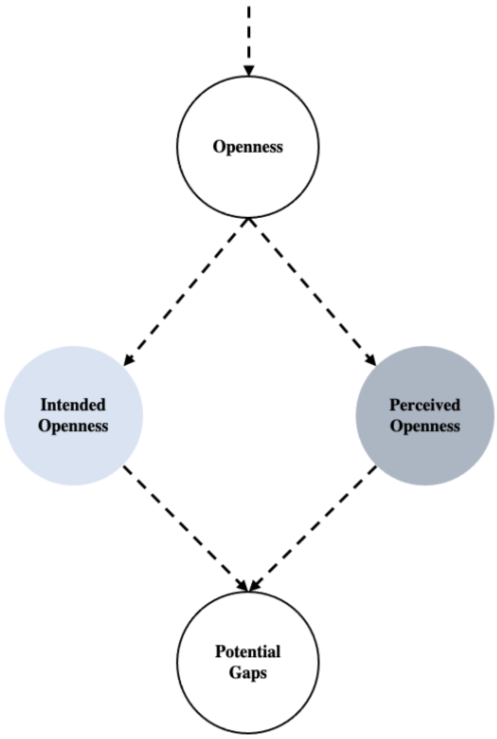

Open standards within the EV charging ecosystem

A comparative case study exploring potential gaps between the intended and perceived openness

Master's thesis in Entrepreneurship and Business Design

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Cover:
Illustration of the overall research approach, of investigating an openness framework to further investigate the intended openness and perceived openness and explore potential gaps, see Figure 8.

Gothenburg, Sweden 2023

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Abstract

The urgent need for the development of sustainable transportation solutions has called on electrical vehicles as part of a potential solution. In parallel the automotive industry is facing a shift going from hardware to a software solution focus. Thus, putting pressure on the knowledge intensity of the firms and requiring a greater knowledge stock to be distributed throughout the organizations. Open innovation tools, such as open standards, have been pointed out as potential facilitators for the development of sustainable transportation solutions. However, with the presence of paradoxes of innovation and a current knowledge gap in how to apply open standards to improve the interoperability of the solutions, the actors of the electric vehicle charging ecosystem are left with a complex dynamic of challenges.

By understanding the potential gaps between the various layers of electrical vehicles interoperability, one may start to prioritize the efforts of enabling open innovation collaborations. Through a comparison of the layers of; *communication* - open standards (within the electric vehicle charging ecosystem), and *business* - the Swedish electro-mobility business ecosystem, this paper investigates the openness, intended openness, and perceived openness, to explore potential gaps, to further the insights of how open standards can be used to facilitate the electrical vehicle adaptation of sustainable transportation solutions.

The findings of the study show that the electric vehicle charging ecosystem is indeed a current area of great interest for sustainable transportation, with the potential for information and communications technology developments to be used within cross-industry and cross-sectional applications. The study confirmed the existence of potential gaps between the intended and perceived openness. The results allured at there being a dissonance in the early and late phases of the standard development. Specifically pointing towards the (technical) interoperability, where the intended openness was evaluated to be high, while the real-world experienced openness where not perceived to be at an optimal level for the application. Further, the study displayed that the absence of a common concept of *openness* could be directly correlated to the lack of both internal and external interoperability in the business layer of electrical vehicles. Thus, creating barriers for the knowledge sharing that is required for the innovation efforts to be effective. The electro-mobility business ecosystem actors' positive attitude and realization of the need for open innovation, such as open standards, indicate that there is a common perception that the complexity of the emerging information and communications technologies within the electrical vehicle adaptation, invokes new forms of open innovation management. However, the actors were hesitant to be the ones to make the first move. With the high stakes of losing out on value creation through poor intellectual asset management, the participant hinted at the need for a higher governance structure to take on a more operational functionality than the current governing organs of the innovation ecosystem. Hence, generating a clearer landscape with set rules, designated recipients, and responsible roles. This may very well be the primary action needed for mending the gaps and the creation of a stable environment for future open innovation collaborations to grow within.

Keywords

EMBE, EV, Interoperability, Openness, Open Standards, Open Standard requirements

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This master thesis project has had the wonderful opportunity of being conducted through an internship at a firm that shares the passion for innovation as much as the student. The contacts made and events attended during this period have been a tremendous source of inspiration. It is the hope of the author that the results of this master's thesis may be part of a greater journey for all parties involved.

To the supervisor at the company that not only guided but also supported the project at its core, displaying the true meaning of collaboration within innovation. I am truly grateful for having had the opportunity of working alongside such brilliant and knowledgeable people. Explaining my professional horizons in a safe environment for education.

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Lastly, to my ever-loving and supporting family that has brought me coffee and hugs, your infallible presence has motivated me to reach the finish line. To all the friends and animals, thank you for carrying me through.

Sara Friman, June 2023

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List of abbreviations and acronyms

ADR	Automated Demand Response
CPO	Charge Point Operator
DNS	Domain Name System
DR	Demand Response
EMBE	Electro Mobility Business Ecosystem
EMS	Energy Managed Systems
eMSP	Electric Mobility Service Provider
EV	Electric Vehicles
EVSE	Electric Vehicle Supply Equipment
IA	Intellectual Asset
IAM	Intellectual Asset Management
IAB	Internet Architecture Board
ICT	Information and Communications Technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Intellectual Property
ISO	International Standardization Organization
ISOC	Internet Society
ITU	International Telecommunication Union
OASIS	Organization for the Advancement of Structured Information Standards
OCA	Open Charge Alliance
OCPP	Open Charge Point Protocol
OS	Open Standards
OSR	Open Standard Requirements
SDG	Sustainable Development Goals
SDP	Standard Development Phase
SoC	State of Charge
SoS	Systems of Systems
TCP	Transmission control protocol
W3C	World Wide Web Consortium

List of key definitions

The main concepts of the research study are listed below, with the selected definitions, referenced sources, and a brief comment on their respective relevance in the study. These will be further elaborated on in Chapter 2.

Concept	Definition	Source	Relevance
Electro mobility business ecosystem	“a typical innovation ecosystem” (Giesecke, 2014, p 1) “including actors, their roles and their challenges” (Giesecke, 2014, p 2)	Giesecke, 2014	The specific business ecosystem which the actors are operating within
Innovation ecosystem	“the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution” (Adner, 2006, p. 2).	Adner, 2006	An innovation model in which some of the actors are operating within
Interoperability	General: “the ability for multiple systems to work together without restriction” (EPRI, 2019) A technology perspective: “interoperability covers the technical issues of linking computer systems and services. It includes key aspects, such as open interfaces, interconnection services, data integration and middleware, data presentation and exchange, and accessibility and security services” (Aliprandi, 2011p. 7) An organizational perspective: “interoperability concerned with ensuring that the premise meaning of exchanged information is understandable by any other application that was not initially developed for this purpose. Semantic interoperability enables systems to combine received information with other information resources and to process it in a meaningful manner.“ (Aliprandi, 2011, p 6-7)	EPRI, 2019 Aliprandi, 2011	Part of the openness concepts. There are multiple definitions mentioned through the study. These are the two perspectives focused on in the study. The technology perspective will be connected to the intended openness, while the organizational perspective is connected to the perceived openness from the industry actors.
Open innovation	“the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively” (Chesbrough, 2006, p 16)	Chesbrough, 2006	The toolbox that will be utilized to achieve the purpose of the study
Standard	"a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose." (ISO, 2019)	ISO, 2019	The tools that will be utilized to achieve the purpose

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1 Introduction

In this first chapter, an introduction will be presented through the description of the background, the research problem, and the research questions. The delimitations of the projects, as well as the overall outline of the study's disposition, will also be included.

1.1 Background

The complexity of sustainability challenges calls for collaboration (Lozano, 2007). With the environmental challenges having a global impact, it has been deemed too large to tackle in isolation. Therefore, creating new shared value through innovation is urgent (Costa & Matias 2020). As evidenced by the COVID-19 pandemic, the effectiveness of collaboration can aid in achieving time-sensitive initiatives such as the rapid development of vaccines (Druedahl et al., 2021). The digital transformation and universal interaction providing momentum to exponential growth in innovation led to shared values (Costa & Matias 2020), namely sustainable innovation. The idea of eco-innovation has been assigned to changes in sustainable development that covers; technological, social, and institutional innovation (Renning, 2000). With the United Nations (UN) post-pandemic recovery plan, along with government incentives, the European Union (EU) is taking actionable steps towards a long-term shift towards eco-innovation. With European transportation being responsible for 20% of the total European global greenhouse gas emissions, this entails adaptational challenges that lie ahead for the industry (El Sheikh, 2022). Transforming the transport sector is one of the foundational cornerstones for achieving the UN’s global *sustainable development goals* (SDGs). Innovation and developing technologies will be critical in addressing some of the difficulties and roadblocks related to EVs (IEA, n.d.-b). The steering towards this change is already being displayed in the doubling of *electric vehicle* (EV) units sold globally between the years 2021 and 2022, much to do with a boost of adaptation (“Global EV Outlook 2022,” 2023). However, Reporters at Bloomberg NEF argue that despite the rapid rise in EV adoption, road transport is still not on track for carbon neutrality by 2050 (Trudell & Davis, 2022). According to the UN secretary-general, there is an urgent need for further efforts for sustainable transportation solutions (Guterres, 2022).

Sweden has long been seen as an innovator in the automotive industry (EPO and IEA Team up to Shed Light on Trends in Sustainable Energy Technologies - News, 2020). The national automotive business ecosystem building up knowledge and skills for several decades. In 2016, the automotive industry was Sweden’s largest export industry with a share of approximately 14% of Swedish goods export. This international focus has required the actors to enter into knowledge-based partnerships and the development of innovation processes to maintain and strengthen the companies (Pohl, 2017). This traditional automotive industry is currently facing a revolutionizing transformation. Actors from across the business ecosystem are coming together to pave the way for a more sustainable flow of people and goods. In turn, making Sweden home to one of the most advanced and vibrant clusters in the world for *electro-mobility* (E-mobility) and offers numerous opportunities for sustainable manufacturing, auto testing, and incubation of new ideas (RISE, n.d.). In Sweden, achieving a fossil-fuel-free vehicle fleet is a government goal that drives essential expenditures in e-mobility (Regeringskansliet, 2009). The governmental pressure on the transportation sector is pushing for a decrease in the Swedish climate impact by 70% in 2030, compared to 2010 (Regeringskansliet, 2021). This can also be seen as a testament to the urgency of revolutionizing this area. The rapid transformation of the traditional automotive supply chain into a value network is forecasted as great potential as the transportation industry enters into a new era of electrification. Making Sweden's *electro-mobility business ecosystem* (EMBE) a captivating example of open innovation as a potential pathway for driving sustainable transportation solutions.

Vehicle electrification was introduced as a new strategic competence area in data classification. This has redirected innovation focus, from previously being on design, manufacturing, and developing electronics and mechanics, to nowadays being on software as a key component in the industry's value proposition (Tsvetkova et al., 2021). Software and digital technologies are now equivalent to approximately 50% of the vehicle's total value (Albert et al., 2021). The widespread adaptation of EVs will depend on seamless integration with *information and communications technology* (ICT) (Werther & Hoch, 2012). The ICT field is currently calling for open innovation tools to enable technology advancements and a fair play for the actors participating in the developments (Aliprandi, 2011). This entails interoperability and compatibility between entities from various sectors (e.g. Automotive, Energy, Transportation and logistics, Smart cities, Finance, and Insurance). Thus, this will create a *system of systems* (SoS) that will have to be navigated. Combining multiple layers of interoperability in a complex ecosystem for operating EVs in an effective and sustainable manner. A way of managing this is by enabling a common language, for example in the form of *open standards* (OS) (Enel X, 2021).

Decades ago, Moore (1993) described how the success of a firm is depended on its ability to innovate though collaborations with other companies (Moore, 1993). This stands even more true today. In a world characterized by rapidly changing demands and high product complexity, the internal capabilities of companies are challenged, which has led firms to explore other collaborative models of innovation (Gassmann et al., 2010). The industry shift towards a knowledge-based economy has given rise to the concept of open innovation (Chesbrough, 2003). The open innovation model implies companies opening up their innovation process to utilize external knowledge and share their unutilized ideas (Drucker, 1985). From a strategic point of view, open innovation involves actively seeking out and leveraging internal and external sources of knowledge and ideas to drive the development of new products, services, and technologies (Chesbrough, 2003). The shared *intellectual assets* (IA) can be that of *intellectual property* (IP) and/or *knowledge assets*, depending on their potential for legal protection mechanisms (Gregoris Mentzas et al., 2012). Open innovation has been shown to be a promising approach for driving innovation and sustainability in other sectors (ex. the food sector (Arcese et al., 2015), (Venturelli et al., 2022).

Open innovation puts emphasis on collaboration and knowledge sharing (Bogers, 2012). Through its utilization of IAs, it can thus enable greater interoperability and integration across disparate systems, applications, and organizations. (Kianto et al., 2014). Exemplified in the form of OSs being used as drivers for innovation (Aliprandi, 2011). The *International Standardization Organization* (ISO) has been seen as a contributor to all of the SDGs, mainly towards SDG 9: industry, innovation, and infrastructure with over 13,000 standards (ISO, 2015). There are more examples of standard organizations developing standards to solve the challenges of climate change, even specifically within the e-mobility industry. An OS is a specification that is publicly available and accessible to allow for interoperability and compatibility between different software, hardware, and systems. Not many people are aware of the complex dynamics of the of standards, particularly in relation to the globalized and technology advancing world we live in today (Aliprandi, 2011). Therefore, there is currently a knowledge gap in how to apply OSs to improve interoperability (Klotz et al., 2018)

(Karpenko et al., 2018). Leaving the actual definition of openness of an OS still up for debate.

The concept of *openness* has many overlapping definitions and uses of its attributes (Schlagwein et al., 2017). There is however a contradiction to be made in the balancing of how much should be open and closed innovation in a firm. This has been referred to as the "innovation paradox" (Bogers, 2011).

As part of the balancing act, the focus on sustainability vs profitability has been placed on the opposite side of the firm's agenda. From the internal setting of a company, sustainability has become an increasingly important aspect to consider, not only to comply with laws and regulations that encourage corporate sustainability (Norzalila Jamaludin et al., 2012). It has also become a way for companies to gain competitiveness (Greenberg et al., 2014). Therefore, firms are in need of aid in navigating the tension of exploring new opportunities and exploiting existing capabilities simultaneously. This development of ambidextrous capabilities can in turn help them create sustainable innovation (Cancela et al., 2022). In the EV business ecosystem, actors must balance the two focuses, to be able to collaborate and cooperate to find sustainable transportation solutions. Being careful in protecting their IAs and maintaining their competitive advantage and value creations.

1.2 Prior research

This research study utilized the prior research of multiple sources. As part of the literature review, the following prior research were identified to be key for this study.

The first literature that became relevant for this study was the openness dimension framework of West (2005). West's framework became a foundation on which others aimed to design an OSR framework from. Secondly, this study will mainly use the OSR model of Mutkosi (2011), since it is a revised version of West's work, combining it with different framework that have emerged over the years such as Krechmer (2006), *Organization for the Advancement of Structured Information Standards* (OASIS) (2009), and Mutkoski (2011).

When investigating previous applications of openness frameworks, there were two research studies that became most interesting. Specifically because of their connection to the open innovation strategy of OS with the application in the EV charging ecosystem. First was the works of Deniz (2015), who claim that his article - *An empirical analysis of the openness dimension of OCPP standard* were to his knowledge, the first attempt to describe OCPP from an OS perspective within the context of the infrastructure for electric vehicle. Using the framework of West (2005), the author summarized the attributes of the OCPP according to the *standard development phases* (SDPs), and the OSRs under respective phase (Deniz, 2015). The reasoning of Deniz separation between requirements and into sub-requirements will also be an inspiration for the study.

In the article publish a few years later by Neaimeh and Andersen (2020a) – *Mind the gap - Open communication protocols for vehicle integration*, an evaluation of multiple Oss within the EV charging ecosystem were performed (Neaimeh & Andersen, 2020a). The authors used a different OSRs framework by Krechmer (2006), which gave a nuance to the evaluated parameters of openness.

This study has focused on a different, but related, framework for openness compared to the previous research. To the extent of the authors knowledge, this research study employs a new perspective on the case of open innovation strategies for the EV sector, specifically applied to the Swedish EMBE.

1.3 Problem statement

Electric vehicles are being spotted to hold great potential to dramatically cut greenhouse gas emissions, effectively rendering a more sustainable transportation future. The automotive industry is facing a rapid transformation turning to e-mobility. With the addition of timeline pressure from governing structures and SDGs, this has resulted in standardizations in the EV charging ecosystem to facilitate the adaptation of EVs, and thus sustainable transportation solutions.

While open innovation has been shown to be a promising approach for driving innovation and sustainability in other sectors, the innovation paradox still presents challenges for actors in the automotive industry seeking to improve their competitive advantages. To move forward with effective and collaborative innovation efforts, the Swedish EMBE's perception of the openness of OSs in the EV charging ecosystem needs to be further explored. Within the concept of OSs, there is a need to understand potential gaps between the intended openness and what is the perceived reality.

1.4 Research purpose

The aim of this thesis is to explore the potential gaps between the intended openness of OSs, within the EV charging ecosystem, and the Swedish EMBE perception of the openness of OSs as facilitators for sustainable transportation solutions. Describing the openness dimensions, referred to as the OSRs, of a set of OSs for the context of the EV charging ecosystem and comparing the intended openness with the actual reality perceived by the industry. This will aid in further exploring the future for this form of open innovation strategy by driving discussions of trends and prioritization in this area.

1.5 Research questions

From the mentioned background and problems statement above, the study will aim to investigate to aid in the understanding of the levels of openness and relevant characteristics and attributes of OSs.

To generate this framework, the following research questions will be explored:

Main research question	*Are there potential gaps between the intended openness and perceived openness of OSs within the EV charging ecosystem, that would be relevant for the facilitation of sustainable transportation solutions?*

Research question 1	*Which OSs, within the EV charging ecosystem, are relevant for the facilitation of sustainable transport solutions?*
Research question 2	*Which OSRs are relevant for the facilitation of sustainable transport solutions?*
Research question 3	*How are the identified OSRs of the OS-set mapped out according to their intended levels of openness?*
Research question 4	*What is the Swedish EMBE's perception of the openness of OS within the EV charging ecosystem, and the relevance of OS as facilitators for sustainable transportation solutions?*

The first two research questions will utilize existing literature and interviews with experts to describe openness and investigate the relevance of OSs and OSRs. By looking at openness frameworks and their application in the EV charging ecosystem. Leading to the generation of an *Openness model* to utilize in the further comparisons of the cases of the intended and perceived openness.

The third research question will then utilize the *Openness model* to investigate the intended openness of the OS-set. Utilizing existing data (documents and protocols) and literature (prior research).

The fourth research question aims to investigate the perceived openness of OSs by the actors working within the Swedish EMBE. For this, main interviews with the actors working within the EV charging ecosystem were performed. The responses were then analysed using the *Openness model*.

Together, the above listed research questions aim at answering the main research question of exploring if there are potential gaps between the cases of the intended openness of the OS-set and the case of the perceived openness of the Swedish EMBE, in the context of the EV charging ecosystem. Therefore, the last step of the study was to compare the intended and perceived openness using the *Openness model*, to identify connection points and potential trends.

1.6 Delimitations of scope

The limitations will mainly be a consequence of the restricted time frame for this research study. The project will include processes of data gathering and analytics, literature reviewing, and continuous re-evaluation. With the humble insight of the time consumption these steps will require, along with the potential for delays in the process due to the many interactions needed, limitations of the study's objective will have to be installed.

Another delimitation includes the terminology and definitions used throughout the thesis. With confusingly similar and interchangeable concepts, this thesis will rely on the listed definitions of the terms (see **Error! Reference source not found.**). Knowingly having the potential of excluding relevant literature as it is not aligning with the explicit definitions used.

Looking at the limitations of the objects of the study;

First, the study will be operating in the context of the EV charging ecosystem, thus being part of the challenges for adaptation of EVs as a sustainable transportation solution. As a result of the prior literature review, there was an indication that this was one of the main challenges of the EV adaptation.

Secondly, the companies studied will be limited to the Swedish EMBE. For the study to be manageable, the scope will also be narrowed to focus on actors in the current supply system of EVs. This includes car manufacturers, supply manufacturers, and other actors supplying EVs. The process of identifying the actors' positions relative to one another will be performed using existing frameworks for the EMBE. This is done with the complexity of the innovation network in mind.

Thirdly, with the prerequisite that some of these actors are competitive and rely on heavy secrecy measures when it comes to their innovation assets, the companies will be anonymous throughout this thesis. The interview questions, categorizations of the responses, and analyses, have been structured in a way that explores the data without exploiting or surpassing the scope of the research. With the companies generously taking their time to contribute to this study, this trust cannot be overstepped.

And lastly, the selected participants for the main interviews are limited to the department of; *Innovation, IP and/or Strategy,* at the respective company. Due to the knowledge and insights needed for the interviews to yield sufficient results on the topics of open innovation and *intellectual asset management* (IAM). The experts used in the initial and concluding interviews will be from various positions, and since the interviews are of an unstructured nature, used in combination with literature, and not used for evaluation purposes this would not affect the bias of the roles of the interview participants.

1.7 Thesis outline

This disposition of the thesis will include; seven chapters, a list of references, and an appendix. The chapter outline is stated as:

The first chapter is the *Introduction* to the thesis and includes; a background, prior research, problem statement, research purpose, research questions, delamination, and scope.

The second chapter describes the *Theoretical Framework*. Here, the two main fields of theory used in this study will be presented. Including their respective underlayers of theoretical frameworks that will be applied later on.

The third chapter of the study depicts the *Methodology*, which includes; Research strategy, epistemological and ontological analysis, quantitative and qualitative research considerations, research design, research method (including data collection and analysis), research quality, and ethical considerations.

The fourth chapter *Results* of the research study. This chapter goes into the main findings of this comparative case study, relating to the four research questions.

The fifth chapter is the *Analysis*, where the results are analysed through various method and related to the theoretical frameworks. Finally answering the research questions.

The sixth chapter frames the *Conclusion* of the study, by summarising the main findings of the research study.

The seventh chapter is a *Discussion*, where a discussion of contributions to research, research limitations and future suggestions are described.

2 Theoretical framework

In this section, the theoretical framework is described. The two main objectives of this study the open innovation strategies and e-mobility. There will be an introduction to the necessary knowledge transfers that enable interoperability between layers of systems of EV adaptation. The key concepts and their implications are described in order to create an aggregated theoretical framework for the coming study. Several of the cited works have considerably more in-depth descriptions than were deemed necessary for this work.

2.1 Open innovation strategies

The topic of "open innovation" opens up for naturally incorporates the three perspectives of; *Business, Law, and Technology*. Here the business perspective is represented by understanding open innovation models and the implications of knowledge transfers. The legal perspective incorporates considerations of governmental incentives, IP rights, and contractual specifications. Lastly, the technology perspective will introduce the open *standards development phases* (SDP). The specific technical focus on EV adaptation will be discussed in later sections. Together the three perspectives will produce an overview of the object, apply strategic point of view, and aid in understanding the complex challenges described below.

2.1.1 Open innovation models

Historically, companies have primarily adopted a closed innovation model focused on internal resources and capabilities, to generate competitive advantages. The emergence of *the knowledge revolution* and the rapid development and diffusion of digital technology has shaped our society into what we know it to be today (Drucker, 1992). With the widespread adaptation and integration of *information and communication technologies* (ICTs), the need for *openness* has become an increasingly important aspect of managing innovation. This paradigm shift has been described as the creation of a new economic order in which the key strategic resource is knowledge. This knowledge-based economy depends on innovation, creativity, and intellectual capital (Drucker, 1994). It also holds the power of altering the rules of the game in all sectors of society (Schwab, 2016). Schwab (2016) went on to add that, apart from the positive effects this entails, it also creates new challenges for governance, regulation and accountability. As defined by Castells (1996), knowledge should be seen as a public good, and its creation and dissemination should follow principles of equity, diversity, and sustainability (Stark & Castells, 1996). Displaying how knowledge in the format of assets has the potential for creating greater common value.

This importance of collaboration in innovation have been stressed before by Drucker (1985), who stated how innovation requires knowledge to be shared. The author did initiate ideas of collaboration between a wide range of stakeholders to create and capture value (Drucker, 1985). A decade later, Moore added to this by describing the competitive environment, explaining that the boundaries of the firm are blurring and that there was an increase in firms relying on relationships with other firms to create products, processes, and markets (Moore, 1993). With these precursors for systematic innovation, collaboration, and knowledge-sharing, Chesbrough (2003) went on to coin the business model concept of *Open Innovation*.

The author describing the concept as a paradigm that suggests that firms should use external and internal knowledge as a way of advancing their technology (Chesbrough, 2003).

The rapidly changing demands and high product complexity challenge the internal capabilities of companies, and this has led firms to explore other collaborative models of innovation (Gassmann et al., 2010). Therefore, *open innovation* has become increasingly important for companies to consider, not only to be in compliance with laws and regulations that encourage corporate sustainability, but it has also become a way for companies to gain competitiveness (Chesbrough, 2006). This has been evidenced in other sectors such as the food sector (Arcese et al, 2015), (Venturelli, 2022). Further expanding on the possible areas of applications of open innovation.

