *"who wins"*; being either incumbents or entrants. For example, incumbents are seen as too rigid, reluctant to cannibalize on their profits, tied to their current value and customer network, and turning their core competencies into core rigidities (Christensen, 1997; Henderson & Clark, 1990; Leonard-Barton, 1992; Reinganum, 1983;

[1] *Cyber-physical systems* refers to a new generation of systems with integrated computational and physical capabilities that can interact with humans through many new modalities (Baheti & Gill, 2011).

Tushman & Anderson, 1986). While entrants do not have these constraints and have been portrayed as advantageous challengers (Christensen, 1997; Christensen & Rosenbloom, 1995; Lieberman & Montgomery, 1988). Alternatively, the assumption of the *"incumbent's curse"* or the *"attacker's advantage"* is increasingly found to be incorrect: the tendency that incumbents have great difficulty in the face of radical technological innovation is not universal (Hill & Rothaermel, 2003) and incumbents actually do innovate radically (Chandy & Tellis, 2000). More so, the ability of entrants to disrupt incumbents has been overestimated (Bergek, Berggren, Magnusson, & Hobday, 2013). Still, the propensity of explaining either the incumbents' or entrants' side remains a stronghold in the literature (Ansari, Garud, & Kumaraswamy, 2015; Ansari & Krop, 2012)

There are two problems with *"choosing sides"*. First, scholars have looked for determinants of successful performance and focused less on how incumbents and entrants influence sociotechnical transitions by their actions. Second, in relation to incumbents and entrants it has led to outcome focused research on transitions instead of a focus on the processes of unfolding transitions. This is ironic as transitions take decades and the demise of firms does not happen from one day to the next. So, the role of firm agency together with the endogenous processes of a transition deserve more attention.

Therefore, this thesis focuses on both incumbent and entrant players' actions in relation to technological and institutional change. The aim is to see what their different contribution is in a sociotechnical transition as well as to account for their interplay. Here, technological change and institutional change are viewed as equally important, co-determinant and co-evolving. This leads to the following research question:

How do incumbent and entrant firms differ in their contribution to technological and institutional change within a sociotechnical transition?

Specifically, this research studies the sociotechnical transition towards autonomous vehicles and has an exploratory nature. Four incumbent and four entrant firms are studied over the period 2009-2016. By using different qualitative methods, i.e. a media analysis, secondary data, and stakeholder interviews, an extensive overview of the shift towards autonomous vehicles over the period is given. I will show that AV technology has undergone an acceleration as a result of the contribution of both incumbent and entrant firms and their interplay with technology and institutions.

By looking at firm agency, this thesis steps away from the focus on outcome and performance determinants and opens up a new way to look at the *"incumbents vs. entrants"* debate. Thereby I also contribute to existing literature by providing more insight in the endogenous processes of a sociotechnical transition, specifically by showing that incumbents and entrants need each other in transitions. Moreover, this thesis broadens the view on transitions with regard to the increasing emergence of "*Fourth Industrial Revolution"* technologies by providing handholds on how to incorporate this in future research. Finally, it gives practitioners, policymakers, and academia a first insight in the recent unfolding of the emergence of autonomous vehicles.

This thesis is organized as follows. Section 2 describes the theoretical framework used for this research. Section 3 covers the methodology. The findings are presented in Section 4 discussing incumbents and entrants in relation to technological change, then institutional change, and finally reflecting upon the entire interplay. The paper concludes with Section 5, providing a discussion, theoretical and practical implications, and a final conclusion.

2. Theory

2.1 Sociotechnical transitions: stable regimes through technology & institutions

If technological change radically transforms the way societal functions – *such as transportation* – are fulfilled, this is referred to as a sociotechnical transition (Geels, 2002, p. 1257). Previously studied transportation examples are the shift from sailing ships to steamships between 1780-1900 (see Geels, 2002), or from horse-drawn carriages to automobiles from 1860-1930 (see Geels, 2005). Currently, society is at the brink of the sociotechnical transition from vehicles driven by human beings to fully automated vehicles driven by a control system.

To understand transitions, scholars use a sociotechnical systems perspective as it incorporates a configuration of not only different technological elements, but also institutional elements (Geels, 2004; Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). Specifically, technology and institutions are seen as the two central, co-evolving, interdependent pillars of a sociotechnical system that are at constant interplay with system actors, such as firms or policymakers (Fuenfschilling & Truffer, 2016; Geels, 2004). These actors influence technological and institutional change but are also in turn affected by them (Berger & Luckmann, 1966; Dosi, 1982; Hughes, 1986; Lawrence & Suddaby, 2006).

Central within the sociotechnical systems perspective is the concept of a sociotechnical regime (Dosi, 1982; Geels, 2002; Nelson & Winter, 1982; Rip & Kemp, 1998), defined as *'the complex of scientific knowledge, engineering practices, production process technologies, product characteristics, user practices, skills and procedures, and institutions and infrastructures that make up the totality of a technology'* (Van den Ende & Kemp, 1999, p. 835). Within a sociotechnical regime, there is a dominant, co-aligned technological and institutional logic that results in a coherent, highly interrelated and stable structure (Markard & Truffer, 2008). As a result, sociotechnical regimes are inert and rigid, making a transition to another regime difficult and lengthy.

On the one hand, this stability – *or inertia* – is a product of how technological progress unfolds. Technology is defined as *'a set of pieces of knowledge, both practical and theoretical, know-how, methods, procedures, experience of successes and failures and also, of course, physical devices and equipment'* (Dosi, 1982, pp. 151–152). Technological progress follows a technological trajectory, i.e. stable patterns of technological developments consisting of a cluster of possible technological directions whose outer boundaries are defined by the regime it is in (Dosi, 1982; Geels & Raven, 2006). The concept of trajectories implies that technological innovation activities within the regime proceed gradually along paths influenced by the sociotechnical regime itself.

On the other hand, stability is strengthened even more by the institutional environment of the regime. The concept of institutions comes from *'the idea that there are enduring elements in social life – institutions – that have a profound effect on the thoughts, feelings, and behavior of individual and collective actors'* (Lawrence & Suddaby, 2006, p. 216). Ranging from a continuum of the conscious to the unconscious (Hoffman, 1999), there are regulative, normative, and cultural-cognitive institutions (Scott, 2013). Regulative institutions are *formal* and structure repeated human interaction, while normative and cultural-cognitive institutions are *informal* and constrain behavior through codes of conduct, taboos, or standards of behavior (North, 1990; Wirth, Markard, Truffer, & Rohracher, 2013). Still, institutions are in a constant interrelated dynamic, they gradually change and changes in cognitive institutions will likely affect formal institutional change (Woolthuis, Hooimeijer, Bossink, Mulder, & Brouwer, 2013).

2.2 The role of firm agency in sociotechnical transitions

Firms play a significant and direct role in sociotechnical transitions, as they are the ones that mainly drive technological change and have considerable institutional influence. Specifically, due to vested interests and existing investments, firms are responsible for technological stability and incremental improvements, but they also drive radical technological change (Bergek et al., 2013; Chandy & Tellis, 2000; Christensen, 1997). Likewise, firms have institutional influence by applying institutional strategies (Oliver & Holzinger, 2008; Wesseling, Farla, Sperling, & Hekkert, 2014), either by maintaining established institutions (Baysinger, 1984; Smink, Hekkert, & Negro, 2015), or by undermining them and creating new ones (Battilana et al., 2009). Thus, firms are potential contributors or inhibitors to the radical technological and institutional change necessary for a sociotechnical transition. Still, scholars agree that the role of firms and agency in transition processes has not often been covered extensively nor explicitly in transitions literature (Fuenfschilling & Truffer, 2016; Geels, 2014; Wesseling, 2015).

Broadly, in a sociotechnical transition there are two types of firms: incumbent firms that are embedded within the sociotechnical regime built around an established technology and entrant firms that are not. As a result, it is likely that incumbents and entrants will inherently differ in their objectives and backgrounds and will thus play a different role within a transition by contributing differently to technological and institutional change.

2.2.1 Technological change

Scholars have used numerous categorizations of innovation to highlight the dichotomy between incremental and radical technological progress (Abernathy & Clark, 1985; Utterback & Suarez, 1993). Because on the one hand, technology provides regime stability and usually proceeds along a trajectory, while on the other hand, radical technological change does happen (Breschi, Malerba, & Orsenigo, 2000). Categorizations are e.g. competence-enhancing versus competence-destroying innovations (Tushman & Anderson, 1986), sustaining versus disruptive innovations (Christensen, 1997), and modular versus architectural innovations (Henderson & Clark, 1990). Still, despite the different specific focusses, they all refer to whether technological change is in line with the current sociotechnical regime or not, which will be the distinction used in this thesis.

