A Sociotechnical Transition to an Electric Autonomous Vehicle System

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Abstract: Modern economic growth has been based on mass industrial production and consumption, which have heavily relied on fossil fuels and energy waste since the 18th century. Hence, current socio-technical systems are unsustainable in meeting humans' basic needs, such as energy and mobility. Fossil energy resources are non-renewable and, on the one hand, contribute to emissions that cause unreliable harm to the environment. In this research, the prime theory of Transformational Change illuminates how to use science and technology policy to meet social needs sustainably and inclusively in societies. This article answers questions regarding the essential policies and governance measures that states need to implement for the transition to electric autonomous vehicles (AVs) in the socio-technical system. Using meta-synthesis, followed by a case study and interviews with experts in the electric AV field, the article identifies state policies and governance measures to facilitate the transition of the sociotechnical system into electric AVs. The conceptualization of these roles determines that the state's role is influenced by

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policy, governance, and legal decisions, which are ultimately implemented through specific combinations of policies.

Keywords: Electric Autonomous Vehicle, Transition, Sustainable Sociotechnical System, State Policy, Sustainable Transportation

1. Introduction

The focus of both large and small companies on meeting the current market demands prompts industries to ensure the profitability of their businesses by designing and producing products and services that align with market needs. On the other hand, products that are offered to the market at low prices due to mass production and provide extensive after-sales services always receive a higher reception from customers. Over time, this mutual relationship leads to the formation of sociotechnical systems. Systems that provide technical products to industries on one side, and the society that relies on these products on the other side. This bilateral communication leads to the customer's trust and willingness to adopt the current technology, while also instilling fear in the industry of market failure in the event of a technology change. This dynamic creates a kind of lock-in within the industry. Therefore, it is the responsibility of states to facilitate the technological transition from sociotechnical systems formed on the basis of unsustainable and incompatible technologies to those that promote public welfare. This can be achieved by adopting policies and incentives that target both sides of this relationship. Transformational change, as the fundamental theory in this research, serves as a guiding principle to illuminate how state policies and governance measures should align with sociotechnical change towards a more sustainable technology, such as electric AVs. This research attempts to answer the recently raised question of what kind of public policies can facilitate the transition from the current sociotechnical system to autonomous vehicles (AVs). States can function as facilitators that push and champion the diffusion of innovation in the electric AV field.

2. Research Background

The conventional fossil fuel vehicle is an example of an unsustainable and incompatible technology that has led to the development of a sociotechnical system. Societies' reliance on vehicles that consume fossil fuels for decades has shaped numerous social habits among the general public and has also resulted in the development of various occupations and expertise, including design, manufacturing, after-market services, and customer services. While conventional fossil fuel vehicles generate heat and emissions that devastate the environment, they also limit the independence of youth, the elderly, and the disabled in terms of mobility. Human errors and distractions lead to significant crash casualties and fatalities. Additionally, non-smart pathfinding results in traffic jams, causing a loss of time and money.

On the other hand, electric autonomous vehicle (AV) technology not only replaces fossil fuel with electricity, promoting sustainability but also provides independence for individuals with disabilities and the elderly, as well as enabling young people to use cars. Additionally, this technology optimizes energy consumption, reduces labor costs, and minimizes car depreciation. These are all the advantages of electric autonomous vehicles (AVs) over fossil fuel car technology that relies on the driver. These advantages motivate states to adopt the Transformative Change Paradigm and implement policies that facilitate the technological transition from the conventional vehicle socio-technical system to the new socio-technical system of electric AVs.

AV is already a reality; cars that can park automatically, the trains with drivers that commute in capital cities all around the world, are just examples instances of how autonomous are transforming transportation. Transport. The situation in this area is changing rapidly. While prominent automobile manufacturers are primarily focused on increasing the level of automation in their passenger and cargo vehicles, Google and a few other companies have recently begun testing fully automated self-driving vehicles (SDVs), also known as AVs. Currently, autonomous driving and autonomous vehicles (AVs) are among the most frequently researched subjects and popular technologies in the transportation industry. Not only engineers but also movie producers and journalists have developed future-oriented narratives about the merits of self-driving vehicles to promote the social acceptance of this technology.

Self-driving cars benefit from intelligent automation. Generally, automation refers to the technology used for data selection, information transformation, decision-making, and process control. Artificial intelligence (AI) is the underlying technology used in decision-making processes (Hengstler, Enkel, & Duelli, 2016a).

The multinational automotive standardization body, SAE International, published a classification system for levels of autonomy in 2018. According to the SAE standardization organization, six distinct levels of automated vehicles are defined: from conventional driving where the driver is in total control (level 0), to level 5 where the vehicle is totally autonomous and without a driver (only passengers). This technology is potentially disruptive as it promises improvements in mobility systems, optimized use of transport infrastructure, and enhanced accessibility. Beside these technical advantages, questions are raised regarding user and societal acceptance. On one hand, some experts suggest that the application of self-driving vehicle technology in a carsharing or taxi environment would pave the way for the technology to become popular. Because it would be able to provide on-demand mobility at an affordable price and also facilitate multimodality through last-mile travel solutions (Merfeld et al., 2019; Helveston et al., 2019). Past studies indicate that electric autonomous vehicles (AVs) may become increasingly accepted by the public and emerge as a viable transportation option in the near future (Gurumurthy & Kockelman, 2020a). However, the ease with which the general public will adopt this new technology will ultimately determine the trajectory of this new socio-technical system (Borrás and Edler, 2020a). Throughout the past few years, technology has progressed rather quickly, leading to pilot tests being conducted in several cities, most notably Boston, Gothenburg, and Helsinki (Taeihagh & Lim, 2018). Around 30 U.S. states have already passed legislation concerning autonomous vehicles (AVs) (Stocker & Shaheen, 2019). Conventionally, road and vehicle safety decisions are made within a complex framework of regulations from both the private and public sectors. In this arena, the role of the state appears critical due to its regulatory power to establish the limits and patterns of road safety and liability, as well as its role in designing transportation and infrastructure. Therefore, in the process of transitioning the sociotechnical system to electric autonomous vehicles (AVs), the state plays a prominent role. State actors can initiate pilot projects in urban areas and suburbs, experimenting with regulatory support. Furthermore, the states can, to a great extent, act as facilitators, while the responsibility for physical infrastructure planning lies with

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them. Public-wide acceptance of electric autonomous vehicle (AV) socio-technical systems entails planning and implementing public policies, such as the creation of new driving zone classifications, the installation of modern physical traffic signs, and sufficient long-term investments in transport infrastructure.

Purposively, innovation policy is designed to address specific problems. By the same token, it is generally expected to support and provide guidance not only for the development of innovations but also for their dissemination and implementation. This has triggered beliefs that innovation policy should play a salient role in the transformation from the current system to a more societally desirable one, and therefore it should be considered “transformative”. This requirement from the state to develop transformative innovation policies sounds reasonable. However, it has to take into account the empirical and theoretical perspectives simultaneously, particularly regarding the diverse roles that the state must fulfill. In this article, the effective factors in the change of sociotechnical systems are studied. This research attempts to better describe state policies and how they relate to the transition from conventional vehicles to electric autonomous vehicles (AVs) in the socio-technical system. The next section discusses the research methods used, which include meta-synthesis, case studies, and interviews. The research method employed was intended to be systematic and appropriate for the nature of the problem. Section 4 considers the analysis of the research findings, which includes the policy measures taken by the states to facilitate the change from the current sociotechnical system to electric AVs. Section 5 includes a case study and multiple interviews with experts. The research findings are then compared to previous articles, and the research contribution is presented at the end of the section. Ultimately, in section 6, the research conclusion and final suggestions are provided. However, the nature of the research question necessitates planning a research method that addresses both the theoretical and empirical aspects of the issue.