Enabling *openness* facilitates rapid innovation by welcoming new agile and disruptive players (such as aggregators) into the market. It also empowers established energy and automobile companies to adapt, reinvent themselves, and keep pace with a dynamic and evolving landscape, ensuring their survival. (Hughes, 1986). Utilizing open innovation enables "*the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively"* (Chesbrough, 2006b, p.16). To describe the direction of the knowledge flows Gassman and Enkel explored three types of *open innovation models*; *inbound, outbound,* and *coupled.* With the latter framework being a combination of the first two. The authors *coupled model* entailed a mindful approach concluding both the perspective of the company's strengths and where there are gaps in their approach to innovation while using their organizational "radars" to detect opportunities or threats (Grassman & Enkel, 2004). These organizations know that the most effective business strategies need to consider both internal practicalities and external factors. Examples of coupled open innovation models include *hubs*, collaborative *networks*, and *ecosystems*. Where the fast-changing pace of ICT could be seen as an explanation for the realization of companies that moving forward in a more collectively driven action is the better way of deigning their businesses (Deniz, 2015). Short description of each of the open innovation models, with examples in the Swedish industry, is listed below. For the open innovation hubs and open innovation networks, there will be representatives involved in the data collection later in this study.

Open innovation hubs are physical spaces that bring together a variety of stakeholders to foster innovation and entrepreneurship. Designed to provide a supportive environment for innovation and collaboration. Examples of open innovation hubs in the Swedish e-mobility sector include; MobilityXlab and Kista Science City. MobilityXlabs brings together automotive industry companies such as Volvo cars, CEVT, Ericsson, Veoneer, and Zenuity, with start-ups and academia (MobilityXlab, n.d.). Kista Science City was dubbed the *Silicon Valley of Scandinavia* with their concentration of high-tech companies and start-ups with a heavy focus on innovation and economic development in the ICT field (Kista Science City, n.d.)

Open innovation networks refer to networks of organizations that bring together internal and external resources and expertise to co-create new products or services. The focus for these networks, according to the European Commission, is to find a new way of organizing innovation. Based on a collaborative approach to knowledge sharing and problem-solving among actors across organizational and sectoral boundaries (Curley & Salmelin, 2013). Examples of these may be innovation clusters, technology platforms, and research and development consortia. Examples in the Swedish e-mobility sector include; Drive Sweden.

Which is a platform focused on the development of sustainable mobility solutions) (Drive Sweden, n.d.).

In contrast, *open innovation ecosystems* are broader in scope and involve a range of actors from different sectors and industries working together to create value. Bogers et al. (2016) referred to open innovation ecosystems as a dynamic and continuously evolving set of actors and resources that create and capture value through complex, multilateral, and interdependent relationships among firms, universities, research institutions, governments, and other stakeholders (Bogers et al., 2016). Important to note is that in open innovation ecosystems, there is both collaboration and competition happening simultaneously among the participants. An example of a typical innovation ecosystem is the EMBE (Gisecke, 2014).

For an open innovation model to be successfully applied in real-world contexts, there is a need for a way of managing the flow of knowledge and ideas between the firm boundaries (Bogers et al., 2016). Amongst the knowledge transfer, it is yet important for organizations to maintain a degree of independence and flexibility while collaborating with external partners (Chesbrough et al., 2006). There needs to exist a degree of autonomy while maintaining some structure and coherence (West & Lakhani, 2008). Or as described by Vanhaverbeke and Cloodt (2006), in order to foster successful open innovation, striking the optimal balance between loose coupling and tight alignment is crucial (Vanhaverbeke & Cloodt, 2006). By creating loosely coupled relationships between organizations, each can contribute their unique knowledge and expertise to a project or initiative without being overly dependent on one another. This can aid organizations in creating value and driving innovation in a rapidly changing business environment (Chesbrough et al., 2006). The loose coupling theory was coined by Miller (1978) and refers to the idea that in complex systems, different components should be designed to operate independently, with minimal interaction or interdependence between them (Miller, 1978). For example, in open innovation networks different organizations might contribute with their knowledge and expertise without being involved in all aspects of the project. This allows each organization to focus on its strengths and to contribute to the overall project without being burdened by unnecessary coordination or bureaucracy (Miller, 1978). Understanding the implications of balancing structure vs independence is key to incentivizing organizations to partake in open innovation. This level of flexibility will be mentioned later in this study as part of the openness dimensions.

2.1.2 Intellectual asset management (IAM)

Theories of open innovation management emphasize the importance of managing *intellectual assets* (IA) to support innovation and create value. An IA has been described as a intangible asset that can be transferred or leveraged to create value for the firm (Huang, 1998). Petrusson (2004) later added that IAs are the intangible assets of an organization which are recognized as having particular strategic value (eg. Patents, trademarks, copyrights, trade secrets, and other forms of IP). The author also pointed out that non IP assets can also be categorized as IAs, including; knowledge, expertise, networks, and relationships that contribute to a competitive advantage (Petrusson, 2004). *Intellectual asset management* (IAM) involves identifying, capturing, protecting, and leveraging these assets to maximize their value and enhance competitive advantage (Petrusson, 2004).

Intellectual property (IP) assets and *knowledge assets* differ in their nature and role in OSs. With IP, an asset can have legal rights granted to inventors and creators for their IP, meaning they can be protected through IP laws such as ownership rights and usage rights. With these protections, there may be an added hinder to collaboration and innovation in the context of OSs. As IP rights create barriers to entry for new entrants and limit the scope of participation in standardization processes. This has called for a more balanced approach to IP in OSs, taking into account the need for collaboration and knowledge-sharing as well as incentives for innovation and competition (Hawkins et. Al., 2017).

On the other hand, *knowledge assets* are harder to protect as they have not yet been objectified as an IP and therefore lack the legal mechanisms for protection. The knowledge assets is described to be important for the driving of innovation, growth, and competitiveness in the global economy. The accessing, usage, and combinations of knowledge can result in new products and services, thereby spurring economic growth and social welfare. (Hawkins et. Al., 2017).

The discussions of risks and the *value vs control* within open innovation have rendered important challenges unsolved, hindering businesses to realize the full potential of openness. (West et al., 2014). Earlier, West (2005) has described each of the positive and negative implications that OSs may have on IAs. The potential benefits being; an increased innovation from building upon existing knowledge and technologies, increased collaboration allowing for faster and more effective development, and an increase in adaptation from the wide availability due to lack of restrictions and low to no licensing fees. The potential downsides the author mentioned were of; reduced control over the ownership and distribution of the asset, reduced profitability from loss of economic compensation to access, and increased competition with the emergence of new entrants (West, 2005).

Firms need to find effective ways to protect their IAs while still collaborating with other stakeholders (Mehlman et al., 2010). A firm's *knowledge intensity* refers to the extent to which *intangible assets*, such as knowledge, contribute to the value of a product, service, or industry (Andreeva & Kianto, 2011). The importance of the link between *knowledge intensity* and *value creation* continues to be emphasized (Elg, 2014). Especially in knowledge-intensive industries as the most valuable assets are often knowledge and skill related (Chesbrough & Spohrer, 2006). In the context of OSs, knowledge intensity is an important factor as the effective management of knowledge assets is crucial for the development and adaptation of successful OSs. Knowledge intensity refers to the degree how much an organization relies on its knowledge assets to create value (Grant, 1996) (Cohen & Levinthal, 2000). Open innovation and OSs can be seen as effective ways of managing IAs in the context of innovation (Enkel, & Gassmann, 2010). By being inherent knowledge-intensity activities (Chesbrough, 2003). However, there is a current knowledge gap in how to apply OSs to improve interoperability (Klotz et al., 2018) (Karpenko et al., 2018). This is what will be key to investigating the main research question of this study.

2.1.3 Open standards (OS)

OSs can be seen as “powerful tools of governance that regulate the behaviour of a range of actors across diverse domains of social and economic life" (Russell, 2014-a). The importance of OSs lay in their ability to enable collaboration and widespread adaptation of otherwise proprietary technology (Chesbrough, 2003). The collaborative nature allows for the knowledge to be disseminated and generate new ideas more effectively. Contributing to the overall knowledge stock in an economy and improving the efficiency of use of capital, and/or labor (ISO, 2021). The *knowledge stock* refers to the accumulated knowledge within an organization or society, making it a valuable resource. Thus, similar to the previous concept of knowledge intensity, but with a difference in focus (Nonaka & von Krogh, 2009) (Grant, 1996).

OSs may also lead to reduced costs and risks, and an accelerated pace of innovation. Creating new solutions built on the collective strengths of the partners and with the potential for the development of complementary components that benefits the end-user (Maxwell, 2006). With these functions, OS can modulate and provide a loose coupling of components that can be implemented by different groups which leads to a more diverse ecosystem of components and services. Allowing for enhanced flexibility and robustness of systems (Lakhani & Von Hippel, 2003). However, it has been noted that OSs can have both positive and negative impacts on innovation (Russell, 2014-b) (Fransman, 2010). Russell remarked on OSs being dependent on the context in which they are developed and implemented. (Russell, 2014-b). Fransman (2010) expressed the importance of policymakers understanding standards, to be able to design innovation-friendly efforts. (Fransman, 2011). The author also notes that standards can provide a common platform for collaboration and innovation but can also create barriers to entry and lock in dominant players. Ultimately suggesting that policymakers can play a role in promoting OSs that facilitate innovation and competition (Fransman, 2010).

2.1.3.1 Standard organizations

The primary function of a *standard organizations* is to establish goal-directed networks for innovators to jointly shape technology and markets through standards (Wiegmann et al., 2022). The establishment of standard organizations has been utilized as a tool for enabling trade and business. From an engineering perspective, standards become increasingly important at the onset of the industrial revolution, with the need for high-precision machine tools and interchangeable parts. Today, governments, industrial companies (private and public sector), and individuals participate and contribute to various standardization bodies (Blind & Gauch, 2008)

The influence of a Standard organization can be broken down according to geographic designation; international, national, regional, and local. The nature of a standard will be determined by its origin and structure. If it is produced by *standard-setting organizations* (SSOs) the standard covers consensual approaches where a committee of experts sets discrete cut scores on continuous proficiency scales (Pant et al. 2009). On the other hand, if it comes from *standard-developing organizations* (SDOs) it is accredited as having been developed using open and transparent processes. SSOs and SDOs are recognized by the government and have a formal role in the development and maintenance of standards. Typically having a higher number of resources (Bharadwaj et al., 2020). On the other hand, consortia typically consist of industry-driven organizations that voluntarily collaborate to develop standards in areas that are not covered by SDO standards, or to supplement or extend SDO standards (Hawkins, 1999). Typically making the consortia more agile in their response to market changes and can develop standards quicker. This research study will investigate OSs originating from both SDOs and Consortia (Pohlmann, 2014). To review the different perspectives of these in regard to openness dimensions.

2.1.3.2 Standard development phases (SDP)

The term *standard* has been defined by the *international organization for standardization* (ISO) as a document that states the requirements, specifications, guidelines or characteristics to be used to ensure that the materials, products, processes, and services are correct for the intended use." (ISO, n.d.-b). A standard can provide a common solution to a reoccurring problem, with the aim of creating homogeneous and transparent routines for actors to agree on (Opensource, 2023). Therefore, standards can be used to distill knowledge, provide a common language, determine the markets and help with externality challenges (CIE, 2006).

The role of standards has become especially popular and appreciated, even emerging as an alternative to traditional competitive frameworks (EU Commission, 2022). One needs to vary that the concepts of *standards* and *dominant design* are not the same. Although they frequently occur at the same time, thus, leading to confusion, Gallagher (2007) argued that they are two different yet complementary concepts. Dominant design is the result of competition between different design approaches that are architectures of systems. With the presence of network effects, these architectures can be cantered on standards or embody them as components. Standards are the results of competition between different interface protocols and can thus be proprietary. Therefore, standards can serve as important elements of a dominant design (Gallagher, 2007).

The SDP are, according to West (2005), as follows; SDP1 - *Development*, SDP2 - *Implementation and Complement*, and SDP3 - *Usage* (West, 2005). The process model for standards has been illustrated below (see Figure 1).

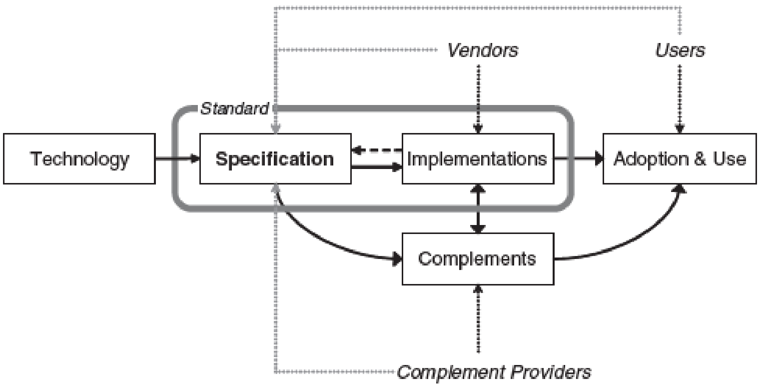

Figure 1. Process model for stakeholders in creation and adaptation of standards (West, 2005)

Standardization overlaps with the latter SDPs, as it describes the process of implementing and using the technical standards (ISO, n.d-b). *Technical standards* establish a norm for a repeatable technical task that can for example be applied to a product and/or process. This relies on technical contributions from various sources. The contributions may contain IP rights such as patents. If a patented technology is perceived necessary to be able to operate equipment or methods which comply with a standard, it can be deemed a *Standard Essential Patent* (SEP) (ETSI, 2023).

A successful standard has been described to be one that has many implementations, as it can be considered a win from a development perspective (Walli, n.d.). Standards that have been approved by a standard-setting organization, can be referred to as a *formal standard*. If a standard becomes generally accepted and dominant it can be referred to as a *de facto* ("in s practice but not necessarily ordinated by law") standard. A market-driven standard is developed in response to market demand. They tend to be proprietary. However, they can also be developed to set a de facto standard in the industry (ETSI, 2023).

Market-driven standards, by their nature, tend to focus on meeting the specific needs of a particular industry or organization. In contrast, standards developed by standard development organizations or consortia are developed with a broad multi-industry problem (Schmidt, 2022) (IEEE, 2014). For example, *technology interoperability standards* which define the boundaries between two objects. These types of standards have been put through a recognized consensus process. The process can be a formal *de jure* (established by law) supported by national standard organizations (eg. ISO), an industry or trade organization (eg. IEEE), or a consortium with a narrower focus (eg. OASIS). The optimal interoperability standards provide the customer with a choice in the marketplace (ISO, n.d.-b).

The timing of the standardization matters (Walli, n.d.). Walli (n.d) explains that once standardization happens on the market it is time to adapt to the "standardized base". He pointed out that if a standardization happens too early or ahead of the market it is difficult, as good standards codify proven ways of doing things, as they are based on existing knowledge (Walli, n.d). Additionally, it is important to be aware of is that standards are dynamic tools. This entails that time can also affect them not just as they emerge but as they evolve over time, as the application area is evolving (Fukawa et al., 2021).

There have been many successful standards that have shaped the way we live our lives today. An example is the standardization of 3G and 4G networks. This creation by the *international telecommunication union* (ITU) spearheaded the promotion of international cooperation in telecommunications. Assigned by the UN, the ITU developed a set of technical specifications and protocols that ensured interoperability through a common language and seamless communication between different devices and systems (ITU, 2019). Another example, but of OS development, is that of the internet (Hafner & Lyon, 1996). Led by the *internet engineering task force* (IETF), originally steaming from a community of researchers and engineers working on various network technologies, this effort of developing and promoting Internet standards has led to, among other OSs, the *Transmission Control Protocol* (TCP), the Internet Protocol, and the *Domain Name System* (DNS) (IEFT, n.d). Each of the examples has allowed for the development of a truly global network that has transformed the way we connect with each other. The main differences between them lay in their level of openness and flexibility. The OS of the internet is based on a loose coupling approach which allows for a higher level of interoperability. The approach allows for greater modularity, scalability, and adaptability, which has been seen as the key factors in the success and growth of the internet (Farrell & Saloner, 1992) (Janssen et al., 2012).

In recent years, we have seen the OS approach being applied as an effective tool in situations of times sensitive challenges. Exemplified by the COVID pandemic, where the openness of standards for sharing knowledge assets (health data) played a significant role in the development and distribution of vaccines (Lurie et al., 2020) (Shen et al., 2021).

Moving forward, for the e-mobility sector to be able to adapt to sustainable transportation solutions, there is a need to develop and implement innovation effectively. OSs hold great potential of promoting innovation in the electric vehicle charging infrastructure. Ensuring that the developed solutions are compliant with all EVs. (Ahmad et al., 2018). With standards being the language of engineers, vehicle makers, electricians, utilities, municipal, and regulatory professionals. These professionals are often the gatekeepers to infrastructure deployment and must be assured that all aspects of charging systems, not just at the point of connection to the grid, but to the vehicle as well, have been carefully studied, developed, and implemented safely (ABB E-mobility., 2022). There have been successful applications of OS as facilitators for achieving large and time-sensitive common goals (EEI, 2019). OSs within e-mobility need to be further evaluated to identify the potential and challenges of bridging industries and sectors, in order to achieve sustainable transportation solutions.

2.1.3.3 Open standard requirements (OSR)

Being *open* has been promoted for compatibility standards as a universally good thing (West, 2005). Openness contributes to the; setting of a level playing field, quicker innovation by opening up the market to new agile and disruptive entities, the evolution and re-invention of existing industry actors catching up and surviving changing environments (Hughes, 1986) (Neaimeh & Andersen, 2020a). Thereby, openness can be seen as one of the core values in standardization settings (Díaz-Marta & Ferrandis, 2020). However, the attempt of promoting OSs relied on utopian ideals. In the real-world of standards, things are rarely fully open or fully closed (West, 2005).

There is still a lacking of unified consensus of what an OS is and is not. Different standard organizations offer different guidelines (Opensource, 2023). The dilemma stems from two sides, first the definition of what openness is, and second the spectrum of dimensions of openness. To capture the concept of OSs, various models have been created to investigate the degree of openness that is displayed in OSs. A few of the most cited are created by; *recognized persons* (eg. West (2005), Krechmer (2006) and Mutkoski (2011), *governmental bodies* (eg.OASIS (2010)) *and standardization bodies* (eg. the Institute of Electrical and Electronics Engineers (IEEE), Internet engineering task force (IETF), Internet Society (ISOC), world wide web consortium (W3C), Internet engineering task force (IETF), and internet architecture board (IAB) among others (Open-stand, n.d.)). The initial sets of *open standard requirements* (OSRs) were produced by recognized people in the mid to late 2010s. Shortly after governmental bodies and standards organizations started to produce their version of the framework (OASIS, 2022) (Open-stand, n.d.). The timing of the publications of OSs and OSR framework allure at the high relevance of these as strategic tools for facilitating EV innovation solutions. With the dynamic nature of standards (Fukawa et.al., 2021), any changes to the initial OSs need to happen soon if the standards are to be effective in achieving the SDGs of the UN by 2030 (ISO, 2015).

An attempt at combining most of the mentioned frameworks were performed by Murkowski in 2015. With the above-mentioned sets of requirements having multiple overlaps, the main difference between the different approaches, according to (Mutkoski, 2011), is the difference in the grouping of the criteria. Mutkoski (2011) suggests a set, based on the common five criteria with the addition of two sub-requirements adapted to the implementor. This combined the common topics and elements of West, Krechmer, and OASIS (West, 2005) (Krechmer, 2006) (OASIS, 2010). Mutkoski's framework included the seven ORSs; (1) *Permeability*, (2) *Transparency*, (3) *Structural Attributes*, (4) *Accessibility*, (5) *Claims*, *Market Success* (6) and (7) *Interoperability* (Mutkoski, 2011). A brief description of each of the ORSs and how they relate to the openness dimensions of an OS, is outlined below.

Permeability refers to the SSO creating of the specification for the stakeholders. Defining who is involved in the specification. The transparency requirement includes the decision-making process and governance concepts. Defining how can and to what degree they may influence the decisions of the standard specifications. The structural attributes relate to the characteristics of the organization creating and maintaining the specification. The availability sets limitations or restrictions on who and how much of the specification one can access. This requirement has been further elaborated on by later authors, and this will be touched upon later. The claims are relatively straight forwards in their relation to IP rights of who owns and has the right to utilize the technology within the OS. Defining the licensing terms for patents. The market success was referred to by the author as an important unity of a standard. The interoperability has in Mutkoski's framework been defined as a requirement in itself instead of separate from the concept of openness. The interoperability discussed here is that of a technical perspective (Aliprandi, 2011), with universal terms this form of interoperability could entail open communication and exchange of data between and among entireties and/or systems (Mutkoski, 2011).

The author chooses to exclude the latter two criteria (related to the concepts of market success and interoperability) in his article *"Defining open standards"* due to them being less related with the *specification* and more to the *implementation* (Mutkoski, 2011). However, this thesis will include them as it seeks to apply the industry perspective across the SDPs and investigate nuances in the openness dimensions.

2.2 EV interoperability

Building a functioning system for EVs requires a multidimensional perspective. With the increasing complexity of interoperating layers, applying system thinking is necessary to understand the advantages and disadvantages of EV technologies and utilization (Grauers et. Al., 2013). Interoperability has been defined as "the ability for multiple systems to work together without restriction" (EPRI, 2019). E-mobility includes technical challenges across perspectives with the combination of industry sectors, actors, and technologies needed to achieve EV solutions. Such as in the ICT field, where there is a growing need for standards to enable technology convergence and integration (Aliprandi, 2011). To understand the different layers of the challenges, this calls for a description of the system of systems. The term *system of systems* (SoS) was coined by Maier (1998) while examining and defining the characteristic of systems that grow in scale and complexity through the integration of several independently developed subsystems (Maier, 1998). To be able to understand the various layers of interoperability that would need to take place within e-mobility, the model by the CEN-CENELEC-ETSI Smart Grid Coordination Group can been applied (CEN-CENELEC-ETSI Smart Grid Coordination Group, 2012). The *EV interoperability model* has been described by Kirpes et.al. (2019) to be divided into five layers, of which the first four will be part of this thesis. This includes; *business layer, function layer, information layer, communication layer*, and *component layer* (Kirpes et.al., 2019). A simplified version of the model has been illustrated below (see Figure 2).

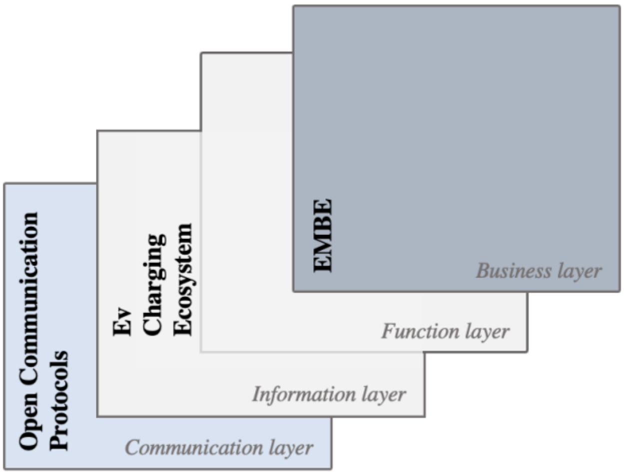

Figure 2. EV Interoperability layers

The upcoming sections describe the various layers translated into the setting of e-mobility. The fifth and last layer of the EV interoperability model - *the component layer*, represents physical aspects. Due to the nature of this research study, this layer will not be investigated further as it becomes too technical to be insightful the strategic perspectives of the research questions.

2.2.1 The electro-mobility business ecosystem (EMBE)

First, the business layer represents the viewpoint on the information exchange, such as; regulatory, and economic structures, business models, business processes, and business cases of stakeholders (Kirpes et.al., 2019). In the context of EVs, this is represented by the *electro mobility business ecosystem* (EMBE) (Giesecke, 2014). Understanding the positioning of the various industry actors in a non-linear value chain, where actors may hold multiple roles within the same ecosystem.

The *international energy agency* (IEA) defines e-mobility, as the use of electric vehicles (EVs), charging infrastructure, and related technologies and services that enable the movement of people and goods using electric power (IEA, 2021). Gartner (2023) has added to this, emphasizing that the concept entails much more than the passenger car. As it has evolved to include developments for reworking the mobility network means revolutionizing the culture that influences how people choose their mode of transportation. For example, by including e-buses, car sharing, e-scooters, e-bikes, bike paths, pedestrian areas, and others (Gartner, 2023).

In the traditional *business ecosystem*, Moore (1993) described companies to"*co-evolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations"* (Moore, 1993, p.76). Moore (1996) suggested that the environment the actors find themselves in requires the actors to proactively seek to develop symbiotic relations with customers, suppliers, and even competitors, in order to face the challenges of particular niched newly arriving competition (Moore, 1996). Further anchoring Moore's metaphor of this type of *ecosystem* to the ecological origin definition of an "element embedding the living creates in their environment" (Tansley, 1935). In more recent years, Giesecke (2014) has proposed, in accordance with the IDEF0 standard (NIST, 1993), that the ensuing roles should be applied to the *business ecosystem* (see Figure 3).

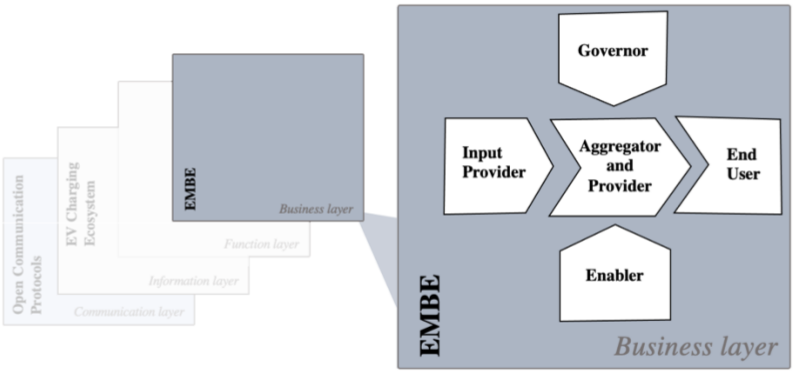

Figure 3. EV Interoperability layer 1 - EMBE

Important to note is that the same actor may hold many roles in the same ecosystem (see Table 1). Placing this business ecosystem-type role framework within EMBE. And this is focusing on the supply system (typically one-time revenue).

