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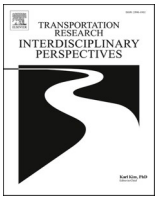

Too much pressure? Driving and restraining forces and pressures relating to the state of connected and autonomous vehicles in cities

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ABSTRACT

Connected and Autonomous Vehicles (CAVs) are predicted by many analysts to transform the transport system over the coming decades. Which direction and path this transformation will take remains highly uncertain, as do the related environmental effects. In the present study we examine the introduction of CAVs in cities in terms of the indirect or underlying processes (drivers) and the direct expressions of interest that are related to specific actions, events or processes (pressures). The drivers and pressures are identified in interviews with stakeholders from across the quadruple helix (academia, industry, government and civil society). We then use an analytical framework that combines the drivers and pressures of the DPSIR (Driving forces, Pressures, States, Impacts, Responses) model and force field analysis. This framework is used to map survey data on the strength of the driving and restraining forces and pressures behind the introduction of CAVs in cities, and to identify which stakeholders are involved in this socio-technical transition. Results showed that there was a strong belief across stakeholder groups that CAVs should be connected with mobility planning strategies. This need for planning has been discussed at length in other contexts, and now our results show that respondents find this need is also present in the Swedish context. An unexpected finding was that those who are sceptical to CAVs may form unique groups with a broad range of stakeholder types, for example elderly people, cyclists, people who are concerned because of conspiracies related to new technology, and those who are concerned about environmental effects.

Introduction

Connected and Autonomous Vehicles (CAVs)[1] are predicted by many analysts to transform the transport system over the coming decades. Which path this transformation will take is today highly uncertain and the plausible, yet divergent, directions that this development may take are plentiful (Papa & Ferreira, 2018). Following Loorbach (2010) it will imply transitions that intervene at different levels - e.g. cultural, structural and practical levels - that have different time frames and scales.

There is a great deal of research into the potential use of CAVs and resulting effects on - e.g. policy, urban planning, public health, safety, energy and environmental concerns (Milakis et al., 2020). However less research exists on the actual processes, occurring before CAVs are in place, that contribute or hinder the introduction of CAVs in the transport system, including the stakeholders involved in such processes. More specifically, there are two clear knowledge gaps that emerge when we examine how these processes of a transition towards CAV introduction can be facilitated or hindered. The first knowledge gap concerns which driving forces (Adelfio et al., 2018) can positively or negatively influence the introduction of CAVs in cities. The second refers to the local stakeholders' interests and considerations (hereby defined as pressures) (Adelfio et al., 2018) that could impinge on the introduction of CAVs in cities.

In addressing these knowledge gaps we aim to make an empirical contribution to the existing body of CAV research, in terms of identifying driving forces, pressures and stakeholders that can facilitate or hinder the introduction of CAVs in cities. In addition, we aim to make a methodological contribution by using the Driving forces – Pressures – States – Impacts – Responses DPSIR framework as a guide for interview content analysis, combined with force field theory (Burnes & Cooke, 2012; Lewin & Korsch, 1939) to further analyse interview data through a survey.

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[1] We use the term CAV – Connected and Autonomous Vehicle, because it has been established that the ability to communicate between vehicles, infrastructure and other parts of the transportation system (the "Connected" component) is just as important to a self-driving system as the sensors in an individual vehicle (the "Automated" component) (Botello et al., 2019).

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This study focusses on the city of Gothenburg, Sweden, because the city has a strong automobile industry which has helped to make it a hub for CAV research. Certain results could be biased by the car-oriented tradition of Gothenburg, but these results could then perhaps be relevant in another car-oriented city, such as Stuttgart or Ghent (another city dominated by Volvo production). Furthermore, part of the reason for explaining Gothenburg's car-oriented history is to underscore how much more knowledgeable interviewees from Gothenburg might be, since it is difficult to be involved in any civil, industrial, academic or government activity (e.g. the four quadruple helix categories) without also having a working knowledge of the automobile industry.

Based on the identified research gaps the following research questions (RQ 1 and RQ 2) have been formulated:

RQ1: What are the driving and restraining forces and pressures, that facilitate or hinder the socio-technical transition towards the introduction of CAVs at the city level?

RQ2: What stakeholders, representative of the driving/restraining forces and pressures, are involved in such a socio-technical transition?

The paper is structured in the following way: Section 2, provides some background information on CAVs and cities, stakeholders, socio-technical transitions, and the context in Gothenburg. Section 3 explains the theoretical and analytical frameworks behind the methodology, and the methods used in this study. Section 4 presents the empirical interview and survey data, and Section 5 finishes with a discussion and conclusion.

Background on CAVs in cities, and car-oriented tradition in Gothenburg

This section is comprised of a State of the Art that considers relevant literature, and a Background Information section that gives some context for the study.

State of the Art

This section presents some of the most relevant CAV research in the context of this study, focussing on research that examines the introduction of CAVs in cities, different stakeholders who have an influence or who are influenced during this introduction, and the role of CAVs in socio-technical transitions.

CAVs and cities

The extent to which, and the reasons why, cities are considering facilitating the introduction of CAVs differ greatly depending on their size, financial resources, and political leaning (Freemark et al, 2019). Some of the policy-related aspects of CAVs are affected by national governmental institutions working together with regional governments to create new transportation policies (Freemark et al, 2019; Gavanas, 2019). On a more local level, the lack of municipal government preparedness for CAVs is an issue that has arisen in the literature, but the lack of preparedness seems to stem from different perspectives and causes. In some cases, municipal officials have stated that they do not think their city is prepared for CAVs in terms of policy (Freemark et al, 2019), while in other cases this dearth is expressed as a need for more data to inform policy planning (Gavanas, 2019), or a lack of investment in and understanding of the necessary infrastructure for CAVs (Duarte & Ratti, 2018).

CAVs and stakeholders

When considering the introduction of CAVs to be a socio-technical transition, there arises an implicit need to engage with a multiplicity of stakeholders. However, the specific roles of different stakeholders in the transition are still underexplored, leaving a research gap regarding the role of stakeholders in the socio-technical transition towards CAVs being introduced in cities. Among the few studies relating CAVs to stakeholders, (Hess, 2020) discusses the different strategies that are used by civil society organisations in the USA in relation to a CAV transition. Hess starts from the outlook that the transition to CAVs is currently being led by incumbents, meaning large industrial automobile corporations. He suggests that many of the civil society groups involved who want to be involved in the transition support a "modest" change in the status quo of industry-led transitions, that would focus on safety rules and driver-assisted technologies. But since CAVs could "…be profoundly disruptive for almost every stakeholder in the automotive ecosystem" (KPMG, 2012, p. 3), modest or incremental policies may not be the most appropriate way to regulate this new technology.

In terms of stakeholders who are commonly associated with CAVs, people with impaired mobility are often mentioned as being interested in the technology (Templeton, 2020). However, Fraedrichs et al. (2016) found that this group could be even less interested in CAVs as compared to those with full mobility. Nielsen and Haustein (Nielsen & Haustein, 2018) discuss the expectations of CAVs in regard to stakeholders in Denmark who are categorized as enthusiasts, indifferent stressed vehicle drivers, and sceptics. The enthusiasts were "typically male, young, highly educated, and live in large urban areas", and the sceptics were " older, car reliant and more often live in less densely populated areas" (Nielsen & Haustein, 2018, p. 1).

Cohen et al. (2020) make a detailed argument for the importance of researching public opinion around emerging technologies. Especially with respect to CAVs, much research has focussed on how certain users might interact with CAVs, neglecting a broad swatch of potential technological opportunities, and many stakeholders who do not fit neatly into the traditional vehicle owner description. Legacy et al. (2019) discuss the importance of action on the part of transport researchers, in terms of creating new frameworks that can reconcile the private development of CAV technology, and the public-led development of city and transportation planning. In this case researchers have a somewhat symbiotic relationship with municipal governments and industry, since the actions of government and industry provide material for research which in turn might inform future policy.