3. Research Method

In this research, meta-synthesis is used as the primary method. Meta-synthesis, as a fundamental scientific research method, enables researchers to gain a comprehensive understanding of the “lay of the land” by integrating and interpreting research findings from multiple qualitative primary studies. The researcher can thereby identify, evaluate, and synthesize previous research findings to provide a summary of current evidence that may contribute to evidence-based practice. Secondly, to empirically evaluate the output of the meta-synthesis, a case study and multiple interviews with experts have been conducted. Consequently, the policies that receive over 75% of the total score from experts are presented as the research results.

The following steps describe the stages of meta-synthesis in this research (Walsh and Downe, 2005; Hoon, 2013).

3-1. Paper Selection Procedure

First, the research subject was searched through the publications in the Web of Science database. For this purpose, the recently published research on related subjects was investigated by searching the keywords in the Web of Science database. The keywords “self-driving” and “policy” were searched in the Web of Science database. According to the results, a total of 45 cases consistent with these keywords were found, which were published by Q1 journals.

3-2. Inclusion and Exclusion Criteria

In this step, a search for previous articles and a meta-synthesis was conducted. For this purpose, first, the aforementioned keywords of this research were searched among Q1 scientific research journals on the Web of Science database, specifically focusing on the most frequently published articles from 2017 onwards. Secondly, the sources found in the previous step were evaluated and screened in a step-by-step manner as follows, to obtain the most valid articles and sources.

A: The titles and abstracts were studied, and unrelated articles were set aside. The articles that proposed policy measures for AVs were approved, while the papers that excluded public policies for AVs were dropped.

B: The content of the remaining articles was thoroughly examined to ensure alignment with the focus of this research. Any irrelevant papers were set aside. The papers that had studied the state policy measures towards autonomous vehicles (AVs) were reviewed.

C: The remaining articles from the previous steps were checked in terms of results, and articles contradicting the necessity of state measures to transform into AVs were excluded.

D: In the last step, evaluation, deep analysis, and synthesis of findings were performed. The remaining sources were thoroughly studied for this purpose. Figure 1 depicts the procedure for selecting papers.

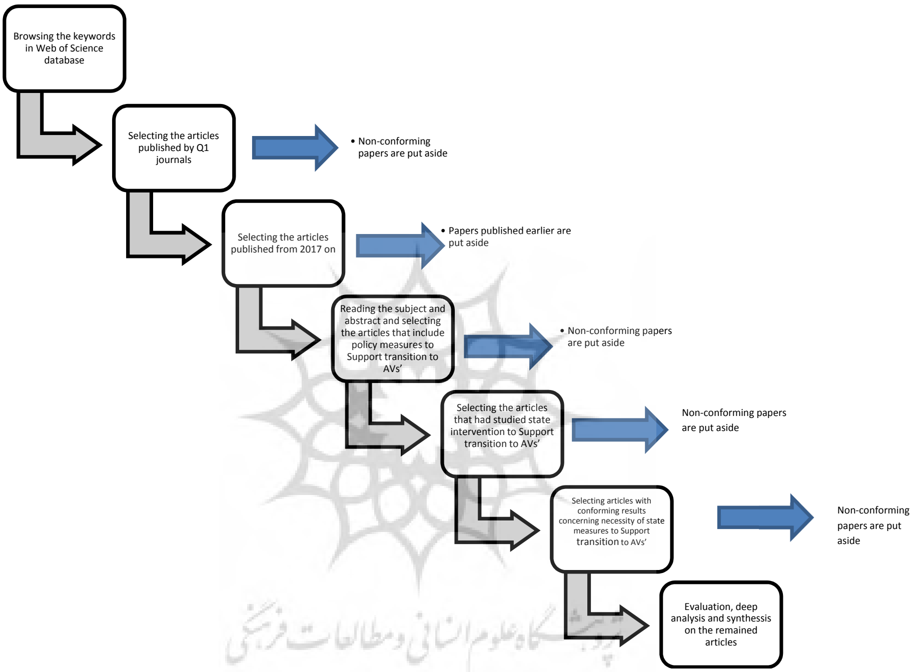

Figure 1. Procedure for selecting papers.

3-3. Paper Selection Procedure Flowchart.

Table 1 presents the 19 final papers, including details such as the distribution of papers per year, the journals in which the papers were published, the methodological aspects of the retrieved articles, and their levels of analysis.

Table 1 presents the final papers, including details such as the distribution of papers per year, the journals in which the papers were published, the methodological aspects of the retrieved articles, and the levels of analysis.

Table 1. Review of the past studies

Year & Title & Author	Research subject	Research limitation	Journal	Methodological Aspects	Level of Analysis
2021 Re-examining path dependence in the digital age: The evolution of connected car business models (Bohnsack et al., 2021) (Bohnsack et al., 2021)	To explore how and why Proliferating digitalization process affects organizational path dependence	The interaction between resource-based and cognitive path dependency still needs to be studied.	Research Policy	a longitudinal multiple case study on connected car business models.	Firm level
2021 Rejecting acceptance: learning from public dialogue on self-driving vehicles (Stilgoe & Cohen, 2021) (Stilgoe & Cohen, 2021)	this paper, explores the tensions between democratic experiments and technological ones with a focus on policy for nascent self-driving/ automated vehicles	The social science in debates about self-driving vehicles is undermined	Science and Public Policy	exploring the flaws in some model of public engagement that imagines increased public awareness	State policy
2020 The roles of the state in the governance of socio-technical systems' transformation (Borrás & Edler, 2020a) (Borrás & Edler, 2020a)	This paper studies the embedded role of the state in four distinct modes of governance of socio-technical systems (cryptocurre-ncies, smart cities, automated vehicles, and nuclear power).	Not considering issues such as time and the change of the roles the state plays over time.	Research Policy	Using a three-pillar analytical model	State policy Level

Year & Title & Author	Research subject	Research limitation	Journal	Methodological Aspects	Level of Analysis
2020 Modeling Americans' autonomous vehicle preferences: A focus on dynamic ride-sharing, privacy & long-distance mode choices (Gurumurthy & Kockelman, 2020b)(Gurumurthy & Kockelman, 2020b)	It provides insights on privacy concerns, safety and dynamic ride-sharing with strangers, long-distance travel and preferences for smarter vehicles and transport systems.	It lacks critical inquiries into new AV and Shared AV design in the absence of a driver such as a public trust making plan	Technological Forecasting and Social Change	Using multinomial logit models	Micro Level
2020 Public attitude toward self-driving vehicles on public roads: Direct experience changed ambivalent people to be more positive (Liu & Xu, 2020a)(Liu & Xu, 2020a)	It recorded changes in attitude structure (positive, negative, ambivalent, and indifferent) toward the issue of whether AVs should be allowed riding on public roads	young students were referred as the sample and people from other walks of life views is ignored.	Technological Forecasting and Social Change	Multiple quantified scenarios	Policymakers and automakers Level

Year & Title & Author	Research subject	Research limitation	Journal	Methodological Aspects	Level of Analysis
2020 More friends than foes? The impact of automobility-as-a-service on the incumbent automotive industry (Wells et al., 2020) (Wells et al., 2020)	the paper argues that AV is not necessarily disruptive to the incumbent automotive companies	inter-dependence of socio-technical systems and incumbents has not received enough attention	Technological Forecasting and Social Change	a longitudinal immersion study	Industry Level
2020 Designing coopetition for radical innovation: An experimental study of managers' preferences for developing self-driving electric cars (Czakon et al., 2020) (Czakon et al., 2020)	The major premise of this study is that managers purposefully shape the business context for radical innovation	the interaction between coopetition design factors such as formal governance and knowledge sharing as well as individual factors is not well studied	Technological Forecasting and Social Change	Scenarios & Hierarchical Bayes Multinomial Logit Regression	Interfirm Level