Table 1. EMBE Roles

Role	**General features** *Source: (NIST, 1993)*	**EMBE Actors** *Source: (Giesecke, 2014)*
The governor (analog to "control")	Providing standards, laws, policies, norms or (ethical values)	• Governing authority • Standard provider • Electric market regulator • (User Group) • (Association) • (NGO) • (Lobbyist)
The input provider (analog to "input")	Provides inputs, which then change in the subsequent process (ex. Components, energy, information, investments etc)	• Charging management software provider • Charging components supplier • EV parts supplier • Battery supplier
The enabler (analog to "mechanism")	Provides assets in tangible or intangible form that do not change subsequently.	• Insurer • Researcher
The aggregator and provider (analog to "function")	Aggregates inputs into comprehensive products or services, often directly aimed at end-users.	• EV manufacturer • Charging system integrator • Charging system supplier • E-mobility infrastructure supplier
The end user (analog to receiver of "output")	Consumes the energy, product, service and may provide cash flow and/or feedback to other roles.	• Professional end-user • Individual end-user

As illustrated in the EMBE model (see Figure 3), the *governor* role applies pressure on the *aggregators and providers* to be in compliance with the legal frameworks. The governments and regulatory bodies play a crucial role in creating supportive policies and regulations, as well as building the necessary infrastructure (IEA, n.d.-a). With the EV market still in a nascent state, the balancing role of risk assessment and regulatory compliance will become a challenge for the widespread adoption of e-mobility. Exemplified by the lagging of legal frameworks at the European level previously seen for GDPR and now AI, where the rapid technology development and deployment of these technologies are far ahead. The regulations require a coordinated approach between stakeholders, policymakers, industry representatives, and experts in the fields (European Commission, 2022). Inevitably leading to a game of catch up and/or step backs to ensure compliance, unless the governor role can successfully be included in the network of the EMBE, and thereby simultaneously develop with the technology forefront. This research study will focus on including multiple perspectives from different roles in the Swedish EMBE to be able to investigate the attitudes of open innovation.

2.2.2 The EV charging ecosystem

The second layer in the EV interoperability model - *the function layer*, describes system use cases, functions, and services including their relationships from an architectural viewpoint, independent from actors and physical implementation of applications, systems, and components (Kirpes et.al., 2019). Applied to the understanding of the operational functions of e-mobility, models for *EV charging ecosystem* will be used (Neaimeh & Andersen, 2020a). Displaying the interactive points in the network structure needed for EVs to be effectively functioning.

When observing the EV ecosystem there are multiple entities to consider. Opposed to the EMBE model, that describes the industry actors’ relational positioning in the business ecosystem, the EV charging ecosystem focuses on the operational aspects between entities. The entities described in the EV charging ecosystem represent both actors and objects involved in the operational communication between the standards. Examples of entities includes; car manufacturers, *Electric vehicle* (EV), *Electric vehicle supply equipment* (EVSE), *Energy managed systems* (EMS), Third party operator, *Electric mobility service provider* (eMSP), *Charge point operator* (CPO), energy supplier, balance responsible party, electricity network operator, and aggregator (Neaimeh & Andersen, 2020a). The EV charging ecosystem is emerging from the hardware-software paradigm shift, making it more depending on ICT solutions to enable interoperability between entities (Deniz, 2015). The function layer has been illustrated below, showing how the entities connect with third party operators (see Figure 4). This research study has been focusing on OSs from a third-party operator perspective, mainly that of car manufacturers.

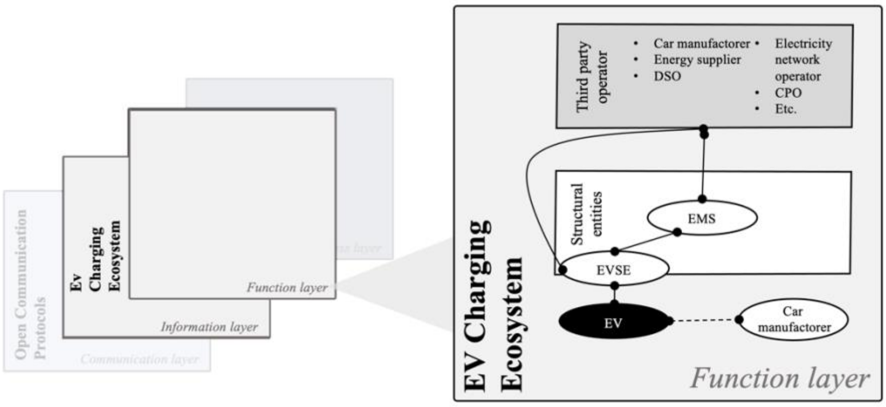

Figure 4. EV Interoperability layer 2 - EV Charging Ecosystem pt.1

The EV interoperability model's third layer – *the information layer,* describes the information flow and the corresponding information objects that are exchanged between functions, services, and components and their underlying canonical data models, representing the common semantics for an interoperable information exchange (Kirpes et.al., 2019). With this layer being a direct sublayer to the previous one, a similar model can be applied with the distinction between the layers of function and information.

The entities in the EV charging ecosystem are connected by streams of information. These information flows allow for "information objects" and "control objects" to flow up and down the system. Examples of information objects would be; *identification, battery state of charge (SoC), battery info, next trip info.* Examples of control objects would be; *active and reactive power set-points*. These exchanges need to happen with seconds and ultimately sub-second responses required by some grid services (Andersen et. Al., 2019). The profile of the information flow can be *front-end* and *back-end.* Front-end protocols "define the link between car and charge point and specific requirements for plugs; charging typologies; communication, safety and cyber-security" (Neaimeh & Andersen, 2020b). While back-end protocols work by "emphasizing communication and cyber security requirements, define the link between charge point and a third-party operator" (Neaimeh & Andersen, 2020b). The information layer has been illustrated below, showing the directions of the different flows of information (see Figure 5). In this research study, the focus has been kept broad in order to incorporate OSs of different operational characteristics.

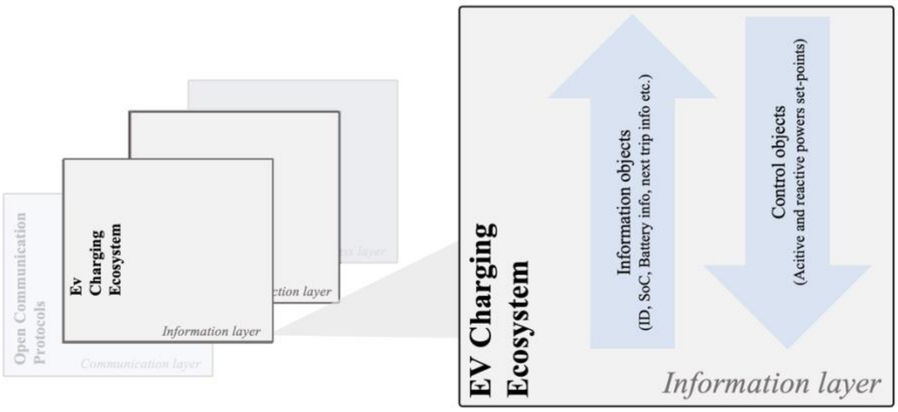

Figure 5. EV Interoperability layer 2 - EV Charging Ecosystem pt.2

There are multiple challenges identified within the EV charging ecosystem (Werther & Hoch, 2012). A practical example of a challenge is the electricity demand peak reduction. For this challenge to be addressed there needs to be an exchange of information between BEV chargers and entities to allow electric system support. This type of information would include*; car identification, battery SoC, battery size,* etc. Based on the information, and on information collected from the electricity system infrastructure (eg frequency, current, and voltage data) (Zhang et. al., 2018), chargers' power set points are determined and sent down to control the charging process, ensuring proper integration of vehicles into the electric grid (Andersen et. al., 2019). Another challenge is the geographical location of the charging points. The natural parking time of a vehicle varies at different locations and the charge location can be divided between two categories. Destination charging, include; *home, work,* and *other* such as *marketplaces*, or *charging destination*, including; *filling stations*. The most time is seen spent at home or work locations. The energy infrastructure puts limitations on the energy demand and there only allow for normal (<=22kW) charges at these locations. For the other and filling station locations, there is an increased availability and practicality to supply quick (50-150kW) and or fast (>=150kW) charge. These secondary charge locations are usually located in urban areas or along long-distance travel corridors (Neaimeh et. al., 2017) (Nicholas & Hall, 2018).

Many of the failures of innovation in this area can be related to the inability of solutions to adapt to the changes and needs of the industry at a particular given time, much to do with the lock-in effects they face (Deniz, 2015). To address the challenges in the EV charging ecosystem, *third-party operators* need to consider the interoperability of their technology products. With the complexity of the coordination and communications between vehicles and energy entities, one must consider multiple strategies for EV charging (Neaimeh & Andersen, 2020a). This requires an understanding of both the *function layer* and the *information layer.*

2.2.3 Communication protocol landscape

The fourth layer of the EV interoperability model - *the communication layer*, describes communication protocols and technologies for the interoperable exchange of information between components in the underlying function and related information objects or data models (Kirpes et.al., 2019). These specific communication protocols can be placed in a *communication protocol landscape* (ElaadNL, 2017). The span of the protocol's operational functionality and position is displayed in accordance with the previously described entities of the EV charging ecosystem (see Figure 6).

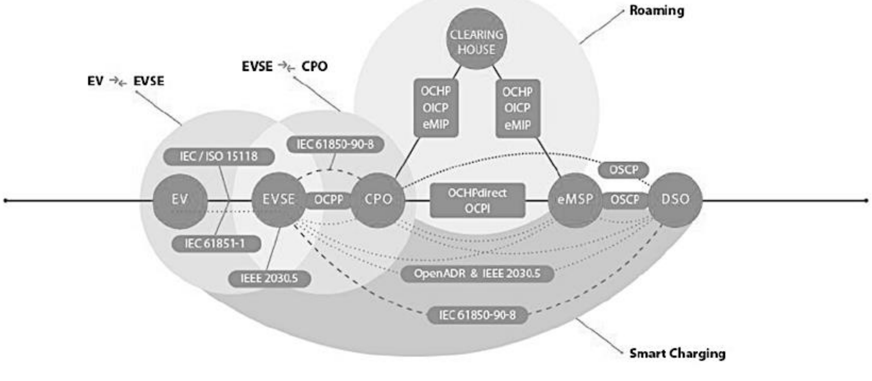

Figure 6. Open communication protocol landscape (ElaadNF, 2017)

The OSs of this study are all included within *open communication protocols*. An open communication protocol is described as a set of rules and standards that allow devices or systems to communicate with each other (Ahlgren et al., 2016). An open communication protocol can thereby contain one or more OSs. By adopting open communication protocols, firms can work together effectively and share knowledge and resources according to a set framework, thereby making it clearer and easier to manage (West & Gallagher, 2006). In a simplified format, one can map the communication landscape of the EV charging system according to the model of the ElaadNF. This has been illustrated below, in combination with the EV charging ecosystem entities (see Figure 7).

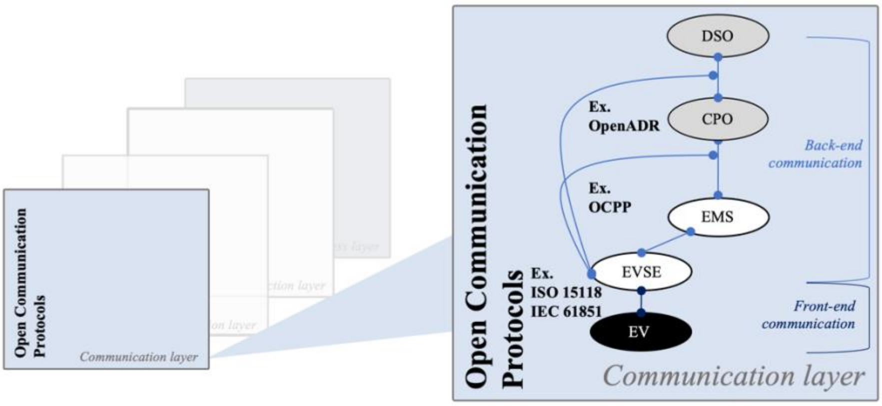

Figure 7. EV Interoperability layer 3 - Open Communication Protocols

The focus of this thesis will be limited to the open communication protocol standards that are part of the integration of EVs into the electric grids and the immediate communication links that are needed to facilitate EV charging management strategies, according to previous works of Neaimeh & Andersen (Neaimeh & Andersen, 2020a).

2.3 Summarizing the theoretical frameworks

Open innovation strategies are in request, from companies seeking a deliberate plan of action to leverage open innovation to achieve their business and sustainability goals. The concept of open innovation was not coined until the year 2003. However, the existence of some kind of openness concept has been discussed in multiple works over the course of the aftermath of the knowledge revolution. Today open innovation is being applied in a multitude of industries, where part of its beneficial means of utilization stems from its structural frameworks and models that enable companies to engage in accelerated innovation activities. The various levels of business models in open innovation provide different prerequisites for the collaborating actors, as exemplified in the case of the EMBE. In the context of the EV charging ecosystem, a higher level of open innovation model needs to be considered, to include the complex and dynamic challenges of the ICT developments related to the EV adaptation.

In the EV charging ecosystem, there are multiple levels of interoperability. By understanding the knowledge flow and its requirement for effective asset management, the open innovation model can be a successful tool for businesses to apply loose coupling and balance the maintenance of a degree of independence and flexibility. Thereby focusing on contributing to the collaborations using their individual strengths to create value for themselves and others. IAs have been emphasized as directly adding to a firm's knowledge intensity and thus their potential value creation. Effective management can help create a competitive advantage and support long-term growth and sustainability. Understanding the protection mechanisms and utilization is key to evaluating the risks and determining the value vs control of participating in open innovation activities. OSs have been seen as a specifically powerful tool for enabling modularization and loose coupling of system components. Thus, facilitating the integration of third-party innovations and assuring a faster pace of innovation development with increased interoperability. However, there a still pros and cons of applying OSs that need to be considered. To be able to predict and strategically apply OSs there is a need to investigate the nature of the OSs and review previous examples of OS development. What makes them open is yet not defined by a common consensus. Various frameworks intend to evaluate necessary openness dimensions for companies to consider.

To understand the challenges of OSs, within the EV charging ecosystem, as facilitators for sustainable transportation solutions, there is a need to comprehend the interoperability layers of EVs. With the business interoperability layer of relational positionings and roles of the actors in the ecosystem, the informational and functional interoperability layers of the information flows and units of the EV charging system, lead down to the communication interoperability layer with open communication protocols which can be based on one or more standards (which include the focus of the technical interoperability). The study will aim to analyze the model in Figure 2 from left to right. Investigating the intended openness (left) – by looking at OSRs in different OSs, and the perceived openness (right) – through interviews with EMBE actors. By doing this, potential gaps in openness may be displayed.

3 Methodology

In this chapter the method of the research study will be described in detail. The methodology includes a description and outline of the main considerations in relation to the chosen research strategy and research design. Aspects of the research method and relevant quality aspects will also be included, along with ethical considerations.

3.1 Research strategy

The description of the research study aims at providing a general orientation of the overall approaches adopted to address the research questions. A clear research strategy allows for the study to achieve and maintain a higher level of quality for the research method and its links to theory (Bell et al., 2019-a).

The overall research strategy can be described as a combination of parallel data collection and continuous research, where the aim was to conduct four phases of investigation. The phases of investigation included; phase 1 - *Openness model*, phase 2 - *Intended openness,* phase 3 - *Perceived openness,* and phase 4 - *Potential gaps.* The first phase builds a foundation for the second phase and the third phase, which are then carried out in parallel. The results of which are then used for the last phase as it looks at potential gaps through the comparison of the intended vs the perceived openness. The phases have been illustrated in the figure below (see Figure 8).

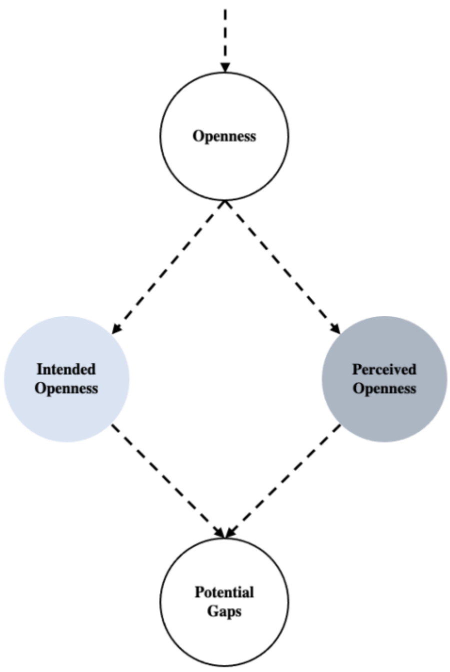

Figure 8. Overall research approach

Listed below are the descriptions of; the *relationships between research and theory*, explaining the *inductive* and/or *deductive* approaches of the research study, the *epistemological* and *ontological positioning* of the research questions, and the study's *quantitative* and/or *qualitative* nature.

3.1.1 Relationship between research and theory

For this study, the research approach consisted of a series of combinations of both inductive, deductive, and abductive reasoning. Inductive reasoning can be described as moving from empirical observations towards developing theory. Deductive is when a theoretical framework is tested or evaluated. While abductive is the developing of new understanding. For example, an abductive approach can be moving from empirical observations and deviating from theory (Bell et. al., 2019-a).

Different steps within the research process utilized varying degrees of inductive and deductive approaches. The summary of the steps of the research approach have been illustrated in Figure 9.

For the theory of this study, there were two main categories of concepts; *open innovation strategy* and *EV interoperability*. The first were the concepts of *open innovation* (including *intellectual asset management*), *open standards,* and *open standard requirements*. These concepts were used to generate an understanding of frameworks used to measure openness. Second, were the concepts of *interoperability*, *EMBE*, *EV charging ecosystem*, and *open communication protocols*. Together, the second set of concepts aimed at forming a basis for the application of openness to the concepts in the real-world industry of the Swedish EMBE.

For the first phase - *investigating openness* (according to Figure 8), a combination of inductive and deductive reasoning was applied. The first literature review was deductively applied in the initial interviews with experts. This in order to investigate the relevance and draw insights from their observations of the industry. The inputs from the interviews were then applied to revised theory. Based on the utilization of observed patterns, and identified themes, this could be seen as an inductive step. A second literature review was performed and the results of which was then used deductively to generate a model of openness to be utilized in the study.

For the second phase - *investigating the intended openness*, the phase was mostly deductive, however, some parts did include inductive approach. The model was deductively applied to prior research evaluations to generate the intended levels of openness based on the secondary data of prior elaborate evaluation studies. Due to some gaps between the overlap of the frameworks of prior research and the model of this study, *some data points* were directly collected from official websites and inductively applied to the model.

For the third phase - *investigating the perceived openness*, the study used a series of inductive and deductive steps were used. The main interviews consisted of questions that were deductively inspired by the secondary literature review. The responses from the interviewee's observations were inductively related to the previously generated *Openness model*. The results were then analysed using the deductive reasoning of statistical techniques. The conclusions from the analysis of the perceived openness were then applied by having concluding interviews with the experts to confirm the results aligned with the experts' observations of the industry, as well as exploring alternative theories to the results of this study. This step can be considered inductive since it relied on observations and empirical evidence from the interviews to generate new ideas and hypotheses. This step also utilized the *Openness model* previously generated, and thus its application could be considered an inductive step.

For the fourth phase - *potential gaps*, the approach could be considered to be abductive. By looking at the probable conclusions from what was learnt from the previous results and analyses. This phase combined the previous data from the intended and perceived openness phases, and compared it to observe patterns, categorize themes, quantify them, and generate new insights.

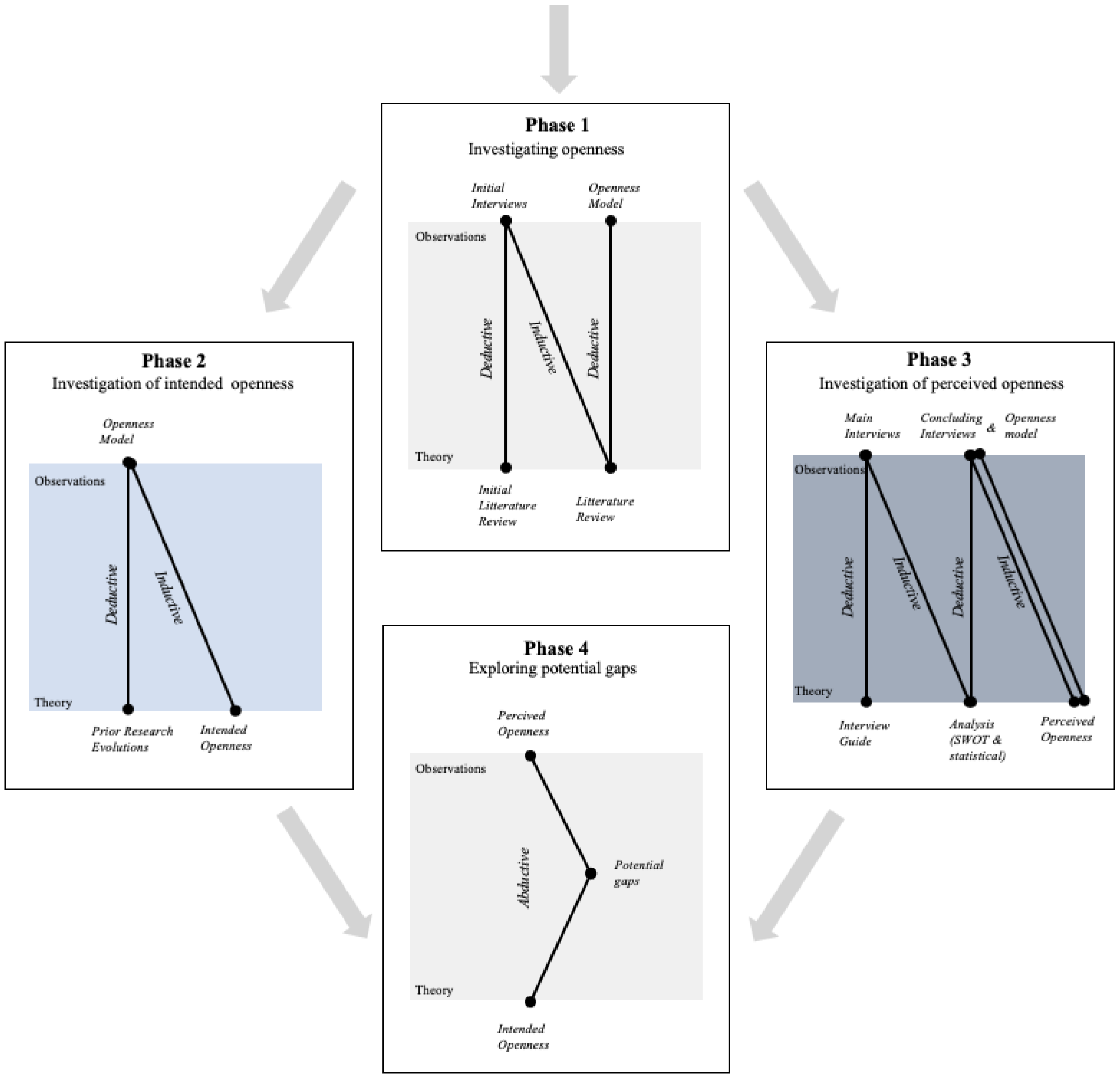

Figure 9. Methods of reasoning for the phases of the study

3.1.2 Epistemological & ontological positioning

The research questions are designed to strategically address the various levels of each of the studies concepts, to be able to apply it into the real-world context of the EV charging ecosystem. As two key philosophical concepts, Epistemology and Ontology are used to underpin the nature of the study (Bell et. al., 2019-a). Epistemology relates to the study of the knowledge, and the ways of which it is acquired, validated and justified. In other terms it describes the essence, or nature, of knowledge. Explaining how we know what we claim to know (Guba & Lincoln, 1994). While Ontology concerns the study of reality or existence. How it is and how it can be understood. In other words, it depicts what exists, if it counts as reality and can be said to exist in reality (Crotty, 1998). Together, each of the perspectives need to be considered as it guides the research deign and data collection strategies of a study (Saunders et al., 2019).

In Figure 10, the epistemological and ontological perspectives of the research questions of this study have been considered. In the figure, the ontological scale addresses the level of how the question is relating to facts and entities. While the epistemological scale demonstrates how the question is relating to claims and judgments. The scales go from an objective - *same for all*, to a subjective - *different for all*, approach (Saunders et al., 2019).