CAVs as leading to socio-technical transitions

Geels (Geels, 2004) suggests that by studying socio-technical systems, one can focus on the dynamic relationship between technology and society within a larger transition. When the transition to CAVs is viewed as a socio-technical system, the relationships between stakeholders and the evolving technology can be viewed as connections that channel driving forces, but also viewed as connections which create barriers, or restraining forces. For example, Hopkins and Schwanen (2018) discuss how incumbents, in terms of industry and politics, have until now largely led the AV transition in the UK, and how this has led to lower levels of openness, democracy and participation from other groups. In this case the barriers are not necessarily against technological development, but rather barriers to the inclusion of non-incumbent stakeholders in the process. Examples of such barriers emerged in other countries, such as the USA, in the way that most large automobile companies have self-driving technology programs, which are almost exclusively managed by industry organisations or industry-government partnerships (Hess, 2020).

Cohen and Cavoli (Cohen & Cavoli, 2019) take a different perspective on CAV transition, looking at the consequences of government intervention or lack thereof. They start from the hypothesis that a "laissez-faire" government approach to CAV regulation could create traffic issues and discuss which interventions might be most effective under certain conditions. This approach reflects much of the literature on CAV transitions and policy, which is focused on when and how governments should start creating regulations and policies for CAVs in cities in order to avoid negative consequences of the technology (Legacy et al., 2019; Li et al., 2019; Milakis et al., 2017; Pernestål Brenden et al., 2017).

Table 1
Passenger cars in use in the biggest Swedish municipalities, Västra Götaland and Sweden at the end of year 2019 (Trafikanalys, 2020).

Place	Passenger cars in use	Total number of cars per 1000 persons
Stockholm	352 138	361
Malmö	120 967	352
Göteborg	189 565	327
Västra Götaland Region	789 311	458
Sweden	4 887 904	474

Table 2
Percentage of number of trips undertaken with different transportation modes out of all the trips taken in, to, and from Gothenburg. Figure redrawn from (Trafikkontoret, 2019).

Transport mode	2011	2019	2035 goal
Car	48%	43%	29%
Public Transportation	25%	30%	36%
Bicycle	5%	7%	12%
Pedestrian	22%	21%	23%

Table 3
CAV-related projects related to the City of Gothenburg (Göteborgs Stad, 2020).

Project name	Start	Main Partners
AD Aware Traffic Control	2016	Ericsson, Carmenta, Swedish Transport Administration
Drive Me	2017	Volvo Cars
Coexist	2017	VTI, and more
Virtual Reality Lab in Gothenburg	2016	Drive Sweden, RISE, Vinnova
DenCity	2016	Vinnova, Closer, RISE, Swedish Traffic and Public Transport Authority, and more
Digitalized Infrastructure - Environmental and Speed Zones	2018	Volvo Cars, AB Volvo, Scania
NordicWay2	2018	Public and private actors in Finland, Norway, Sweden and Denmark
S3: Shared Shuttle Services	2017	RISE, and more

Context in Gothenburg: a city with a car-oriented tradition

Gothenburg is a city historically linked to the production of cars, mainly associated with the Volvo brand. Statistics show that Volvo Cars and AB Volvo are the largest employers in the Gothenburg Region (data from 2017) and those reporting the largest turnover in 2016 (Business Region Göteborg, 2018). Despite Volvo's presence, the motorization rate of Gothenburg is lower than the two other major cities in Sweden (327 passenger cars per 1000 persons against 352 in Malmö and 361 in Stockholm), see Table 1.

In 2014 the City of Gothenburg created a transportation strategy for the city with the target year 2035. The *Gothenburg Transport Strategy for a Close-Knit City* covers a range of transportation-related measures, including increasing public transportation use so that it makes up 55% of motorized trips (Helleberg et al., 2014). The city started measuring the breakdown of trips by private car, public transportation, bicycle and on foot in 2011. Since then, public transportation has increased by approximately 33% to become 30% of total trips. Table 2 shows the breakdown between different forms of transportation for trips to, from, and within Gothenburg (Trafikkontoret, 2019).

The *Gothenburg Transport Strategy for a Close-Knit City* makes a passing mention of CAVs, but they are not explicitly stated as a tool for helping to reach the 2035 goals. Since 2014, however, the City of Gothenburg has been involved in a number of projects that examine potential effects of CAVs (see Table 3). These projects are diverse in scope, some relate specifically to freight, others to liveable neighbourhoods, and others to completely digitalised solutions to CAV regulation. Taken all together, this shows that the City of Gothenburg is emphatically engaged in developing plans for CAV use in Gothenburg.

Perhaps the most well-known of these is a project called Drive Me, which included many partners, but was best known for being a collaboration with Volvo Cars that aimed to loan families in Gothenburg self-driving Volvo cars and observe their travel behaviour (Rothoff et al., 2019). Drive Me did not reach as many families as originally planned and the level of automation was less than planned (level 2 instead of level 4). Volvo Cars presented the results from the project in spring of 2020, stating that most of the findings were safety-related (SAFER, 2020).

Methodology

Theoretical framework

This research is theoretically underpinned by a combination of transition management (Loorbach, 2010) and field theory (Lewin & Korsch, 1939). Transition management supports the idea that the introduction of CAVs will imply a socio-technical transition that "not only entail[s] new technologies, but also changes in markets, user practices, policy and cultural meanings" (Geels, 2010, p. 508). The need for stakeholder engagement stems from the fact that, when new technologies such as CAVs are emerging, but still not implemented, their societal implications come to fruition in the future. This makes it difficult to conceptualize these societal implications in the present (Geels, 2010). This is also why this study focusses on the Driving Forces and Pressures components of DPSIR. We can be more certain about these perceived components than about what a potential future State will be.

To capture the stakeholder engagement that is central to transition management the selection of stakeholders to interview was based on the quadruple helix structure. This builds on the triple helix of academia, government and industry by adding civil society (Hasche et al., 2020). Using the quadruple helix to identify and group interviewees helped ensure a diverse range of stakeholders, while still focussing on interviewees who had some knowledge of or connection to CAVs.

The second theoretical resource that this paper is grounded on is field theory, which was originally conceived by the psychologist Kurt Lewin. The idea behind field theory was that the time and setting of an event must be included in the analysis of how that event could change (Lewin & Korsch, 1939), or how those contextual forces could affect the change. In this study the event in question is the socio-technical transition to CAVs in cities.

Field theory has been rediscovered by several contemporary scholars and re-applied in a broader context of organisation and social change (Burnes & Cooke, 2012; Cronshaw & McCulloch, 2008). It has also been the basis for an analytical tool called force field analysis, which is essentially the application of field theory in a given context to identify and measure forces affecting change.

Analytical framework

The main analytical tool in this paper is a causal chain framework called DPSIR that was developed by the European Energy Agency (EEA) as a means for organising and analysing the causes (driving forces, pressures) of changes in the state of a particular environment (Smeets & Weterings, 1999). In the current research, these driving forces are causes or processes that stakeholders suggest could influence the state of how CAVs will be used in cities. The pressures are expressions of more specific interests of different stakeholders. In the final steps of DPSIR, the impacts of those changes could then be mapped as could appropriate policies (responses). We have mapped the I and R components in a complementary article.