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Year & Title & Author	Research subject	Research limitation	Journal	Methodological Aspects	Level of Analysis
2020 The role of policy entrepreneurs in defining directions of innovation policy: A case study of automated driving in the Netherlands (Gironés et al., 2020)(Gironés et al., 2020)	how and by whom the directions of innovation policy are set	Little attention to the assessments and evaluation of contribution of technologies to transformative change goals	Technological Forecasting and Social Change	Case study	State policy Level
2020 Incumbent-led transitions and civil society: Autonomous vehicle policy and consumer organizations in the United States (Hess, 2020)	explores the role of civil society in the acceleration and deceleration of sociotechnical transitions	Overestima-tion of general public’s low opinion of AVs.	Technological Forecasting and Social Change	A dataset which was developed by reviewing the news-related web pages of the active CSOs on CAV policy issues in the U.S.	Macro Level

Year & Title & Author	Research subject	Research limitation	Journal	Methodological Aspects	Level of Analysis
2020 An empirical discourse on forecasting the use of autonomous vehicles using consumers' preferences (Saeed et al., 2020) (Saeed et al., 2020)	studies the consumers' preferences in small- and medium-sized metropolitan areas, based on their travel behavior and household characteristics, socio-demographic features, awareness about AV technology and new travel choices, psychological factors, and built environment features.	Public transport modes (e.g., autonomous buses for the last mile) has not received enough attention.	Technological Forecasting and Social Change	a random parameters logit model is employed to study	Micro Level
2020 What drives the acceptance of autonomous driving? An investigation of acceptance factors from an end-user's perspective (Nastjuk et al., 2020)(Nastjuk et al., 2020)	It studies how social influence, system characteristics, and individual factors determine individual acceptance of autonomous driving.	The factors that shape the user's acceptance such as such as private ownership, leasing, or shared autonomous vehicles and Rides were not clarified to the participants.	Technological Forecasting and Social Change	a qualitative research model based on the technology acceptance model, validated with an online survey of 316 participants	Micro level

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Year & Title & Author	Research subject	Research limitation	Journal	Methodological Aspects	Level of Analysis
2019 Who will drive the transition to self-driving? A socio-technical analysis of the future impact of automated vehicles (Marletto, 2019)	To show that the impacts automated driving will generate depends on the competition between different networks of innovators, each supporting its own approach to the integration of automated driving into the system of urban mobility.	Undervaluing the top-down innovation policy making for transition.	Technological Forecasting and Social Change	Scenarios	Network Level
2019 Understanding Smart Cities: Innovation ecosystems, technological advancements, and societal challenges (Appio et al., 2019)	Understanding Smart Cities: Innovation Ecosystems, Technological Advancements, and Societal Challenges	Overfocusing on the role of smart cities in transition	Technological Forecasting and Social Change	data analysis using thematic clusters	Ecosystems Level

Year & Title & Author	Research subject	Research limitation	Journal	Methodological Aspects	Level of Analysis
2019 Carsharing with shared autonomous vehicles: Uncovering drivers, barriers and future develop-ments–A four-stage Delphi study (Merfeld et al., 2019)	A holistic understanding of drivers, barriers, and future developments in carsharing with Shared AVs over the next ten years.	Not paying attention to the necessity of policy making for public trust in privately owned AVs.	Technological Forecasting and Social Change	a four-stage exploratory Delphi-study with 40 international experts	State policy Level
2019 Perceptions and expectations of autonomous vehicles – A snapshot of vulnerable road user opinion (Penmetsa et al., 2019)	It explores opinions regarding the perceived benefits and challenges of AVs' among vulnerable road users – in particular, pedestrians and bicyclists	The sample is only limited to bicycle-users	Technological Forecasting and Social Change	Analysis of the survey-based data	Micro Level

Year & Title & Author	Research subject	Research limitation	Journal	Methodological Aspects	Level of Analysis
2019 Towards an integrated urban development considering novel intelligent transportation systems Urban Development Considering Novel Transport (Richter et al., 2020)	This article proposes a concept of how to tackle mandatory digitalization of cadastral information	data distributed to different stakeholders is "out of control" of the data owner and different versions of the very same data circulates. These issues do not exist if an integrated framework is used	Technological Forecasting and Social Change	Some Heuristic qualitative method	State policy and industry level
2019 Testing future societies? Developing a framework for test beds and living labs as instruments of innovation governance (Engels et al., 2019)	this paper, develops an analytic framework for test beds and living labs as a distinctive approach to innovation.	very little explicit attention was paid to regulatory, political, or social differences between the current setting and the rest of the world.	Research Policy	in-depth empirical analysis of data from two case studies	Network Level

Year & Title & Author	Research subject	Research limitation	Journal	Methodological Aspects	Level of Analysis
2018 Level 5 autonomy: The new face of disruption in road transport (Skeete, 2018)	This paper assesses the major policy challenges that face industry regulators s and examines the early-stages of the AV transition within the EU automotive industry	Lack of consideration of empirical data	Technological Forecasting and Social Change	Not illuminating that how AVs will be embedded into the existing road transport system	State policy Level
2016 Applied artificial intelligence and trust—The case of autonomous vehicles and medical assistance devices (Hengstler et al., 2016b)	This paper explores how firms systematically foster trust regarding applied AI	Total reliance on case study	Technological Forecasting and Social Change	Empirical analysis using nine case studies in the transportation and medical technology industries	Firm Level

4. Analysis of Findings

As a radical innovation in the automotive industry, electric autonomous vehicles (AVs) are gradually becoming more common. The Society of Automotive Engineers (SAE) has classified driving automation into six levels. Among these levels, vehicles with moderate automation (Level 3), high automation (Level 4), and total automation (Level 5) are capable of operating in a “self-driving” mode using an intelligent automated system. Level 5 autonomous vehicles (AVs) are equipped with an automated system that can perform all driving tasks in any situation. Generally, the term “AV” refers to vehicles ranging from Level 3 to Level 5, while the term “SDVs” (which stands for self-driving vehicles) exclusively refers to Level 5 AVs. Human errors are known to be the major causes of traffic crashes. Research conducted by Read et al. (2021), Breen et al. (2020), and Cai (2020) found that over 90% of traffic crashes are directly related to human errors or choices. Hence, autonomous vehicles (AVs) with built-in artificial intelligence systems are replacing fallible human drivers. Electric AVs are expected to substantially mitigate traffic crashes (Accelerating the Next Revolution in Roadway Safety, n.d.). For this reason, public policies that support the transition to electric autonomous vehicles (AVs) are generally considered convincing due to their potential to significantly reduce fatalities on the roads (Hess, 2020). Wide popularity of electric AVs also promises to decrease congestion and automotive emissions, increase mobility for those who are currently unable to drive, improve battery consumption efficiency, maximize space utilization, and enhance productivity. However, it also entails risks and challenges regarding passenger safety, data security, legal liability, and other regulatory issues (Haboucha et al., 2017; Hardman et al., 2019; Penmetsa et al., 2019; Pettigrew et al., 2019). As people are a decisive factor in technology adoption and diffusion, it is essential to pay attention to public opinions and perceptions. Because the general public's positive attitude is important for the widespread adoption of electric AVs. Also, a positive attitude change may be beneficial for improving electric AV safety (Hilgarter and Granig, 2020; Moody, Bailey, and Zhao, 2020). Becoming more positive, people will support increased testing and operation of autonomous vehicles (AVs) on public roads. This will result in higher vehicle mileage and, consequently, improved AV safety. On the contrary, if public attitudes and concerns about a technology are met with reluctance by industry or regulators, it will trigger dissatisfaction and public resistance (Liu and Xu, 2020a). For this reason, resistance to change involved in the configuration of a complex socio-technical system (including infrastructure, regulation, or even supply chains) has to be figured out. One congruent policy is to encourage the holders of accumulated manufacturing knowledge. It means entrant startups as well as Incumbents of electric AV area should be encouraged by states (Wells et al. 2020).

For instance, states should encourage them to invest in electric AV patents, manufacturing plants, or related equipment (Bohnsack, Kurtz, and Hanelt, 2021). States can play a role in mobility sociotechnical systems through road safety authorities and transport planners. Policies can be developed to allocate land or prepare infrastructure, and regulations can be planned to facilitate the successful introduction of electric autonomous vehicle (AV) technology into the market (Saeed et al., 2020; Penna & Geels, 2015).