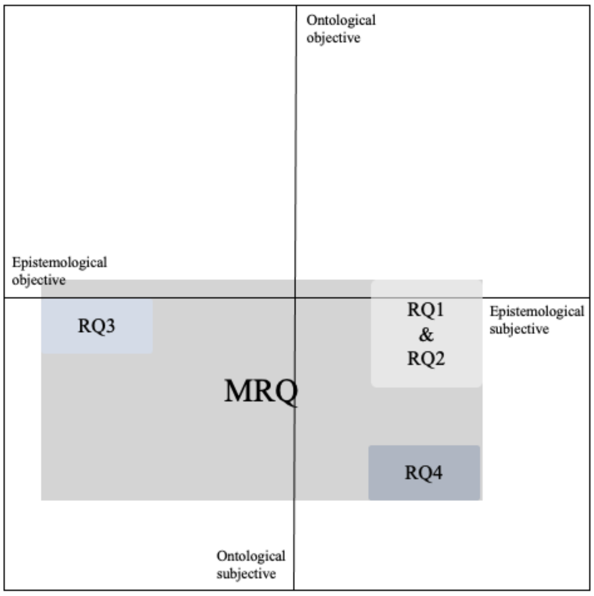

Figure 10. Epistemological and Ontological positioning

The first and second research questions are aimed at describing the current state of the OS cases and the OSRs. With these descriptive strategies, the questions should be placed at the lower end of the subjective plane for both the epistemological and ontological positioning. The reason for this is that OSs are dynamic in nature. Updating the documentation and the protocols over time, to stay relevant to the current business climate. This makes it valued at a low subjective (almost neutral) regarding the ontological positioning. For the epistemological positioning, based on judgment calls, there are existing theoretical frameworks and models that attempt to define *open standards* and *openness*. However, the degrees of OSs are not mutually exclusive, therefore allowing for a medium subjective epistemic positioning of the research questions. The interpreted "relevance" is also a subjective interpretation and may vary between interviewees, pushing the research questions further toward the subjective direction on the epistemic line.

For the third research question, a combination of existing data and data from official sources have been reviewed and evaluated to enable a mapping of the dimensions of openness, according to the previously generated *Openness model* from the first and second research questions. The approach is utilizing theory without steering away from the objectiveness of the research question. Therefore, the positioning can be deemed to be highly epistemologically objective. The definition of OSs is not consensually conclusive, and thus, cannot be considered as are ontologically objective. Therefore, the third research question has a low subjective ontological position.

The fourth research question applies the theory to the real-world context of actors for them to evaluate the already subjective matter of the openness concept. Therefore, the positioning is located at the very subjective plane of the ontological and epistemological axis.

All in all, the main research question, that is answers with the aid of the research questions above-described research questions, will span over the full epistemological axis and mostly on the subjective ontological axis. With the lack of common definitions of the main concepts of the study, this level of subjectiveness is to be expected and welcomed to drive the discussion from the research results further in identifying potential gaps between intended use and actual use, and to understand how OSs can be used as facilitators for sustainable transportation solutions.

Together, the epistemological and ontological positionings of the research questions indicate that the knowledge assumptions of the research study are collected from a broad perspective of what openness is (both objectively and subjectively). As well as adding more subjective existential conditions of what levels of openness exists in the context of the EV charging ecosystem.

3.1.3 Quantitative and qualitative research considerations

There are two fundamental types of clusters of research methods. These have been described to be; quantitative and qualitative (Bell et.al., 2019-a). Qualitative research is characterized by its focus on exploring and understanding social phenomena in depth. This way of understanding the meaning of the context can be obtained by considering the detailed descriptions and narratives, studying the phenomena in a setting, and adapting the method based on emerging insights and new directions that emerge during the study. Quantitative research on the other hand involves systematic collection and analysis of numerical data to identify patterns, establish relationships, and draw conclusions. This may include statistical techniques to ensure consistency, examination of relationships between variables and determining the significance of the findings, and large-scale data collection. (Yilmaz, 2013).

The main research question of this study can be identified to require a combination of quantitative and qualitative research. The reasoning behind using a combined approach is because the complexity of the concept of OSs calls for both an exploratory and correlational approach.

For the qualitative approach of the study, the definition of the OS-set and the data for the *perceived openness* were reliant on the inputs from the interviews with the industry. As a way of placing the concept of OSs in the setting of the EMBE. The analysis of themes that were identified through the SWOT analysis was described in detail to depict the attitudes from the qualitative data collection. The SWOT acted as a way to analyze the perceived openness from a business perspective.

For the quantitative approach of the study, various statistical techniques were applied. For the *intended openness,* scaled variables were used to analyze the data in various graph formats; Column graphs, Circle graphs, and Radar graphs. For the *perceived openness* there were multiple steps of quantitative research methods. The data from the interviews were analyzed using a response distribution according to the; SWOT categories, different focuses (internal vs external), and different aspects (positive vs negative). The standard deviation was calculated to depict the interviewee's contribution to each of the SWOT categories. The theme distribution of the responses was also evaluated, to allow for reflection on the detailed variation within the SWOT categories. It is worth noting that the sample size was small (initial interviews: 3, Main interviews: 3, concluding interviews: 2), however, the samples do incorporate the largest and most influential actors in the EMBE (as verified by the experts), and can therefore be deemed sufficient in the context of investigating the perception the Swedish EMBE.

For the identification of potential gaps between the intended and perceived openness, an examination of relationships between the variables was performed. Where the number of connection points could be used as an indication of relevance, to be able to measure and position the potential gaps relative to each other. The concluding methods were the result of adaptations based on emerging insights during the course of the study. Meaning that the final part of the analysis was a combination of quantitative and qualitative research methods. With the aim to understand the correlational relationships of the concepts of OSs and its requirements of openness applied to the case of EV adaptation to obtain sustainable transportation solutions.

3.2 Research design

A research design can be described as a framework and method of collecting and analyzing data (Bell et.al., 2019-a). According to the authors "*A research design relates to the criteria that are used to evaluate the quality of business research*" (Bell et.al, 2019-b, p 3). It has also been referred to as the investigational plan, structure, and strategy developed to find solutions to research problems or questions. The overall quality and reliability of a study can be determined by the research design. In addition, a well-structured research design ensures that the research questions are answered effectively (Creswell, 1994).

The research design is structured to be investigating the data from the perspective of comparing the results of the cases of the *intended openness* and *perceived openness*, that are positioned at different layers in the EV interoperability model (see Figure 2). The research design has a more specific structure compared to the research strategy, however, it is dependent on the research strategy and therefore the illustration of the research design below (see Figure 11), which follows the path of the research strategy prior (see Figure 8).

With the complexity of the adaptation of EVs spanning multiple industries, this study has focused on the cases of the specific *OS-set (within the EV charging ecosystem)* and *EMBE*. With the cases positioned on different layers in the EV interoperability model (see Figure 2), this becomes a way of comparing the different layers by looking at the intended openness of the OS-set, to the perceived openness from the EV industry.

Within the OS-set there will be four OSs that will be used for the investigation. The selection of the set of OSs was based on *literature and verified by initial interviews with experts*. The common feature of the OSs in the set was that they were all related to the adaptation of EVs, specifically the *EV charging ecosystem* which from the background of the study was identified as a highly relevant challenge for the EV sector.

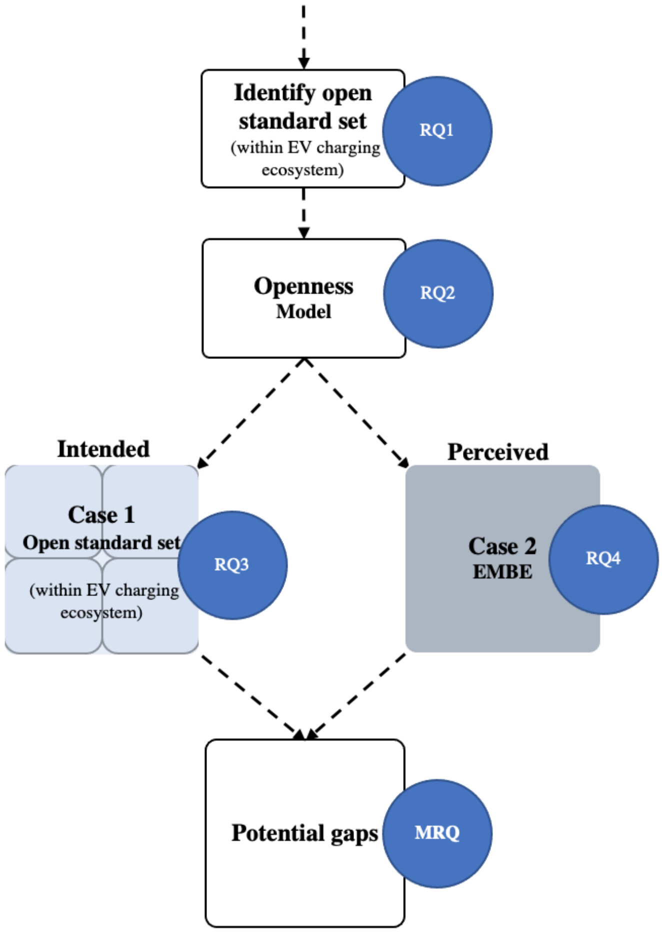

Figure 11. Research Design - Comparative Case Study

3.3 Research method

The research method is the technique used to collect data that is needed to answer the research questions (Bell et. al., 2019-a). For this study, the data consisted of both qualitative and quantitative data. Here follows the description of; the main data collection for the research study, the research process of collecting the data, the data analysis methods, and the research quality considerations.

3.3.1 Main data for research study

This research study focuses on answering one main research question and four sub-questions, as shown in Figure 11. The first research question focuses on describing a set of OSs within the EV charging ecosystem and investigating their relevance in the case of *adaptation of EVs for sustainable transportation solutions.*

Similar to the first research question, the second question also focuses on describing. Here, frameworks for OSRs were investigated, and prior applications of the OS-set were reviewed.

The insights collected generated a model for openness that could be applied to the *intended* and *perceived* openness of this study.

For the third research question, data from protocols of OSs, published articles reviewing protocols, and documentation on analysis of the protocols have been utilized to position the OS-set from the first research question, according to the openness model generated by the second research question. This baseline was used to describe the current state of the *intended* openness of the OS-set.

The fourth research question aimed at describing the real-world application of OSs in the Swedish EMBE. The investigative part of the question allows for the collection of new data from interviews with industry actors, and the analytic part related the results to the openness model, through various sub-steps. The sub-steps included; categorization of the responses according to a SWOT, analyze the response distribution, identification of themes, analysis of themes, and correlation of themes to the *Openness model*. By having a last step of expert interviews, this data could be confirmed, and further trends could be investigated.

Lastly, the main research question of exploring potential gaps was performed by comparing the analysis of the intended openness to the analysis of the perceived openness, and finally connecting the dots.

3.3.2 Research process

A research process is described by Crotty (2018) to be a dynamic and iterative journey (Crotty, 1998). This systematic and structured approach describes the path of how a researcher investigated a particular topic or problem. According to Bell et.al. (2019-a), the subsequential steps should generally be included in the existing research process; Formulating the research question, Reviewing of existing literature, Defining the research design, Collecting data, Analysing data, interpreting and drawing of conclusion (Bell et.al., 2019-a). For this study, the research questions were formulated before the initial interviews, and after the initial literature review. As per the order of the four phases, the research process consisted of various steps to achieve the results and analysis of this study. The steps of the research process have been summarized in Figure 12. The colored blocks indicated if the steps were part of the *results* or the *analysis* of the study. Listed below is the description of the steps that were performed throughout the research process of this study.

For the first phase of investigating openness, there were two parts: identifying an OS-set and generating an *Openness model*. The first part started by the performance of an initial literature review to gather relevant information and insights from existing studies on potential OSs that may be of interest, and their application within the EV charging ecosystem. After this, interviews with experts in the field were conducted to obtain valuable perspectives and recommendations regarding the research topic and OSs. This led to the identification of an OS-set, which was then investigated to see further understand its relations to the EV charging ecosystem. The investigation included; looking at characteristics and attributes. For the second part of the first phase, a second round of literature review was conducted. This literature review focused on reviewing frameworks relating to OSs, OSRs, and applications of such frameworks onto the previously identified set of OSs. Different frameworks and guidelines for OSRs were compared to determine their similarities, differences, and potential applicability to the research context. The selected OSR framework was revised and adapted to align with the specific needs and objectives of the comparative case study. As a summarizing overview of the second literature review, the historical development and timeline of the OS-set were explored to gain a deeper understanding of its evolution and impact over time.

In the second phase of investigating the intended openness, the selected OS-set was evaluated according to the *Openness model* to assess the levels of openness from different perspectives. Primary data was collected from official sources such as documents, reports, and official records related to the OS-set and their specification development (specifically for their permeability and transparency of decision-making processes). Secondary data was gathered from prior research studies that have examined the same OSs while using a different (but related) OSR framework. The evaluations of the level of openness from the prior research were translated to the *Openness model* of this study. Thus, the level of openness of the OS-set was measured. The results were then scaled and the values, representing the level of openness, were graphed and visualized to facilitate comparisons and analysis.

For the third phase of the investigation of the perceived openness, different perspectives, and viewpoints on the OSs in the EV charging ecosystem context were compared, taking into account the opinions of various stakeholders or actors involved. First, the interview actors were positioned within an appropriate theoretical framework (the EMBE), to later be able to analyze their roles and contributions in relation to the responses. The main interviews were conducted with key industry actors or stakeholders who have experience and involvement with the EV charging ecosystem, and thus the OS-set. The results of the interviews were transcribed, and quotes were identified, numbered, and categorized. Various analysis techniques were employed to gain insights from the interviews, including SWOT analysis, response distribution analysis, word cloud visualization, and theme identification and analysis. The findings from the interviews were analyzed in relation to the *Openness model* assessing the alignment of the OS-set with the model.

In the last phase of exploring potential gaps, the intended openness and perceived openness were compared using the *Openness model*. The analysis used connection points to display where connections could be made, where the number of connection points could be seen as an indication of how effectful one parameter may be in relation to the others. All in all, the conclusions could be used as an indication of where to focus efforts if OSs are to be used as a facilitator for sustainable transportation solutions.

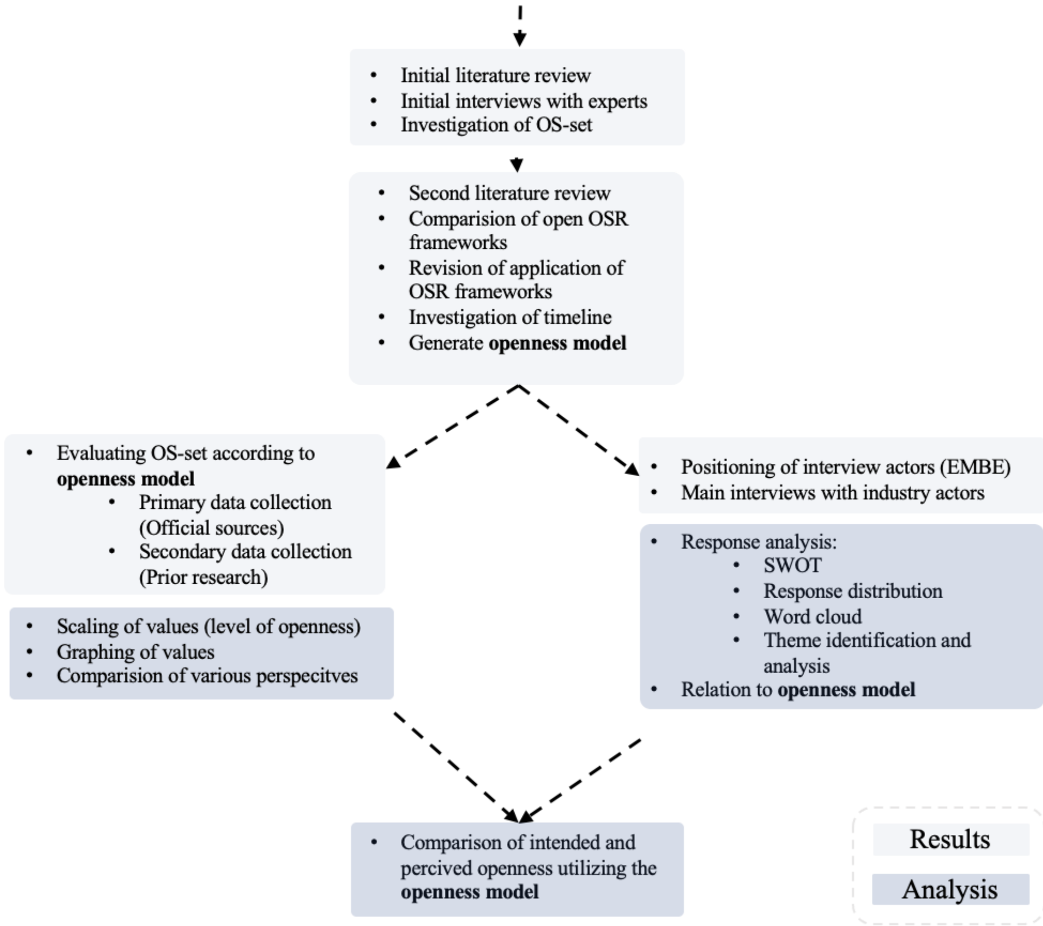

Figure 12. Research Process

3.3.3 Data collection

With the comparative case study research design, there were two main methods of data collection, these were; (1) literature review, and (2) interviews. Where the first two represent secondary sources of data. While the last data collection consists of primary data. Here follows a description of the data collection methods used in the research study. The strengths and weaknesses of each method were deliberated on. Further means for increased research quality are described later in this chapter.

3.3.3.1 Literature analysis

The literature analysis relied heavily on published research articles and published books on the concept of OSs and OSRs. This analysis was performed with a dual purpose, to; generate an *understanding* of the main concepts, and to revise the findings from the later phases of data collection.

Publications related to the topics of this study were read and assessed by using online databases for literature (eg. Google Scholar, Research Gate, Web of Science, ScienceDirect, Elsevier, and the Chalmers University of Technology database). With the limited timeframe, a collection of articles was gathered and analyzed. These were assessed to be highly relevant based on attributes such as; publication year, citations, and references. Since the industry is rapidly advancing, reports from well-established firms and official sources were used for discussion parts of the interviews.

The strengths of using literature lay in that if performed in accordance with quality research, it allows for multiple perspectives of the same topics to be reviewed. The selected research articles were retrieved from well-renowned publication databases and the publishing years spanned from over two decades of research efforts from researchers across the globe. With this broad coverage in terms of both time and settings, resulted in a well-based theoretical model that could be applied to this research study and evaluated according to previously proven concepts and models. Potential weaknesses may occur due to bias from either the selectivity of the article collection, or potential reporter bias of the authors of the original articles.

3.3.3.2 Interviews

The main data collection of this study is the input data from interviews, and questionnaires based on the theory from previous data collection through literature analysis and document/protocol analysis. There are three main interview techniques that can be used to gather qualitative information; *structured*, *semi-structured,* and *unstructured interviews*, (Bell et.al., 2019-a). With that said, there are 3 phases of interviews performed in the entirety of the research study, all with the aim of collecting qualitative data. The interview was performed separately. By having them separate, each of the interviewees could provide their perspectives without the influence of each other.

The first is the *initial unstructured interviews with experts* to verify and aid in directing the focus from the initial literature review. By having the study proceed with the first interviews as unstructured, allowed for the interview subjects to elaborate on the topics. Bringing new perspectives and adding to the scope. The experts were gathered for their knowledge within the governor and/or academic perspective of the Swedish EV charging ecosystem.

The second is the *main semi-structured interviews with industry actors*. This takes the form of pre-determined open-ended questions that are asked to each of the interview subjects. This was in order to drive a more focused discussion and allow the interview subjects to answer relating to the research questions. The companies selected for the study were large corporations with great influence on the Swedish automotive industry, thus enabling a generalized overview perspective. The interviewees were selected from each company's innovation and/or IP departments. This was done in order to familiarize them with the topics and provide quality answers to the questions. The interviews were mainly held on digital platforms due to the various geographical positions of the companies. However, the data collected from interviews being checked by each of the interviewees, to assert that their response was accurately depicted.

The last interviews were the *concluding unstructured expert interviews*. This is where the results of the analysis are discussed in the current Swedish EMBE context and in that of future potential that may be entailed for the cases of OSs in this context. Interviews have the added strength of being targeted to the topic of the case study. The empirical observations of the interview subjects provide insights and display the industry attitudes from perceived causal inferences. On the downside, there are weaknesses to interviews such as bias and reflexivity. However, there have been several measures considered to mitigate these weaknesses and increase the quality of the research results.

The interviews were assessed to be necessary to gain the perspective of the industry in order to answer the research question. In total 3 initial interviews, 3 main interviews, and 3 last interviews were performed, see Appendix .A for the complete list.

3.3.4 Data analysis methods

The research study used data analysis following different methods for quantitative and qualitative data.

For the quantitative data of the intended openness, methods of; Scaling and graphing of values. For the qualitative data of the perceived openness, the method used were; Role distribution, SWOT analysis, Response distribution analysis, Pattern identification analysis, and Connection point analysis.

3.3.4.1 Scaling and graphing of values (level of openness)

The method of scaling of values was used for assigning numerical values to measure the level of openness in the data. This process allows for quantification and comparison of the data based on specific criteria or dimensions. The method turned the previously used scale of low-high into a scale of 1-5, for which a low: 1 and high: 5. This method facilitates the statistical analysis and modeling that followed. However, this method is limiting in that it may oversimplify the complex concepts or dimensions of openness. By assigning the values, the method becomes subjective which can introduce bias. The method may also risk overlooking qualitative nuances.

These values were then analysed by graphing the scaled values, providing a visual representation of the data distribution and patterns. This facilitated the identification of trends, variations, and potential relationships within the data. Different perspectives were compared by analyzing and contrasting the data from multiple sources or viewpoints. Providing a more nuanced analysis. This method helped to identify commonalities, differences, and relationships among the perspectives being examined. The methods may be limiting in that they can mask individual variations. It can also be interpreted in a subjective manner depending on the visual presentation of choice.

3.3.4.2 Role analysis

The interviewed actors were positioned within the EMBE framework, to situate their roles, contributions, and alignment with specific dimensions or criteria within the framework (Bowen et al., 2009). This facilitates a structured analysis of interview actors' roles and contributions. Thus, enabling further analysis of the responses.

3.3.4.3 SWOT analysis

The SWOT analysis method was used to analyze the strengths, weaknesses, opportunities, and threats related to openness in the research context. The framework allows for the evaluation of *strengths* (S), *weaknesses* (W), *opportunities* (O), and *threats* (T) (Pahl et al., 2018). In this study, the SWOT categories will be related to OSs and open innovation.

Important to note is that one must be careful to oversimplify complex factors and interrelationships when using a SWOT analysis (Pahl et al., 2018).

To enable this analysis, the responses were transcribed and separated into quotes, which were randomly numbered, while still keeping the relation to which interview questions the response adhered to. This way of organizing the responses allowed for the SWOT framework to be applied and the categorization to act as coding for the responses which could then be looked at from various analytic methods (eg. Statistical, Semantical, and Relational)

3.3.4.4 Response distribution analysis

The SWOT analysis of the responses, enabled the distribution analysis. Since the SWOT categorizes the responses and identifies frequencies and spread of viewpoints (Pahl et al., 2018). This provided an opportunity to statistically analyze the responses in each of the SWOT categories to investigate each actor's contribution. The distribution between; *SWOT categories*, *internal vs external* perspectives, *positive vs negative aspects*, and *the standard deviation* were evaluated. To avoid the risks of not capturing the depth of the individual responses, an in-depth analysis of the quotes from the responses was performed.

3.3.4.5 Content analysis

Content analysis is a research method for objective, systematic, and quantitative description of the evident content that were communicated (Krippendorff, 2004). It can thus be used as a reliable and valid analysis of qualitative data (Elo & Kyngäs, 2008). In this study a combination of content analysis was used; word cloud, word frequency, and conceptual analysis.

To identify patterns/themes, a word cloud analysis visually represented the frequency and prominence of words or phrases in the data, aiding in the identification of key themes or narratives related to openness (Coppersmith & Kelly, 2014). The process of theme identification and analysis involved systematically categorizing and analyzing recurring themes or patterns in the data, providing deeper insights into the concept of openness (Luborsky, 1994). However, word cloud does run the risk of subjective interpretation. Thus, a word frequency analysis was performed in relation to the world cloud limit of these risks. This analysis will help identify the most commonly mentioned keywords within each category.

To compare the distribution of themes and openness levels, across the parameters in the *Openness model*, a conceptual analysis was performed. By using conceptual analysis, the researcher uses the natural language speaker intuition to detect the meanings of expressions (Vogel, 2018). This helped in understanding the relationships between the identified themes and the *Openness model*, as well as the connections between the OSRs of the *intended openness* and the *perceived openness*. This study is alluding at a complex issue and the methods have risks of subjectivity and are based on multiple assumptions, However, connecting the dots can be seen as a way of providing insights on themes that can then be further researched. The step helps identify potential connections and dependencies between different aspects of the analysis. By identifying key parameters and their relation to the *Openness model*, based on the frequency of occurrence and patterns identified, the analysis can help prioritize and focus on the key parameters that emerged from the interviews. Which can potentially enhance decision-making, allows for efficient resource allocation, and aid in risk management.

3.4 Research quality

Researchers should, according to Bryman (2012), make an effort to conduct high-quality research practices. The research quality can be enhanced by deploying careful planning and systematic data collection and analysis, with transparent reporting of the process. This involves adapting rigorous methodologies, using appropriate instruments, and keeping with ethical considerations (Bryman, 2012).

In order to address potential weaknesses of the chosen research methods, several measures of quality criteria have been applied to the study. The criteria for quality are based on a combination of prior models for qualitative and quantitative research (Patton et. al., 1993) (Erlandson, 1993-a). Here follows the research quality considerations for the qualitative parts, including; Internal and external validity, Reliability, and Objectivity. As well as the quantitative parts, including; Credibility, Transferability, Dependability, and Confirmability.