Following the logic that incumbents are vested inside a sociotechnical regime and entrants outside of it, this dichotomy has implications for firm activity related to technological change. If the innovative activity of firms gradually builds upon the existing technology it fits within sociotechnical regime. However, if the new technology is too radical and thus too disparate from the traditional technology, it does not fit within the sociotechnical regime. Therefore, I propose the following:

Proposition 1: *As a result of being embedded in the established socio-technical regime of vehicle manufacturing, incumbents will have a gradual approach to implementing automated vehicle technology.*

Proposition 2: *As a result of being an outsider to the established socio-technical regime of vehicle manufacturing, entrants will have a radical approach to implementing automated vehicle technology.*

2.2.2 Institutional change

Actors are important influencers of institutional change as institutions are socially constructed (Berger & Luckmann, 1966). That is why institutional theory scholars have started to study the role of agency in institutional change, referred to as *"institutional work"* (Lawrence & Suddaby, 2006). Actors influence institutional change via three different strategies: *maintenance* of the institutional environment, *creation* of new institutions, and the *disruption* of the institutional environment (Lawrence & Suddaby, 2006). Within this broad strategy typology different tactics have been distinguished aimed to change formal and informal institutions (for an overview see Lawrence & Suddaby, 2006).

Regarding formal institutions, firms can *maintain* them by facilitating or supporting the creation of rules or aim to ensure compliance through enforcement or monitoring. Firms that aim to *create* formal institutions are active in lobbying or advocating independently or via lobby groups. Finally, firms can also disconnect certain sanctions or rewards from a set of practices, technology, or rules, thereby *disrupting* current formal institutions.

Regarding informal institutions, *maintaining* tactics can be to deter institutional change by establishing coercive barriers, or firms can provide the public with positive (valorizing) and negative (demonizing) examples that reinforce certain normative or cognitive foundations. Also, firms can maintain norms by embedding and routinizing certain practices into everyday life of society. Firms *create* norms or cultural-cognitive beliefs by defining a new relationship between an actor and the technology and re-making connections between practices and the moral and cultural foundations the practices are set in. Moreover, firms can frame new practices beneficially in order to stimulate or ease adoption and firms can theorize about abstract chains of cause and effect (of the technology for instance). Lastly, firms can *disrupt* established norms and cultural-cognitive beliefs by undermining them or by disassociating the practice or technology from its moral foundation as appropriate within a specific cultural context. This decreases the perceived risk of the innovation.

Additionally, firms can influence institutions by expressing technological expectations. The articulation of expectations contribute to successful furthering of the technology when they are shared by many actors and substantiated by ongoing projects (Schot & Geels, 2008; Smith & Raven, 2012). The interplay of such expressed expectations affects the attention, or hype, surrounding a technology (Van Lente, Spitters, & Peine, 2013). The expression of technological expectations by firms can be seen as a specific part of their institutional strategy.

I posit that these institutional strategies are not mutually exclusive and that it is probable that firms use multiple strategies concurrently. It is expected that incumbent firms must reinforce and sustain the current institutional environment they are embedded in. However, they must also create new institutions to allow for incremental technological innovation (Dosi, Freeman, Nelson, Silverberg, & Soete, 1988). On the other hand, entrant firms not served by the current institutional environment will work to undermine and attack existing institutional regime (Bourdieu, 1993). But entrants will also work to create new institutions for their technological innovations, though most likely focused on a new institutional environment and not the prevailing one. Following this delineation, I propose the following:

Proposition 3: *As result of being embedded in the established sociotechnical regime of vehicle manufacturing, incumbent firms will maintain current institutions and create new institutions to allow for their gradual approach to automated vehicle technology.*

Proposition 4: *As a result of being an outsider to the established sociotechnical regime of vehicle manufacturing, entrant firms will disrupt current institutions and create new institutions to allow for their radical approach to automated vehicle technology.*

3. Methods

3.1 Case study design

This thesis studied the recent dynamics of autonomous vehicle technology within the automobile industry via a longitudinal case study. The focus was on the United States of America; in particular the state of California. The automobile industry has been extensively covered in innovation and transitions literature (e.g. Abernathy & Clark, 1985; Bergek et al., 2013; Cohen, 2012; Penna & Geels, 2014; Wesseling, 2015). It has been characterized with a concentrated and rather stable population of innovators (see Breschi et al., 2000), with Tesla Motors (est. 2003) being the only major new entrant in the past 80 years. A focus on California is chosen as it is one of the largest car markets in the world and it has a history of progressive car policy (Wesseling et al., 2014). Specifically related to AV technology, California was one of the first states to allow autonomous vehicle testing (Kelly, 2012) with testing permits granted to a variation of incumbent automakers and entrant firms (State of California Department of Motor Vehicles, 2016).

Eight firms were studied to gain a full overview of incumbents and entrants aimed at developing and bringing AV technology to market[2]. These firms were a subset of all the firms that have obtained a permit to test automated vehicles from the California Department of Motor Vehicles (State of California Department of Motor Vehicles, 2016). To obtain information rich cases, firms with little overlap in characteristics, e.g. country and market focus, were selected (**Table 1**). The four incumbents were Ford, Mercedes-Benz, Nissan, and Tesla Motors. The four entrants were Google, Drive.ai, Faraday Future, and Zoox. Tesla Motors is categorized as an incumbent as it has sold cars to consumers for the past years. It should be noted that Tesla displays original equipment manufacturer (OEM) as well as software technology company features, and it only sells electrically powered vehicles. Tesla should therefore not be viewed as homogeneous to the other incumbent firms but more as a hybrid incumbent-entrant (Hardman, Shiu, & Steinberger-Wilckens, 2015; Niu, 2016). Google is a multinational technology company and one of the world's largest and highly valued companies, while the other entrants are three newly established startups (Crunchbase, 2016a, 2016b, Factiva, 2016a, 2016b).

***Table 1** Selection of firms aimed at developing and marketing automated vehicle technology (State of California Department of Motor Vehicles, 2016)*

Firm name	Type	Founded (year)	(State), Country
Ford	Incumbent (mass public)	1903	Michigan, US
Mercedes-Benz	Incumbent (luxury segment)	1926	Germany
Nissan	Incumbent (mass public)	1933	Japan
Tesla Motors	Incumbent (luxury EV segment)	2003	California, US
Google	Entrant (major tech company)	1998	California, US
Drive.ai	Entrant (software focus)	2015	California, US
Faraday Future	Entrant (luxury EV segment)	2014	California, US
Zoox	Entrant (*"robo"* taxi focus)	2014	California, US

3.2 Data collection

Three different qualitative data types were used, as the transition to autonomous vehicles takes place in a complex social setting that can better be understood by using qualitative data (Fuenfschilling & Truffer, 2016; Greenwood & Suddaby, 2006). The main data type was media data, complemented by secondary data, as well as semi-structured interviews with US stakeholders. By triangulating these data sources a

[2] It is important to note that this thesis does not include incumbents that do not focus on AV technology.

comprehensive overview on the developments of AV technology over the past years was obtained.

The media data was retrieved from LexisNexis covering all "Major World Publications" with the query *"firm name"* and in the title or lead and the terms *"driverless"* or *"autonomous vehicle"*. To retrieve additional information on the startup firms a query was added with the terms *"firm name"* and *"driverless"* or *"autonomous vehicle"* in the entire article. The time period ranged from January 1, 2009 up to September 30, 2016[3]. Autonomous vehicle technology started receiving increasing attention since the announcement of the Google *"Self-driving Car Project"* in October 2010 (Markoff, 2010). Therefore, the starting date of January 1, 2009 was chosen to account for other activity prior to this announcement. The search yielded a total of 2355 articles that were read and coded using NVivo 11 software.

Coding proceeded via a priori coding as the theoretical framework provided categorical guidelines (Weber, 1990). The coding of the media data served two purposes. First, to understand the important developments and dynamics of autonomous vehicle technology in relation to the firm selection in the past years. Second, to analyze institutional change strategies of firms, operationalized in Section 3.3.

Secondary data sources data consisting of press releases, online documents and company websites were used to complement the LexisNexis. This served the purpose of gaining a better understanding of automated vehicle technology and assessing market launches of technologies by the selected firms. More insight in autonomous vehicle technology was gained by the definitions and descriptions provided by SAE International[4].