Municipalities can participate part these such policy order foster breed societal (Abel, (Abel 2021). The governance of experimental spaces, including information transfer from vehicle to vehicle and vehicle to infrastructure instruments, is another issue that deserves policymakers' attention. They are better off being held by state-owned institutions. Also, a strong focus on state experiments and tests is needed. This is to highlight the feasibility of vehicle automation. Making use of public infrastructure as an asset not only facilitates experiments but also encourages international players to test smart mobility innovations in the country. Furthermore, policies such as exempting tests on automated driving on public roads can be effective in facilitating the alteration of sociotechnical systems (Gironés, van EST, and Verbong, 2020). That is why U.S. lawmakers tend to remove barriers for testing and field operations to promote autonomous driving (Nastjuk et al., 2020; Mahdavian et al., 2021).

Temporary exemptions from regulatory authorities for pilot projects and test beds launched by private firms some university campuses or are is another example of facilitative taken by of states. Policymakers should also focus on improving existing infrastructure, such as dynamic traffic signal coordination, to reduce safety problems (Nastjuk et al., 2020). Actually, traffic signs need to be compatible with autonomous systems. Hence, the provision of new physical traffic signs and adequate long-term investment plans for transport infrastructure by the government can be effective. Promoting the development of shared autonomous transport services is also suggested (Borrás and Edler, 2020b; Fraedrich et al., 2019). This may change the ratio of cars to owners because every single self-driving taxi has the potential to replace between 6 and 10 privately owned cars (Skeete, 2018).

Societal acceptance of electric autonomous vehicles (AVs) relies on public trust in the implementation of artificial intelligence (AI) (Seetharaman et al., 2020; Wu, Wang, and Yuen, 2023). Operational safety and data security are decisive factors that promote the performance dimension of trust in this technology.

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Cognitive compatibility (how people think and feel), trialability, and usability are the primary factors associated with the dimension of trust in a technology. High public transparency is crucial for the development of electric AV technology, which can be achieved through the gradual introduction of the technology. Beside early, proactive, and application-based communication, as well as the transmission of benefit-related information to the general public, all together brings up societal trust in electric AV technology (Hengstler, Enkel, and Duelli, 2016b). For this reason, policies aimed at increasing trust in autonomous driving seem to be necessary. Policymakers and manufacturers can also strongly influence the positive public perception of the usefulness of autonomous vehicles by clearly highlighting the advantages they have over conventional vehicles (Nastjuk et al., 2020). Liability is another important issue. Actually, in the event of a crash involving a driverless car, who would be held responsible - the car manufacturer or the software provider? The legal dilemma deserves illumination (Phillips and Linstone, 2016; Martinho et al., 2021; Alawadhi et al., 2020; Etienne, 2022). The public perception of what is considered ethical in crash cases, as well as similar situations such as determining blame for a computer's decision or establishing criteria for using electric AVs, has not yet been determined (Gurumurthy and Kockelman, 2020b). Research findings on legislative, juridical, and public support measures for electric AVs suggest that liability may shift from the vehicle occupant to the manufacturer or fleet operator (Richter et al., 2020). For this reason, stakeholders in the insurance industry estimate that autonomous vehicles (AVs) will reduce private automotive insurance premiums by as much as 80% (Skeete, 2018). Information and Communications Technology (ICT) and advanced traffic management strategies, summarized as intelligent transport systems (ITS), are both precursors to autonomous vehicle technology (Richter et al., 2020). Ownership of data is another major concern for users of AV technology, which necessitates a robust legal infrastructure (Skeete, 2018; Ljubi and Groznik, 2023). Clear and robust security standards must be defined by policymakers, as hacking or terrorism in the context of autonomous driving poses a threat to societal security (Nastjuk et al., 2020).

Taking into account the growing concerns regarding the use of personal information, such as the recording of user locations by Smartphone GPS, there is a clear need for legislation in this area (Gurumurthy and Kockelman, 2020b).

In addition to command-and-control (CAC) policies, policies aimed at facilitating Intelligent Transportation Systems (ITS) at the EU level for both passengers and the transport of goods are regulations that seek to persuade consumers and producers to modify their behavior. “Technology-forcing” policies, such as mandating performance standards to drive specific technological outcomes, are sometimes implemented by states. In exchange for shifts in stakeholders’ behavior, market-based instruments (MBIs) can be provided as financial incentives to stakeholders involved in conventional technology. Also, market acceptance policies that target factors such as public acceptance, usage costs, service convenience, business opportunities for providers, and the changing value of privately owned vehicles may be effective for social acceptance of electric AV technology (Merfeld et al., 2019). Policymakers should also ensure that pre-launch investment costs are not passed on to the end user, as mass production will significantly reduce these costs. (Nastjuk et al., 2020). Because policies aimed at reducing the price of technology could result in increased public willingness to pay (Penmetsa et al., 2019). Policymakers should subsidize relevant research to investigate aspects such as performance improvement and successful market penetration (Nastjuk et al., 2020; Helveston et al., 2019).

Sustainable mobility is an issue that has issue has become important. Consequently, consequently policy interventions to foster sustainable have has found supporters (Penna Geels, Geels 2015). Hence, states resort to policies as a means to facilitate the adoption of electric AVs. Pilot test facilitation to increase the diffusion rate of electric autonomous vehicle (AV) innovations is an example of such policies (Marletto, 2019). Also, public informing policies for better perceptions and acceptance (Penmetsa et al., 2019), in addition to providing opportunities for direct experience, will be helpful for the formation of positive attitudes and the diffusion, as well as the greater adoption, of electric AV technology (Liu and Xu, 2020b; Stilgoe and Cohen, 2021).

Another term that has recently gained attention and has been used for various purposes is “smart city.” Smart city constitutes an ecosystem of people, companies, products, services, and society that cooperate creatively to facilitate innovation within the city (Cosgrave, Arbuthnot, and Tryfonas, 2013; Dana et al., 2022; Gupta, Panagiotopoulos, and Bowen, 2020). State policies supporting smart city infrastructure, as well as policies to support test beds and living labs, represent an experimental and co-creative approach to testing, demonstrating, and advancing new sociotechnical arrangements (Engels, Wentland, and Pfotenhauer, 2019). Such policies bring about the opportunity for dialogue with citizens (Stilgoe and Cohen, 2021) and help governments raise awareness of citizens' views. This paves the way for planning co-creation programs with citizens regarding electric AVs and sustainable transportation (Penna and Geels, 2015). Also, environmental policies that rely on smart and sustainable transportation (Appio, Lima, and Paroutis, 2019) are examples of policies that facilitate the alteration of sociotechnical systems. Beside state-side support (Helveston et al., 2019), electric AV technology developers need to conduct awareness campaigns to account for the rural applications of this technology at the development stage. Policy-makers, transport planners, service providers, highway agencies, vehicle manufacturers, and all other stakeholders will need to design comparable levels of preparedness (Saeed et al., 2020). Policymakers and manufacturers could inform the public with clear information based on the functionality of autonomous driving (Nastjuk et al., 2020). Governments can actively participate in designing this mobility revolution by educating lawmakers. Educating lawmakers about the benefits and implications of these innovative services and persuading them to not restrict their communication efforts solely to consumers is crucial. It is important to consider that electric AV technology allows for greater accessibility to mobility, benefiting various groups such as the elderly, children, and the handicapped. Spaces could be allocated for co-creation between policymakers and entrepreneurs to strategize national and international initiatives for vehicle automation. Also, roundtables could be set up to facilitate the exchange of information and enable discussions among experts in each respective domain. Generally, these experts, who are industrial and business representatives, public officials, and policymakers, come together to provide input for future policy developments in automated driving (Gironés, van Est, and Verbong, 2020). Therefore, legislation is required to regulate not only driving, but also relevant topics such as insurance, data protection, borderless mobility, and cyber-attacks. This legislation aims to minimize barriers to the development of technological maturity of electric AVs and enable iterative elaboration on long-term solutions (Merfeld et al., 2019).