3.4.1 Internal validity/ Credibility

Internal validity describes the quantitative research criteria of quality, while credibility refers to the qualitative (Bell et. al., 2019). Together they describe the level at which the finding can be trusted by the participants of the study. To increase the trustworthiness of this study, the main method used was triangulation. Triangulation, according to Bryman (2012), involves a combination of data from multiple sources and methodological approaches to further understand the research topic (Bryman, 2012). This was performed in the quantitative research by collecting the data from various sources of literature and documentation/protocols, as well as for the qualitative research by interviews with actors with different role perspectives, such as; industry actors and experts in the field.

Other methods used were referential adequacy to enhance the internal validity of the usage of material from previous research articles/studies, by using material that was published to renowned research databases. As well as member checking by having the insights from the responses of the main interviews checked with experts in the concluding interviews. This also aided in mitigating potential weaknesses of bias.

3.4.2 External validity/ Transferability

The external validity relates to the quantitative research criteria of quality, while the transferability (also referred to as the applicability or fittingness) refers to the qualitative. Each of these describes how the findings can be applied in other contexts (or with different participants). Guba and Lincoln (1994) argued that qualitative research focused on providing a rich and contextualized description that can be meaningfully transferred to similar contexts (Guba & Lincoln, 1994).

The study is focused on the context of the Swedish EV charging ecosystem. With the cases of; the set of OSs (four OSs), and the Swedish EMBE. There was a purposive sampling of the OSs in the set, as well as the actors for the interviews. This study only applied the perspectives of a few, however, meaning full, OSs and actors. The actors were selected from large and influential companies to depict the general perception of the industry. With OSs being applied at various organizational levels, up to global capacity, the transferability of the method for qualitative research can be deemed to meet the quality criteria, providing an accurate representation.

With there being plenty more OSs within the EV charging ecosystem to be investigated. In addition, actor perspectives to explore. Therefore, aiming for high applicability would enable more useful contexts to be explored in the future. To ensure this, thick descriptions were provided. Explaining the various concepts and methods used, actors interviewed, and frameworks generated. So that the *Openness model* and the industry insights could potentially be positioned in and/or inspire different contexts to evaluate the OSRs.

The results may not be directly transferable to other industry fields without additional data collection for those specific contexts. However, there is a borderline in the discussion of the results that may be of interest to other industries with the development of open innovation strategies for the EV charging ecosystem. The ecosystem spans across industries, making it increasingly difficult to address the cases with solely one single industry in mind. By providing thick descriptions of the industry actor's position and roles in the context and selected cases the transferability was increased.

3.4.3 Reliability/ Dependability

Reliability refers to the quantitative research criteria of quality, while dependability relates to the qualitative. These research quality criteria are used to enhance the extent of how the study may be repeated and the variations may be understood.

The study has employed different steps of audit trails of the procedures and processes to increase the stability and repeatability of the findings. With the frameworks and measurements of the parameters used being displayed. Emphasizing the extent to which the quantitative research findings can be replicated or produce consistent results in similar conditions.

For the qualitative research parts, having actors from different perspectives and the experts review the insights from the main interviews was also a way of ensuring that the responses were not outliers from the general industry perceptions. Adding more sources for the triangulation of the study.

3.4.4 Objectivity/ Confirmability

Objectivity (or neutrality) describes the quantitative research criteria of quality, while confirmability refers to the qualitative. These research quality criteria are used to decrease the extent to which the findings are based on the bias and personal values of the researcher.

To ensure the neutrality of the research methods, several strategies have been applied. Mainly triangulation, similar to previous quality criteria, where multiple sources are used to generate both qualitative and quantitative results.

To increase the confirmability of the qualitative results from the interviews, member checking was applied. Where the interview objects had the opportunity to review the transcripts of their interview and change, retract, and or add to their statements. This process allowed for the verification of the accuracy of the interpretations of the interviews and to gain a deeper understanding of the participants' viewpoints.

All in all, there are risks for subjectivity in this type of research study. An audit trail of the process and data analysis were employed to mitigate these risks. Showing if and how such inputs had been utilized.

3.4.5 Ethical considerations

The already mentioned complexity of the research questions and contexts of the study have led to multiple ethical considerations. The importance of ethics in research has been expressed by Erlandson (1993) as "*not a cumbersome 'add on' to naturalistic inquiry, but a logical outcome of the paradigm*" (Erlandson, 1993-b, p 132). Thus, the following main considerations were made.

Within the qualitative analysis, there is a risk of bias when interpreting the responses from the interviews. As described in the research quality above, the steps in the method have been designed and performed in transparency, to minimize this risk. Leaving the reader with the option of their own interoperation.

The study acknowledges that the specific context and small sampling, due to time restrictions, account for the higher dependability of both the qualitative and quantitative results. However, with the aim of understanding the general attitudes the method chosen was in accordance with the goals of the study. By leaning on the inputs of prominent actors of the Swedish EMBE. The anonymity of the interviewees has been respected, and the numbering and analysis of the responses have been kept in line with such procedures. The interviewees have given their consent to the responses being utilized in this study.

4 Results

This chapter presents the findings of the investigation of the *openness*, *intended openness*, and *perceived openness*. The results of the collected data are structured according to the first three phases of the research process. The first phase of the *openness* included the identification of the OS-set and the investigation of its relevance within the context of the EV charging ecosystem along with the investigation of OSR frameworks and applications. Together, this generates an *Openness model* to be applied in the context of this study. The second phase is the *intended openness*, which includes applying the openness model to existing data. The third phase is the *perceived openness*, where the interview participant was positioned in the EMBE, and data from the main interviews were collected and structured.

4.1 Investigation of Openness for EV Interoperability in Sweden

To be able to understand the *intended* and *perceived* openness of important OS for e-mobility in Sweden there is a need to first understand openness. This is done in two parts. First by identifying the set of OS that is relevant to the Swedish e-mobility ecosystem (understanding their function and relevance). Secondly by investigating the OSR frameworks, and insights from previous applications.

4.1.1 Identifying the OS-set

For the research study's purpose of investigating OSs as facilitators for the development of sustainable transportation solutions, literature analysis and initial interviews with experts were conducted. The interviews aimed at confirming the relevance of the OS-set, in relation to the Swedish e-mobility ecosystem. To gain insights into the relevance of various characteristics and attributes of the OSs.

4.1.1.1 Results from initial interviews

The initial interviews were conducted with experts in the field, working with industry actors but with a more institutional perspective (see section 2.2.1). They confirmed the previously collected information on the relevance of the challenges of the EV charging ecosystem (see section 2.2.2), and from the open communication protocol (see 2.2.3) they identified four OSs to be highly relevant to address the challenges of the adaptation of EVs. Thus, indicating them to be part of the OSs that are used to facilitate the development of sustainable transportation solutions.

In the comments made by the experts of the initial interviews, they mentioned two OSs that may be of interest due to the OSs nature of being building blocks for other standards (eg. ISO 15118 and IEC 61851). The experts also described two OSs that work on more specific scopes that will come to play a major role in the adaptation of EVs (eg. OCCP and OpenADR). From the initial interviews, there was a consensual interest expressed for covering different origin types of OSs; that of SDOs vs Consortia, as well as including the different information flows profiles of Front-end vs back-end.

From the inputs of the initial interviews, the resulting OSs were selected for the OS-set of this research study:

- ISO 15118
- IEC 61851
- OCCP
- OpenADR

The characteristics and attributes of the OS-set will be further explained in the upcoming sections. The relevance of these standards has been referenced in previous works (Deniz, 2015) (Neaimeh & Andersen, 2020a). Exemplified by the investigation of the OCPP, Deniz went on to define the criticality of the standard for further development of the charging market (Deniz, 2015). All in all, this further displays the previously researched level of relevance of the OS-set for the interoperability of e-mobility (see section 2.2).

4.1.1.2 Investigating OS-set relevance

The characteristics and attributes of the OSs set are included in Table 2, to generate an overview of relevance and comparison of them to each other. The acronyms of the author organizations are as follows; *International Organization for Standardization* (ISO), *International Electrotechnical Commission* (IEC), *Open Charge Alliance* (OCA), and *Open Automated Demand Response Alliance* (OpenADR Alliance).

Table 2. OS-set – Characteristics and Attributes

OSs	Author/s	Year of first publication	Currently under development	Version (Year of publication)	Information flow profile	EV charging ecosystem position	Source
ISO15118	ISO	2010	Yes	2 (2014)	Front-end	EV charging point	(ISO, n.d.-a)
IEC 61851	IEC	2001	Yes	2 (2010)	Front-end	EV charging point	cie.co.at
OCPP	OCA	2010	Yes	1.6 (2016)	Back-end	Central system - charging point	(IEC, 2023)
OpenADR	OpenADR Alliance	2003	Yes	2.0b (2015)	Back-end	Smart charging	(OpenADR Alliance, n.d.)

ISO 15118 and IEC 61851 are created by SDOs (as described in 2.1.3.1), and therefore such organizations tend to have a higher level of authority. The OCPP and OpenADR were developed by consortia. Stemming from an industry need, with companies and organizations coming together to solve a common challenge. Later in the year 2015, OpenADR 2.0b was translated into an IEC standard - IEC 62746-10-1. Thus, increasing the accendibility of the standard. ISO, similar to IEC, has representatives from each participating country. These are referred to as national bodies and national committees, respectively (ISO, n.d.-a) (IEC, 2023).

Timing-wise, as previously described (see section 2.1.3.2), the OSs in the set are still being developed and improved upon. The first version appeared between the years of 2001-2010. For the specific versions investigated in this study, the publication years spanned between 2010-2016. There was an intensification of publications of newer versions starting from 2010 and continuing to be the case today. The IEC 61851 standard was the earliest in the set, and together with the ISO 15118, it set the stage for the development with their broader scope. ISO 15118 can be seen as a more advanced complement to IEC 61851, as it includes additional features such as secure communication and bi-directional power flow (Neaimeh & Andersen, 2020a). The version history represents the version that has been considered in this study. Any earlier or later versions have not been included for the purpose of aligning with the secondary data collected from the previous research evaluation of Neaimeh and Andersen (2020a). There are also parts in the series of communication protocols that may also have their own version history. The timeline of the version history will be illustrated later (see Figure 13).

For the operational functionality of the OS-set, there are two types of open communication protocols: *front-end* and *back-end*, as described previously (see Section 2.2.2). ISO 15118 and IEC 61851 are front-end protocols and work by linking the vehicle and the charge point, transferring information that is specifically required for the plugs. OCPP and OpenADR on the other hand, are back-end protocols. Entailing that they are working to establish information flows between the charge point and third-party operators.

Together, the standard set is positioned across multiple units in the previously described open communication protocol landscape (see section 2.2.3). ISO 15118 and IEC 61851 are focused on the EV charging point (EV- ESVE), while the OCPP and OpenADR have a narrower scope, including the central system of the charging point and smart charging, respectively (EVSE to CPO, and EVSE to DSO). As illustrated by the examples in Figure 7.

The OS-set is identified to have a broad span of various characteristics and attributes, such as; the nature of origin, the timing of publication, operational functionality and information flow types, and the scope of the protocol. They all have the aim of creating an effective approach to adapting to EVs (ISO, n.d.-a) (IEC, 2023) (OCA, n.d.) (OpenADR Alliance, n.d.). Therefore, the OSs of the OS-set are set to be relevant as facilitators of EV adaptation, and thus, the development of sustainable transportation solutions.

4.1.2 Investigation of OSR frameworks

In parallel to the developments of the publication of the OSs, there have been multiple attempts at defining the set of requirements for determining the degree of openness of OSs. The frameworks used for the comparison in this research study can be seen in Table 3. With the previously described (see section 2.1.3.3) Mutkoski's framework, being the set of OSR selected as the basis for further analysis in this research study (Mutkoski, 2011). Listed below are the results of the literature review of the OSRs included in each of the frameworks (see Table 3).

Table 3. Comparison of OSR frameworks

Author	Creation origin	Year of publication	Nr of OSRs	List of OSRs
West *Source: (West, 2005)*	Recognized person	2005	4	(1) Access or participation permeability (2) Nature of decision-making process (3) Specification rights (4) Intellectual property rights access
Krechmer *Source: (Krechmer, 2006)*	Recognized person	2006	10	(1) Openness: all stakeholders may participate (2) Consensus: all interests are discussed, and agreement found. No domination (3) Due process: balloting and an appeals process (4) One world: same standard for the same function worldwide (5) Low or no charge for IPR necessary to implement (6) Open documents: access to drafts, documents, and final version of the specification (7) Open change: process for updating is carried out within the organization (8) Open interfaces (9) Objective conformance mechanisms and testing (10) Commitment to support
OASIS	Governmental body	2010	5	(1) Developed through an open decision-making process (2) Mature

Source: (OASIS, 2010)				(3) Global (4) Openly published, either with no royalties and other restrictions on reuse, or with any such restrictions offered on reasonable and non-discriminatory terms (5) Well supported in the marketplace.
IEEE, ISOC, W3C, IETF, and IAB Source: (Open-stand, n.d)	Standardization body	2012	5	(1) Cooperation relating to the respectful cooperation between standard organizations, in regards to autonomy, integrity, processes and IP managed rules (2) The adherence to principles included five fundamental principles of standard development; a. *Due process* – equal decision power, b. *Broad consensus* – allow for all views, c. *Transparency* – open display of the records, d. *Balance* – not exclusively dominated and e. *Openness* – open to all interest and informed parties. (3) Collective empowerment included several steps of striving for expertise, global interoperability, scalability, stability, and resilience, amongst others. And the mention of global competition and building blocks for further innovation that can benefit humanity (4) The availability should be implemented under fair, reasonable, and non-discriminatory terms (FRAND) (5) Lastly, the (5) voluntary adaptation ensures that the success of the standard is determined by the market
Mutkoski Source: (Mutkoski, 2011)	Recognized person	2011	7	(1) Permeability (2) Transparency (3) Structural (4) Accessibility (5) Claims (6) *Market Success* (7) *Interoperability*

As evident by Table 3, there have been multiple frameworks trying to describe the same concept – the OSRs of an OS. The exemplified frameworks shown in Table 3 were collected from of the different form of sources; *recognized persons*, *governmental bodies*, *and standardization bodies*, as described in section 2.1.3.3. The initial attempts originated from recognized persons, such as West (2005) and Krechmer (2006), among others. After which governmental bodies and standardization bodies performed their own attempts at formulating a set of OSRs. Some by themselves such as OASIS (OASIS, 2022), other in a joint effort, exemplified by the case of the *Institute of Electrical and Electronics Engineers* (IEEE), *Internet Society* (ISOC), *world wide web consortium (*W3C), *Internet engineering task force* (IETF), and *internet architecture board* (IAB) (Open-stand, n.d.). However, since the IEEE, ISOC, W3C, IETF, and IAB- framework was not included in Mutkoski (2011) combination of prior works, it will not be considered further in the study. The timeline for the publications of OSR frameworks will be illustrated later (see Figure 13).

All the frameworks mentioned in Table 3 have similarities and overlaps within their respective sets of OSRs. The overall goal of the various requirements is to promote transparency, inclusiveness, and fairness in the development of standards, ensuring that they are freely accessible, documented, and developed in an open and collaborative manner. Including requirements that consider perspectives of interform both internal and external points of view from across the standard development phases (Mutkoski, 2011).

As described previously (see section 2.1.3.3), Mutkoski (2011) aimed to combine the previous works of West (2005), Krechmer (2006), and OASIS (2010). The author believed the main difference lay in the grouping of the requirements (Mutkoski, 2011). Compared to the other frameworks of Table 5, Mutkoski (2011) developed his framework after the others, allowing for a level of maturity within OSs before realizing the broader potential for categorization of the common requirements. The authors framework was built upon seven requirements, which was more than that of the standardization organizations, as with the governmental organizations (eg. OASIS (2010)) and that of some of his predecessors (E.g West (2005)). But less than that of other researchers (eg. Krechmer (2006)). This potential sweet spot of the number of requirements allows for important distinguishments to be made between the OSR, while keeping the framework minimal and applicable to real-like context.

As described previously (see section 2.1.3.2), OS development can be divided into three SDPs; *specification rights, implementation, and complementing rights,* and *usage rights* (West, 2005). Understanding these conditions allow for the Mutkoski (2011) framework of OSRs to be applied to the SDPs of West (2005). With the various OSRs accommodating different SDPs of the OS. The relationships between the SDPs and the OSRs will be displayed later (see Table 5).

4.1.3 Investigation of previous applications of OSRs on OS-set

The combination of applying a set of OSRs onto one or more of the selected OS for this research study has been done prior. However, it has not, to the extent of the study's knowledge, been done using Mutkoski's OSR framework (Mutkoski, 2011). Here follows the results of the reported levels of openness for two applications: Deniz (2015) and Neaimeh & Andersen (2020a).

4.1.3.1 Application 1 – West's framework onto OCPP

In 2015, Deniz performed an application of West's (2005) framework on the OCPP (Deniz, 2015). In the application, the author described his insights in response of using the OSRs of West (2005) as seen in Table 5). The findings and insights of Deniz (2015) will be used to later generate an *Openness model* to be used for this study.

For the results of the works of Deniz (2015), in terms of the first standard development phase – *specification rights*, the author stated that for the access or participation *permeability*, anyone who pays the membership fee and declares an interest in the EV charging industry is eligible to participate in the ongoing development of the OCPP protocol. Deniz went on to add that the participants can access and be part of the *decision-making* processes using a platform for discussion, development, and documentation of the OCPP specification and that only versions that have been released are freely accessible to the public. The Author described the evolution of the OCPP, going from a more closed state into a more open state because of the industry's demand for participating. The increasing demand was stated to be a result of the realization of the flexibility of the protocol by various EV charging industry participants. The author argued that in the early phases of technology standards, the general availability of the work in progress can represent a measurement of openness. The article went on to describe the indications from the results, confirming the findings of previous works that the actual level of openness in consortiums tends to be higher than conventional thinking. Regarding the levels of openness across the members in developing the specifications. Deniz described the non-discretionary membership style as a tool for encouraging different core competencies which according to the author implies that the latest technologies can be integrated into the solutions. In turn, making it responsive to changing industry dynamics (Deniz, 2015).

In terms of the second standard development phase – *implementation and complementing rights*, the OCPP protocol specifications are available, but the protocol is not open source. Relating to the requirements for claims, the protocol can be licensed royalty-free under the Elaad foundation, the implementation does not require any additional payments from the end user. The author stated that *"any firm can access it to develop its own implementation as well as develop complementary offerings to their business operations*" (Deniz, 2015, p 3). The author also described opportunities for the OCPP from the complementary perspective between EV and charging infrastructure. Expressing how this area needs strengthening, and that the adaptation of EV can be supported by the new charging infrastructure (Deniz, 2015).

For the third standard development phase – usage rights, the author states that in the case of the OCPP, "*when access to the specification document is equally distributed among economic agents a standard tend to be a defined as an open*." (Deniz, 2015, p 3). There OCPP has two possible implementations (the JSON and the SOAP), this further adds to the openness (Deniz, 2015).

In the article, the Author also made a point of separating some of the requirements of West's framework into sub-requirements, such as in the case of availability and interoperability. Where availability could be divided into; The differentiation being that between *implementation* vs *complementation*. Where the first relates to the availability of the complete specification and the second to the information available to encourage complements. Since there is an underlying mechanism of potential lock-in effects, openness needs to be evaluated with both consumer interaction and other operation integrations in mind. Similarly, interoperability should be divided into; *interoperability* to lessen *buyer constraints*, and *interoperability* that enable functionality *between standards* (Deniz, 2015). This separation will be utilized later in this study in the generation of the *Openness model*.

4.1.3.2 Application 2 – Krechmer's framework onto ISO 15118, IEC 61851, OCPP and OpenADR

In their article *Mind the gap - open communication protocols for vehicle grid integration* published in 2020, Neaimeh and Andersen utilized the works of Krechmer (2006) (see Table 5), as a OSR framework for evaluation multiple EV standards. Along with definitions and assessments made by ElaadNL and EPRI (ElaadNL, 2017) (EPRI, 2019). Among the applications were the set of OSs for this research study: ISO 15118, IEC 61851, OCPP and OpenADR. The insights of Neaimeh and Andersen (2020a) will be used to later generate an *Openness model* to be used for this study. The results the authors evaluations will later in this study be utilized to investigate the intended openness results.

The authors used a simplified version of the Krechmer's (2006) framework. Dividing the OSRs into four requirements; *Openness*, *Interoperability*, *Maturity* and *Market adaptation*. Each of the parameters including one or more of the aspects of Krechmer's (2006) framework. For the first requirement of *Openness*, the authors used the definition of ElaadNL (ElaadNL, 2017), where openness indicates if a protocol; (1) Has been developed by an accredited standard organization, (2) Whether it is subject to IP rights, and (3) If it is publicly accessible to no (or minimal cost). The authors also used Krechmer's definition (Krechmer, 2008), where the author stated that openness also entails; (4) facilitating the possibility for different e-mobility entities to participate in the protocol development process. For the second requirement of *interoperability*, the authors used the definition of EPRI (EPRI, 2019), where it encompasses aspects of; (1) Technical interoperability, (2) Detailed description vs generic description, and (3) Clarity of specification. For the parameter of maturity, the authors used; (1) Number of realizes, (2) Time in use, (3) Certification possibility, and (4) Availability of testing. Lastly, for the parameter of market adaptation, they used the current number of users of the protocol. Neaimeh and Andersen did point out that the maturity and market adaptation of the EV market, in the year 2020, were considered to still be low. Making it hard to compare it to the market adaptation and maturity of other protocols, such as the internet (Neaimeh & Andersen, 2020a).

For the corresponding OS-set the authors evaluated each of the parameters on a low – high scale. The results of the evaluation of Neaimeh and Andersen (2020a) are displayed in the table below (see Table 4). One insight from this application is that the parameter of *Maturity* and *Market adaptation* may be excluded. As verified by the authors' own statement of the still perceived low adaptation of the EV market, as of the year 2020.

Table 4. Prior evaluation of the OS-set (Neaimeh & Andersen, 2020a)

OSRs / OSs	Openness	Interoperability
ISO 15118	High	High
IEC 61851	High	High
OCPP	Medium/High	High
OpenADR	High	Medium

The author's remarks regarding the evaluations were the following. For the ISO 15118 and the IEC 61851 there was no further comments on the evaluation, and for the OCPP the openness evaluation was motivated to be "*Medium because OCA is not accredited*." (Neaimeh & Andersen, 2020a, p 7). The OCPP interoperability had no further comment. For the OpenADR the authors motivated the evaluation by saying referring to the OpenADR version 2.0b, becoming a full IEC standard, thus increasing the openness. For the interoperability of the OpenADR the motivation for the medium score was due to the" *Generic description making it less interoperable*" (Neaimeh & Andersen, 2020a, p 7). The reviewing the works of Neaimeh and Andersen resulted in the insight that maturity and market adaptation can be overlooked in this case of generating an *Openness model* to be applied in the EV charging ecosystem. The authors' evaluations of the OS-set will be utilized for the investigating the intended openness described in later sections.

4.1.4 Summary of the investigation of *openness*

The set of OS for this study has been identified to contain the OS; ISO 15118, IEC 61851, OCPP, and the OpenADR, as shown in Table 2. The results of the initial interviews indicated this from the desire to maintain a broad span of; nature of the interoperability, specific scope, origin, and information flow. The OS-set was investigated through a secondary literature review of the respective characteristics and attributes, which indicated that they were of high relevance as facilitators for the EV adaptation, and thus, the development of sustainable transportation solutions.

A timeline of the events of publications and applications of OS and OSRs has been summarized below (see Figure 13). This shows the timing of the collection of the results from the; OS-set (see Table 2), OSR framework publications (see Table 3), and OSR framework applications (see section 4.1.3).

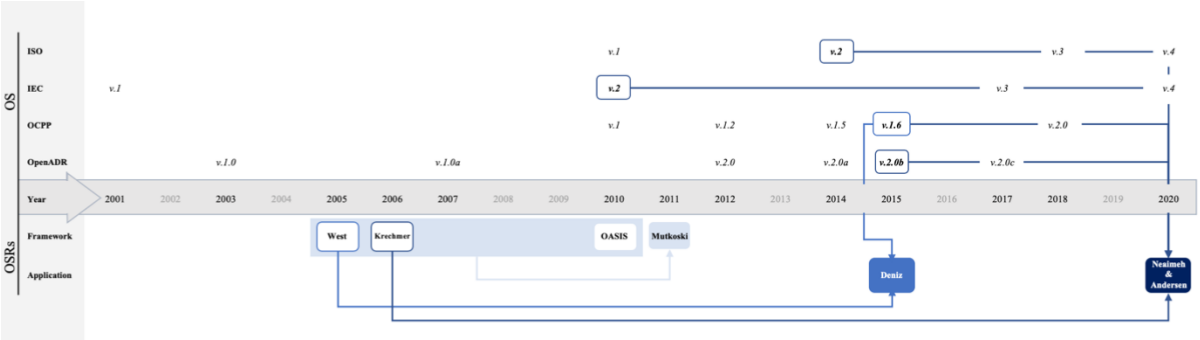

Figure 13. Timeline of OS and OSR (publications and applications)

From Figure 13 there is a depiction of a shift in the utilization of openness standards in the e-mobility sector, over the last two decades. The frameworks have been building on each other, and the number of requirements to define the OSs is still up for debate. Figure 13 also shows the correlation between what OSs and OSR frameworks have been used in each of the applications. Mutkoski's (2011) framework is a combination of some of the most recognized frameworks. Therefore, it utilized the combined aspects of the previous works, with the advantage of being able to reflect on the evolution of OSs over the previous decade since the first mention of West (2005).