An important extension of the DPSIR framework used in this research

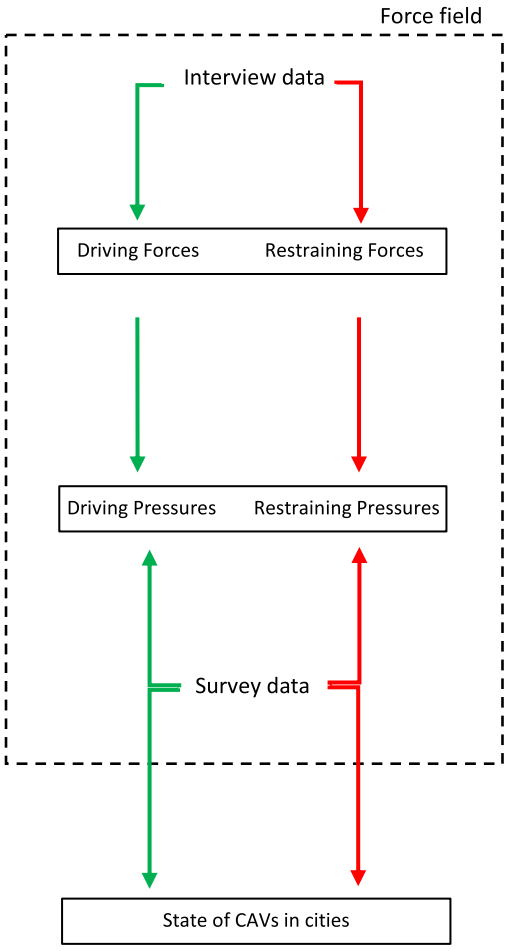

Fig. 1. A simplified diagram of the analytical framework described in Section 3.2.

is the characterisation of driving forces and pressures as both positive and negative, or "driving" and "restraining". Since this is a framework created for addressing environmental issues, much of the literature assumes the drivers and pressures cause negative impacts. This work classifies driving forces and pressures as negative (restraining) or positive (driving), where restraining is associated with behaviours that might lead to increased travel and energy demand, and driving is associated with behaviours that might lead to decreased travel and energy demand. In making this positive–negative distinction, we combine force-field analysis with DPSIR as a "technique for evaluating forces affecting change" (Thomas, 1985, p. 54). Lewin's original intention for force field analysis was to analyse the rate and strength of change over time (Cronshaw & McCulloch, 2008). We do not capture the time aspect, but by asking survey respondents to weigh a list of Pressures we are able to analyse the strength of the pressures in terms of how much each Pressure would influence the changing State of CAVs in cities.

The entire analytical process, including the force field, is visualised in Fig. 1. Since the pressures are directly related to the driving forces, the latter are included in the force field analysis.

The State is often assumed to be a negative change in the state of an environment in most studies that use DPSIR. In this study we suggestion that the State is in fact many possible versions of a State that involves diffusion of, widespread access to, and use of CAVs.

Materials and methods

This paper adopts a mixed method research approach, with a qualitative dominance. The research process goes through different steps.

Table 4
Description of Interviewees.

Number of Interviews	Type of Organisation	Quadruple helix category
6	Architecture Firm, Original Equipment Manufacturer, Real Estate Development Firm, Swedish automobile industry organisation, Consulting Firm	Industry
2*	University	Academia
1	Cycling Advocacy group	Civil Society
3*	City Government, Regional Government	Government

* One interviewee was an academic who was also involved with the city government, so they answered for both quadruple helix categories. Thus, the sum of the "Number of Interviews" column in is 12, even though the total number of interviews was 11.

First, to achieve a sufficient diversity of perspectives, CAV-related stakeholders were categorized using a quadruple helix model (society, industry, academia and government), based on the model described by (Carayannis & Campbell, 2009).

Second, eleven semi-structured interviews were conducted with interviewees from each part of the quadruple helix. The sampling technique used to choose the interviewees was contingent purposive sampling (Bryman & Bell, 2015), which in this context meant that the interviewees belonged to a quadruple helix category, and had some professional knowledge of or connection to CAVs. Table 4 shows the type of organisation that each stakeholder represents, and which quadruple helix category they belong to. The interviewees answered questions from an interview guide, but the interviewers also followed up on topics that were uniquely salient in specific interviews. All interviews were carried out in English, because not all of the researchers involved in the interviews and analysis spoke fluent Swedish. However, the first language of many of the interviewees is Swedish, and thus there are minor grammatical errors in some of the supporting quotations. Due to the restrictions caused by Covid-19, all interviews took place via video call.

Third, content analysis (Hsieh & Shannon, 2005) was used to analyse the semi-structured interviews. The interview transcripts were analysed to explore the DP components of the DPS framework, described in Section 3.2.

Fourth, and lastly, after the interview analysis, an online survey was distributed to an expanded list of respondents, including interviewees. Following the contingent purposive sampling method, the units of analysis changed according to findings during the research (Bryman and Bell, 2015), and the additional survey respondents were recruited from the stakeholder categories that were identified in the interviews. A total of 21 people submitted responses. These 21 were mainly from industry and academia, but many of them were involved in work with urban planners, landowners and developers, public transportation providers, all of which were stakeholder categories identified in the interviews.

The survey asked respondents to rank driving and restraining pressures extracted from the stakeholder interviews on a 1 to 3 scale (weak, medium, strong). This ranking served to weight the force-field analytical mapping (see Section 4.4). The descriptions of each driving and restraining pressure used in the survey are the same as those presented in Section 4.

The survey is used as a complement and to deepen the insights of the information that was extracted from the interviews, rather than a purely statistical validation of the interview data; hence, we do not aim for any statistical significance from the survey. The data gathered from interviews was unexpectedly dense, and thus the first two sections of the survey exceeded 50 questions about driving and restraining pressures. For this reason, in the findings, we will display the median value of each pressure to demonstrate its overall strength according to the respondents, and range between the 0.25 and 0.75 percentiles to show the dispersal of responses. Due to the large amount of information, the full

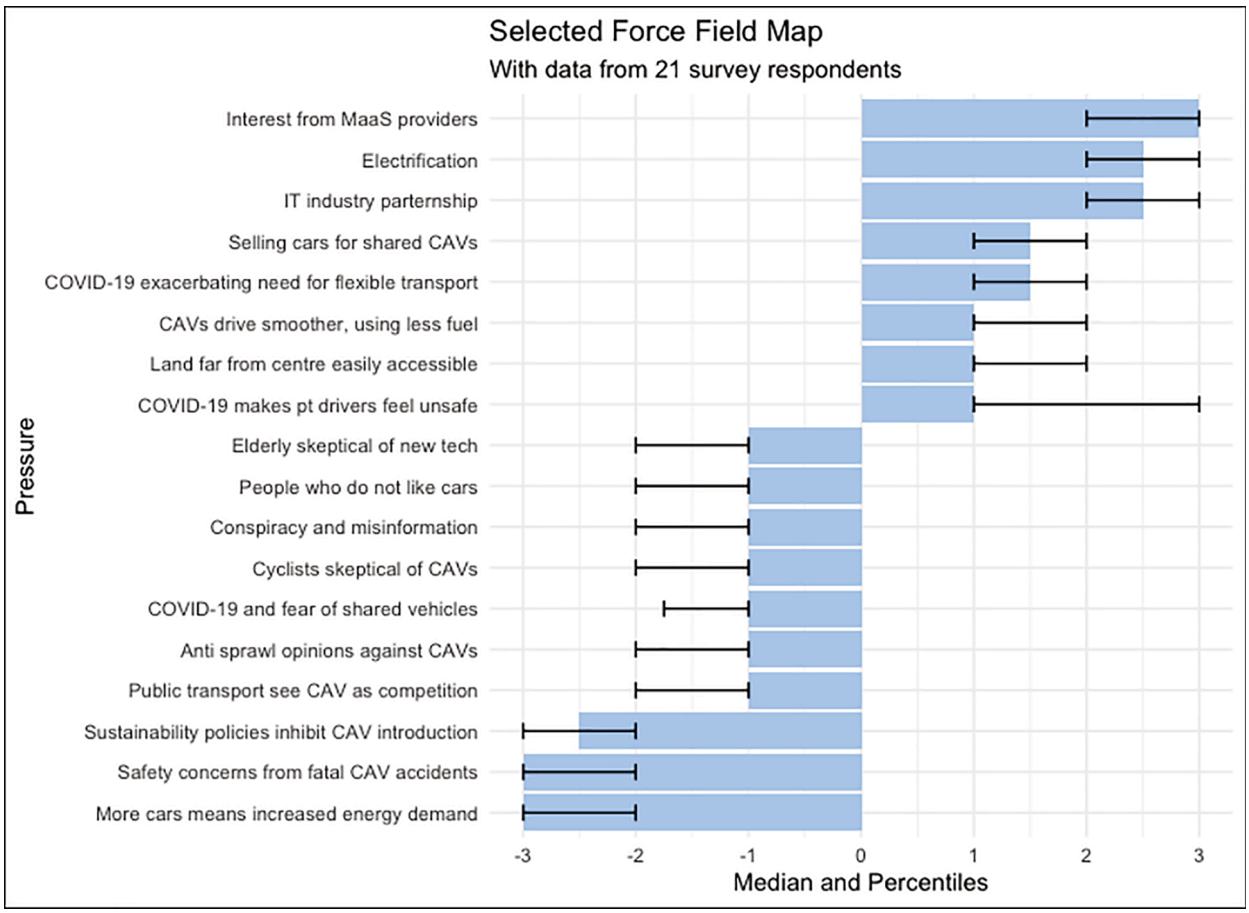

Fig. 2. Selected Force Field Map showing all survey results for all pressures that did not have a median value of 2 or -2.

results of survey are displayed in Fig. 3 in Appendix 2, while a simplified version including the most relevant data are showed in Fig. 2 in Section 4.4.