Recent research has revealed that electric AV technology deserves to be regulated and supported by national innovation policies (Skeete, 2018). However, this research attempts to challenge the findings in the real arena. For this purpose, the researchers implemented a study on a case in the same area and then conducted interviews with two experts. The case study investigates a knowledge-based entrant that has recently started developing autonomous vehicle technology for trucks.

5. Case Study

5-1. Case Context

This case study is the result of research and study Autoro Company during the summer of 2022. Autoro knowledge-based Co.[1] company that specializes in designing and implementing smart robotic and mechatronic systems. They are the developers of the hardware, software, and subsystems necessary for self-driving cars. The systems designed by Autoro company, which combine high-precision imaging technology with neural network technology, provide the foundation for the use of artificial intelligence in autonomous driving. The history of Autoro, a knowledge-based company, dates back to 2017. Initially, this company started as a startup team and focused on designing an intelligent driver assistance system. And it considers achieving a fully autonomous self-driving system, without the need for a driver, as the ultimate goal of its future endeavors. Autoro Company was legally established in 2021 and became one of the Knowledge-Based Companies in Iran. In 2022, Autoro Co. also became one of the knowledge-based companies in Tehran University Science and Technology Park. The company's developed product is called Autorobox, which is an advanced driver assistance system.

Autor box at level 1 in terms of the 5 levels of self-driving. Autoro Co. has recently obtained quality approval from the reference laboratories approved by the Iranian National Standards Department for installing its system on the Ataman Lorry, a new product by Iran Khodro Diesel Co. Additionally, Autoro Co. has entered into negotiations with Amico, another major Iranian truck manufacturing company.

1. Autoro.co

The key features of the company's developed product:

1. Assist system for driving between lanes
2. Emergency Braking System
3. Driver Distraction and Sleepiness Sensor System and Warning System

5-1-2. Challenge Description

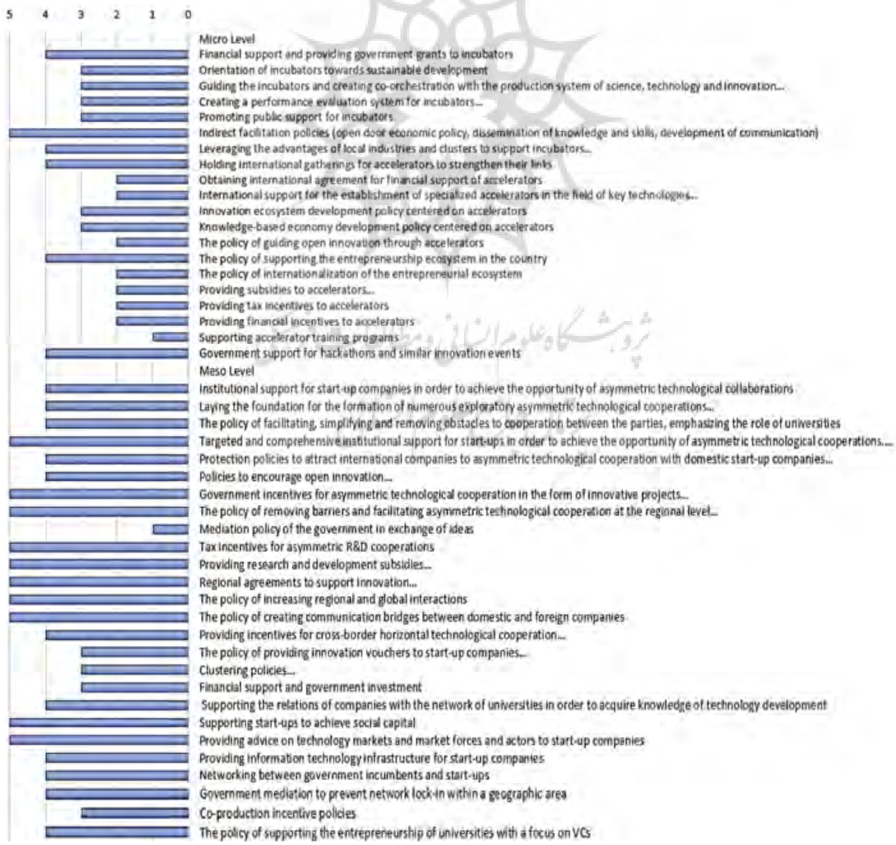
The study conducted on Autoro reflects the fact that this new knowledge-based company has always sought asymmetric technological cooperation with the leading domestic automobile companies to obtain complementary assets. One of the significant efforts made is Autoro's request for cooperation with Amico, an Iranian truck and lorry manufacturer. It is worth mentioning that goods transportation by truck requires many hours of non-stop driving, which increases driver fatigue and the possibility of human error. Therefore, the necessity of an autonomous system that intelligently manages the vehicle is crucial.

Domestic car manufacturing companies do not show much desire to upgrade the technology of their products due to the government's unconditional support policies for domestic manufacturers. This policy has resulted in the formation of an oligopoly market. This statement can be interpreted from the perspective of science and technology policy. It suggests that the government's support policies have inadvertently contributed to the entrenchment of conventional non-intelligent cars in the socio-technical system. To transition to a self-driving socio-technical system, it is necessary to revise these policies. On the other hand, the National Iranian Institute of Standard's reluctance to mandate the upgrade of current vehicle technology has contributed to the factor mentioned above. According to the team leader of Autoro, it is also stated that Amico Truck Company, which manufactures both heavy and light trucks, serves as evidence for this assertion. Amico Truck Company has not accepted Autoro's proposal for asymmetric technological cooperation. This decision is based on their confidence in selling their products in the current, relatively non-competitive market. Additionally, there is no obligation from authorities such as the Iranian Standard Institute to engage in such cooperation.

Among Autoro Co.'s various experiences with asymmetric technological cooperation, one notable collaboration is with Iran Khodro Diesel Co. This ongoing project, which started in 2021, involves Autoro Co. adapting its intelligent driving assistance technology to a newly developed product by Iran Khodro Diesel called the Ataman Truck. For this purpose, Autoro Co. made an effort to apply Iran Khodro Diesel standards in its products and tried to obtain various approvals from laboratories approved by the Iranian Standard Institute. Despite the progress of this asymmetric technological cooperation, the reluctance of the incumbent domestic car manufacturing company has slowed down the process.

5-1-3. Interview with Autoro Team Leader

At the next part of the study, the Mr. Haddad Tabrizi of the team, team was called to participate participating in an open interview. He was asked about the expected government policy measures to facilitate asymmetric technological cooperation between startups like Autoro and incumbents like Iran Khodro Diesel. The essay from this interview was analyzed using MAXQDA software, and the results are illustrated in Figure 2.



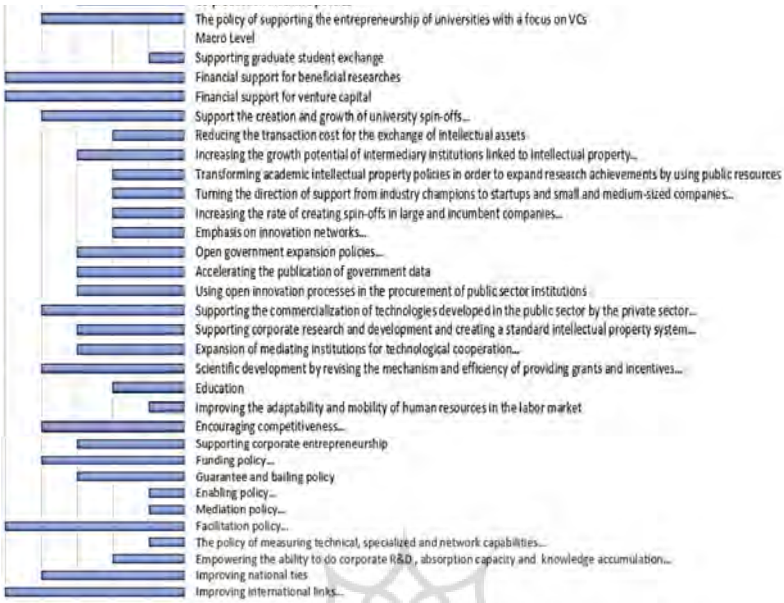


Figure 2. Case study analysis bar chart depicting the effectiveness degree of Hi-Tec startup support policies from the perspective of Autoro knowledge-based team

Having synthesized the findings in section 4, a list of policies and governance measures to facilitate the transition from conventional vehicles to electric AV sociotechnical systems has been obtained. That list forms the foundation for interviews with experts. During the interviews, each interviewee is asked to rate the effectiveness of every item on a scale of 1 to 5.