Finally, to gain an even deeper understanding of AV technology and the developments of the past years nine semi-structured interviews were conducted. The interviewed stakeholders were (automated) mobility experts, policymakers involved in formulating AV policy, and firm representatives either working on AV technology or in public affairs (**Table 2**). The interviewees were targeted using the network of the Institute for Transportation Studies at the University of California Davis (UCD) and through the *"Coast to Coast E-Mobility"* program affiliated with the Consulate General of the Netherlands in San Francisco. Not all firms from the selection were interviewed. Notably, Tesla and Google had a strict no-interview policy outside of what they publicly communicate. The interviews took 30 to 60 minutes, were recorded when permission was granted, and transcribed. Interviews were either conducted face-to-face or via telephone as certain interviewees were not located near the UCD area. All interviewees were granted anonymity for this study considering the development of an emerging technology is a strategically sensitive topic.

Table 2 *List of interviewees and their role in the auto industry in the USA*

Position	Interviewee
State policy advisor	1
State policy advisor	2
Senior product engineer (incumbent)	3
Global public affairs manager (incumbent)	4
State agency deputy director	5
Government & external affairs director (incumbent)	6
Automated driving director (entrant) & university professor	7
Head automated driving (incumbent)	8
Innovative mobility university professor	9

3.3 Operationalization

Operationalization of technological change

To study how firms contribute to the progress of autonomous vehicle technology a distinction was be made in the degree of automation using the levels of automation defined by SAE International (SAE International, 2014). In total there are six levels ranging from no automation (0) to full automation (5). The levels are distinguished by

[3] This end date was necessarily chosen as a result of the fixed time period set for a the MSc. Innovation Sciences thesis.

[4] *"SAE International"* was initially established as the Society of Automotive Engineers.

whether a human driver or an automated control system executes three criteria: (1) the steering – *lateral control* – and the acceleration/deceleration – *longitudinal control* – of the vehicle, (2) the monitoring of the driving environment, and (3) who is responsible for fallback when the automated system fails. Criteria (1) and (2) are together referred to as the *"dynamic driving task"* Also, a distinction is made for whether the automated driving system focuses on a specific *"driving mode"*, e.g. expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, or all driving modes, i.e. full-time performance. The narrative SAE definitions are presented in **Table 3**. It is important to note that these levels imply no particular order or market introduction and that the criteria indicate a minimum of requirements of system capabilities per level rather than a maximum (SAE International, 2014).

Technological change from level 0 up to level 5 was studied by looking at the market release date of driver assistance systems and automated driving systems by the selected firms. Within in level 1 there are many different types of driver assistance systems for longitudinal control, e.g. adaptive cruise control (ACC), and the lateral control, e.g. blind spot assist, or left turn assist (Automated driving director & university professor, 2016). In level 2 these different systems are combined into one system. Therefore to study technological progress from level 0 to 2 this research focused on ACC development and is not exhaustive on all different (small) driver assistance systems. The development of ACC is a good proxy for level progress as these systems were the first automated control systems to be introduced, they form the basis of an automated control system and their development has followed a gradual path, i.e. from limited speed range, full speed range, up to complete stop-and-go (Automated driving director & university professor, 2016).

***Table 3** Narrative definitions of vehicle automation levels (source: SAE International, 2014)*

Level	Narrative definition
0	The ***full-time performance*** by the **human driver** of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems
1	The ***driving mode-specific*** execution by a **driver assistance system** of either steering or acceleration/deceleration using information about the driving environment and with the *expectation that the **human driver** perform all remaining aspects of the dynamic driving task*
2	The ***driving mode-specific*** execution by one or more **driver assistance systems** of both steering and acceleration/ deceleration using information about the driving environment and with the *expectation that the **human driver** perform all remaining aspects of the dynamic driving task*
3	The **driving mode-specific** performance by an **automated driving system** of all aspects of the dynamic driving task with the expectation that the **human driver** will respond appropriately to a request to intervene
4	The **driving mode-specific** performance by an **automated driving system** of all aspects of the dynamic driving task, even if a **human driver does not respond appropriately** to a request to intervene
5	The **full-time performance** by an **automated driving system** of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver

OPERATIONALIZATION OF INSTITUTIONAL CHANGE

Institutional change strategies were operationalized to assess the *type* of strategy and the *effect* of the strategy (

Table 4). The *type* of strategy firstly corresponds to the three types of institutional change: maintain, create, and disrupt. The institutional actions were firstly plotted over time onto three horizontal axes, each representing a type of institutional change strategy. Secondly, the average of all actions was counted to depict the overall trend in institutional strategies and to see if firms changed in their institutional actions. This resulted in a trend line across the same three horizontal axes over time. Additionally, the technological expectations of firms for when a certain SAE level was expected to be reached were analyzed and plotted over time.

The *effect* of institutional strategies was measured in three ways. First, the number of institutional actions was counted to assess the weight of the strategy. The weighted strategy was combined with the earlier mentioned trend line to be depicted together. Second, to account for the general effect of firms' institutional strategies the absolute and relative amount of media attention per firm was measured throughout the period. Media attention gives an indication of how much attention the firm received, the influence each firm had (through media), and thus who influenced the general (public) opinion most. Third, to assess formal institutional change, the change in US state and federal legislation was assessed. Legislative changes are objective events covered in media and are a decent indicator for how the formal institutional environment changed.

Table 4 *Operationalization of type and effect of firm institutional change strategy*

Concept	Sub concept	Indicator	Data
Type of institutional change strategy	Maintaining actions	Existing regulation, norm, or cultural-cognitive belief concerning human driven personal vehicles that is reinforced, cultivated, or valorized *or* New regulation, norm, or cultural-cognitive belief concerning AV technology that is deterred or demonized	Coded institutional actions in media database
	Creating actions	New regulation, norm, or cultural-cognitive belief concerning AV technology that is constructed, linked to existing practices, framed, or theorized upon	Coded institutional actions in media database
	Disrupting actions	Existing regulation, norm, or cultural-cognitive belief concerning human driven personal vehicles that is disconnected, undermined, or disassociated	Coded institutional actions in media database
	Trend of institutional strategy	Average over time of coded actions per firm categorized as either *maintain*, *create*, or *disrupt*	Coded institutional actions in media database
	Technological expectations	Expressed *year* expected to reach an *SAE level* of automation.	Coded expectations in media database
Effect of institutional change strategy	Weight of institutional strategy	Count of coded institutional actions per firm	Coded institutional actions in media database
	Effect of institutional strategy *(in general)*	Absolute and relative amount of media attention by count (per month) of all media articles including the terms *"driverless"* or *"autonomous vehicle"* and *"<firm name>"*.	All articles in media database
	Effect of institutional strategy *(on formal institutions)*	Changes in U.S. state or federal legislation	Coded legislative changes in media database

4. Findings

Section 4.1 discusses technological change. **Section 4.2** covers institutional change consisting institutional strategies. **Section 4.3** puts in context how effective the institutional strategies were by first looking at the absolute and relative media attention (2009-2016) and secondly by zooming in on what US policy has changed during the same period. Last, **Section 4.4** reflects upon the identified incumbent-entrant interplay and their contribution to the transition of autonomous vehicle technology, pinpointing the most important findings of this thesis. On a side note, the presented quotes are meant to be illustrative and supportive, not exhaustive for the entire studied media database. All findings presented in the following section are based on the media database, secondary online sources, and interviews as discussed in **Section 3**.

4.1 Technological change

Mercedes

Mercedes is and has over the past two decades been a technological leader in AV technology (**Figure 1**). It first introduced partial adaptive cruise control (ACC) – *a level 1 system* – in 1998 and has over time upgraded this longitudinal control system (Larsen & Krueger, 2013). In 2013, Mercedes was the first to combine the longitudinal control system with the lateral control system into a level 2 system (Automated driving director & university professor, 2016). In the beginning of 2017 this level 2 system was upgraded into the most advanced level 2 systems available (Golson, 2017).

Nissan

Like Mercedes, Nissan introduced partial ACC in the late 90s and upgraded its ACC technology over time, but with less advances and smaller steps (Moran, 2007). In 2016 it released a prototype for a level 2 system that hit the market early 2017 (Nissan, 2016, 2016). This is a single-lane system, making it less advanced than Mercedes' systems (**Figure 1**).

Ford

Ford has not been a frontrunner when it comes to developing and selling automated vehicle technology. The firm first introduced partial ACC, in 2006 (Nunez, 2007). This was upgraded to full range ACC in 2012. At time of writing, it did not yet have a level 2 system on the market.