Findings and analysis using an adapted DPSIR model

This section shows the interview and survey results. The driving and restraining forces and pressures, as well as the types of stakeholders, presented are extracted from the interview transcripts based on the application of the DPS components of the DPSIR model. As mentioned in the Methods section, the analysis was limited to Drivers, Pressures and State due to the sheer volume of data. The State, Impacts and Responses will be analysed in a second, complimentary article.

Stakeholders

It can be relevant to know which stakeholders identify different driving and restraining forces and pressures, because future analysis can be done on the levels of legitimacy, urgency, and power of each stakeholder (Mitchell et al., 1997), using the same interview data. In the following section Table 5 and Table 6 display the connections between driving and restraining forces, pressures, and stakeholders.

The following stakeholder types were identified in the interviews as being relevant in this context, and are connected to specific driving and restraining forces and pressures in the next sections:

- Car user (passenger or driver)
- Car producer (individual companies)
- Car industry
- Mobility users who cannot drive
- Generic citizen
- Public transport provider
- Private transport provider
- Private transport driver
- Landowner
- Land developer
- Urban planner
- Politician
- Mobility consultant

Driving forces and pressures

In the interviews a set of driving forces were identified and then classified as: environmental concerns, market economy, technological advance, urban planning, politics and policy, health, and socio-cultural habits.

The driving pressures, being several for each driving force, emerge in the interviews as expressions of interests of different stakeholders such as companies, environmentalists, citizens, or authorities. Therefore, the terms interest and pressure are used as synonyms in this section.

Table 5 summarizes the driving forces, the associated driving pressures, and the stakeholders that argue for driving pressure being important. In this section, each interviewee is connected to their quadruple helix category, but not identified in a more granular stakeholder group (like those described in the previous section) to preserve anonymity.

Environmental concerns

Within the driving force of environmental concerns, the pressure to reduce fuel consumption is raised by both car users and the car industry.

Table 5
Driving Forces, Pressures and key stakeholders.

Driving Force	Driving Pressure	Key Stakeholders
Environmental Concerns	CAVs expected to drive smoother and slower, using less fuel	Car User, politician
	Car sharing would make CAVs more acceptable for environmentally-sensitive people	Generic citizen
Market Economy	Economic interest of car producers	Car producer
	Interest from Mobility-as-a-service providers e.g. car sharing companies, Uber… (saving money by not paying drivers)	MaaS provider
	Promotion and marketing shaping idealized, futuristic imagery of CAVs	Car producer
	Cheap land away from city centre can become more accessible with CAVs (attractive for land owners and developers)	Land developer, Land owner
	People selling their cars and using shared CAVs	Car user
Technological Advance	Expected efficiency advantages with self-driving and self-parking technology	Car producer, land developer?
	Expectation of improved safety with CAVs	Car user
	IT industry interested in partnership with car industry	IT industry, car industry
	New technologies' (such as CAVs) usefulness taken for granted	IT industry, car industry, car user
	Electrification of cars helps CAV promotion (as it provides multiple benefits for CAVs such as energy efficiency, money saving, less noise)	Car producer, transport provider, car user
Urban Planning	Mobility consultants supporting local authorities shape visions for the mobility of the future	Mobility consultants
	Need for improved mobility in rural areas (public transport not currently economically efficient)	Urban planners
	Pilot studies are being conducted which anticipate CAVs introduction	Multi-stakeholder
Politics and Policy	Politicians need to understand the implications of CAVs in cities	Politicians
	Government economically dependent on (or, at least, tightly intertwined with) car industry	Politicians
	Authorities with a history of continued investments in upgrading infrastructure can be more responsive when adapting to CAVs	Politicians
Health	Covid-19 exacerbating need for flexible transport	Generic citizen
	Covid-19 makes public transport drivers feel unsafe	Public transport provider
Socio-cultural habits	People using taxis and public transit are prepared for CAVs, especially shared CAVs	Generic citizen
	Demand for productive use of time (work or recreation) while driving	Car user
	Some urban dwellers prefer not to own cars (and instead demand shared CAVs)	Generic citizen
	People interested in cars and new technologies in general can be interested in CAVs	Generic citizen
	People who cannot drive (e.g. elderly, disabled…) have more opportunities with CAVs	Generic citizen
	Ongoing work on legislation and regulations as preparatory work for CAVs	Multi-stakeholder

CAVs could affect fuel consumption by potentially letting the vehicle drive slower and more smoothly as compared to a human driver. For example, one interviewee pointed out that "[CAVs] will not speed or accelerate very rapidly" (Interview 8, Industry).

It was also suggested that CAVs as shared cars could be more accepted by environmentally concerned citizens because a situation where every person had their own private CAV would not fit in a "sustainable society" (Interview 10, Industry). Another interviewee highlighted that existing shuttle bus pilot projects could be considered shared rides, so "if we can leverage the head start of shared rides, that might mitigate against a lot of the negatives associated with if just everybody who drives a regular car swaps it for a private AV" (Interview 3, Academia).

Market economy

From the interviews the market economy system emerged clearly as a major driving force. In this case, market economy as a driving force is expressed as market capitalism in a broader sense involving supply and demand of products, profit seeking and accumulation of wealth.

Particularly relevant as an expression of pressure are "companies, of course, wanting to produce the cars" (Interview 1, Industry). One interviewee mentioned an event where car industry actors were asked "how many of you are working on a product you want cities to buy?" (Interview 3, Academia) and every person raised their hand. Therefore, it is reasonable to assume that the car industry is a source of pressure and has an interest in collaborating with local authorities to facilitate CAV introduction.

One specific part of this is the interest of the car industry to adapt streets to CAVs. For example, this is stressed by an interviewee as "if you look at the experiment of Volvo, currently ongoing, it is limited to certain streets because they're the streets that are relatively simple to manage from a technology point of view" (Interview 4, Civil Society).

The pressure from the car industry is also expressed through marketing and advertisement techniques as commercials shape the imagery of CAVs. One interviewee even mentioned that "it's quite hard to separate how I envision them from the commercials" (Interview 7, Government).

Another pressure is represented by mobility companies who stand to gain from CAV development, such as "Robo taxis, mobility as a service (MaaS) fleets … it's really the companies that have most of the interest" (Interview 3, Academia). For MaaS providers, the "financial benefit is if you pay wages to your cab driver or to your bus driver or to your lorry driver and you can replace them with technology" (Interview 4, Civil Society).

One interviewee suggested that citizens who are inclined to replace cars with a mix of travel modes for economic reasons, for example "people who are on the edge of trying to choose to save a lot more money and engage in biking … that would be a group that should have a vested interest in either the AV shuttles… and in some combination with the AV taxis" (Interview 3, Academia).

In the countryside, the interest of developers and property owners can be a source of pressure as cheap land away from the city centre can become more accessible with CAVs. One interviewee put forward that "I think it will be inevitable that private interests buy cheap land outside of cities" (Interview 1, Industry), as CAVs make longer car travel easier.

Technological advance

When considering CAVs an expression of technological advance, one pressure is exerted by the possibility for CAVs to be "more effective with parking and driving closer – the vehicles can get closer to each other" (Interview 1, Industry). This pressure comes from car users, who stand to gain in terms of time and reduced stress if they no longer have to park their own vehicle, and property developers who may be able renovate or redesign parking garages to be smaller and use the excess space for other purposes.