Interview No. 1

The first is[1] a Ph.D. holder in control and power from the Queen Mary University of London and a full professor at the Shiraz University of Technology. Also, he is the head of the newly established Intelligent Vehicle Design Center at this university. The Intelligent Vehicle Design Center of Shiraz University of Technology has recently succeeded in developing the "Oxygen" electric vehicle[2] through an asymmetric technological cooperation with Khodro Sazan Jonoob (KSJ Motors) and Iran Telecommunication Manufacturing Company (ITMC) in 2022.

1. Please see Dr. Akbar Rahide's web profile
2. Oxygen EV : Iran Unveils Its First and World's Cheapest All-Electric Car in 2022. Please follow the link

During this interview, which was conducted using a structured questionnaire, the interviewee was asked rate to the effectiveness of governance measures and facilitating on a scale of 1 to 5. The focus of the interview was the transition from conventional vehicles vehicle to the electric AV socio-technical system.

From this expert's point of the state should take the state's positive in the field of self-driving electric vehicles. These measures may include legalizing the use of commuting of self-driving electric ensuring sufficient necessary bandwidth for the traffic of these vehicles, implementing cars that promote sustainable and environment-oriented technology, and facilitating regular continuous meetings between experts and investors in field. These actions are crucial for are that to play a significant role envision in the development field of self-driving electric vehicles. On the other hand, this expert disagrees with the policies that support subsidies and tax exemptions. Also, he rejects forcing consumers to change their behavior.

Interview No. 2

The second expert[1] holds a Ph.D. in power engineering from Shiraz University of Technology and a post-doctoral degree in power engineering from the University of Michigan, USA. He is an assistant professor at Shiraz University of Technology. His research fields are data security, renewable energy, and artificial intelligence. He has also gained experience working in a self-driving electric vehicle development team at the University of Michigan, USA. This expert was also asked to give scores ranging from 1 to 5 to evaluate the effectiveness of state policies and governance measures in facilitating the transition from conventional fossil fuel-powered cars to the sociotechnical system of electric self-driving vehicles.

From this expert's point of view, the most effective policies include state incentives for incumbents to invest in the field of self-driving electric cars and their trial production, government subsidies to parts suppliers, government facilities to generate the necessary urban and road infrastructure such as charging stations, and legislation to facilitate the traffic of these cars. Additionally, allocating the government budget for cooperation between the Ministry of Industries and the Ministry of Science to advance joint projects in this field are the most effective governance measures and facilitating policies for the transition to electric AVs.

1. Please see Dr. Abdollah Kavousi Fard's web profile

On the other hand, according to this expert, the least effective state policies in this field are technology education and technology dissemination policies, policies that subsidize technology for consumers, and the state's role in designing systems based on self-driving electric vehicle technology.

Interview No.3

The third expert is Dr.Behrouz Safarinejadian[1]. He is a recognized researcher and a full Professor of Electrical Engineering at Shiraz University of Technology. Dr. Safarinejadian's research subjects of interest include Multi-Agent Systems, Intelligent Control, Computational Intelligence, System Identification, Distributed Control, Stochastic Control and Distributed Sensor Networks.

From this expert's point of view the most effective policies includes Investment policy to create urban and suburban transportation infrastructure with self-driving electric vehicles. The least effective policies according to this expert include Policies to change the behavior of consumers and producers through monitoring and inspection for the mandatory use of self-driving electric vehicle technology by the consumer and compliance with the special standards of self-driving electric vehicles by the manufacturer, Environmental protection policies relying on local solutions for sustainable and smart transportation, Granting car purchase subsidies to consumers of self-driving electric cars and The policy of granting subsidies to foreign manufacturers who have the technology to produce batteries, motors and control systems inside the country. This expert states that the transition to autonomous AV sociotechnical system entails long term studies and steady governmental plans.

Interview No. 4

The fourth expert is Dr. Mohammad Hossein Shafiei 2Professor of Electrical Engineering at Shiraz University of Technology. Dr.Shafiei's research subjects of interest include nonlinear control, optimal control, Control of air vehicles, Guidance and navigation, robust control, and Autopilot.

According to this expert the most effective policies on transition to autonomous AVs include: The policy of pushing incumbents to invest on intellectual property,

1. Please see Dr Dr.Behrouz Safarinejadian's web profile
2. Please see Dr. Mohammad Hossein Shafiei's web profile

infrastructure, production facilities and equipment necessary for self-driving electric cars, Providing government incentives to incumbents to enter the self-driving electric vehicle supply chain, Creating a legal infrastructure in the field of transportation governance and road safety for the traffic of self-driving electric vehicles, Governance policies in the field of vehicle-to-vehicle and vehicle-to-information technology infrastructure, Policies to facilitate sustainable transportation, Granting car purchase subsidies to consumers of self-driving electric cars, The policy of supporting the increase in the production of self-driving electric cars to mass production in order to minimize the consumer price through economies of scale, The policy of providing subsidies for the purchase of electric cars to consumers and the government's investment in electric car infrastructure and charging stations, Subsidization and tax exemption for creating urban and road infrastructure for electric AV transportation, Step-by-step improvement of the required standards of electric AVs and related infrastructure in exchange for granting subsidies and exemptions. According to the fourth expert's remarks social acceptance of electric vehicles should be the priority of the governmental plan and markedly be pondered before autonomous-ness. He also states that lessening the consumer price lies meaningful effect on the transition to AVs.

Interview No. 5

Expert no.5 is Dr. Seyed Habibollah Tabatabaeian 1 a member of the Faculty of Management and Accounting of Allameh Tabataba'i University and the editorial board of the Journal of Technology Development Management. His Research Interests include Policymaking in science and technology; Technology Management and Technology evaluation. This expert values the entire list of policies the most. He believes that total engagement of the state in all aspects is bare-bone essential.

Interview No. 6

Expert no.6 is Dr. Tahereh Binazadeh Distinguished Researcher of Shiraz University of Technology a faculty member and Professor of Control in this university. Her research subjects of interest include Nonlinear control, Optimal control, robust control, Complex systems, Optimal control, Time-delay systems,

1. Please see Dr. Seyed Habibollah Tabatabaeian's web profile

Fractional order systems, Singular systems, Positive systems, Autopilot Design, Guidance, and navigation. The scores given by this expert is shown as “Expert no.6 scores” in Table 2.

The list of policy mixes obtained from meta-synthesis and were given to the experts subsequently is in Table 2. Each of the experts has scored the effectiveness of the policy mixes with scores 1 to 5.

Table 2. Contains the list of policies and interviewees’ scores.