Tesla

Tesla jumped from level 0 directly to an advanced multi-lane level 2 system – *"Autopilot"*– in 2014 (**Figure 1**) (Tesla, 2014). Since then this system has received yearly upgrades for new as well as existing Tesla users through *"over-the-air"* software updates (Harwell, 2015). Via these updates Tesla is unique in treating its consumers as software technology users, but also via Tesla's way of autonomous vehicle technology testing. Namely, Autopilot is in *"public beta-testing"* making the users of Tesla vehicles test drivers of their automation system (Musk, 2016). This allows Tesla to garner vast amounts of data of everyday traffic situations through these users. Contrastingly, incumbents mention that they only introduce technology after severe in-house and private testing (Global public affairs manager, 2016; Government & external affairs director, 2016).

Google

Google's intentions with autonomous vehicle technology became clear after the announcement of their *"Self-Driving Car Project"* in October 2010 (Markoff, 2010). Google has since then not sold any AV technology. However, Google has manufactured a friendly, bubble-shaped prototype (Markoff, 2014), this is elaborated upon later. Still, Google has over time frequently publicly announced how many test miles they have driven: *224,000* in 2010; *770,000* in 2012; *1,200,000* in 2014; *2,250,000* in 2016, creating the idea of technological progress.

Other entrants

Faraday Future released a futuristic prototype at the annual Las Vegas Consumer Electronics Show (CES) 2016 and the firm mentions it wants to be leading in the field of AV technology (Mitchell, 2016). Still, neither Faraday Future, nor Drive.ai, nor Zoox have produced or sold any AV technology since they were founded in respectively 2014, 2016 and 2016.

Overall assessment of technological change

Vehicle automation technology is not new and up to date the technology has not been developed by *"disruptive"* entrants. An overview of the AV technology that has been brought to market over the past two decades is categorized per SAE level and presented in **Figure 1**. Supporting the figure, one interviewee mentions: *'all these things we developed 12, 14, 15, 16 years ago and they hit the market in the last couple of years. This also shows that how long the innovation cycles are typically in the automotive industry'* (Automated driving director & university professor, 2016). It can thus be concluded that incumbent OEMs have played a major role in progressing AV technology gradually for the past two decades or more.

This gradual technological progress affects the institutional environment as well. Level 1 systems were first only available on luxury models but over time these systems have become widely available in economy cars as well. Therefore, incremental AV innovations have become more embedded into everyday life of consumers. However, current level 2 systems are only featured on high-end models. This implies that regarding user norms and routines (i.e. institutions) the leap to even higher levels (3, 4 and 5) of autonomy is still very large for many consumers.

Finally, while incumbents have played a major technological role it is striking to see the what part Google and Tesla Motors have played. First, Google started testing its vehicles at a high level of autonomy (test level 4), without having previously produced any vehicles nor AV technology and at a time when the automobile industry had nog yet even combined the longitudinal and lateral control systems into a level 2 system. Second, while being the youngest car manufacturer around Tesla jumped from no automation straight to an advanced level 2 system in 2014. This shows how both Tesla Motors and Google have taken bold technological actions in relation to the *"traditional"* incumbents (**Figure 1**). Still, the efforts of OEMs, like Mercedes, in the first place can be seen as a stepping stone towards these bold actions

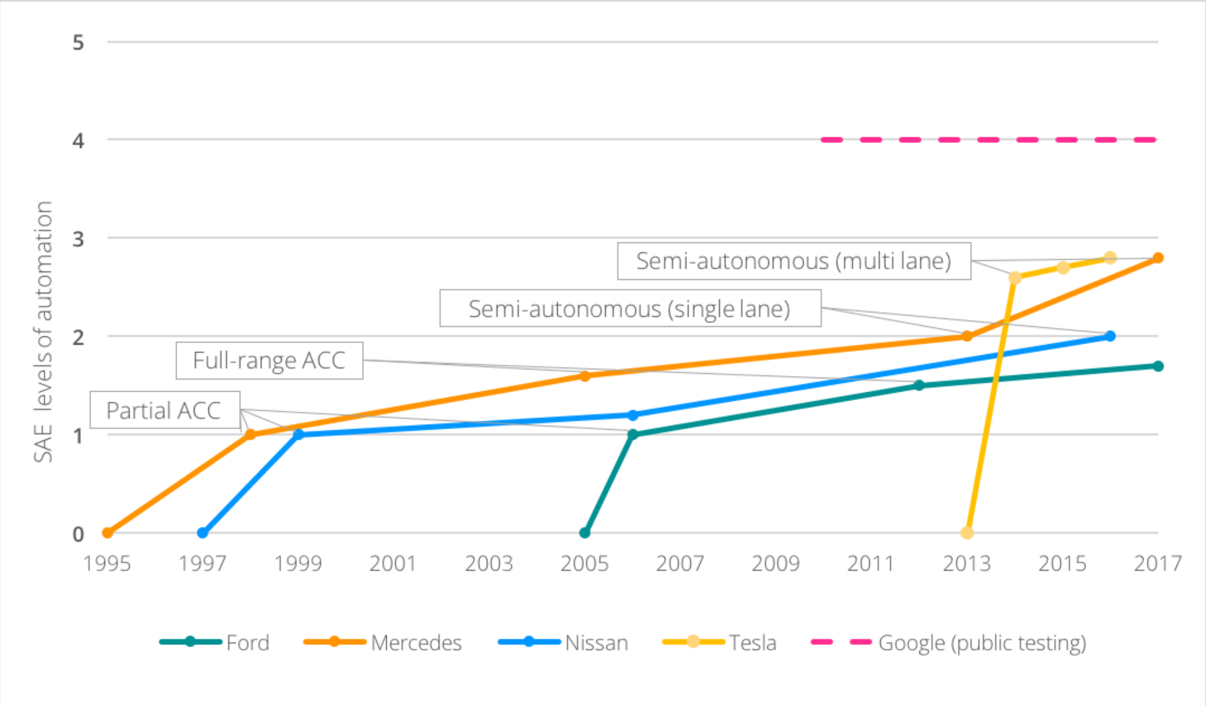

Figure 1 *Development and production of autonomous vehicle technology from 1995-2017 based on SAE levels of automation*

4.2 Institutional change

4.2.1 Institutional change strategies

Mercedes

As a luxury brand Mercedes is set on giving its customer the best experience through innovations, but also through manual driving. This two-folded aim is reflected in Mercedes' institutional strategy where it uses several creating tactics but also maintaining tactics (**Figure 2**). To maintain institutions Mercedes has used deterring and valorizing/demonizing tactics in the media. This is illustrated through the following statements: *'what happens if a child steps out into the street and the radar misses it' 'would our customers be willing to accept such a system?'* (Knapman, 2012). Or *'the car that will take you home after you have had too much to drink is a long way off, but is that what we really want?'* (English, 2014). And *'mostly we don't think people will give up their own cars. Americans like to do everything in their cars'* (Hardy, 2015). Moreover, Mercedes is set to keep a steering wheel in the car: *'we decided that in the future we will go for a steering wheel, because there are situations where I will take over'* (Hall, McCowen, & Ottley, 2015). Ultimately Mercedes aims to *'never automate the cool part of driving'* (Curtis, 2013).

But Mercedes is a leader in technological advances of driving automation; this is also visible in its institutional strategy from early on (**Figure 2**). By theorizing they show that their automation system could *'prevent or lessen the severity of 27 per cent of all accidents at road junctions resulting in personal injury. That equates to some 20,000 accidents a year in Germany alone.'* (Davis, 2013). Also, over the years the innovations first introduced in their high-end models have become standardized throughout the more model lines as well, embedding AV technology into the daily routines of a larger group of consumers. Lastly, by introducing several prototypes at auto shows Mercedes constructs new identities and fantasizes about possible technological futures. Examples of these prototypes are the *F015 "Luxury in Motion"*, and the *"Mercedes Vision Tokyo"*, also a futuristic prototype aimed at the needs of *Generation Z.*[5]

Nissan

Nissan's institutional strategy is similar to that of Mercedes: maintain-create (**Figure 2**). Nissan also aims for AV technology to *assist* the driver, not takeover completely. For example, a Nissan executive mentioned in 2010 right after the entrance of Google that *'removing control completely from the driver is not something the driver wants. If you want complete removal of control then you might as well get a bus or a train'* (Ottley, 2010). On the other hand, Nissan also introduced several prototypes with automation, theorizes over the advantages that automation features in vehicles have. It has also engaged in research partnerships for i.a. publicized pilot projects with universities, such as Oxford, Stanford, MIT, Carnegie Mellon and the University of Tokyo.