The main differences between the investigated OSR frameworks come down to the categorization and/or grouping of requirements. Emphasizing different features is important for the overall degree of openness (see 4.1.2). The results of the review of prior applications of OSR frameworks (Deniz, 2015) (Neaimeh & Andersen, 2020a), on any or all of the OS in the set (see Table 2) of this study have resulted in two main insights. First, from Deniz's (2015) application the insight of sub-requirements for the OSRs of Availability and Interoperability were identified. Secondly, from Neaimeh and Andersen (2020a) the insight that *Maturity* and *Market adaptation* could be overlooked in the context of this study, due to its, as of 2020, low application. Thus, one can overlook the OSR of *Market success* within Mutkoski's (2011) framework (see Table 3). These two main insights, together with the Mutkoski's (2011) framework, enabled the generation of the *Openness model* (see Table 5).

Table 5. Openness model

OSRs	*Source:*
SDP 1: Specification rights	*West, 2005*
Permeability (P) Transparency (T) Structural attributes (S)	*Mutkoski, 2011 (built on West, 2005)*
SDP 2: Implementation and complementing rights	*West, 2005*
Availability – complete specification (A1) Availability – encourage complements (A2)	*Deniz, 2015 (built on West, 2005)*
Claims (C)	*Mutkoski, 2011 (built on West, 2005)*
SDP 3: Usage rights	*West, 2005*
Interoperability – buyer constraints (I1) Interoperability – between standards (I2)	*Deniz, 2015 (built on West, 2005)*

The *Openness model* in Table 5 is founded on the results of West's framework but is mainly reliant on the modified version by Mutkoski, and additions from Deniz (West, 2005) (Mutkoski, 2011) (Deniz, 2015). The resulting *Openness model* is based on six OSRs; *permeability* (P), *transparency* (T), *structural attributes* (S), *availability* (A), *claims* (C), and *interoperability* (I). Two of the OSRs have dual sub-requirements; availability – *complete specification* (A1) and *encourage complements* (A2), and interoperability – *buyer's constraint* (I1) and *between standards* (I2). All in all, resulting in a total sum of eight requirements to be investigated. Distributed under the three SDP's of West (2005) (see Figure 1).

With the study's intention of identifying potential gaps, having these sub-requirements is part of the nuances of the various levels of openness. This is done to lay a foundation for an investigation of the importance of requirements in each of the OS in the set for the research study. As reasoned by the results from the above investigation.

4.2 Investigation of *intended openness*

The intended openness is defined as the level of openness that the OSs were developed to achieve according to; documents, protocols, and the previous evaluation of Neaimeh and Andersen (2020a) (see Table 4). The intended openness level of each of the ORSs will be described in order of West's SDPs, as described in the previous theory (see section 2.1.3.2), following the OSRs of the *Openness model* generated above (see Table 5). The scoring still aligns with that of the previous research, with scores ranging from: low-high.

4.2.1 OSRs for SDP 1

There were two OSRs in the *Openness model* that were not interpreted to be included in the evaluation of Neaimeh and Andersen (2020a), the *permeability* (P) and *transparency* (T). For the evaluation of openness level for these OSRs, data will be collected from the official websites of the respective standard organization.

The nature of a standard can be determined by its origin and structure (see Section 2.1.3.1). Therefore, a compilation of the organizations and consortiums relevant to the OS-set of this research study has been conducted (see Table 6).

Table 6. Standard organizations related to Swedish EMBE (Characteristics and Attributes)

Name	Characteristics	Nature of organization	Year	Structure	Participation			Official website
					Members	Membership fee	Nr of participants	
International Organization for Standardization (ISO)	International standard organization	SDO	1947	Privately established. Composed of national standard bodies (NSB)	Members may be non-govermental organization or govermental agencies as selected by ISO. Different levels of memebers.	Cost	168	iso.org
International Electrotechnical Commission (IEC)	International standard organization	SDO	1906	Privately established. Composed of national standard committees	Members may be non-governmental organization or governmental agencies as selected by IEC.	Cost	60	iec.ch

Swedish Standards Institute (SIS)	National standard body	SDO	1922	Privately established.	Members from the private and public sector. No private individuals.	Cost	1800	sis.se
OASIS Energy Interoperation TC (OASIS)	Standard body/Consortia	SDO	1993	Consortium	Individuals, organizations, and governments	Free	177	.oasis-open.org
OpenADR alliance	Standard body/Consortia	SDO	2010	Consortium	Individuals, organizations, and governments	Free/ Cost	177	openadr.org
Open Charge Alliance (OCA)	Standard body/Consortia	SDO	2009	Consortium	Individuals, organizations, and governments	Free/ Cost Paid for certification	220	openchargealliance.org

For ISO the purpose of the organization is to bring experts together and share knowledge to develop international standards that support innovation (ISO, n.d.-a). For IEC their vision is to ensure safety, efficiency, reliability, and interoperability to facilitate broad electrical access (IEC, 2023). The ISO and IEC are two of the largest and most well-established standards organizations. As a national standard body, the SIS provides a network for the Swedish efforts of developing standards and acts as a project manager in response to the ISO and IEC (SIS, n.d.-a). ISO, IEC, and SIS all have memberships at a cost (ISO, n.d.-a) (IEC, 2023) (SIS n.d.).

On the other hand, there are alliances or consortiums that are built on agreements between groups of members, where the membership is not restricted to one per country. Allowing for individual members. The OASIS, specifically the OASIS Energy Interoperation Technical Committee has the purpose of enabling a collaborative and transactive use of energy (OASIS, 2022). The OpenADR alliance was created with the specific objective of standardizing, automating, and simplifying the demand response and distributed energy resources for energy demand and production (OpenADR Alliance, n.d.). While the OCA focuses on the objective of EV charging infrastructure through development, adaptation, and compliance (OCA, n.d.). Both OpenADR and OCA offer two types of memberships, one paid and one free, with different levels of additional benefits and responsibilities (OpenADR Alliance, n.d.) (OCA, n.d.). The level at which a member holds a position may affect their ability to hold leadership positions and influence the direction of the organization, including in decision-making processes.

Neaimeh & Andersen (2020a) evaluated the requirement of *Openness using the definition of* ElaadNL. Within this definition, there are mentions of *Openness* relating to if a protocol had been developed by an accredited standard organization. Thus, the OSR of *structural attributes (S)* in the *Openness model* may be correlated to the evaluation of Neaimeh and Andersen (2020a) (see Table 4).

With the described data above, combined with the previous evaluation of the Structural attributes (S) collected from Neaimeh and Andersen (2020a), the result of openness levels describing the first OSRs of the *Openness model*; *permeability* (P), *transparency* (T), and *structural attributes* (S) have been summarized (see Table 7).

Table 7. OSRs of SDP 1 for OS-set

OS \ ORS	*Permeability (P)*	*Transparency (T)*	*Structural attributes (S)*
ISO 15118	Medium	High	High
IEC 61851	Medium	High	High
OCPP	High	Medium	Medium/High
OpenADR	Medium/High	Medium/High	High

The ISO 15118 and IEC 61581 scoring of the *permeability* (P) is based on the limitations of who can join the standard development. Since the ISO organizations only allow for national standard bodies to join it can be evaluated as more closed, than if any organization were to be able to join. On the other hand, the national standardized body is comprised of a network of national industry actors which still generates an openness in the permeability aspects, although the direct individual influence might be diluted at each increasing level of the organizations. The SIS's low membership fees also allow for members from the private and public sectors to join in the national efforts, thus having the potential to indirectly influence the ISO. The IEC, similar to the IOS, only allows for national standard committees, as representatives of each country, to be part of the standard development. Which makes it similar to the ISO. Therefore, both ISO 15118 and IEC 61851 can be interpreted to have the intended openness score of a *medium* in terms of permeability. For the OCPP the high score is the result of the evolved openness, as mentioned by Deniz (2015) (see section 4.1.3.1). Along with the no membership fees. For the OpenADR, there are low membership fees. This combined with the creation of it becoming an IEC standard generates the interoperation of the score to a *medium/high.*

The *transparency* (T) of established standard development organizations can be perceived to be *high*, with the documentation and influence between the members being fairly distributed. For the OCPP there is an openness between the members, however, since it is a consortium it can be interpreted to be less open than an established standard development organization. Thus, generating a *medium* score. Since the OpenADR is a consortium but has influence from the IEC, they have become a *medium/high* score in transparency.

In terms of *structural attributes* (S), established standard development organizations are perceived to have a greater level of openness compared to consortiums. The privately established organizations may have a higher openness in their structure. All of the standard organizations in the OS-set have been around for at least a decade at this point. Thus, most of them score on the higher end of the openness level for structural attributes. The OCPP is the latest in the game, as well as the only one that is not part of an established SDO, thus receiving a *medium/high score*, while the others all score *high*.

The intended openness levels of the OSRs in the first phase of the specifications rights are perceived to align with the results from previous research (ElaadNL, 2017) (Deniz, 2017) (Neaimeh & Andersen, 2020a).

4.2.2 OSRs for SDP 2

From the prior evaluation of Neaimeh & Andersen (2020a), the correlation between the requirements of *Openness* used by Neaimeh and Andersen (2020a), and the OSRs from the *Openness model* in Table 5, will be as follows. According to the ElaadNL definition of

Openness, as used by Neaimeh and Andersen (2020a), openness relates to; if a protocol had been developed by an accredited standard organization, if it was subject to IP rights, and if it is publicly accessible at no (or minimal) cost (ElaadNL, 2017). This relates to multiple aspects of the *Openness model* (see Table 5), such as; *structural attributes (S)* (as previously addressed, see 4.2.1), *availability (A)* (*complete specification* (A1) and *complements (A2)*) and *claims (C)* (see section 2.1.3.3). Thus, the evaluations from the previous research will be correlated to each of them respectively, and thus also the *Openness model* of this study (see Table 5). The sub-requirements of availability – *complete specification* (A1) and *encourage complements* (A2), will follow the evaluation of the main requirement. Listed below are the OSRs of the second SDP according to the *Openness model* (see Table 8).

Table 8. OSR of SDP 2 for OS-set

ORS / **OS**	*Complete specification (A1)*	*Encourage complements (A2)*	*Claims (C)*
ISO 15118	High	High	High
IEC 61851	High	High	High
OCPP	Medium/High	Medium/High	Medium/High
OpenADR	High	High	High

The high evaluation of the ISO15118, IEC 61851, and OpenADR, along with the medium/high evaluation on the OCPP, in accordance with the same motivation as that given for the parameters of openness in prior section (see 4.1.3.2).

4.2.3 OSRs for SDP 3

Similar to the evaluation of the second SDP, the third phase follows the evaluation of Neaimeh and Andersen (Neaimeh & Andersen, 2020a), in terms of their defined parameter of *interoperability*. The Krechmer (2008) definition of *interoperability*, as used by Neaimeh and Andersen (2020a), can be directly related to Mutkoski's version of *interoperability (I)* (see section 2.1.3.3), and thus the sub-requirements from Deniz of *interoperability* of *buyer constraint* (*I1*) and *between standards* (*I2*). Therefore, the evaluations of Neaimeh and Anderson (2020a) have been translated to the requirements fitting the Mutkoski (2011) framework, and thus, again, also to the *Openness model* of this study (see Table 5). Below are the generated results (see Table 9).

Table 9. OSR of SDP 3 for OS-set

ORS / **OS**	*Buyer's constraint (I1)*	*Between standards (I2)*
ISO 15118	High	High
IEC 61851	High	High
OCPP	High	High
OpenADR	Medium/High	Medium/High

The High evaluation for ISO 15118, IEC 61851, and OCPP, as well as the medium/high evaluation on the OpenADR, in accordance with the same motivation as that given for the parameter of openness in the prior section (see 4.1.3.2).

4.3 Investigation of *perceived openness*

This section describes the results of the positioning of the actors that participated in the interviews, and the initial results of the main interviews that were conducted to investigate the perceived openness of OSs and open innovation in the real-life application of the EMBE.

4.3.1 Positioning of the interviewees

The positioning helped in understanding the perspectives of the various interviewees and to see how the answers compared to that of actors with different positions. The participants were selected within the Swedish EMBE and their respective roles maps according to the descriptions of Table 8. The results are illustrated below (see Figure 14).

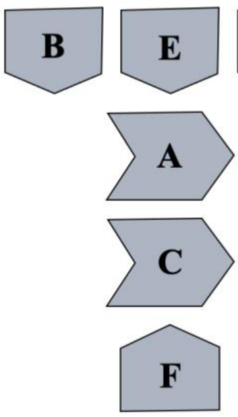

Figure 14. EMBE roles of interviewees

The participation of the actors in the interviews is described to be the following. The initial interviews utilized actors from the companies of; E and F. The main interviews were conducted with actors from the companies of; A, B, and C. The expert interviews utilized actors from the companies of; A, D, and F. For some interviews, there were different interviewees at the companies participating in the different interview phases.

As described in Gieseck's (2014) EMBE framework (see Section 2.2.1), the position will affect the role that each participant has and therefore also may affect their response during the interviews. This is worth considering, to enable a fuller image of the current perception of the various industry perspectives, before generalizing any result. Further descriptions of the companies participating in the study can be viewed in Table 14 in Appendix .A.

4.3.2 Main interview results

For the main interviews, there was a script of interview questions that can be viewed Appendix .B. The resulting responses of the interviews were separated into quotes and given a randomized *Quote ID* to keep the results anonymous, see Appendix .C. From the responses, further analysis was made, which will be described later.

The responses were put in a word cloud to visualize the main themes mentioned (see Figure 15). From the word cloud it was interpreted that the actors' discussions revolved around the EMBE perspective, finding innovative solutions, and that standards could be a potential tool.

Further analysis of the *key words* and *word frequencies* will be conducted in later sections of this study.

Figure 15. Word cloud from main interviews

The results of the word cloud analysis showed that there was a focus on the external aspects of *actors*, *standards* and the *industry* at large (see Figure 15). Further analysis will be conducted in later sections.

To capture the overall essence the responses, one quote did an excellent job. When referring to reasoning behind open innovation and OSs, one participant said:

> *"It will only look stupid if companies compete on a regional, national, and even European level if the consequences are that the earth will succumb to the climate changes. This is an existential threat."*

(Quote 9)

Thus, summarizing the industry's aim of utilizing open innovation in the context of finding sustainable transportation solutions.

5 Analysis

From the investigations of the *intended* and *perceived openness* further analysis is needed to translate the results to the *Openness model*. By doing so it becomes possible to identify *potential gaps* between the intended and perceived openness, which may show which OSRs are in need of future development. Thus, aiding in the prioritization of improvements for the open innovation strategy, to achieve the goal of facilitating the EV adaptation.

First, an analysis of the intended openness levels for different perspectives, which will be visualized in the graphs below (see Figure 16 - Figure 19). Then an analysis of the perceived openness will be conducted. Utilizing a SWOT analysis to look at various perspectives, as well. This analysis will then be combined, and using the *Openness model*, they will be compared to identify connection points and potential gaps. Lastly, the research questions of this study will be answered.

5.1 Analysis of intended openness

From the combined results of Table 7-Table 9, the values were ranked from *Low-High*. To visualize the results, the rankings were weighed, according to a scale of 1-5 (the previous rankings corresponding accordingly; *Low: 1, low/medium: 2, medium: 3, medium/high: 4, High: 5*). The weighted results are displayed below (see Table 10).

Table 10. Intended openness of OSRs of the OS-set

OSR / **OS**	**SDP**							
		Phase 1			*Phase 2*		*Phase 3*	
	(P)	*(T)*	*(S)*	*(A1)*	*(A2)*	*(C)*	*(I1)*	*(I2)*
ISO	3	5	5	5	5	5	5	5
IEC	3	5	5	5	5	5	5	5
OCPP	5	3	4	4	4	4	5	5
OpenADR	4	4	5	5	5	5	4	4

The results show that all OSRs scored between a 3-5, implying that the openness is intended to be fully open or just about fully open. This can be seen as a display of the utopian ideals West (West, 2005), discussed to be desirable when promoting the compatibility of OS as mentioned before (see section 2.1.3.3). With the slight variations, there can also be an implication of Mutkoski's recognition of the importance of categorization of openness requirements (Mutkoski, 2011). As well as Deniz's sub-requirement categorization (Deniz, 2015). As a way of fully understanding the nuances of the OSs potential.

To further display this nuance, the result has been put into graphs to discuss the potential gaps and differences between the OSRs and the OS in the set of this research study.

5.1.1 Comparison of OS-set

Comparing the OSs, the data points have been placed in a column graph where the overall openness of each of the OSs is displayed relevant to each other (see Figure 16).

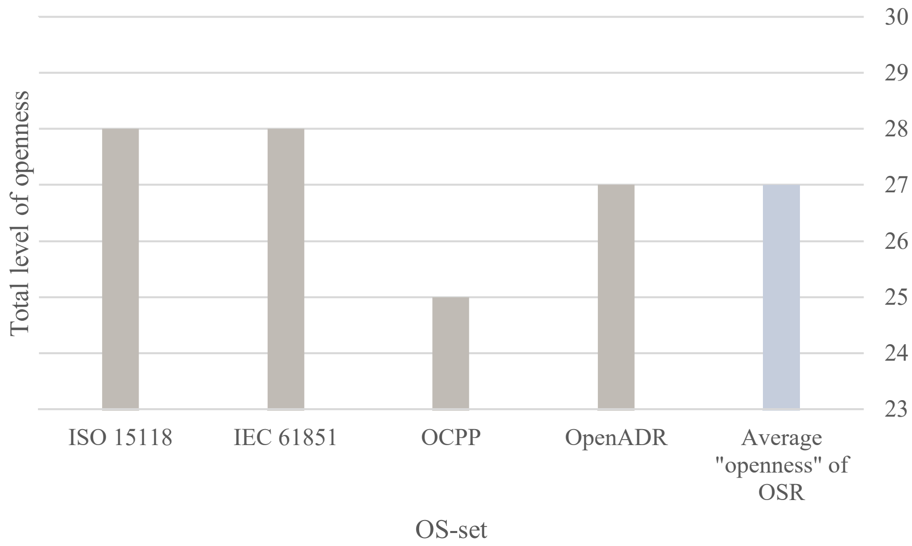

Figure 16. Total level of openness by OS

The column graph illustrated the trend of OSs (see Figure 16). Looking at the set of OS, the average openness level of the sum of OSRs for each OS was at a 27. A general *low score* would land on a total sum of 6, while a general *medium score* would receive a total sum of 18, and a general *high score* would generate a total sum of 30.

For all of the OSs, the score landed on the medium/high to high levels of openness, as illustrated in the graph above (See Figure 16). The ISO 15118 and IEC 61851 scored above the average, at a 28 respectively. The OCPP scored the lowest, at a 25. While the OpenADR scored right at the average of 27. None of the OSs in the set achieved the total openness of a 30.

It can be perceived that the OS developed by the SDO tend to have a higher degree of openness for all OSRs. While the consortium standards have a few OSRs that rate a bit lower, still medium to high, on their degrees of openness, as described previously (see Section 4.2.1). The differences in the OSRs openness score varied between the consortiums. With the availability being affected for the OCPP and the interoperability in the OpenADR, the degree of openness was equal to 4 for both respective cases. Again, displaying the slightly lower degree of total openness of the consortium-developed standards.

5.1.2 Comparison of SDPs

To understand variations in levels of openness between the SDPs of the collective OS-set, a comparison was performed. The results of which, is visualized in the column graph below (see Figure 17).

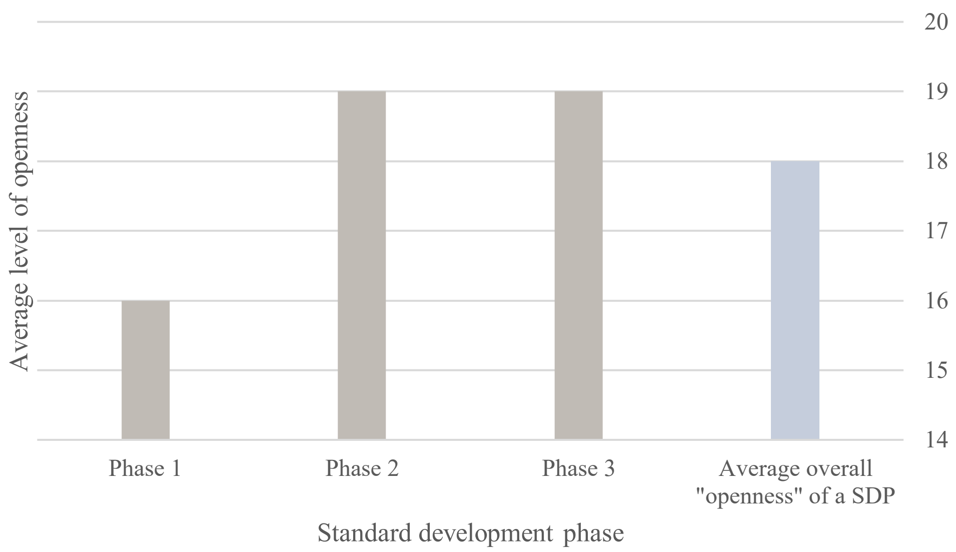

Figure 17. Total level of openness by SDP

The Figure 17 displays the SDPs correlating to the OSRs according to the previously described model (see Table 5). The *average level of openness* corresponds to the average of the sum of the collective openness levels of the OSRs relating to the phase, for all of the four OS in the set. A generally *low score* would generate an average level of openness of 12. A generally *medium score* of the average level of openness would correspond to a 16. While a generally *high score* of average level of openness would land at a 20.

Each of the SDPs displays the average value of the sum of the OSRs in the phase, divided by the total number of OSRs in that phase. To allow for a fair comparison between the SDPs where the numbers of OSRs are different from each other. The overall average describes the average compared between all of the SDPs and corresponds to an average overall openness level of 18. The first phase contains the OSRs; *permeability* (P), *transparency* (T), and *structural attributes* (S). Together, they scored an average level of openness of a 16, which was lower than that of the overall average openness of an SDP. For the second phase, correlating to the OSRs; *availability* (A) (*complete specification* (A1) and *complements* (A2)), and *claims* (C). Together they received an average level of openness score of a 19, which was above the average overall openness of an SDP. For the last phase, the OSRs related to; *interoperability* (I) (*buyer's constraint* (I1) and *between standards* (I2). The last phase received an average level of openness score of a 19, which was also above the average overall openness of an SDP. None of the SDPs scored an average level of openness of 20.

From the previously explained tendencies of different SDPs (see section 2.1.3.2), the results of in Figure 17 could potentially be explained by the early adaptation stage of the OS-set. As descried by Deniz (2015) in the case of the OCPP (see section 4.1.3.1), early technology phases of technology standards can be used to describe the general openness. The author also described how the evolution of the OS moved from a more closed state into becoming more open. Connecting this to the statements of Neaimeh and Andersen (2020a) (see section 4.1.3.2), where the authors described the adaptation of the EV still being perceived to be low, this could be a reason for why the first phase is less open than the later. Thus, leading to further speculation of if the openness levels are to increase as time goes by. The investigated OS-set is still being developed and a slow increase in the levels of openness may be due to an increased demand from the industry actors, as described by Deniz (2015) in the case of the OCPP evolution (see section 4.1.3.1). Thus, openness may be the result of the dynamic nature of an OS. Where with time, it can become more open along with the technology becoming more of a commodity. Leading to the intended openness of the early phases, such as SDP 1, to be lower than that of the later, as seen in Figure 17.

5.1.3 Comparison of OSRs

To compare the openness dimensions across the OS-set, the data pointes were categorized according to OSRs and displayed in a column graph (see Figure 18).

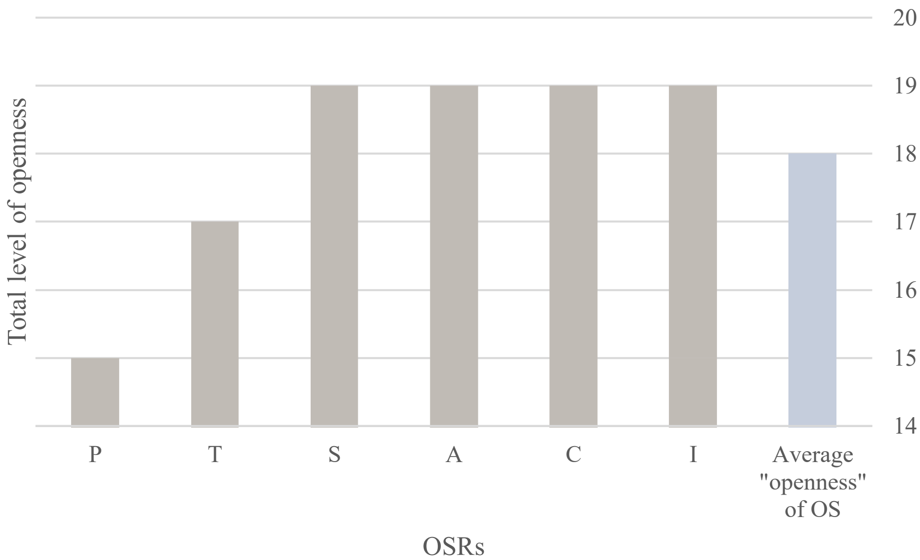

Figure 18. Total level of openness by OSR

Another way of displaying it is according to the total openness of each of the OSRs for the collective set of OS (see Figure 18). The scaling is according to the addition of each of the OS scorings for each of the OSRs. A general *low score* would land on a total sum of 4, while a general *medium score* would receive a total sum of 12, and a general *high score* would generate a total sum of 20.

All of the OSRs score on the medium to high levels of openness, as illustrated in the graph above (See Figure 18). The average score of the sum of the OS for each of the OSRs was at an 18. The parameter of *permeability* (P) received a lower score than the other parameters, at a 15. The *transparency* (T) also scored below the average, at a 17. The other requirements; *structural attributes* (S), *availability* (A), *claims* (C), and *interoperability* (I), all score above the average, at a 19. None of the ORSs of the OS-set achieved the total openness of a 20.