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs‘	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
The policy of pushing incumbents to invest on intellectual property, infrastructure, production facilities and equipment necessary for self-driving electric cars.	4	5	4	5	5	2	25
Providing government incentives to incumbents to enter the self-driving electric vehicle supply chain.	2	5	2	5	5	2	21
Supporting start-up companies active in the field of self-driving electric vehicles.	4	3	3	4	5	1	20
Creating a legal infrastructure in the field of transportation governance and road safety for the traffic of self-driving electric vehicles.	4	5	4	5	5	1	24
Establishing regulations in the field of urban transportation for the traffic of self-driving electric vehicles.	5	4	3	2	5	1	20
Development of government programs in order to allocate resources for self-driving electric vehicles.	1	5	4	3	5	2	20

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs‘	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Diffusion and education policies for the social acceptance of self-driving electric vehicles.	4	3	3	3	5	1	19
Governance policies in the field of vehicle-to-vehicle and vehicle-to-information technology infrastructure.	4	2	4	5	5	1	21
Legal support for the experimental use of self-driving electric vehicles in urban and suburban environments.	3	4	3	4	5	2	21
Temporary exemptions from governance rules for pilot production projects by private companies, universities and science and technology parks.	1	3	4	4	5	3	20
Investment policy to create urban and suburban transportation infrastructure with self-driving electric vehicles.	4	3	5	3	5	2	22
Supporting the expansion of shared public transportation services using self-driving electric vehicles.	2	4	2	3	5	2	18
Education and diffusion policies to gain public trust in self-driving electric vehicle technology	3	3	2	4	5	2	19
Personal data and information governance policies aimed at protecting the privacy of self-driving electric vehicle technology users.	4	4	4	2	5	2	21

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The governance measures and state policies in line with the transition to the socio-technical system of electric AVs'	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
The policy of conditional support for the developers of self-driving electric vehicle technology, provided that user security is upgraded to the level of global standards in a very limited period of time.	4	2	3	3	5	1	18
Government support policy for high-tech start-ups and knowledge-based firms for negotiation and technological cooperation with leading foreign companies active in self-driving electric vehicle technology.	3	3	2	3	5	3	19
Development of a legal infrastructure to transfer responsibility for damages and losses caused by accidents from the owner and driver of the self-driving car to the technology manufacturer and supplier.	4	3	3	4	5	1	20
The policy of providing information technology infrastructure and bandwidth necessary to support artificial intelligence equipment used in self-driving electric cars.	5	2	4	3	5	2	21

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs‘	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Policies to change the behavior of consumers and producers through monitoring and inspection for the mandatory use of self-driving electric vehicle technology by the consumer and compliance with the special standards of self-driving electric vehicles by the manufacturer.	1	3	1	2	5	2	14
Providing financial incentives to stakeholders, (both producers and consumers,) in exchange for accepting self-driving electric vehicle technology.	2	4	4	4	5	1	20
Policies to facilitate the intelligent transportation of cargo and passengers.	4	3	3	3	5	1	19
The policy of transferring responsibility for damages and casualties caused in self-driving car accidents from the owner and driver to the manufacturer and smart cargo and passenger transport companies.	4	3	3	4	5	1	20
Policies and rules governing access to data and data ownership of self-driving electric vehicle users.	3	2	4	2	5	2	18
Supporting the use of self-driving electric vehicles in the city taxi fleet.	4	4	2	3	5	1	19

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs'	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Education and diffusion policies for the use of self-driving electric vehicles	4	2	3	4	5	1	19
Policies for the dissemination of innovations in the field of artificial intelligence and self-driving electric vehicle batteries and engines.	2	3	4	4	5	2	20
The policy of facilitating the limited and experimental production of self-driving electric vehicles.	3	5	3	4	5	3	23
Policies to facilitate sustainable transportation.	4	3	4	5	5	3	24
The policy of supporting the creation of smart city infrastructure to know the views of city residents and co-creation with citizens regarding electric vehicle technology and the necessary infrastructure for sustainable transportation.	4	3	2	4	5	3	21
Environmental protection policies relying on local solutions for sustainable and smart transportation.	5	4	1	3	5	3	21
Granting car purchase subsidies to consumers of self-driving electric cars.	3	2	1	5	5	1	17
Policies to create opportunities for suppliers and facilitate the provision of services required by self-driving electric vehicles.	3	3	2	3	5	1	17

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs'	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Establishing regulatory laws regarding insurance, user data protection and security against cyber attacks	4	2	4	3	5	2	20
Policies to remove barriers, facilitate, and support research and development in the field of artificial intelligence and directing it towards self-driving electric cars.	4	3	4	2	5	2	20
The dynamic role of the government in the design of transportation systems based on self-driving electric vehicles.	2	2	4	3	5	2	18
Regulatory policies to protect the data of self-driving car technology users from disclosure.	4	3	4	2	5	2	20
Establishing laws regarding responsibility for damages and casualties caused by self-driving car accidents.	4	4	3	4	5	2	22
Education and diffusion policies to help create positive attitudes around self-driving electric vehicle technology	3	3	2	4	5	2	19
Providing incentives to incumbent firms to invest in self-driving electric vehicle technologies.	2	4	3	4	5	2	20
Providing facilities for granting land for charging stations in urban and suburban areas for electric vehicles.	4	5	3	4	5	3	24

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs'	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Providing facilities for the preparation of information technology infrastructures and urban and road infrastructures for self-driving electric vehicles.	5	3	4	3	5	2	22
Policies of education and dissemination of self-driving electric vehicle technology in urban and rural areas.	3	3	2	4	5	2	19
Providing incentives to service providers for self-driving electric vehicles in transportation and road welfare affairs.	2	2	3	4	5	3	19
The policy of supporting the manufacturers of self-driving electric vehicles for a limited period and conditioned to the attainment of international standards.	4	3	2	4	5	4	22
Facilitation policies, such as providing a license for the experimental use of self-driving electric vehicle technology in some regions of the country.	3	4	4	3	5	3	22
The policy of supporting the testing of innovations in the field of self-driving electric vehicles by companies with international technology in some regions of the country	4	3	2	3	5	4	21

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs'	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Supporting the holding of specialized meetings of policymakers with experts in the field of self-driving electric cars and investment companies in this field, with the aim of formulating appropriate policies in the field of self-driving electric cars.	5	2	3	3	5	4	22
The policy of supporting the creation of technology testing platforms such as living labs as well as supporting co-creation events for the transition to the socio-technical system of self-driving electric vehicles.	3	3	3	2	5	3	19
Subsidizing policy to reduce the price of self-driving electric car technology for the public.	2	4	2	4	5	3	20
Policy of public education and diffusion of self-driving electric vehicle technology for public acceptance of this technology.	3	3	2	4	5	2	19
Credit allocation policies to create information technology infrastructure for smart transportation.	3	3	4	2	5	3	20

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The governance measures and state policies in line with the transition to the socio-technical system of electric AVs‘	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Generating a legal infrastructure for the governance of the user data, insurance regulations and the transfer of responsibility for damages and losses of self-driving electric vehicles from the user to the technology supplier.	4	2	3	4	5	2	20
Diffusion policies and public education, as well as facilitating the supply of self-driving electric vehicle technology in cities and roads	3	2	2	4	5	2	18
The policy of supporting the increase in the production of self-driving electric cars to mass production in order to minimize the consumer price through economies of scale.	2	4	3	5	5	1	20
The policy of allocating credits to the improvement and modernization of urban and suburban roads and their signs in accordance with the needs of self-driving electric vehicles.	4	5	3	4	5	1	22
The policy of facilitating and removing obstacles from the experimental use of self-driving electric vehicles in urban and suburban roads.	3	3	3	4	5	2	20
Education policies and diffusion of self-driving electric vehicle technology for the public.	3	2	3	2	5	2	17

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs'	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Policies to improve the social security standards of self-driving electric vehicle technology users in order to deal with cyber-attacks into infrastructure and terrorism.	4	2	4	4	5	3	22
Policies to support applied research in the field of optimizing and increasing the continuous efficiency and effectiveness of self-driving electric vehicle technology with the aim of ensuring the provision of high-quality and cost-effective products to consumers.	3	3	4	4	5	3	22
Diffusion policies and governance of self-driving electric vehicle technology.	3	3	2	3	5	2	18
The policy of creating the possibility of dialogue between the government and the community regarding the public expectations of self-driving electric vehicle technology in the areas of security, access, justice and privacy.	4	3	3	3	5	3	21
Development of research and development support programs on a limited scale in the first step; And secondly, the government's full support for large-scale research and development projects with an emphasis on the localization of electric AV technology.	3	2	4	4	5	3	21