Ford

Ford started out with a maintaining and creating institutional strategy, but later also started disrupting certain institutions (**Figure 2**). At first Ford remained cautious and skeptical of AV technology. For example, Ford used maintaining tactics to instill doubt of the feasibility of full autonomy *'as long as [a driver] is fully focused they are probably safer than a system, which, in certain conditions might try to take over driving and make the wrong decision'* (English, 2010). Another example is in 2016, where Ford questioned the capabilities of technology companies*: '[on Apple] it'll have a great interface, but you can't reboot a vehicle as you're going down the highway at 70 miles an hour'* and *'to talk about Google without sounding too offensive, understanding the technical complexity of a car, the number of lines of code is not what is in your smartphone'* (Bowles & Yadron, 2016).

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[5] Generation with birth years that range from the mid-1990s to early 2000s.

But also in 2015 and 2016 via its Smart Mobility program – *aimed at the next levels of connectivity, mobility, autonomous vehicles, customer experience, and big data* – it frames its future strategy and steps away from being perceived as an old industry *"dinosaur"*, creating legitimacy for its future technological innovations. Moreover, Ford has begun to undermine certain traditional institutions. Instead of being a carmaker, the auto company now views itself as a mobility provider (Nimmo, 2016). An illustrative quote from its CEO in September of 2016: *'For years we have very much thought about the "thing" and how much of the "thing" we sold. Now we are thinking more about usage'* (Mortished, 2016). Concluding, on the one hand Ford predicts we will all be paying Spotify-style subscriptions for transportation, while on the other hand remaining *'very bullish about [their] traditional business model'*(Dean, 2016).

Tesla

Unlike the older incumbents, it is found that Tesla does not maintain current institutions but has a create-disrupt strategy, with a focus on create (**Figure 2**). By treating its Autopilot technology like a software product its consumers become software users, creating new norms concerning AV technology. Moreover, its CEO claims bold ideas, asserting in 2016 that Autopilot – *a level 2 system* – was *'probably better than a person right now'* and saying that in a year or two it would be feasible to summon a Tesla from the opposite side of the country (Markoff, 2016). Another example where future ideas and beliefs are created is in Tesla's *"Master Plan, Part Deux"*, a ten year plan released in September 2016: *'in cities where demand exceeds the supply of customer-owned cars, Tesla will operate its own fleet, ensuring you can always hail a ride from us no matter where you are'* and that a future goal is to *'develop a self-driving capability that is 10X safer than manual via massive fleet learning'* (Musk, 2016).

Additionally, Tesla undermines certain held beliefs. For example, its CEO stated that car ownership might have to be outlawed – *'it's too dangerous. You can't have a person driving a two-ton death machine'* (Corcoran, 2016). Another example is the following, *'any cars that are being made that don't have full autonomy will have negative value'* (Thompson, 2015). Also, Tesla does not follow the rules set up by the California DMV completely, *'Tesla is testing autonomous driving technology in a variety of ways (…) [just not] in a way that falls within the specific classifications of the DMV'* (Fung & McFarland, 2016).

Google

Google's institutional strategy is the boldest and most clearly visible from the data, namely disrupt-create (**Figure 2**). Continuously, Google has undermined beliefs and disassociated norms related to cars and car use. The CEO stated in 2010 *'Your car should drive itself. It just makes sense. It's a bug that cars were invented before computers'* (Siegler, 2010). By releasing a bubble-like prototype (without a steering wheel, pedals, and 'friendly'-looking) vehicle in 2014 Google showed the world an alternative view of an autonomous vehicle and proved that a technology company was capable of developing a prototype car.

Repeatedly Google has propagated that AV technology '*improves people's lives by making driving safer, more enjoyable, and more efficient'* (Cain Miller & Wald, 2013) and that it will make mobility inclusive for all, i.e. people currently too old, disabled, too young. Moreover, Google is a strong protagonist for full autonomy (level 4-5) and denounces semi-autonomy (level 2-3). Illustrative media quotes here are:*'[a partially automated car] doesn't help a blind man get lunch or help an ageing widow get to here social events'* (White & Winkler, 2014) and *'the assumption that humans can be a reliable backup for the system [i.e. level 2-3] was a total fallacy'* (Dougherty & Kessler, 2015). Specifically regarding formal institutions, Google has often been mentioned by media as having been a central force in lobbying for state legislation in Nevada and California to permit the testing of autonomous vehicles (Cain Miller, 2012; Markoff, 2011).

OTHER ENTRANTS

Just as Google and Tesla, the entrant firms Faraday Future, Drive.ai, and Zoox do not maintain current institutions. Their focus on either disrupting current or creating new institutions. Nevertheless, and in line with the little media attention they receive (discussed in **Section 4.3.1**), their institutional strategies are by far less visible and weaker than of the other firms in the selection.

OVERALL ASSESSMENT OF INSTITUTIONAL CHANGE STRATEGIES

The institutional strategies of the firms are presented in **Figure 2**, where all institutional actions are categorized into either maintain, create, or disrupt, per month (multiple actions per month are indicated as one data point). In **Figure 3** these actions are averaged into one weighted line showing the overall strategic trend of the firm and the relative *"strength"* of the strategy.

As expected, incumbents do apply a maintain-create strategy. Mercedes, Nissan, and Ford all reinforce current institutions. However, throughout the period these incumbents have also been influential in creating new institutions within the current regime that allow for an increasing role of AV technology. Tesla differs from the older incumbents as it does not maintain institutions, but only focuses on creating new ones and undermining certain current ones. This underpins that Tesla acts more like a hybrid incumbent-entrant.

All entrants focus on creating and disrupting institutions. Striking is how early on Google has been undermining current institutions as well as creating new institutions through lobbying state regulatory departments. Moreover, as **Figure 3** shows, Google's trend line is far *"heavier"* than Ford, Mercedes, and especially Nissan. Only Tesla has in the shorter period of time also received a relatively high amount of attention compared to the other incumbents. **Figure 2** and **Figure 3** show how significant Google's influence has been in breaking down current institutions, creating new ones, and thereby redefining the boundaries of the institutional regime essential for an AV transition.

Apart from the influence of Google and Tesla it is most interesting to see how Ford adopts their strategy (in part) by starting to undermine certain institutions itself. This is exemplary for the interplay between influential entrants and industry incumbents. Ford adopts a hybrid strategy in that it still aims to sell cars under the current circumstances while also have one foot in the door of the future. Another example for the interplay between incumbents and entrants on an institutional level is the lobbying coalition called the *"Self-Driving Coalition for Safer Streets"* that was established in April 2016 between incumbents Ford and Volvo, ride-hailing startup companies Uber and Lyft, and Google (Hawkins, 2016).

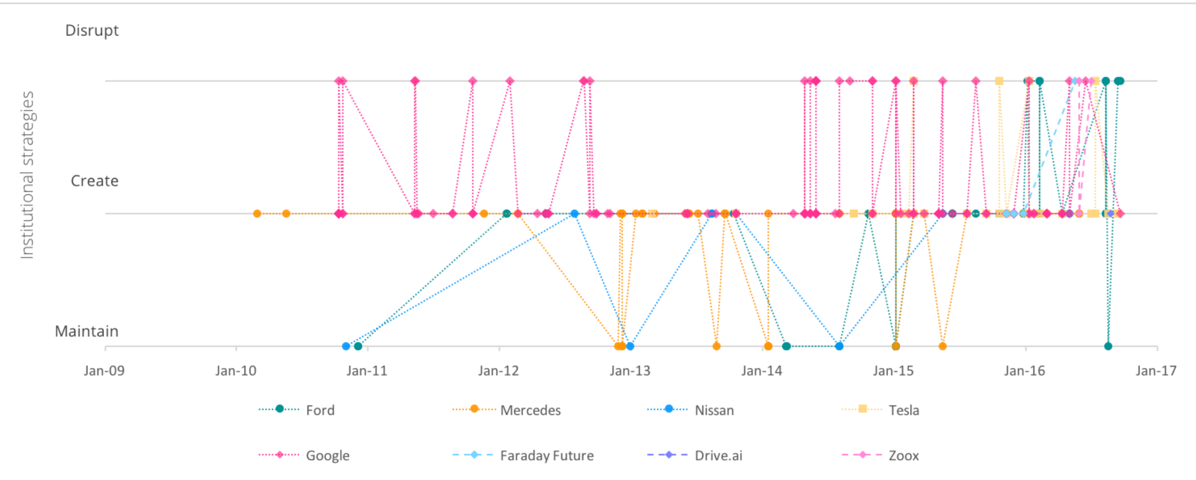

Figure 2 Institutional strategy presented per maintain/create/disrupt "action" in the LexisNexis database per year from January 2009 to September 2016 (per firm, a dotted line connects each events)