Another expression of interest from a user perspective constituting a pressure is that CAVs "tend not to take larger risks as humans do, when they drive … so they expect to not be involved in as many accidents as humans" (Interview 8, Industry).

A specific pressure comes from the IT industry, where much of the technological development for CAVs started. As one interviewee phrased it: "The IT industry really kicked all this off. There were already

plenty of folks in computation, working on mapping and they kind of said, 'hey, we've got enough infrastructure in the computation field. We think we can really make driverless cars happen' " (Interview 3, Academia). The IT industry has historically been interested in creating a partnership with car industry, and "that's where an amazing amount of money and human intelligence effort has gone" (Interview 3, Academia).

A rather surprising pressure that emerged is that citizens tend to take for granted that new technology is necessary and useful, and daily routines should be adapted to use that new technology rather than the other way around. This was expressed by an interviewee as:

"Instead of having the technology that's new and then making up the need for it… what does the city need or what does its people need and then what is the role of autonomous vehicles?" (Interview 6, Industry).

The emergence of electrification of cars represents another pressure towards the introduction of CAVs. In fact, those actors involved in electrification of cars can also have an interest in CAVs. One interviewee suggested that electrification of CAVs is deemed as positive from an economic perspective, but could also lead to quieter and cleaner city centres, saying "there's so much economic sense for [CAVs] to be electric, but that might take some time before they really all are, but if they all are electric, that means that the denser parts of cities will be quieter, have less emissions and suddenly, our urban streets will be so much more liveable" (Interview 3, Academia).

Urban planning

Urban planning as a driving force is related to multiple stakeholders exerting different types of pressures. One example is consultants that support local government in understanding the role of CAVs in city mobility. One interviewee explained how consultants "could do more projects like we've already done like helping cities develop a strategy on how they should react to these kinds of vehicles and how they should plan for them and benefit from them" (Interview 6, Industry).

Town planners of rural areas can be also interested in the introduction of CAVs. The question of rural areas and the need for more viable public transport is linked both to market economy as driving force but also to urban planning in a broader sense, including mobility. In fact, rural areas for which public transport is not economically effective, "could have self-driving mobility service systems" (Interview 6, Industry).

Lastly, those actors involved in CAV pilot studies exert pressure towards introduction of CAVs. The interviewee mentioned that "One thing that's already happening in this city is gaining knowledge from these pilot studies" (Interview 6, Industry).

Politics and policy

Sometimes intertwined with urban planning, politics and policy issues also emerged as a driving force per se. In particular, politicians are an expression of pressure as they enable CAV introduction in cities. One interviewee stated that "[city bureaucrats] also have, as a response to the wishes of all our politicians, independent or whatever political party they represent, we produced this strategy for how we, as an administration, will work with electrification, digitalisation and automation of the transportation system over the next coming three years" (Interview 9, Government).

On another political level, "the Swedish government has supported the car industry for a long time because they're very dependent on them (…) and at the same time, making people drive less because it's bad for the environment and for health…" (Interview 6, Industry).

Moreover, the car industry has historically been reliant on local authorities to create the infrastructure for mobility, so their pressure will impact local authorities as enablers of a transition towards CAV implementation: "The traditional car industry, if you call it that, they have been very reliant on governments and cities building infrastructure to make people having to buy a car to survive … so governments and planners will still be powerful actors in this transition" (Interview 6, Industry).

Those authorities that are keen on periodically upgrading infrastructure, are also exerting a positive pressure towards the introduction of CAVs. The latter is facilitated by "the quality of their infrastructure and the likelihood of their continued investment in infrastructure" (Interview 3, Academia).

Health

The question of health was mentioned with regards to the ongoing Covid-19 pandemic, which can also be a source of pressure. For instance, autonomous vehicles can give necessary adaptivity during health crisis situations. One interviewee spontaneously brought up the Covid-19 pandemic, saying "I was just reflective of how that will impact [the introduction of CAVs], the total that drive and the public transport, that goes in different directions, right?" (Interview 2, Industry), meaning both that the pandemic could cause more people to use private cars, but if there was a need for different public transportation patterns (e.g., more frequent busses so that there could be fewer people on each bus), CAVs could help facilitate that need.

Public transportation drivers were mentioned as they can feel unsafe in a pandemic. Moreover, "that's a whole lot of discussion of how any form of shared rides, really, how does it adapt to the virus and even still, post virus, if people continue to feel pretty nervous about it for quite some time" (Interview 3, Academia).

Socio-cultural habits

Society and social culture constitute a major driving force. Within the group of users that can be interested in CAVs, those who are accustomed to using cabs or public transit as driven by someone else, they could be prepared for CAVs because "in terms of services, it's nothing new because we already have taxis and public transport" (Interview 4, Civil Society).

Time saving convenience is also a reason for individuals to be interested in CAVs since while the car is moving, "you can do other things, as a single person" although there can be "a big risk that the autonomous self-driving vehicles could lead to extensive use of single person transport because it becomes very convenient and you don't lose any more working time or leisure time while being in transport" (Interview 5, Government, Academia and Civil Society).

Other types of interests in shared CAVs stem from diverse kinds of demands of societal groups. For instance, "People living in the central areas would have an interest in that they could use a car when they need to and not have to own one" (Interview 6, Industry).

Other groups exerting pressure are represented by "groups in society that would like to have new cars, flash and shiny with the new kind of cars and vehicles" (Interview 7, Industry).

Mobility users who are not able to drive could exert a pressure towards CAV, since "one third of the population, approximately, can't drive, they're too young, too old, too disabled, they'll have an enormous interest, I think, in autonomous vehicles of any kind, especially the private" (interview 3, Academia).

Finally, a more complex type of societal pressure stems from multi-stakeholder collaboration, including different levels of government, academia and industry, all working together on vehicle legislation and new regulatory systems. This can be summarized by one of the interviewees who said: "In Sweden, we work very much with the vehicle legislation work, both within the United Nations Economic Commission for Europe regulatory work, but also in the EU and we also have discussions and meetings together with (…) the Swedish Transport Agency" (Interview 8, Industry)

Restraining forces and pressures

The restraining forces appearing in the interviews were the same as the driving forces and pressures but operating in the opposite direction, i.e., technological advance, environmental concerns, socio-cultural

Table 6
Restraining Forces and Pressures.

Restraining Force	Restraining Pressure	Key Stakeholders
Environmental Concerns	The sustainability agenda of local authorities can go against the introduction of CAVs, as their environmental impact is unclear	Politicians and urban planners
	More cars means increased energy demand	Car producer and car user
	If CAVs are electric: Environmental movement concerned that increased electricity supply will come from fossil fuels	Generic citizen
	If CAVs are not electric: both air quality norms and climate policy could restrict the increase of CAVs based internal combustion engine vehicles	Generic citizen
	Anti-sprawl opinions against CAVs as they may encourage people to move away from dense urban centres	Generic citizen
Market Economy	Public transport providers see CAV as competitors, and thus want to hinder CAV introduction	Public transportation providers
	Dual infrastructure (for CAVs and conventional vehicles) is expensive	Politicians and urban planners
	Risk of investing in a technology that fails on the market (e.g. if users don't purchase CAVs or subscribe to programs that use CAVs)	Multi-stakeholder
Technological Advance	New technologies need to be mature and safe before being introduced to users (e.g. safety concerns from fatal CAV accidents).	Car producer, car user, IT industry
	Fear of CAV technology being hacked	Car user
	Fear that cities become built around CAVs, rather than creating a liveable city and adapting CAVs to that	Urban planner
Urban Planning	Walking, biking and public transit as planning priority, not CAVs	Urban planners
	In urban development policies the shared use of cars is deemed as more important than the self-driving aspect	Urban planners and politicians
	Streets are not currently designed for CAVs	Urban planners
Politics and Policy	Current international and national laws and regulations are not suitable for CAVs	Politicians
	Lack of political consensus on visions for the future in cities	Politicians
	Lack of knowledge and agreement about strategies from local authorities	Politicians
	The ethical question of who has priority when there is a risk for collision between a pedestrian and a CAV	Generic Citizen
Health	Concern that CAVs may increase congestion	Generic citizen, urban planner
	Covid-19 pandemic and fear of shared vehicles	Generic citizen
Socio-cultural habits	Conspiracy theories and misinformation about new technologies	Generic citizen
	The group of people who do not want to give up control of their vehicle	Car user
	People who do not like cars	Generic citizen
	Elderly people who are sceptical of new technology	Elder people
	Cyclists are particularly sceptical about CAVs, in terms of safety and access to urban space	Cyclist

habits, health, urban planning, market economy, and politics and policy.