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs'	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Allocating funds to joint projects of the Ministry of Industry with the Ministry of Science for the development of electric AVs.	4	5	4	3	5	2	23
Determining a number of cities under the title of pilot cities for the use of electric AVs, especially public transport vehicles.	3	5	4	3	5	2	22
The policy of providing subsidies for the purchase of electric cars to consumers and the government's investment in electric car infrastructure and charging stations.	3	2	3	5	5	2	20
The policy of providing free or subsidized land to the developer of urban and road infrastructure for electric AV transportation.	3	4	2	3	5	1	18
Subsidization and tax exemption for creating urban and road infrastructure for electric AV transportation.	3	3	2	5	5	2	20
The policy of granting subsidies to foreign manufacturers who have the technology to produce batteries, motors and control systems inside the country.	3	5	1	3	5	2	19

The governance measures and state policies in line with the transition to the socio-technical system of electric AVs‘	Expert no.1 scores	Expert no.2 scores	Expert no.3 scores	Expert no.4 scores	Expert no.5 scores	Expert no.6 scores	Total score
Step-by-step improvement of the required standards of electric AVs and related infrastructure in exchange for granting subsidies and exemptions.	3	4	2	5	5	4	23
Policies to promote and support sustainable and environmentally friendly transportation.	4	4	3	4	5	3	23
The policy of providing research and development subsidies to projects related to electric AVs and advanced battery technology.	4	3	4	4	5	3	23
Government marketing strategies for public transport procurement with an emphasis on sustainability and environmental compatibility.	5	3	2	3	5	3	21

Recent research focused on transition and innovation policies has aimed to significantly reduce the role of the state to either correct or create markets. This diminution is partly due to the fact that the search for transition hurdles commonly focuses on market issues rather than the primary hurdles that influence socio-technical systems.

In order to define this critical blind spot, this article goes beyond previous literature to provide an understanding and conceptualization of the different roles of the state in the governance of socio-technical systems' transformation. Hence, in this paper, firstly, the Hi-Tec startup support policies are presented based on the case study. Then, a synthesis of previous literature is conducted to present policy measures that define a comprehensive role for the state in the transition process to electric AVs sociotechnical system.

Diffusion and juridical roles, along with market-correcting and market-creating roles, are defined for the state in this paper. This variation is worth considering when deciding on a specific role that the state might take to influence the transformation of socio-technical systems. Ultimately, the Table 3 presents the prime contribution of the most effective Hi-Tec startup support policies, along with the most effective transition policies into AVs.

Table 3. A framework of policies to support transition to AV sociotechnical system

Governance measures and policies to facilitate the transition to autonomous electric vehicles socio-technical system	Level	Policies to support Hi-Tec startups	Level
The policy of pushing incumbents to invest in intellectual property, infrastructure, production facilities and equipment necessary for autonomous electric vehicles.	Niche Level	Financial support and providing government grants to incubators	Micro Level
The policy of facilitating the limited and experimental production of autonomous electric vehicles		Indirect facilitation policies (open door economic policy, dissemination of knowledge and skills, development of communication)	
		Leveraging the advantages of local industries and clusters to support incubators	
		Holding international gatherings for accelerators to strengthen their links	
		The policy of supporting the entrepreneurship ecosystem in the country	
		Government support for hackathons and similar innovation events	
Providing facilities for granting land for charging stations in urban and suburban areas for electric vehicles	Regime Level	Institutional support for start-up companies in order to achieve the opportunity of asymmetric technological cooperation at the national and regional level	Meso Level

Governance measures and policies to facilitate the transition to autonomous electric vehicles socio-technical system	Level	Policies to support Hi-Tec startups	Level
Allocating funds to joint projects of the Ministry of Industry and Mines with the Ministry of Science and Research for the development of electric vehicles.		Laying the foundation for the formation of numerous asymmetric exploratory cooperation	
Step-by-step improvement of the required standards of electric vehicles and infrastructures produced in exchange for granting subsidies and exemptions.		The policy of facilitating, simplifying and removing obstacles to cooperation between the parties, emphasizing the role of universities in the dissemination of knowledge.	
The policy of providing research and development subsidies to projects related to electric vehicles and advanced battery technology		Targeted and comprehensive institutional support for start-up companies in order to achieve the opportunity of asymmetric technological cooperation	
		Protection policies to attract international companies to asymmetric technological cooperation with domestic start-up companies	
		Policies to encourage open innovation	
		Government incentives for asymmetric technological cooperation in the form of innovative projects	
		The policy of removing barriers and facilitating asymmetric technological cooperation at the regional level	
		Tax incentives for asymmetric R&D cooperation	
		Providing research and development subsidies	
		Regional agreements to support innovation	

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Governance measures and policies to facilitate the transition to autonomous electric vehicles socio-technical system	Level	Policies to support Hi-Tec startups	Level
		The policy of increasing regional and global interactions	
		The policy of creating communication bridges between domestic and foreign companies	
		Providing incentives for cross-border horizontal technological cooperation	
		Supporting the relations of companies with the network of universities in order to acquire knowledge of technology development	
		Supporting start-ups to achieve social capital	
		Providing advice on technology markets and market forces and actors to start-up companies	
		Providing information technology infrastructure for start-up companies	
		Networking between government incumbents and start-ups	
		Government mediation to prevent network lock-in within a geographic area	
		The policy of supporting the entrepreneurship of universities with a focus on VCs	
Creating a legal infrastructure in the field of transportation governance and road safety for the traffic of autonomous electric vehicles	Landscape Level	Financial support for beneficial researches	Macro Level
Policies to facilitate sustainable transportation		Financial support of venture capital	

Governance measures and policies to facilitate the transition to autonomous electric vehicles socio-technical system	Level	Policies to support Hi-Tec startups	Level
Policies to promote and support sustainable and environmentally friendly transportation.		Supporting the creation and growth of university spin offs	
		Supporting the commercialization of technologies developed in the public sector by the private sector	
		Scientific development by revising the mechanism of providing grants and incentives	
		Encouraging competitiveness	
		Funding policy	
		Facilitation policy	
		Improving national ties	
		Improving international links	

This research examines the utility of the approach outlined in this paper, both for analytical and policy-making purposes. From an analytical perspective, the current approach and its further developments should be useful as a guide to illuminate the specific roles of the state in transition processes with a multi-faceted approach. At first, researchers can analyze the type of measures that represent the necessary governance characteristics for a specific socio-technical system. Then, in a second step, the researchers can undertake a detailed evaluation of the policy mixes that shape the fundamental changes in socio-technical systems proposed in this paper.

6. Conclusion

From a policy-making viewpoint, the approach contributed by this paper might be useful in the planning of transformative Science, Technology, and Innovation (STI) policies. Sometimes, policymaking is done by elaborating on individual policy measures in a rather isolated manner, with no attention to various forms of state action or the complexities involved in governing the change of socio-technical systems. On the other hand, sometimes governments formulate transformative policies without considering the need for proper instrumentation, mobilization, and coordination that align with the underlying context and the socio-technical system. Policymakers might consider utilizing this approach to understand the different roles of the state in specific socio-technical systems before implementing specific policy measures, such as funding or regulation. Accordingly, researchers might define the various roles of the state when designing aspects of organizational coordination across different units of public administration and among various organizational stakeholders. Transitional changes to address the complexity of significant challenges may require significant organizational coordination. Therefore, adopting a more explicit and multifaceted approach to understanding governance conditions can facilitate the development of a contextual approach to policy-making.

Normally, the suggested approach in this research has some limitations. First, the state might unintentionally prohibit modification. Even if state missions and visions are clarified and well elaborated, the state may not be capable of effectively responding to the requirements of these missions due to constraints within its own organizational capacity. Second, it is critical to know that the state may not always be constantly transformative. This article examines the role of the state in the transition of socio-technical systems. Future studies are suggested to focus on different types of transitions (e.g., incremental, disruptive, and no-transformation) and pay attention to their various consequences, whether positive or negative.

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