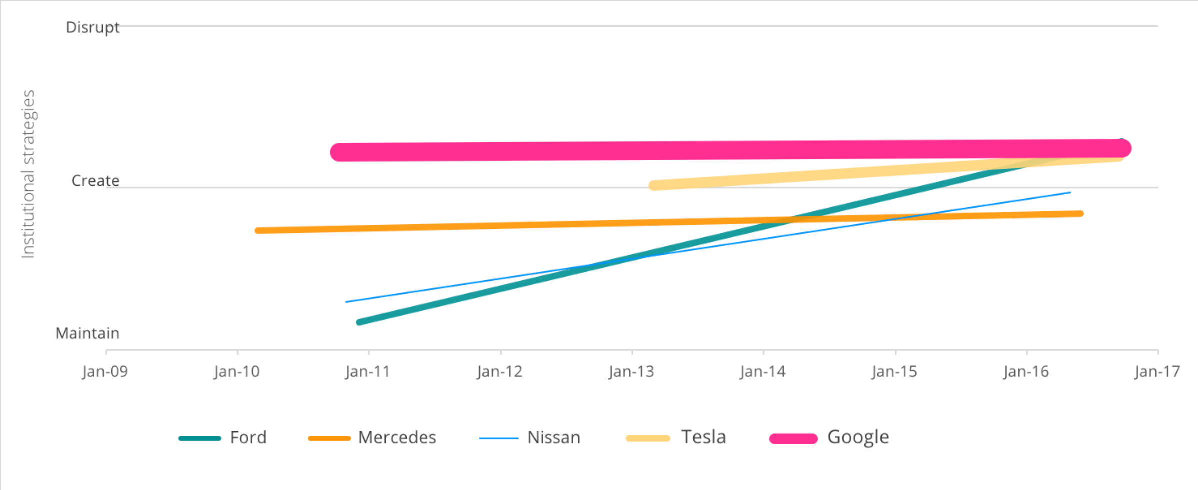

Figure 3 *Institutional strategies in weighted trend lines, based on the average of events from* ***Figure 2***

4.2.2 Expectations for technological progress

Mercedes

Mercedes has not publicly expressed its expectations for automated vehicle technology progress as much as other companies have. In 2013 it announced to have *"self-piloting"* (level 3) models by 2020, with the aim to keep *assisting* the driver (*The Irish Times*, 2013). Announcements of when to expect higher levels of autonomy were not found in the data.

Nissan

Nissan's expectations are also similar to Mercedes, though they are expressed more often and with a more precise road map. Nissan mentioned in 2013 and 2015 it aims to have a level 3 system available by 2020 (White, 2013). In 2016 Nissan released a roadmap for advanced level 2 system in 2018, and up to level 3 in 2020 (Nissan, 2016). Again, these technologies aim to *assist* drivers not replace them (BMI Research, 2016).

Ford

In the beginning, Ford was by far the least ambitious concerning its technological expectations for AVs (**Figure 4**). In 2012, Ford expected semi-autonomous vehicle technology (level 2) to hit the market in 2025. On level 5 they said in 2014, *'I doubt we will ever get there'* (The Sunday Times, 2014). However, Ford adjusted its expectations in 2015 and 2016 aiming to *"skip"* level 3 and instead introduce level 4 robo-taxis in 2021 and for 2025 a consumer-oriented level 4 vehicle suitable for several driving modes, though (probably) not full level 5 in 2025. Reasons for these expectations are that Ford says it does not aim to be the first company to sell autonomous vehicles but that they want to offer it at prices even economy-car buyers can afford (Naughton, 2015). Ford has thus pivoted in its expectations and ambitions, but still does not aim to be the first mover.

Tesla

Tesla's predictions have always been made for the near future and seem to clearly follow a logical roadmap of an increase in autonomy level gradually over time. Tesla has predicted high level 2 for 2016 (2013), level 3 for 2017 (2014), and level 4 for 2018 (2015) (Johnson, 2013; Rodionova, 2015; Sparkes, 2014). Moreover, Tesla announced in 2016 that all new Tesla models will have (advanced) level 4 hardware capabilities (Tesla, 2016). This enables buyers of new Tesla vehicles to obtain software updates up to (advanced) level 4 over time.

Google

Google has been pivotal in expressing its expectations concerning when their automated vehicle technology will hit the road. Its expectations have always been focused on high autonomy, i.e. level 4. Moreover, Google has always expected these levels to be reached sooner than what other carmakers, Tesla excepted, predicted at the time. Google has mentioned AV technology to reach level 4 in 2018 (2010), 2017 (2013), and in 2019 (2014, 2016) (Harris, 2010; Kandell, 2016; The Dominion Post, 2013; The New Zealand Herald, 2014).

Other entrants

The technological expectations of the other entrant firms were not found in the data.

Overall view of technological expectations

Figure 4 shows all expectations expressed by firms in the media data from 2009-2016. Mercedes and Nissan do express expectations for autonomy, still they remain focused on level 3. Both Google and Tesla have over the years expected to reach level 4 sooner, where Tesla has the clearest gradual roadmap. Ford's shift from level 2 in 2025 to level 4 in 2021 again shows how the firm has altered its strategy. These expectations are in line with the broader institutional strategies shown in **Figure 2** and **Figure 3**. Showing that, besides specifically pronouncing a certain technological expectation, firms are also busy changing (maintaining, creating, or disrupting) the broader institutional context correspondingly to those expressed expectations.

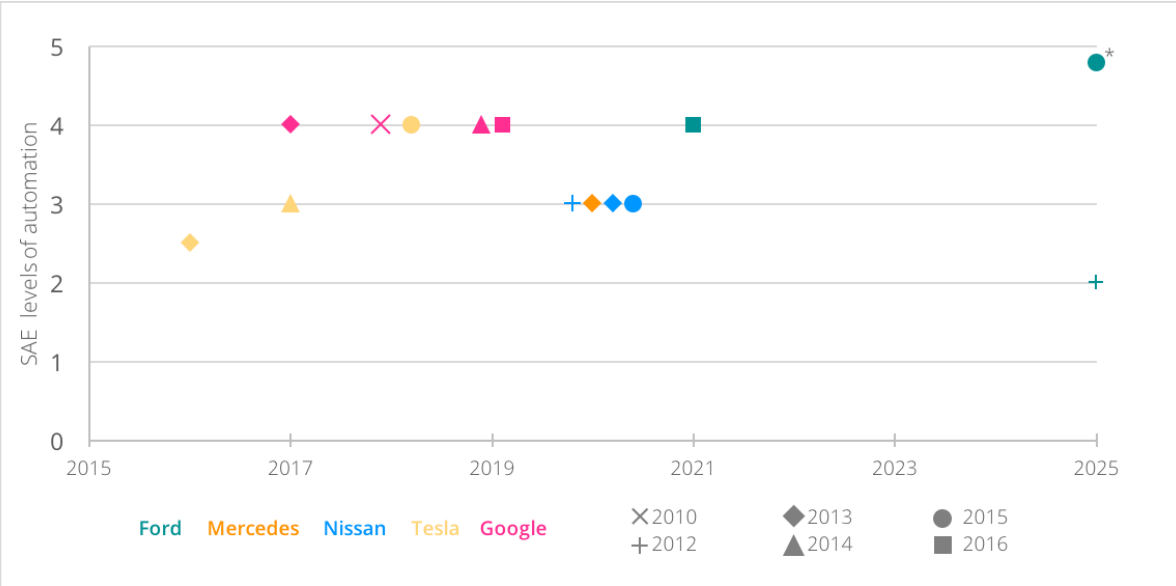

***Figure 4** Changing firm expectations for reaching SAE levels from 2009-2016, forecasts are for 2016-2025*
* "Consumer-oriented" vehicle – indicates upper level 4, but not full level 5.

4.3 Effect of institutional strategies

4.3.1 Absolute and relative media attention from 2009-2016

Mercedes

Mercedes was the first to be mentioned in the media in relation to AV technology (**Figure 5**). Throughout the entire period Mercedes received media attention due to new prototypes or the introduction of new technology in their high-end models. Media attention was the highest during CES 2015 because of the revelation of its futuristic concept car *F015 "Luxury in Motion"*, with autonomous features, though unspecified which ones precisely (Danielson, 2015).