The restraining pressures are also connected to a set of stakeholders and pose a series of challenges to the development and subsequent introduction of CAVs in cities. Table 6 summarizes the restraining forces, associated restraining pressures and associated stakeholders.

Environmental concerns

One restraining pressure related to the restraining force of environmental concerns is that the sustainability targets of local authorities could go against the introduction of CAVs. However, since little is known yet about CAVs "it's very important to see the environmental impact from those because the environmental impact will most likely play an important role in the political agenda" (Interview 2, Industry).

In particular, from the consumer/user side, the question of energy efficiency emerged, phrased as : "If the autonomous vehicles get so effective that people use them a lot, meaning you see more energy [demand], then we have to produce more energy somewhere" (Interview 1, Industry). Furthermore, the interviewees also underline the risk of having electric CAVs due to an increase of energy demand, stating that "…even if we go for electrical, we have to produce the electricity in some way" (Interview 5, Government, Academia and Civil Society).

From the perspective of local authorities, environmental quality norms in cities can represent a restraining pressure, especially if CAVs are not electric. One interviewee mentioned that "We still have some challenges in the City of Gothenburg, at least, to the local environmental quality norms. We have some challenges, day to day, (…) and here, I think that the self-driving vehicles cannot, in themselves, contribute to an increased air quality" (Interview 7, Government)

Lastly, specific environmental concerns are expressed by those who are worried about urban sprawl. This restraining pressure was stated very clearly: "These self-driving vehicles could contribute to urban sprawl more than densification." (Interview 7, Government)

Market economy

Despite its value as a propeller or driving force, the market economy can also act as a restraining force, connected to different restraining pressures. In the interviews, for instance, CAVs are mentioned as competitors with providers of public transport, so the latter can be a source of restraining pressure against CAVs. One interviewee, while reflecting on the interests of different stakeholders, stated that "we ultimately can see that self-driving passenger cars can also be a competitor for the public transport needs" (Interview 2, Industry).

From a financial perspective, a negative pressure can stem from local authorities, "in terms of the city itself which will be an obstacle because they simply can't afford dual infrastructure." (Interview 4, Civil Society). It can be excessively expensive for public finance to invest in dual infrastructure for conventional public transportation and for CAVs.

Lastly, other multiple stakeholders made comments about the importance of reducing "the risk of mis-investment" (Interview 9, Government), meaning these stakeholders could contribute to the set of negative pressures against CAVs, if they consider CAVs in terms of risks for wrong investments.

Technological advance

In relation to technological advance, several pressures contribute to it as a restraining force. One example is related to the user perspective, as new technologies need to be well-functioning and safe before being introduced. An interviewee stated that "the vehicles, of course, need to be safe, secure and they also need to be trusted, both for the users, but also for other persons around in the traffic environment" (Interview 8, Industry)

There is also a security risk from the ICT developer side, given the risk of CAVs being hacked. It was pointed out in an interview that "It's been already proven, if somebody wants to get in [digitally] and turn off the vehicle, they can do that super easily" (Interview 3, Academia).

Finally, from a city perspective, the interviewees detected the fear that cities become built around CAVs, rather than the other way around, which constitutes also a restraining pressure. The interviewees suggested that "Most cities have actually been adapted to the car technology, rather than the other way around and I think there is a certain risk that this will be repeated" (Interview 4, Civil Society)

Urban planning

From an urban planning perspective, a restraining pressure against CAVs stems from the goal of prioritizing walking, biking and public transit. It was suggested in the interviews that it is an important urban planning goal to prioritize "towards walking, biking and public transit … so we don't have a complete car-oriented city all over again" (Interview 1, Industry).

In general, urban development is considered to be geared more towards sharing than self-driving, this could generate a restraining pressure against the introduction of CAVs, since "The implication(s) on the urban development are far more on the sharing side than on the actual self-driving technology side" (Interview 4, Civil Society).

Finally, "what kind of streets should be designed for [CAVs] is a problem" (Interview 6, Industry), meaning that certain types of existing streets might not be appropriate for CAVs and therefore, a restraining pressure against them.

Politics and policy

As current regulations and laws might not be suitable for governing CAVs, the need for their adaptation can constitute a negative pressure against CAV introduction in cities. One interview pointed out that " I think we're just still at a pretty early, early steps." (Interview 3, Academia). This could cause "standardisation issues, but in terms of rules and regulation, they need to be internationalised" (Interview 4, Civil Society).

In general, the interviews have highlighted the lack of consensus on what authorities want for cities, which can be a remarkable restraining pressure. Stated clearly: "Well, there's no consensus, is there. There's not a given answer of what kind of cities we want and of course, there is a political question as well because they're different views" (Interview 4, Civil Society).

Insufficient knowledge about CAVs on the part of local authorities constitutes a significant restraining pressure, where "[local authorities] want to know and need to know more about what does this mean for our city and our region, how can we contribute or how can we benefit from it? That's in an early phase, I would say, even in Gothenburg" (Interview 6, Industry).

Finally, there are many important ethical challenges related to CAV policy design that have yet to be resolved, "if the vehicle has to make a decision between hitting and killing a pedestrian or hurting the people inside the vehicle and possible killing them in the vehicle, which way do you want it to go?" (Interview 3, Academia).

Health

Concerns about health emerged as a restraining force. A restraining pressure is exerted by urbanists who associate car-dependency with public health issues. There is a specific concern that CAV may increase congestion, as stated by this interviewee: "I think urbanists, at least some of them, thinking of health issues and being stuck in cars all the time" (Interview 1, Industry). The ongoing Covid-19 pandemic could also generate pressure against vehicle sharing, interviewees noted that "when the Corona virus showed up, I thought that maybe people won't like to share items at all in the future, unless there is some disinfection procedure" (Interview 5, Government, Academia and Civil Society).

Socio-cultural habits

Society (and more specifically, socio-cultural aspects of it) as a restraining force is delineated through a set of restraining pressures, primarily related to the car user perspective.

Specific societal groups are mentioned as a source of restraining pressures against the introduction of CAVs. Among them, the interviewees have posed the question of people passionate for conspiracy theories: "People who often see conspiracies don't often like big corporations, monopolies, anti-technology of any kind and I think there's a part of society who would be against [CAVs] for those reasons" (Interview 3, Academia). Another group that "could be against it, it could be people who are very fond of driving themselves" (Interview 5, Government, Academia and Civil Society), meaning that, among other things, these people may not want to give up the control and pleasure associated with driving a vehicle.

Furthermore, another segment of the population simply dislikes automobiles per se and would certainly not contribute to a diffusion of CAVs, as detected in the interviews: "… a lot of people who don't like cars" (Interview 9, Government). The context in this particular interview was a longer discussion about a widely negative reaction from at a workshop presentation involving a car-centric plan for the introduction of CAVs.

An even more specific societal group that could generate restraining pressure against the introduction of CAVs is represented by elderly people, who are often reluctant or sceptical towards technology. It was suggested in the interviews that "As everything about technology, it can be harder for elderly people, to learn and to trust, of course" (Interview 10, Industry).