One may see the results as a consequence of the mixture of evaluation methods (consisting of both primary and secondary data collection). The scores from the requirements that were achieved from this studies interpretation of the official sources data (*permeability* (P) and *transparency* (T)), seems to be slightly lower than the scores of the requirements that were the results from the translation of previous research (*structural attributes* (S), *availability* (A), *claims* (C), and *interoperability* (I)). It may be due to the nature of the OSRs. However, such a difference should not be overlooked without confirmation from more sources. The range of the scores may also affect the differences. Since it is up to the interpreter to determine the score and the small range allows for impactful variations if not aligned perfectly with other's perceptions. It could also have to do with the fact that there are more parameters to consider (six OSRs, compared to the OS-set of four OSs), and the differentiation may become greater with a larger number of parameters.

5.1.4 Overall intended openness

The overall openness patterns of each of the OS have all been graphed as radar charts (see Figure 19). Each of the data points of an OSR is represented on a line, expanding outwards from the center of the graph. The further out the data point is positioned, the more open the OSR is considered to be. The scores range from 1-5. With 1 being a *low score*, 3 being a *medium score* and 5 being a *high score*.

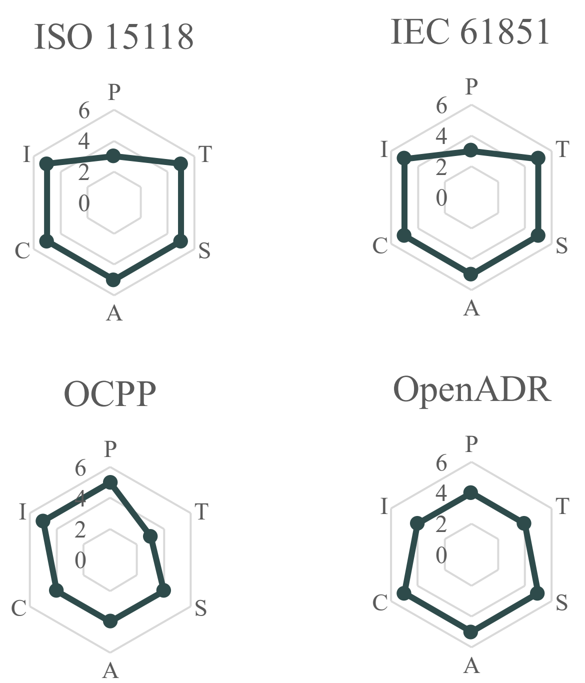

Figure 19. Graph of overall openness for the respective OS

As visualized in the radar charts of Figure 19, most of the OSRs for each of the OS tend to score on the higher end of the range. With some exceptions moving closer to the medium score. The overall openness levels of each of the OS are interpreted to be intended to be high. However, none of the OS in the set achieves a perfectly high overall openness score in all aspects of the OSRs. Implicating the utopian desires for openness and the realities of open innovation as described by West (2005) (see section 2.1.3.3).

5.2 Analysis of perceived openness

From the results of the investigation of the perceived openness (see section 4.3), the interview actors were positioned in the EMBE (Figure 14), and the responses from the interviews with the industry actors, were divided into quotes (randomized number of identification) (see Appendix .C), and put in a word cloud (see Figure 15). Here follow the analytical steps of investigation of the perceived openness. These steps will include; the categorization of the quotes according to a SWOT analysis (as can be seen in the second to last column of Table 16 in Appendix .C), analysis of the SWOT distribution of the responses, identification of themes, and analysis of the themes and their relation to the SWOT (as can be seen in the last column of Table 16 in Appendix .C). The aim of the perceived openness is to investigate how the industry actors see OSs and open innovation as potential facilitators for sustainable transportation solutions.

5.2.1 Main interview response distribution

The results from the main interviews have been analyzed using a SWOT, to identify the core *strengths* (S), *weaknesses* (W), *opportunities* (O), and *threats* (T). The SWOT has been performed using the perspective of the business case analysis of utilizing OSs as a facilitator for the EV adaptation of sustainable transportation solutions. The categorization of responses can be viewed in Appendix .C.

Here follows an analysis of the categorizations of the SWOT, and response variations (internal vs external, positive vs negative, and standard deviation). With comments of the possible implications of these analyses due to the roles of different roles of the industry actors according to the results of the Swedish EMBE (see Figure 14). Inspecting these aspects will indicate if the responses are proportionally distributed to paint a nuanced image of the concept of OSs for sustainable transportation solutions.

5.2.1.1 SWOT categorization

For the first part – the *strength* (S), the analysis has identified statements made relating to the internal excellence of each organization. The second part – the *weaknesses* (W), has identified statements of internal lack of performance and/or areas with room for improvement within each organization. Moving to the external focus, the third part – the *opportunities* (O), identified statements of favorable parameters that could produce a competitive advantage. Describing the categories as they relate to the facilitation of the e-mobility sector and adaptation of EVs. Lastly, the fourth part – the *threats* (T), were identified statements of parameters that hold the potential of being harmful to the overall goal – OS as a facilitator for sustainable transportation solutions. The categories can be viewed in the second to last column of Table 16 in Appendix .C.

In total, an amount of 144 response quotes were collected. Out of these, 99 were deemed to be of interest for this study’s analysis. With one response quote being used as a general comment. The total number of quotes used from the responses where 98. For the four categories of the SWOT, the subsequential distribution of relevant statements could be evaluated (see Figure 20).

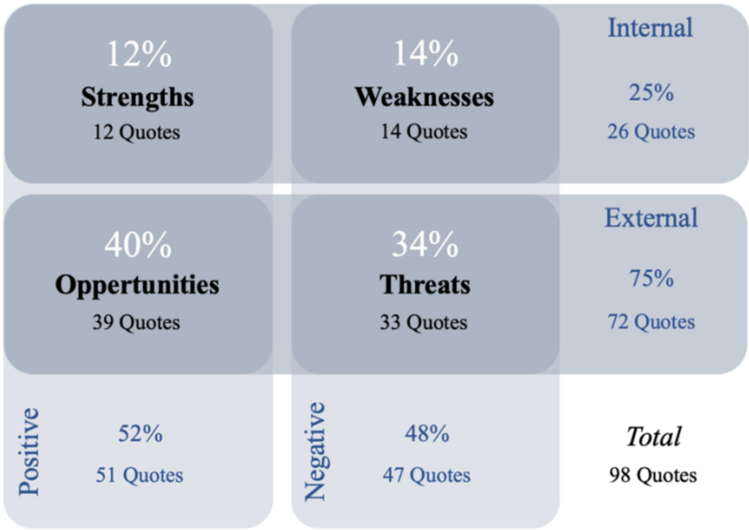

Figure 20. SWOT categorization of responses

The representation amongst the SWOT categories in Figure 20, displays an underrepresentation of quotes related to *strengths*, at 12% of the total number of quotes. On the opposite side, there was an overrepresentation of citations on *opportunities* (O), at 40% of the total number of quotes. The distribution of quotes relating to *weaknesses* (W) were similar to that of the *strengths* (S), at 14% of the total quotes. While the distribution of quotes relating to *threats* (T) were similar, at 34% of the total quotes. If the responses would have been equally distributed, that would have correlated to a distribution of 24,5 quotes (25%) each.

5.2.1.2 Internal vs external focuses

As described in the figure above (see Figure 20), the responses correlated well with the question design of internal vs external question representation. With internal describing being strengths and weaknesses, and external relating to opportunities and threats, according to the SWOT model. In the questions asked to the interviewees, 2 of the total 6 questions were focused on internal issues, representing 33% of the total number of quotes, and 4 out of the total 6 were focused on external issues, representing a fraction of a 66% of the total number of quotes. The interview responses were close to the original question statement distribution, however with a slightly lower frequency of internal focus. The result was that 26 of the response quotes focused on the internal, while 72 of the response quotes focused on the external. This translates to a rough simplification 25% focusing on internal, versus 75% focusing on the external, as can be viewed in Figure 20.

5.2.1.3 Positive vs negative aspects

Looking at the positive vs negative response quotes according to the figure above (see Figure 20), with the mindset where positive represents strengths and opportunities that can be found to be helpful, and negative is represented by weaknesses and threats that can be identified to be harmful, there was a fair distribution of equal amounts of positive and negative responses with 51 of the quotes relating to positive aspects, and 47 of the quotes relating to the negative. The distribution can roughly be simplified to equal parts of the perspectives (50% positive and 50% negative). This entails that the representation can be found to be fair since the evaluation is based on aspects of the issues with both an optimistic and a realistic view in mind.

5.2.1.4 Standard deviation (SD)

The *standard deviation* (SD) between various actors for each SWOT category is summarized in the table below (see Table 11). The equations and calculations used can be viewed in Table 18 in Appendix .E.

Table 11. SWOT category (Sample) standard deviation

SWOT category	**Number of quotes**	**Mean ($\bar{x}$)**	**Variance (s^2)**	**Standard deviation (SD)**
Strengths	12	4	7,00	2,65
Weaknesses	14	4,66	8,33	2,89
Opportunities	39	13	13,00	3,61
Threats	33	11	37,00	6,08

There is a quite small SD value displayed in Table 11 of each of the categories, in relation to the respective mean values. Showing that the responses from the participants are mostly aligned. With some being slightly less aligned, as in the case of the *threats* (T). Where there is a slightly larger portion of quotes is represented by one specific actor's point of view.

The variations may arise as a result of differences in insights of the department of the interviewee. Possibly affected by the perspective of the utilization of OSs in the respective organization. As well as the role position of the company in the EMBE (see Figure 14). Providing them with different conditions for participation and influence in the SPDs.

The size of the sample size is worth mentioning. Even though the sample size is relatively small, the standard deviation can be applied to evaluate the representation within the sample of the actors interviewed and to enable deliberation on the potential implications. The results may give an indication that is useful for beginning to understand the perception of the EV industry actors. In terms of the number of companies represented and the number of interviewees per company, however, it does represent key actors of the *aggregator and provider* roles in the Swedish EMBE (see section 2.2.1). Thus, it can be deemed inspiring for new areas for further research to be performed.

5.2.1.5 Overall response distribution

A summary of the analysis of the distribution of the responses has been visualized in Figure 21. Combining the distributions of; SWOT categories, internal vs external focus, and positive vs negative aspects.

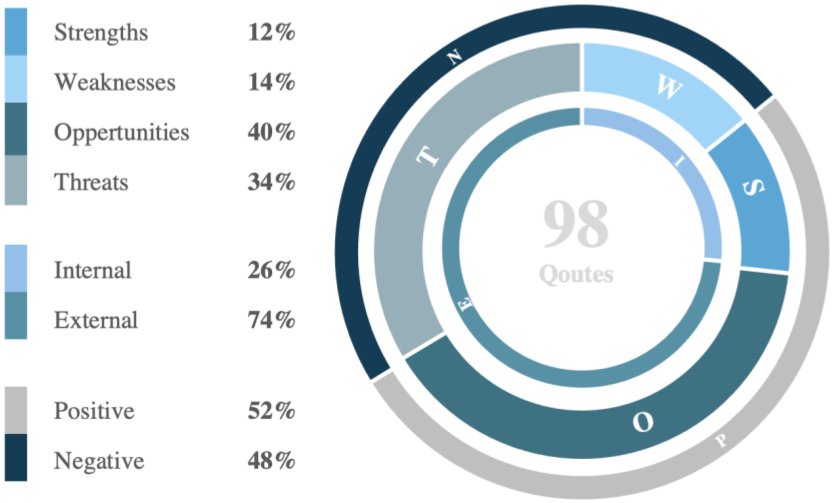

Figure 21. Overall Response Distribution

In total 98 quotes were used for the analysis. Overall, there was a greater focus on the external SWOT categories, represented by 75% of the total quotes. There seems to have been a nuanced depiction in the responses, with the balance of positive vs negative aspects being at an almost equal distribution. All in all, there was an over-representation of quotes related to the opportunities. The potential reasons for the distribution of the SWOT categories will be further investigated in later sections, along with a discussion of the cited quotes (see section 5.2.3).

5.2.2 Identification of themes

From the main interview responses keyword were identified and illustrated in a word-cloud (see Figure 15). The frequency of the keyword could then be used to identify potential themes in the responses. The full word frequency count is listed in Table 17 in Appendix .D. In addition, some keywords that were not frequently mentioned, but strongly emphasized by the interviews were added. The word frequency analysis has prioritized keywords with impactful meanings (relating to the context of the research study), and thus, overlooking words that were less related, sentence-building and/or fill-out words. The results of the identification of themes are displayed below (see Table 12).

In Figure 15, the top five keywords were (with respective word count from Appendix .D); *Actors* (48), *Industry* (38), *Standards* (33), *Solutions* (25), and *Need* (23). The interviewees focused their responses on what others (both actors and industries) are doing, and less on their own contributions to this field. Which is also displayed in the previous response distribution (see Section 5.2.1.1). In addition, they displayed a desire for finding solutions to the challenges related to EV adaptation and sustainable transportation.

Other keywords that were amongst the top 50 were; *Innovation* (17), *Open* (17), *Charging* (17), *Sustainability* (15), *Infrastructure* (15), *Technology* (14), *Development* (13), *Collaboration* (12), *Value* (11), *Common* (10), *IP* (9), *Mobility* (8), *Time* (8), and *Ecosystems* (8). This list further anchors the Swedish EMBE's strive for innovation and sustainability as previously described in the background of this study (see section 1.1). Specifically in addressing the challenge of charging infrastructure. The participant displayed a recognition of *Openness* within *Innovation* as a way of creating common value in technology development.

As well as collaborations using IP and IAs were deemed necessary for this to be possible to achieve within the set timeframe of SDGs. The timing was also seen as being of importance for the success of the developed solution, connection to the theory of IAM (see section 2.1.2). The question of redefining mobility was raised, along with the need for cross-sectional ecosystems.

Three keywords that were used sparingly throughout the responses, but that were heavily implied by the interviewees to be relevant for the context, were; *Interoperability* (2), *Governance* (1), and *Power* (1). Although not expressed literally in the responses, these keywords were indicated to be highly relevant for the context of adaptation of EVs, as described in the responses (see Appendix .C). Alluring at questions of *Who* has the control and *How* to enable effort of work together with others (both actors and industries). Thus, connecting to the top five keyword in an indirect manner.

From the word frequency analysis, and additional keywords identified, nine themes were identified. The themes were then related to each of the SWOT categories. Two of the themes, *Time* and *Interoperability* aspects, were broken down into *internal* and *external* depending on which of the SWOT categories they were in response to (Weaknesses or Threats). This form of interoperability within the themes was related to the organizational perspective (Aliprandi, 2011). Thus, deviating from the previously investigated technical interoperability of the OSRs. The identified themes have been summarized in the table below (see Table 12).

Table 12. Identified themes from main interview responses

Themes	Theme abbreviation	SWOT category
Need for openness and standardization	N	S
Internal interoperability	II	W
Internal time aspects (lagging market application)	IT	W
Desire for higher governance structure	HG	O
Greater common values	GV	O
External interoperability	EI	T
External time aspects (timing and pace of developments)	ET	T
Intellectual asset management	IAM	T
Power imbalances	PI	T

Overall, the combined analysis of the word-cloud and word frequency count were used as a guide to identify themes to further focus the analysis of the perceived openness around. The full response quote list with the correlating SWOT categories and theme categorisation can be seen in Appendix .C.

5.2.3 Relations of themes and main interview responses

The SWOT technique has been used to promote the assessment of the performance, potential, competition, and risks as perceived by the industry actors. As per the SWOT categories of *strengths* (S), *weaknesses* (W), *opportunities* (O), and *threats* (T), the responses have been identified into clusters of common themes (see Table 12), within each of the categories. The full table of quotes and categorizations of themes and SWOT relations can be seen in Appendix .C. Here follows the analysis of the combined quotes relating to each of the themes, including their percentile of total representation in the responses and their relation to the SWOT categories.

5.2.3.1 Need for openness and standardization (N)

When diving deeper into the interview responses there was a display of positivity towards OSs and open innovation. The interviewees showed a strong *need for openness and standardization* (N), as represented by 13% of the responses.

One interviewee described that the positive attitudes of organizations may be “a result of a perceived need for open standards in the electro-mobility industry. Since there is a common consensus that this path of development is necessary for the future of the industry. Therefore, it can be deemed reasonable that there is a couple of standards that everyone is dependent upon and need to become competitive in the market.” (Quote 75). Another interviewee said that “open standards are very important and will be in demand in one form or another for this industry” (Quote 41).

When addressing the shift of the industry, one participant compared the necessary industry shift to the success of Tesla’s shift towards charging infrastructure taking over the market and setting de facto standards (Quote 23). They also pointed out partnerships and ecosystems as tools for innovation utilization (Quote 78). One interviewee stated that the need for standards should not be underestimated. Continuing, “they are something that industry actors can trust and invest in, in order to drive technical developments around this area” (Quote 132). Other interviewees added that open standards may grow and become more prominent (Quote 10, and Quote 19).

Some of the participants stated that they already have dedicated teams set up to work with these important questions (Quote 117). One went on to further add that “standards could hold the potential of pushing the industry in a common direction” (Quote 92). Describing that it could tear down barriers, making it easier for companies to navigate the uncertainties in the market and technology trends (Quote 56).

In discussions of the benefits of OSs, one of the participants discussed the benefits including aspects of increased acceleration of the development of sustainable transportation solutions, and decreased friction within interoperability. Allowing for focus to be placed on other issues (Quote 20). The same actor went on to add that having multiple competing solutions could indicate risks for the end-user experiencing lock-in effects. Increasing the thresholds for consumers to adapt to the EVs (Quote 137). A different interviewee stated that the benefits of standards would not be limited to the end-user. The application could hold great potential for regions and nations as it allows resources to be focused on the infrastructure transformation necessary for the societal and industry shift (Quote 141).

The theme of *need for openness and standardization* (N) can be categorized as falling within the *strengths (S)* of the SWOT analysis. The interviewees displayed a positive attitude toward OSs, pointing at a need for a common tool to adjust to the shifts in infrastructure and industries. They thus, showed support for the intentions of utilizing OSs as a facilitator for EV adaptation.

5.2.3.2 Lack of internal interoperability (II)

A theme not as prominent in the representation of the quotes, at 3%, was the *internal interoperability* (II). Not surprisingly, as the internal focuses of the SWOT were previously presented to be lower (see Figure 20).

On the theme of interoperability within the companies, one participant depicted the consequences manifesting on an organizational level, where the organization's current attitude towards OSs "may differ between the technology department and the innovation/IP department." (Quote 101). They went on to further describe their experience of the technology organization being very positive towards OSs and how this in turn could have a negative effect on the IP perspective (Quote 109). Stating that this most likely was rooted in the issue that "People have an image of a standard always being open; free and available for all. However, an organization in general may have a lack of knowledge of what a standard is and is not. Hard to navigate if a standard is opened or closed, and people take for granted that it is an open standard. Not understanding the process of access and participation." (Quote 131).

The theme of *internal interoperability (IT)* can be perceived as part of the SWOT category of *weaknesses (W)*, as it is implied by the responses that there is a fundamental lack of internal efforts of interoperability. There is an uncertainty due to the lack of knowledge of how to utilize the IAs effectively throughout organizations. Leading to one department aiming for open innovation, while others are pulling on the breaks. Without having a common framework within the organization, it becomes increasingly difficult to implement OSs as they need to be balancing multiple parameters of consideration. Further discussion of IP management will be connected to the external part of the SWOT, later in this Section.

5.2.3.3 Internal time aspects - Lagging industry application (IT)

For the *internal time aspects* (IT), there was a perceived lagging of industry application. On an organizational level, the interviewees indicated that there was a lagging industry application of the OSs were lacking. However, there were, as previously mentioned (see section 5.2.3.1), a perceived need for this to change. The theme represented 11% of the total responses.

One participant pointed out a critical difference in innovation, that between evolution and revolution (Quote 86). The participant stated that for car manufacturers "evolution is not clear enough since any improvement can be categorized as evolutionary" and "the revolutionary perspective is where actual movements and new trends in innovation can be looked at." Hinting at the fact that the innovative steps taken by the automotive industry actors are ta small (Quote 27).

Another participant commented on the perceived clarity of the connection between OSs and sustainable innovation. According to the participant, this connection is highly realized among actors in the industry, "even if they are not being directly discussed or applied in the real-world industry" (Quote 95). On the other hand, other interviewees stood by the efforts, saying that there have been ongoing for quite some time. However, they also pointed out that "it has been far too slow." (Quote 96). The reasoning possibly being connected to the fact that "Car manufacturers tend to become more passive about different technology choices. If there is no force toward one standard, they are less likely to invest in technology that may become obsolete. Either if it is due to legislation or the market heading in a different direction." (Quote 89). Describing consequences that may arise from having multiple sources competing, both standard organization-driven and market-driven alternatives developing in parallel (Quote 47). Worth noting was that these two actors came from organizations of different

sizes and were positioned on opposite sides of the EMBE. Which could have affected the interaction they had with OSs development.
On this note, one interviewee added that less mature companies are more focused on establishing their own internal standard (Quote 12). Comparing it to "a David versus Goliath narrative in the automotive sphere, where smaller actors need to invent their own tools, or slingshots, to be able to compare to the strength of larger actors." (Quote 29). If there are to be equal or even improved terms on transportation service and innovation, it must include openness and collaborative traits for the smaller actors to be able to compare to the big actors (Quote 31).

The development of standards has, according to one interviewee, taken place in a great time of industry need. Although they said it could have occurred earlier. They went on to say that is has not been an issue of the standard lagging after the industry, rather that the standards have enabled certain investment decisions (Quote 135). Lastly, the actor went on to discuss the lack of application of OSs may be due to there not being enough business cases displaying the complexity that the industry is facing. Saying that "The shift in the ecosystem of cars nowadays is still being overlooked in some standards, causing implementation issues." (Quote 133).

The perceived *Internal time aspects (IT)* of lagging of industry application can be viewed as a *weakness (W)* according to the SWOT categories. The automotive industry is being interpreted as traditional and slow to adapt, compared to smaller businesses and start-ups with a greater flexibility in their business strategies. The industry's hesitance towards quick innovation movements, is interpreted to be connected to a fear of running down the wrong path. This may result in the actors becoming stagnant in their acceleration of technical developments. Ultimately affecting the overall pace of the EV adaptation.

5.2.3.4 Higher governance structure (HG)

One of the most displayed opportunities for OSs, at 13% representation of the total responses, was the need for a *higher governance structure (HG)*. Not solely in the setting of standards, but more so focusing on their operational and maintenance capacity.

One interviewee said, that the discussion of e-mobility enables new networks of interactions between stakeholders, with the intentions of building a viable infrastructure solution for the future society (Quote 45). A trend that has been observed by the participants was that of collaboration between big industry actors and start-ups. Creating communication and innovation hubs. One interviewee indicated that this trend may continue to increase (Quote 1). One actor explicitly stated that "There is a lacking today in organizations that manage the responsibilities of asset distribution and innovation diffusion" (Quote 51). The participant described that organizations need to take on more responsibility in the facilitation of sustainable collaboration efforts. "Balancing the power game of small and large actors" (Quote 140).

Hinting at the previously mentioned, consequences of competing standard development from multiple sources (Quote 47). Multiple interviewees expressed a desire for clear directives from above as a way of navigating the technology development trends (Quote 76, and Quote 91). One interviewee said that the Swedish EMBE actors would like to partake in the initiatives but that the push would need to come from above. Again, alluring at the common direction needed for the initiative to make a difference in the pace of the development of sustainable solutions (Quote 44). The same actors added that higher levels of collaboration are important. With the current industry actors lobbying for the conditions needed for the green transportation transformation to be possible (Quote 55). Another actor indicated that it would need to be a large effort, possibly governmental, if it were to be effective (Quote 63).

One interviewee drew parallels to the lack of governance structure resulted in a market-driven standard development. Describing it accordingly, “In the US, they have decided on a different path where actors on the west coast are dictated by defining what type of data that needs to be shared, in this case in the commute traffic, for the cities to be able to coordinate the traffic. This effort, or standard, has spread across to other cities in the US and Europe. This adaptation has happened due to people realizing it to be a necessity for cities to be able to develop a more sustainable society. Here, an example is of where the market drives the standard due to governance structures being too slow.” (Quote 7). Adding the conclusion that a stronger pan-European grip would force the market into a faster evolution (Quote 28).

The strong desire for a *higher governance structure* (HG) can be viewed as an *opportunity (O)* in the SWOT analysis, as this insight generates an opportunity for actors to push for this form of establishment to be implemented. The actors showed strong intentions of collaborating but were hesitant to do so under the conditions that they themselves are not fully aware of the implications of the collaboration. Part of the solution, mentioned by the participant, was having a larger organ to sets the rules and enforce them. The interviewees mentioned a desire for a national organ to operate the innovation network and ensure that the actors reached a common consensus on standards. Mostly discussing the later SDPs. They saw this as an opportunity for it to be obtainable, compared to other solutions that would take longer and be even more complex to implement.

5.2.3.5 Greater common values (GV)

On the theme of *greater common values* (GV), all of the interviewees agreed that there is a high value in maintaining the nation’s image of innovation and sustainability. As strongly displayed in the total response representation of 27%.

As one interviewee commented “Everybody likes the image of Sweden being a sustainability leader. It is in everyone’s interest that this image is upheld.” (Quote 88). Another participant further described multiple examples of both cross-organizational and cross-industry collaborations with the common aim of strategically addressing the challenges through open innovation ecosystems (Quote 39). The interviewee added that this is necessary if they are to drive and manage the sustainability challenges (Quote 118).