Nissan

Nissan peaks in relative media attention in 2013 when the company announced its plans for autonomous vehicles in 2020 (**Figure 6**). Nissan's media attention does not increase in absolute terms throughout 2015 and 2016 (**Figure 5**). Its relative share of media attention decreases notably during this period, indicating that other firms claim the headlines more.

Ford

From 2009-2014 Ford received very little media attention concerning autonomous vehicles (**Figure 5**). This changed during the Consumer Electronics Show (CES) 2015, when Ford announced its *"Smart Mobility Plan"*. More attention also came during CES 2016 when its CEO provocatively mentioned that in the future *'driving with a steering is as antiquated as wanting to ride a horse'* (Bowles & Yadron, 2016). The highest media attention for Ford was in September 2016, when it announced its intensions to skip level 3 and aim for level 4 and beyond. Concluding, in the period 2015-2016 Ford distinctively received more AV media attention than before.

Tesla

Tesla's first AV related media attention begun halfway through 2013, i.e. later than the other firms, when its CEO started speculating about the Autopilot system (**Figure 5**). Since then both Tesla as a firm, with the reputation of an innovative young carmaker, and the Autopilot system, being perceived as technologically leading, have received increasing amounts of media. In the summer 2016 Tesla received the most attention of all firms. First, due to a fatal crash of a driver using Autopilot (Yadron, 2016). But second, due to the brief ten year plan *"Masterplan Part Deux"* that includes autonomy as a central theme, (boldly) published shortly after the crash (Musk, 2016).

Google

Google and its *"Self-Driving Car Project"* have over the years received an abundance of media attention. This is in absolute terms (**Figure 5**), every major announcement by Google regarding AV technology has been widely covered by media. For example, Google's lobbying activities related to state legislation in Nevada and California in 2012 and its bubble-like prototype release in 2014. As well as relatively (**Figure 6**), during the entire time period the specific media attention for Google and autonomous vehicle technology largely coincides with the media attention the technology in general. Only in the second half of 2016 did other companies come close Google's share of media attention.

Other entrants

Lastly, startup entrants Zoox and Drive.ai both received media attention during their launches and after successful funding rounds. Still, both companies are very secretive regarding their other operations. Faraday Future stepped into the spotlight with its futuristic prototype at CES 2016. But besides this, Faraday Future also remains an under the radar company.

Overall assessment of media attention

So, while Mercedes and Nissan have been technological leaders in the 90s and 00s regarding AV technology (**Figure 1**), it is mostly Google, and more recently additionally Tesla and Ford, that have received the largest share of media attention from 2009-2016 (**Figure 5** and **Figure 6**). Up to 2016 Google accounted for roughly 50% of the media coverage where after it became slightly more disperse due to a greater role of Tesla and Ford. Media attention cultivates society's perception of a technology. In this case it shows that without bringing technological progress to market Google has garnered a great hype around this technology. This indicates that Google's institutional strategy has been of major influence.

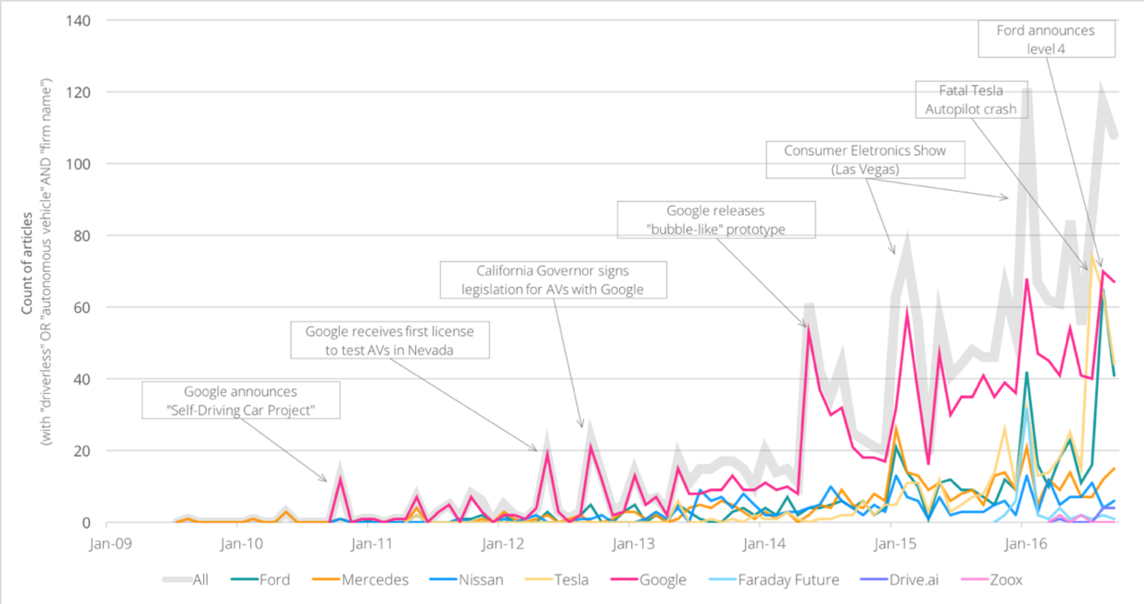

Figure 5 Count (per month) of all media articles including the terms 'driverless' or 'autonomous vehicle' and 'firm' from January 2009 to September 2016.

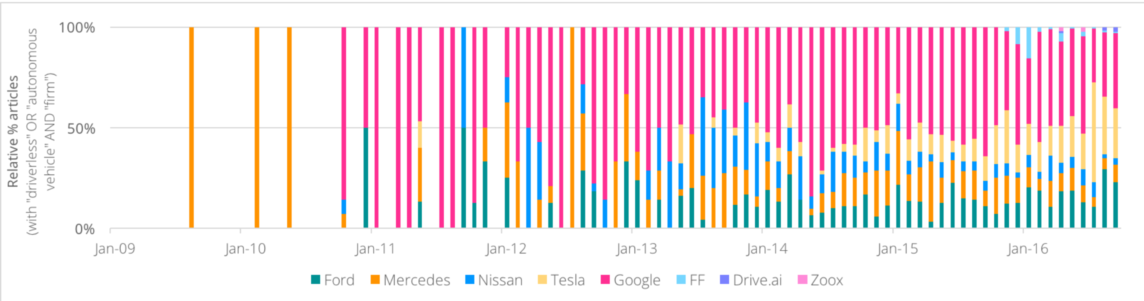

Figure 6 Relative percentage of count (per month) of all media articles including the terms 'driverless' or 'autonomous vehicle' and 'firm' from January 2009 to September 2016.4.3.2 US state and federal policy change (2009-2016)

4.3.2 US state and policy change (2009-2016)

First, regulation lagged AV technological advancement. For example, in November 2012 the National Transportation Safety board recommended that new cars be equipped with level 1 technologies, such as adaptive cruise control and automatic braking. In January 2013, the federal government made its first formal policy statement on autonomous vehicles, with a nonbinding recommendation that driverless cars should not be allowed, except for testing, but that semi-autonomous level 1 features could save lives (Cain Miller & Wald, 2013). To put this into perspective, Mercedes and Nissan had been marketing these technology since the late 90s.

On a state level more ambitious AV legislation had already been proposed in Nevada in May 2011, with the influence of Google (Markoff, 2011), and passed in March 2012 (Marks, 2012). Also Florida in May 2012 (Valdes, 2012) and California in September 2012, again due to the influence of Google (Reuters, 2012), passed legislation concerning the testing of autonomous vehicles. All these activities occurred before the federal government recommended level 1 features of new cars. It is illustrative that Google announced its public testing of AV technology in October 2010 with neither federal approval, nor testing permits from the state Department of Motor Vehicles.

However, later on, firms started advocating for more robust federal legislation to avoid a *"patchwork"* of (conflicting) state legislation (Lewontin, 2016; Peltz, 2016). Moreover, state legislators started working together more with the federal government (Policy advisor 2, 2016;

State agency deputy director, 2016). This finally resulted in that the National Highway and Safety Administration (NHTSA), a federal body, revealed its "*Federal Automated Vehicle Policy*", aimed at level 3, 4, and 5, with the aim to indicate the most pressing issues, whilst remaining open and flexible (U.S. Department of Transportation, 2016). So, within four years the federal government went from lagging behind 1-2 decades in policy for level 1 technologies to formulating policy for future level 3, 4, and 5 technologies.

4.4 Reflection: An interplay between incumbents, entrants, technology & institutions

The section above illustrates the different contributions of incumbent and entrant firms in relation to technological and institutional change. It shows that technology and institutions co-evolve and are interdependent of one another in a sociotechnical transition. Specifically, an interplay between incumbent firms and entrant firms is found in their differing contributions to technological and institutional change in the transition to autonomous vehicles.