Finally, when asked which stakeholder groups could be an obstacle to the introduction of CAVs in cities, one interviewee mentioned cycling organisations specifically, saying "I think politicians, cycling organisations and also, you need to build trust in the society, can we trust to have vehicles [like those] on the street? "

Force field map

The survey results showed which level of strength respondents assigned to each driving and restraining pressure, on a scale of weak (1), medium (2) or strong (3), in terms of the effect of the pressures on the introduction of CAVs in cities. Using the results of the survey, we have created a simplified forcefield map to highlight which of the 52 pressures identified in the interviews were considered to be strongest and weakest by the 21 survey respondents. This was done by calculating the median strength of each pressure to determine the centre-most level of strength that respondents assigned to each individual pressure. We then removed all the pressures that had a median value of 2, following the rationale that since these pressures are not particularly strong or weak. they can be accepted as relevant, but they do not stand out.

The blue bar in Fig. 2 is the median value of the strength of each pressure. The black whisker lines represent the range from the 0.25 to 0.75 percentile of each pressures and show the spread of the assigned strengths. If this spread between the percentiles is larger, the respondent's choices formed a larger range of assigned strengths, and vice versa. The percentile range is represented by the black whisker lines in Fig. 2. In some cases, the end point of the whisker line - corresponds to the median. This happens when the 25th or 75th and 50th (i.e., medan) percentile have the same value. For example, "CAVs drive smoother, using less fuel" has a median of 1 and a range from 1 to 2. This is because 1 was the lowest possible option for respondents to choose, so it is the start of the range, and less than 25% of respondents chose 3.

We can see that the driving pressure with the highest median value was that of interest from Mobility-as-a-Service companies (median = 3). These companies could save money by not having to pay drivers when using CAVs. The general electrification trend, and the partnership between the IT industry and the car industry, were tied as the driving pressures with the next highest median (median = 2.5). On the other side, the restraining pressures with the largest negative median value were the potential for increased energy demand from non-shared CAVs being attractive to use more than a conventional car (median = -3), and safety concerns relating to fatal CAV accidents (median = -3).

Intuitively, one of the driving pressures with the lowest median fits well with one of the restraining pressures with the highest negative median. CAVs using less fuel (median = 1), is identified as a weak driving pressure, while the potential for increased energy demand (median = -3) is seen as a strong restraining pressure. This makes sense from an engineering perspective since CAVs are expected to reduce

specific energy consumption (Wh/km) by driving more smoothly and interacting in a more efficient way with other vehicles and with infrastructure, but CAV technology will likely increase the demand for car mobility (Taiebat et al., 2018). Hence, one could argue that most respondents do not see CAVs as a way to reduce emissions, and our interpretation of this is that they believe that the demand impacts override the potential impacts of increasing the energy efficiency of the individual vehicle or vehicle system level.

It is important to remember that these survey results should be viewed as complementary to the interview data, meaning that Fig. 2 gives an idea of how the different pressures brought up in the interviews are perceived at a more general level. As was mentioned in Section 3.3, these results are not meant to be self-standing quantitative evidence of the importance and variance in pressures.

Discussion and conclusions

In this study we aimed to address knowledge gaps by identifying and mapping the strength of drivers and pressures related to the introduction of CAVs in cities, and by identifying the associated stakeholders. In this section we use our research questions to structure the results of this work, and to show where there are opportunities for future research.

RQ1: What are the driving and restraining forces and pressures that facilitate or hinder a socio-technical transition towards the introduction of CAVs at the city level?

In general, it was clear from the interviews and survey that CAVs are not unconditionally seen as positive, but rather that many stakeholders believe CAVs need to be connected to mobility planning and public transport strategies. This was expressed both explicitly, where interviewees mentioned specific policy actions (such as local government studies, infrastructure planning, and safety regulations); and implicitly, when they expressed worry about what could happen if CAVs are introduced without any guidance. The end result from a lack of planning could be negative, such as increased transportation demand, energy consumption, and related emissions. This need for planning in other jurisdictions has been discussed at length by Freemark et al. (2019), Gavanas (2019), Duarte and Ratti (2018), and now the results of our force-field mapping show that respondents find this need is also present in the Swedish context.

An important driving pressure identified in the interviews and related to the Swedish context was an economic dependence on the car industry as being one of the largest employers in Sweden, particularly evident in Gothenburg. This is not new information, but it is important to take into consideration when analysing the forces related to the introduction of CAVs. A slightly similar methodology of examining the forces behind the introduction of CAVs was used by Legacy et al. (2019), where the authors examined the relationship between of private CAV technology development and the public-led development of city and transportation planning. This study was different from ours in that it looked more specifically at the political economy context of public and private sector partnerships, but both studies found that there was a lack of consistency in terms of policy planning for CAVs at different government levels and in different jurisdictions.

In our study, a common restraining pressure was a fear that Swedish cities would be designed around CAVs, as they were once designed around cars, as opposed to being designed with people in focus. This is a concern that has been brought up in literature by Lundin (2014), when examining the development of Swedish transportation and private car ownership post World War II. Dominance on the part of one actor, such as the car industry, can lead to one-sided development, which is why frameworks that reconcile private technology development, and public-led development of city planning, are important not just in the Swedish context but in all cities and areas undergoing such socio-technical transitions.

RQ2: What stakeholders, representative of the driving and restraining forces and pressures, are involved in such a socio-technical transition?

The complete list of stakeholders that was identified in the interviews was discussed in the empirical work section. Within this list, there are some stakeholder types who have been discussed at length in previous academic work, for example disadvantaged people that are not able to drive (Fraedrich et al., 2016; Templeton, 2020).

Another stakeholder connection to Gothenburg, but also one that is generalizable to cities internationally, relates to the role of participants in pilot projects and involved consultancy companies that promote the introduction of CAVs. Politicians, mobility consultants, and urban planners emerged from the interviews as very active parts of an ecosystem of funding and expertise that has been created around these pilots. These pilots are also connected to the car industry, of course through the technology itself but also through the driving pressure of commercials that was identified in the interviews. This pressure was expressed as the idea that it was hard for the interviewee to imagine CAVs as anything other than how they are shown in commercials created by companies within the automobile industry. These commercials, created for the purpose of selling cars, often portray CAVs in a very positive light (Hildebrand & Sheller, 2018).

During this phase the limits of CAV technology are still uncertain, and the theoretical potential is emphasized. Drive Me (Rothoff et al., 2019) is an excellent example of a pilot that had fairly unexciting results compared to the initial expectations, but the project still served to increase awareness regarding the potential of the technology. This could arguably have had just as large of an impact as the technical findings did. Pilot projects are recognized in academic literature as being an important part of the development of CAV development, but it is important that they allow for "critical citizen engagement and participatory deliberation" (Mladenović et al., 2020, p. 258). Whether or not the pilot projects that have taken place in Gothenburg meet this threshold of citizen participation could be the basis for future research.

There are also stakeholders who are related to the socio-cultural and environmental restraining forces, who exert negative pressures against CAVs due to a variety of concerns including safety and environmental damage. Scepticism against new technology is certainly not a new phenomenon, but in this case the convergence of different stakeholders is potentially unique. Elderly people, cyclists, people who are concerned because of conspiracies related to new technology, and those who are concerned about environmental effects form quite a broad range, which encompasses stakeholders with characteristics from both the enthusiasts and the sceptics that are defined by Nielsen and Haustein (Nielsen & Haustein, 2018). It is important to note here that Nielsen and Haustein used primary data directly from the stakeholders in question, whereas the data in this study are respondent's views on these stakeholders. Nonetheless, this grouping of unlikely bedfellows could represent a new stakeholder category which may have a significant impact on the introduction of CAVs in cities, and merits further research in terms of how sceptical stakeholders form their views of CAVs, and if they have significant negative influence on the introduction of CAVs in cities.

CRediT authorship contribution statement

Ella Rebalski: Conceptualization, Data curation, Writing – original draft, Writing – review & editing. **Marco Adelfio:** Conceptualization, Data curation, Writing – original draft, Writing – review & editing. **Frances Sprei:** Conceptualization, Writing – review & editing. **Daniel J. A. Johansson:** Conceptualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1.

Survey Questions

Tables 7 and 8 show the full list of driving and restraining pressures to which survey respondents were asked to assign a level of strength.

Table 7
Survey questions about Driving Pressures.