Incumbents have played an important technological role. Traditional OEMs have been crucial in the development of AV technology. Over the past 20 years firms as Mercedes and Nissan have invested R&D efforts into spurring this technology by introducing and gradually improving of vehicle automation technologies such as adaptive cruise control, starting at SAE level 1 up to level 2. Together with this technological influence came gradual institutional change: incumbents have gradually influenced customers as well as policymakers to adapt to increasingly more AV technology.

However, it was a new entrant that sparked the massive increase of media attention for and the rapid development of policy catered to AV technology, namely Google. Since its announcement in October 2010 Google has persistently undermined associated beliefs and norms society held concerning personal automobiles. Google has continuously focused on convincing people that autonomous vehicle technology would be safer, more enjoyable, more efficient, and would make mobility inclusive for all societal groups. By focusing on the wide personal and societal benefits the technology would bring, by expressing expectations for reaching level 4, by developing a *"cute"* prototype, and by continuously denouncing SAE level 2 and 3 as a safe and logical option, Google has broken down cultural-cognitive beliefs held concerning vehicles and extended the frontiers of what was thought technologically perceivable and achievable, primarily through institutional influence. Finally, Google has been a determining force in shaping legislation for AV technology, which in turn stimulated the formulation of progressive federal policy.

The role of Tesla, as a hybrid entrant-incumbent has also been of value in the unfolding of this transition. On a technological level Tesla has pushed incumbents' boundaries by showing a faster and more radical approach to car manufacturing and AV technology, through a combination of a manufacturing and software technology mindset. For example, Tesla has taken a risk by putting its level 2 system Autopilot on the road in "public beta-testing". Other OEMs would not dare to take such a risk because of the potential negative consequences, such as bad publicity and liability issues (Global public affairs manager, 2016; Government & external affairs director, 2016). On an institutional level Tesla has been less extreme in its disrupting strategy than Google, though still influential in creating new norms of how to approach car use and beliefs of what is (technologically) feasible in the future.

Though more interesting is how incumbents, such as Ford, have pivoted to catch up with these *"disruptive"* entrants, as if they have learned from past cases (e.g. Christensen, 1997). For example, Ford started to publicly rethink and reshape its approach to vehicles and mobility, and it entered a lobbying alliance with an incumbent, entrant, and ride-hailing startups. Another example is that of General Motors (GM), though excluded from the firm selection in this thesis, through the media analysis it was still found that GM invested $500 million in ride-hailing startup *Lyft* and acquired a Silicon Valley AV startup called *Cruise Automation* for more than $1 billion (Heller, 2016). Another example of this is the alliance Google formed with Fiat-Chrysler Automobiles in 2016 (Woolf, 2016). Or that Ford and Nissan amongst other OEMs have opened R&D facilities in Silicon Valley in the past years. So, incumbents and entrants not only have different contributions to technological and institutional change, but have also started working together to complement one another.

So it seems that at first incumbents were rather coy in terms of radical technological development and disrupting institutional change. Specifically, at first Mercedes, Nissan, and Ford all progressed AV technology gradually and did not disrupt institutions. However, after an entrants push of institutional change (i.e. Google's influence) and to a lesser extent technological change (i.e. Tesla's influence) incumbents started taking over these technological expectations and institutional tactics (Ford) while others hold on to their existing technological and institutional paths (Mercedes and Nissan).

5. Discussion

This research has focused on the single case of autonomous vehicles with a focus on the US and the state of California, hence some caution should be taken when generalizing the findings. Furthermore, this study was limited to only eight firms while the development of autonomous vehicle technology also happens outside the scope of this research. Also, it would be interesting to study to see whether firms that were not focused on the development of AV technology retarded or opposed certain technological or institutional progress (similar to Wesseling, Farla, & Hekkert, 2015). Still, a good overview was obtained with the current selection, through using worldwide media sources and by focusing on internationally operating firms with differing characteristics beneficiary for the exploratory nature of this research.

Reflecting on the data sources it would be fruitful if future research focuses on conducting interviews that complement the media data more comprehensively by holding interviews with all involved stakeholders. This also opens up the possibility for diving deeper into the different institutional tactics firms used. Additionally, I suspect that especially Nissan was underrepresented in the data as they are homebased in Japan causing them to focus more on Japanese regulations, society, and media. A more central role of interviews would also circumvent that possible underrepresentation.

Finally, the subject of autonomous vehicle technology, and broader of Industry 4.0, lacks the blessing of hindsight. However, the current data and timeframe did provide the opportunity to gain insight in the unfolding processes within a transition, which was a central aim in this thesis. Furthermore, these technologies are developing at an increasing pace and it is crucial for academia, practitioners, and policymakers to gain a more comprehensive understanding as soon as possible.

Theoretical implications

This research has looked into the endogenous processes of a transition by looking at what different contributions incumbents and entrants have, and how they need each other. In order to build upon this, future research may look into this interplay of incumbent and entrant firms in other currently unfolding or past transitions. This would help determine whether this is an understudied or new phenomenon due to different technological, contextual, or firm characteristics.

This case study was set in the light of the Fourth Industrial Revolution. It is fruitful to look more specifically at the current transitions literature to see whether this new stream of technologies will influence transition processes differently than before. Building on this, transitions have often been conceptualized as being triggered extreme landscape pressures or events that lead to a fundamental destabilization (Geels & Schot, 2007). But in this case, there is an extreme technological opportunity and push. Moreover, many case examples of the transitions literature are based on historical examples around technologies invented before the rise of information technologies, artificial intelligence, and Big Data. It is imperative for academia to get a grasp on how these new technologies will increasingly change and shape society.

A final recommendation for future research is to look specifically into the *role of entrants* within transitions, possibly in relation to the strategic niche management literature (Schot & Geels, 2008; Smith & Raven, 2012). This thesis has shown that entrants can have powerful (institutional) influence. Examples in other industries of powerful startup entrants are Airbnb (hotel industry), or Uber (taxi industry). But like Google in this thesis, other major global technology companies like Facebook, Amazon, and Apple, seem to be diversifying into different industries such as drone delivery, cars, virtual reality, and smart home devices (Leswing, 2016; Perez, 2016; Popper, 2016; Zuckerberg, 2014). How influential are these entrants, does the current transitions literature still hold regarding their role, and what does this imply for governing future transitions, are all questions worthwhile of future investigation..

Practical implications

This results of this thesis have the following implications for industry practitioners, government, and society. First, practitioners may gain insights in competitive responses of players within the vehicle manufacturing industry heading towards autonomous vehicles, as well as insight in synergetic incumbent and entrant interaction. Second, unravelling the interplay between incumbents and entrants in relation to technology and institutions makes it easier to draft policy that stimulate sociotechnical transitions. Finally, it is important for society to be prepared for transitions with possible major consequences. Insights from this exploratory thesis may help identify and anticipate the transition to autonomous vehicles.

6. Conclusion

In this thesis, I have studied the different contributions of incumbent and entrant firms regarding technological and institutional change within the sociotechnical transition of autonomous vehicles. Here a control system within a vehicle takes over executive driving tasks and the monitoring of the driving environment from a human driver in some, and ultimately all, driving situations. The main finding is that this transition has undergone an acceleration as a result of differing, but complementary and synergetic contributions of both incumbents and entrants to technological and institutional change.

Incumbents were responsible for gradual technological progression, this role should not be underestimated as these incumbents are a source of considerable technological knowledge. Thereby, incumbents also influences the routines of consumers making the society become more accustomed to AV technology. Google, as an entrant, was important for sparking institutional change. Google did this by undermining the notion that cars need to be driven by humans, and framing autonomous vehicles as far safer and more convenient than current vehicles. Tesla, as a hybrid incumbent-entrant complemented this by showing incumbents that technological progress was possible far faster than had been the case, whilst additionally building the institutional case for autonomous vehicles to be better, safer, and more convenient. In turn, incumbents adopted certain technological expectations and institutional tactics from entrants. Moreover, both firm types started working together.

To conclude, this study has stepped away from an outcome oriented view of incumbents and entrants in the face of radical technological change and focused on agency and the processes within an unfolding sociotechnical transition. Specifically finding that informal institutional change early on works as a catalyst to trigger the acceleration of further technological and institutional change. Ultimately showing that incumbents and entrants needed each other to instigate technological and institutional change required for a sociotechnical transition.

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Why incumbents and entrants needs each other:
The road to autonomous vehicles

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MSc. Thesis Innovation Sciences