How strong is each driving pressure in terms of its influence on the introduction of CAVs in cities?	Low strength	Medium Strength	High Strength
Economic interest of car producers			
Promotion and marketing shaping idealized, futuristic imagery of CAVs			
Interest from Mobility-as-a-service providers e.g. car sharing companies, Uber… (saving money by not paying drivers)			
Cheap land away from city centre can become more accessible with CAVs (attractive for land owners and developers)			
If cars drive and park further away from cities, urban parking lots can be converted into more profitable use			
CAVs expected to drive smoother and slower, using less fuel			
Car sharing would make CAVs more acceptable for environmentally-sensitive people			
People using taxis and public transit are prepared for CAVs, especially shared CAVs			
People selling their cars and using shared CAVs			
Expected efficiency advantages with self-driving and self-parking technology			
Expectation of improved safety with CAVs			
IT industry interested in partnership with car industry			
New technologies' (such as CAVs) usefulness taken for granted			
Electrification of cars helps CAV promotion (as it provides multiple benefits for CAVs such as energy efficiency, money saving, less noise)			
Mobility consultants supporting local authorities shape visions for the mobility of the future			
Need for improved mobility in rural areas (public transport not currently economically efficient)			
Pilot studies are being conducted which anticipate CAVs introduction			
Politicians need to understand the implications of CAVs in cities			
Government economically dependent on (or, at least, tightly intertwined with) car industry			
Authorities with a history of continued investments in upgrading infrastructure can be more responsive when adapting to CAVs			
Covid-19 exacerbating need for flexible transport			
Covid-19 makes public transport drivers feel unsafe			
Demand for productive use of time (work or recreation) while driving			
Some urban dwellers prefer not to own cars (and instead demand shared CAVs)			
People interested in cars and new technologies in general can be interested in CAVs			
People who can not drive (e.g. elderly, disabled…) have more opportunities with CAVs			
Ongoing work on legislation and regulations as preparatory work for CAVs			

Table 8
Survey questions about Restraining Pressures.

How strong is each restraining pressure in terms of hindering the introduction of CAVs in cities?	Low Strength	Medium Strength	High Strength
Walking, biking and public transit as planning priority, not CAVs			
In urban development policies the shared use of cars is deemed as more important than the self-driving aspect			
Streets are not currently designed for CAVs			
Public transport providers see CAV as competitors, and thus want to hinder CAV introduction			
The sustainability agenda of local authorities can go against the introduction of CAVs, as their environmental impact is unclear			
More cars means increased energy demand			
If CAVs are electric: Environmental movement concerned that increased electricity supply will come from fossil fuels			
If CAVs are not electric: both air quality norms and climate policy could restrict the increase of CAVs based internal combustion engine vehicles			
Anti-sprawl opinions against CAVs as they may encourage people to move away from dense urban centres			
Dual infrastructure (for CAVs and conventional vehicles) is expensive			
Risk of investing in a technology that fails on the market (e.g. if users don't purchase CAVs or subscribe to programs that use CAVs)			
New technologies need to be mature and safe before being introduced to users (e.g. safety concerns from fatal CAV accidents).			
Fear that cities become built around CAVs, rather than creating a liveable city and adapting CAVs to that			
Current international and national laws and regulations are not suitable for CAVs			
Lack of political consensus on visions for the future in cities			
Lack of knowledge and agreement about strategies from local authorities			
Concern that CAVs may increase congestion			
Covid-19 pandemic and fear of shared vehicles			
The ethical question of who has priority when there is a risk for collision between a pedestrian and a CAV			
Cyclists are particularly skeptical about CAVs, in terms of safety and access to urban space			
Fear of CAV technology being hacked			
Conspiracy theories and misinformation about new technologies			
The group of people who do not want to give up control of their vehicle			
People who do not like cars			
Elderly people who are skeptical of new technology			

Appendix 2

Below is the Complete Force Field Map with all 52 pressures that were addressed in the survey (the Selected Force Field Map in Section 4.4 excluded all pressures with a median strength of 2 or -2). As with the Selected Force Field Map in Section 4.4, the blue bar is the median value of the strength of each pressure, and the black whisker lines represent the range from the 0.25 to 0.75 percentile of each pressure, which represents the spread of the assigned strengths. If this spread between the percentiles is larger, the respondent's choices formed a larger range of assigned strengths, and vice versa.

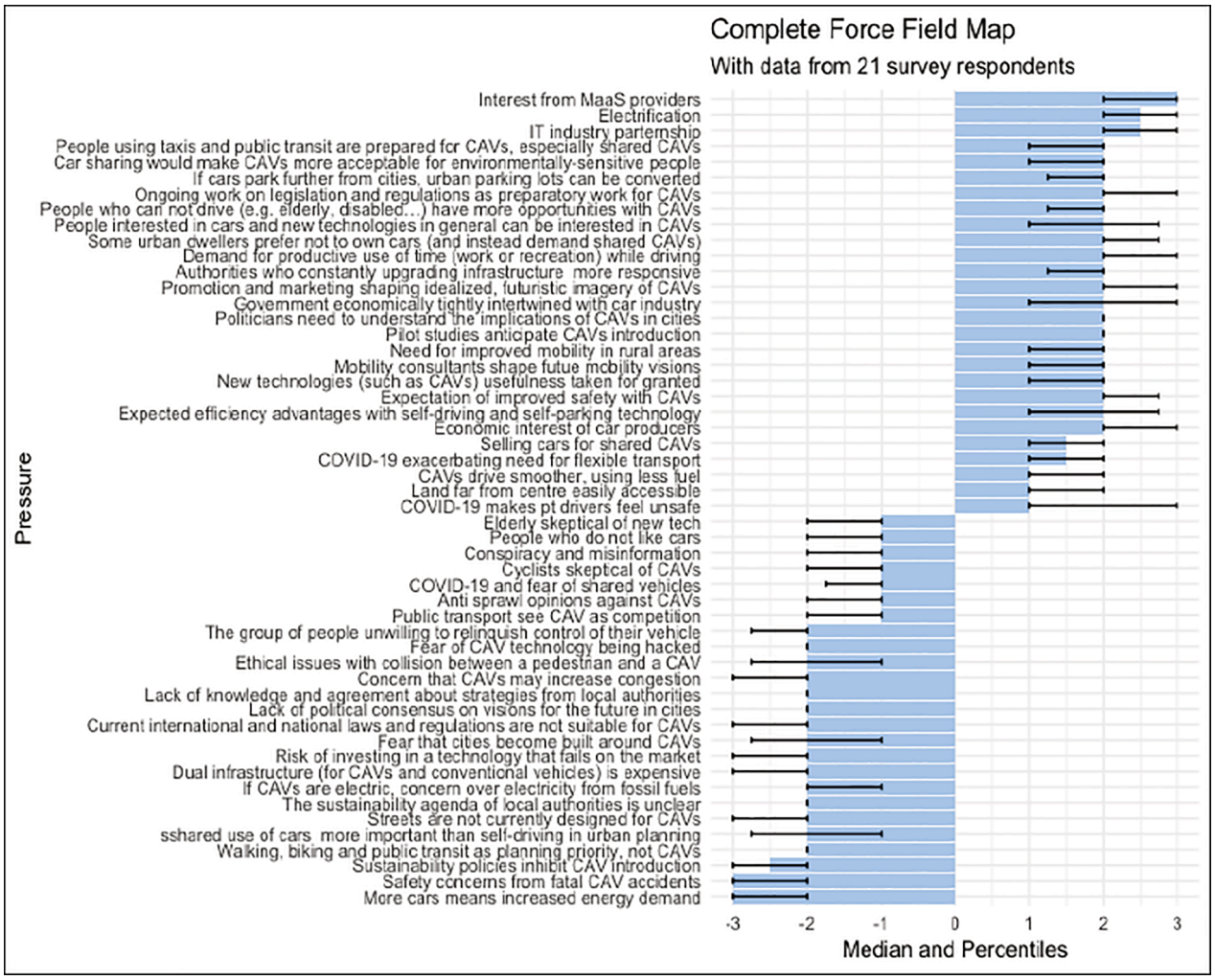

Fig. 3. Complete Force Field Map of all pressures.

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