There are ongoing discussions of which technological developments have a greater value. (Quote 98). A frequently used example of inventions that have been made accessible for the greater good is that of the Swedish three-point belt. Increasing in value once the IP was opened up for everyone to use. Begging the question “are there other parts connected to safety or sustainability that can be used similarly?” (Quote 5). The participant added that there might be greater value in sharing the knowledge specifically in the developments affecting the electric efficiency (Quote 21). This desire to generate a greater societal value is something that has been increasing from inventor’s side. Further displaying the importance these questions have at multiple levels of the organization (Quote 62).

One interviewee listed three areas in the automotive industry that they saw a greater value if there were a decrease in competition. The first two were *cyber security* and *autonomous driven*. However, the last example was that of *charging infrastructure* (Quote 40). Stating that the infrastructure will have to manage an increasing population of EVs. Which in turn will have large effects on the electric grid infrastructure (Quote 81). Bridging the sectors with a common challenge. One participant said that there are more perspectives to consider, the main being “the common perception of what our future society is going to look like” (Quote 125). Another participant stating, “We aim, not to create issues, but to be part of the solution.” (Quote 134). Declaring that sometimes the strive for finding solutions may bring forth new challenges. Specifically using the energy storage solutions as an example, where EVs can be a potential solution, solving its own challenges of energy demand spikes by becoming mobile energy storages that redistribute the energy in the grid accordingly (Quote 119). Another interviewee discussed the shifting focus in the international automotive industry, where there is an increase in demands from companies on their supplier to confirm that the whole supply chain is sustainable (Quote 67). Making a point of noting that some challenges are not directly related to sustainability. Exemplifying this by the performance, size, and weight of the vehicles, which have indirect effects on the environment through the affected fuel consumption (Quote 22). They went on to further state that this could have the potential of greater value if the knowledge were to be made available to others (Quote 21).

The interviewees mentioned a couple of open innovation models that they found interesting, mainly that of open innovation hubs. “Looking at the European automotive industry today where we have multiple innovation clusters.” (Quote 82). The participant went on to describe their desire for a stronger collaboration between these clusters. Saying that “every cluster in itself is an ecosystem. Getting these ecosystems to collaborate would generate a system of systems. This could bring a stronger levering effect.” (Quote 85). However, as another interview stated, the automotive innovation hubs are not as open, in terms of what is shared amongst members, as that of other industries (Quote 73). Adding that the goal of reaching a desired level of openness requires “the automotive actors to dare to let their guard down” (Quote 8).

For the industry actors to participate in the initiatives and obey the required levels of openness, they still need to know that there is something in it for them (Quote 46). Knowing that they are sharing the solutions and creating values that they themselves also get to partake in (Quote 15). Ensuring that it solves their own problems will likely incentivize the actors to be part of solving the challenges (Quote 14). One interviewee describes that for the collaborations to be made possible, there would need to be an alignment of interests. Identifying where the value lies is key for it to proceed. Another adds that if actors were to take on other perspectives, not solely that of sustainability goals, there could be potential for the creation of business values as a possible outcome of the collaborations (Quote 106). The participant did however further explain that this includes, not just customer demand shaping actor’s business models, but also regulatory pressure being put on the actors from above (Quote 115). One interviewee added that for actors with less overlaps in interests, there can still be potential for value creation if they are complementary to each other. Sometimes even making it easier to collaborate under these conditions (Quote 71).

All interviewees agreed on the point that a clear definition of OSs is necessary. Saying that they “Believe that open standards are very important and will be a demand in one form or another for this industry.” (Quote 41) and “Defining *openness* is important for it to be able to aid companies, instead of creating more barriers” (Quote 17). Another actor also added that they believed that “There is a likelihood that there will be more open standards developed as the e-mobility industry progresses in the future.” (Quote 19).

This theme of *greater common values* (GV) can be viewed as an *opportunity (O)* in the SWOT analysis. There is an intention of the participants, of finding a greater common value, that can be interpreted. The actors did express interest in contributing to sustainable transportation solutions. However, for the open innovation collaborations to become a reality, there needs to be clearly defined goals of the openness dimensions. Connecting to the previous theme (see Section 5.2.3.4), having an organ that coordinates this could further ensure the participants of the actual goals and means of getting there.

5.2.3.6 Lack of external interoperability (EI)

For the *external interoperability* (EI), the interviewees generally perceived the EMBE to be *lacking* in this area, with the response representation relating to this theme to be 9% of the total responses. The interviewees shared their insight into multiple barriers and limitations that are in need of addressing.

One participant expressed concerns on the concept of e-mobility being too narrow if the aim was to have a larger impact on sustainability. Them stating that the separation is leading to the formation of gaps between approaches, creating a grey area that hinders innovative solutions. In which some challenges are being overlooked due to lack of responsible parts (Quote 121). Another participant depicted it as a shift where we are about to “see innovation effort that combine industries”. Explaining that the new cross-industry borders will shape how solutions need to be formulated. Implying that the collaborations will “go further down in the supply chain” (Quote 112). They went on to further add that it has been realized that it would be difficult to achieve sustainability without including the suppliers (Quote 25).

From a sector perspective, another interviewee noted the importance of collaborating to avoid limiting each other. The consequences may include a domino effect on society (Quote 24). Previously, there have been uncertainties regarding who would be interested in the ideas. Showing that may be undeveloped potential due to a lack of communication in demand (Quote 100). Another interviewee pointed at the need to lift the challenges above single segments, to fully identify the societal interests in future mobility. Indicating that the broadening would be part of the solution for filling the communicational gaps and finding more viable solutions (Quote 144). Connecting it back to the previous theme of governance structure (see Section 5.2.3.4), one interviewee said “There is no clear recipient or responsible organ. Without this visionary to look at the issues on a national level there will be issues (Quote 130). Moving one step above, the same interviewee mentioned the issue of solely scaling it down to a national level. Saying that the solutions need to happen worldwide. Since actors tend to be more global nowadays, the solutions must adapt, otherwise, there will be more barriers created with multiple competing solutions or standards (Quote 52). By distinguishing between countries will only hinder innovation. The interviewee explicitly stated that “it is the global feature of the companies that will aid in finding solutions” (Quote 128).

As a potential *threat (T)* in the SWOT analysis, the lack of *external interoperability* (ET) may hinder the OS development. With the effects of sustainable transportation solutions being global, the actors are realizing the possible cascade effects and looking at solutions from a sectoral and national perspective. However, the communication between the different layers is still not in place.

5.2.3.7 Power imbalance (PI)

In all forms of joint efforts and collaboration, there is an imminent threat of *power imbalances* (PI), with a lower representation of 6% of the total responses. The participants depicted multiple areas where this could be taking place within OSs and openness in the EMBE.

The positioning of the actors that come together in the collaboration seemed to matter to the participants. In discussions about the structure of partnerships between companies, one interviewee stated that if the companies operate in the same value chain, there is a risk of disproportional distribution of power, which will make it harder for the companies to collaborate (Quote 74). A second interviewee coming from a different position of the EMBE agreed and added that “there will always be a discussion of the power games that evolve from companies directly collaborating.” (Quote 32). One interviewee expressed how actors in the same value chain may experience it to be hard to collaborate. Saying that the key to infrastructure development relies on “jointly developed technological processes and products that fit multiple industry needs” (Quote 2). Adding that “Opportunities for cross-industry collaboration can be far more likely, where the different interests make for a more beneficial exchange. Not one cannibalizing and pushing ahead of the others.” (Quote 136). Another interviewee explored the possibilities of collaborations between manufacturers of smaller electric vehicles and larger vehicles, potentially being more reasonable. Since the common standard could combine the various mobility markets, instead of limiting the development and creating boundaries (Quote 30).

The power held by large companies does hold potential upsides for collaborations if positioned in a conscious manner. As one participant put it, there is a need for standards that address key solutions that go across systems. For “actors providing cross-industry services to be able to merge into ecosystems and be able to deliver their services together with other solutions. However, this would need larger actors as facilitators, since smaller companies do not hold the same capabilities to lead these ecosystems.” (Quote 33). Connecting back to the need for governance structure (Quote 51).

This identified theme of *power imbalance* (PI) in open innovation collaborations can be categorized within the *threats* (T) in the SWOT analysis. Further describing the David vs Goliath previously mentioned in Section 5.2.3.2. The positioning of the actors in the EMBE and the sheer size of the organizations affect how the power is distributed in the projects. Without an unbiased leader, it may become difficult to enable collaborations with actors fighting for the same market.

5.2.3.8 Intellectual asset management (IAM)

One of the expressed concerns in the interviews with the industry actors, at 11% representation of the total responses, where that of the *intellectual asset management (IAM)* in open innovation collaborations. The interviewees depicted uncertainties with the management of intangible assets in collaborations.

One participant said, “Collaboration can be good in the sense that one plus one equals three. It can also become very complicated, especially when it comes to the IP parts.” (Quote 77). They continued by adding that the reason behind the difficulties can be seen as a result of the difference in interest. Spilling over to the questions of “who gets to own what asset, who has the right to use what, is it to be licensed to third parties, etc.” (Quote 68). Another participant said “Everyone has a big self-interest. “what is in it for us”, “we need to be able to do this”, and “they are not allowed to do this”. (Quote 114). Another interviewee added that IP rights are continuously being discussed, possibly creating conflicts (Quote 138). Another interviewee added that there is pressure on having an open innovation strategy. Utilizing the IP in the most effective, possibly passive, manner possible (Quote 37). And again hinting at the fact that the automotive industry is more restricted and closed, even if it tries to display itself as being open in many ways (Quote 142).

Openness has been described as positive for innovation. However, the perceived risks that come from being open are still a prominent challenge for companies. “They are afraid of over-sharing and want to protect their proprietary assets.” (Quote 97). Specifically, there is a perceived threat of losing intangible assets that are not protected by IP rights (Quote 103). The fear of losing IP may become a blocker. Where actors find it hard to draw the line between what to share and not (Quote 143). Afraid of missed opportunities or becoming locked in, they aim to protect their territory. All in all, not contributing “to a very open environment for collaborative innovation.” (Quote 105). In the development of open innovation there might not yet be a level of maturity that invokes confidence in the industry actors. However, discussions are ongoing (Quote 11).

One of the main threats that sustainable transportation solutions are facing is that of the actors fearing to lose control over their *intellectual capital management* (IAM) processes and thus their key IAs. Therefore, this may be categorized as a *threat* (T) in the SWOT analysis. As previously described in the weakness of lack of *internal interoperability* (II) (see Section 5.2.3.2), not being able to transfer knowledge effectively will have effects on the innovation and thereby the value creation of the OSs. With no to low trust and a risk of losing control over IA, as described previously (see section 2.1.2). The industry actors do not dare to join as long as the rules of the game are yet to be defined. Many actors are hesitant to make the first move, fearing potentially losing their edge.

5.2.3.9 External time aspects - Timing and pace (ET)

Another important aspect to consider regarding OSs is time, landing at a 7% representation of the total responses. The *external time* aspects (ET), of timing and pace of innovation development became prominent in the interviews.

Part of the timing has to do with the maturity of the technology and industry. One interviewee said that if there are areas where the technology has matured so that it can be accessed by all, it will then be the versions and complementing features that become the new potential for value creation, rather than the technology base (Quote 48). The interviewee added that sooner or later technology becomes more of a commodity, creating new markets for the competition to take place (Quote 90).

The pacing of different organizations also has the potential of affecting collaborations. One participant said that “big companies generally find it harder to collaborate with smaller businesses, due to the speed at which the collaboration progress". Adding that the smaller firms can move faster due to their natural flexibility (Quote 139).

As seen in the trends of publications of both the OSR frameworks and open communication protocols (see Figure 13**Error! Reference source not found.**), there has been an increase over the last decade. There was a common consensus among the interviewed industry actors that the utilization of OSs are about to increase. One interviewee was clear to point out that collaboration has been seen in other industries to come and go in waves. "Periods of intense collaboration and others with less. Some actors feel the need to do it themselves instead of collaborating. A lot may have to do with the difficulties to reach agreements between parties" (Quote 94). Adding that the waves could be seen as a "trends that periodically result in fatigue in the actors and lead to a decrease in partnerships for a period moving forward, with more "do it ourselves" mindsets again." (Quote 127).

What the future hold in terms of increased openness trends within innovation, to achieve sustainability goals is hard to say, one participant said (Quote 60). Even if not all efforts are directly referred to OSs or even defined as innovation, they can still be opportunities to drive development for sustainability (Quote 64).

There is a clear threat to the adaptation of sustainable transportation solutions that are related to the concept of time. The theme of *external time aspects* (ET), of timing and pace is related to the *threats* (T) in the SWOT analysis. The market is not yet mature, as previously described by Deniz (2015) and Neaimeh and Andersen (2020a). However, the urgency of the matter is pushing for change. In a developing technological field, standards serve their purpose of bridging actors in a common consensus for solutions. The nature of OSs in terms of time is important for them to be applied effusively, as described previously (section 2.1.3). Trends of open innovation may move in high tides and low tides. However, ignoring the constant rising of water levels will not solve the issues.

5.2.3.10 Summary of the theme distribution of the main interview responses

The representation of the various themes (as described in Table 12), has been illustrated below (see Figure 22). The Figure 22 is in accordance with the distribution of the SWOT categories (see Figure 20), with some slight modifications from the rounding of percentiles.

Figure 22. Theme response distribution (according to SWOT)

From the Figure 22, the total number of themes under each SWOT category is not representative of the overall response distribution. Instead, the percentiles indicate the distribution of the theme's representation in the responses. The *grey circles* represent the themes (according to their abbreviations from Table 12. The *blue circles* indicate the percentile of each of the theme's representation in the total amount of responses (98 responses). The theme distribution was according to the results; N (13%), II (3%), IT (11%), HG (13%), GV (27%), EI (9), PI (6%), IAM (11%), and ET (7%). The highest representation was the theme of greater common values, at 27%, and the lowest was the theme of internal interoperability, at 3%. Note that the percentages of the themes in Figure 22 have been rounded to not display decimals, thus the total sum of the percentages of all themes displayed is 99%.

All in all, section 5.2.3.1 – section 5.2.3.9 display that the EMBE's perception of openness, in the form of OSs and open innovation, is positive and depicts a need for common tools to adjust to the shifting infrastructure and industries along with contributing to finding sustainable transportation solutions. They perceived there to be lacking internal and external interoperability, affecting the knowledge transfer and making it increasingly difficult for the implementation of OSs and open innovation. This could risk generating effects on other industries and sectors since the challenges of e-mobility were perceived to have implications beyond the currently narrow scope of the automotive industry. From the perspective of time, the interviewees indicated both internal and external challenges. The responses relating to the internal time aspects focused on the automotive companies in the EMBE and their traditional and slow adaptation. For the external time aspects, the interviewees perceived the level of maturity of the industry to still be lagging. Thus, making collaborations harder for companies with different accelerating levels of innovation development. For some participants there was a realization of an opportunity for OSs to generate a bridge between actors, finding a common consensus for solutions. The interviewees also related the time aspects to the management of IAs, as it was depicted to be a hesitance towards sharing knowledge early on in technical developments. The main concern of losing control over one's intangible assets, thus missing out on opportunities for value creation. The participant depicted a strong intention of collaboration, but a hesitance towards making the first move due to uncertainties about what openness entails and who controls it. From the interviews, the responses showed a general desire for clearer definitions of openness relating to OSs and open innovation efforts, as well as coordination for common goals and joint efforts. Reaching down to the detailed levels of IAM.

The interviewees all realize the EV adaptation to be part of a sustainable transportation solution, and that OSs and open innovation may be used as a facilitator for archiving these goals. Most professionally put, "*It will only look stupid if companies compete on a regional, national, and even European level if the consequences are that the earth will sub come to the climate changes. This is an existential threat.*" (Quote 9). If everyone is to move in the same direction, then someone must make the first move.

5.2.4 Relating the themes to the *Openness model*

The analysis of the themes from the interview responses has led to a broader understanding of the attitudes of the actors operating in the Swedish EMBE. As per the order of the SDPs (see section 2.1.3.2), the OSRs of the *Openness model* (see Table 5*)*, are connected to the themes (see Table 12) through theory, and their potential relations are elaborated on through the inputs of the main interview responses (see Appendix .C) as discussed in prior sections (see section 5.2.3.1 – section 5.2.3.9). Potential causal relations of the participating actors' position in the EMBE (see Figure 14) are also included.

5.2.4.1 Themes related to SDP 1

Prior to the initial SDP, when specifications are to be developed, the OSRs in the *Openness model* are that of; *permeability* (P)*, transparency* (T), and *structural attributes* (S) (see section 2.1.3.3). Described below are the connections and potential relations of the themes and the OSRs in the first SDP of the *Openness model*. Along with comments on the potential causal relation from the interviewees positioning in the EMBE.

The responses of the participants depicted that there could be a risk of low knowledge distribution of OSs in the organization, relating the issue to a *lack of internal interoperability (*II). Thus, this could be pointed out as a potential *weakness* (W). However, some interviewees did mention the importance of being involved and having influence in innovation processes and development of the standardization, connecting back to the previously discussed theory of the first SDP (see section 2.1.3.2). Relating to the theme of *power imbalances* (PI) being seen as a potential *threat* (T). The participants did not respond to their specific participation in the decision-making processes or further involvement in standard development. With this, the connections between the themes and the *perceived openness* according to the *Openness models* OSRs of *permeability* (P) and *transparency* (T), were not able to go further.

All of the interviewees expressed a positive attitude toward the concept of OSs and the origin of the standards stemming from different forms of standard organizations such as that of SDOs and Constoria, as described previously (see section 2.1.3.1). When analyzing the responses from the interviews, the actor's high internal interest and perceived *need for openness and standardization* (N), as directives can be interpreted as a *strength* (S). This, along with the *opportunities* (O) that may arise from the realization of a desire for *higher governance structures* (HG), could further prove OS and the standard organizations as helpful tools for structuring efforts of innovation. The interviewees also stated that there is an *opportunity* (O) to come together to align with a *greater common value* (GV) to enable the collaborative effort of developing standards. This could in turn be related back to the *Openness models* OSR of *structural attributes* (S).

The interviewed industry actors mostly came from a centered position on the EMBE role map (see Figure 14). Only one participant came from an organization holding a governor role in the EMBE. Therefore, their responses align with their roles as they did not directly engage in the initial SDP of participating in the *specification rights* of any of the OS from the set.

5.2.4.2 Themes related to SDP 2

On the topic of implementation of the OS, there were responses connections to both of *Openness models* OSRs of *availability*; *complete specification* (A1), and *encouraging complements* (A2), and to the OSR of *claims* (C) (see section 2.1.3.3). Here follows a description of connections and potential relations between the themes and the OSRs in the second SDP. Along with comments on the potential causal relation from the interviewees positioning in the EMBE.

Many of the participants agreed with the need for the implementation and the positives of having the OSs, relating to the *need for openness and standardization* (N) and the realized *strengths* (S) of them. Thus, supporting a necessary level of accessibility of the *complete specifications* (A1) to many. However, the stages of actual implementations could be perceived to be a consequence of the *lagging industry application* (IT) of OS. Thus, connecting to the timing of standardization, as described previously (See section 2.1.3.2). There were also responses indicating an unrealized potential for the OS to be utilized in strategic planning throughout multiple departments of the organization, due to the *lacking internal interoperability* (II). Together, these issues concerning internal *time* and *interoperability* could be seen as *weaknesses* (W).

On the external side of the second SDP, *complements rights* to the solutions were discussed in the mentions of examples of existing open innovation hubs. The general perception was that being allowed to continue building upon solutions could accelerate the development of better products fulfilling the *Greater common values* (GV) and ambitions of sustainability. For this *opportunity* (O) to be viable, there would need to be a high level of openness of the OSRs of *availability – encourage complements (A2),* as described previously (see section 2.1.3) .

With the discussion from the interviews of the hesitance towards oversharing, many expressed concerns about the *threats* (T) of poor *IA management* (IAM), as described previously in the balance of control vs value (See section 2.1.2). Stating that in the time-sensitivity of these markets, the loss of control could have devastating consequences for the company. The perceived lack of *external interoperability* (EI) further enhances barriers to collaboration and sharing of knowledge through the management of *claims* (C). To combat this, some interviewees again suggested the *opportunity* (O) of a *higher governance structure* (HG). Seeking a solution not only for creation but also for the management of the operational aspects of open innovation projects. Thus, pushing the responsibilities of a governing organ beyond that of the first SDP, and into the second and third.

With the actors oriented at the center of the EMBE map (see Figure 14), their main roles of being *Providers* in the ecosystem make them positioned at the core of the value chain and thus part of the second phase of the standard development – *implementation and complementing rights*. The matter of availability is of high importance for them, as they are the ones utilizing the OS to design future products and services.

5.2.4.3 Themes related to SDP 3

The last SDP regards the usage rights, and thus, the OSRs related to the *interoperability* for both*; buyer's constraints* (I1) and *between standard* (I2) (see section 2.1.3.3). Described below are the connections and potential relations between the themes and the OSRs in the third SDP. Along with comments on the potential causal relation from the participants positioning in the EMBE.

For the final SDP, the interviewees touched upon a couple of trends that they perceived to be negative. Mainly relating to the themes of; *timing* and *interoperability*. They expressed concerns about the dissonance in the pace of innovation developments between actors, and connection to the *external time aspects* (ET), which potentially could be leading to added *threats* (T) for the standardization and risk a *lack of external interoperability* (EI). The timing of standards publication and development was perceived to be important for the participants. Since poor timing potentially brought *threats* (T) of completion and missed opportunities, as described previously (see section 2.1.3.2). Being able to utilize the standards in interoperability with other solutions was perceived as a key for the development to continue to accelerate and lead to sustainable innovation solutions. On the other hand, the interviewees expressed concerns about a perceived lack of *internal* and *external* communication that hinders *interoperability* (II & EI). The participant added that even with the recent development of OSs in the e-mobility sector, there are still lagging aspects in the *industry application* (IT) when it comes to cross-sector implementation. The standards need to be able to be used across different perspectives for the solutions to be effective in transforming industries. Thereby, a lack of interoperability could lead to the creation of barriers and risk lock-in effects, as described previously (see section 2.1.3.2). This could in turn place constraining on both the buyer and the cross-functionality between different standards in development. Overall, the interoperability aspects discussed in the interviews may be correlated with both sides of the OSR in the *Openness model* of *interoperability*; *buyer constraints* (I1), and *between standards* (I2).

The position of the participants on the EMBE role map (see Figure 14), displaying their main roles as *Aggregators* and *Providers*, with only one interview having a governor perspective, could explain their hesitance toward initiating standards that may change the industry. Them being of a centered position and thus part of the third SDP - *usage rights.* The participants all stated that they would like to see the change come from a different direction, potentially higher up. They allure to the potential of there being great risks of creating more barriers, between the existing relationships, if the change were to be initiated from their more centered EMBE position. Implementation from above could generate a more natural flow of change that alters the interoperability downstream in the supply chain. These statements were ultimately followed by the actors perceiving themselves to be forced to focus on their existing solutions, due to the fear of potentially losing partnerships, customers, and/or suppliers.

5.2.4.4 Summarizing the relations of the themes and Openness model

The identified relations of the themes (see Table 12) and the OSRs of the *Openness model* (see Table 5) are summarized in the table below (see Table 13). In total 22 relations were identified.

Table 13. Theme relations to the Openness model

Relation ID	Openness model		Perceived openness	
	SDP	OSR	Theme	SWOT
1	SDP 1	P	II	W
2	SDP 1	P	PI	W
3	SDP 1	T	II	W
4	SDP 1	T	PI	W
5	SDP 1	S	N	S
6	SDP 1	S	HG	O
7	SDP 1	S	GV	O
8	SDP 2	A1	N	S
9	SDP 2	A1	II	W
10	SDP 2	A1	IT	W
11	SDP 2	A2	GV	O
12	SDP 2	C	HG	O
13	SDP 2	C	EI	T
14	SDP 2	C	IAM	T
15	SDP 3	I1	II	W
16	SDP 3	I1	IT	W
17	SDP 3	I1	EI	T
18	SDP 3	I1	ET	T
19	SDP 3	I2	II	W
20	SDP 3	I2	IT	W
21	SDP 3	I2	EI	T
22	SDP 3	I2	ET	T

For the OSRs of SDP1, there were many connections relating to the perceived *weaknesses* (W), mainly of the first two OSRs of *permeability (P)* and *transparency (T)*. While the connections of the *structural attributes* (S) seemed to be connected to positive themes of both *strength* (S) and *opportunities* (O). For the OSRs of SDP2, there was an internal focus on the OSR of availability of *complete specification* (A1), displaying both *strengths* (S) and *weaknesses* (W). However, the OSR of availability of *complements* (A2) and the *claims* (C) requirement focused more on external themes. The complements connect to *opportunistic* (O) themes, while the Claims are mostly connected to themes of perceived *Threats* (T). For the OSRs of SDP3, all of the connections of OSRs (*buyer's constraints* (I1) and *between standard* (I2)), were made to the negative of the SWOT (*weaknesses* (W) & *threats* (T)).

When investigating the responses from the interviews (see Appendix .C), there are many potential connections to the theory and potential relations to the OSRs. This study was aimed at identifying potential key connections and relations. However, there may be more connections yet to be discovered. The identified relations brought up in this part of the analysis (see Table 13), will be further explored in the upcoming section.

5.3 Potential gaps – comparing and correlating the intended and perceived openness

This section aims to make correlations between the intended openness of the OS-set and the perceived openness from industry actors. The evaluated OSRs will be correlated to the themes (see Table 13) through their relations to the *Openness model*, from this, an analysis of the potential implications of SWOTs on the OSRs may be performed.

5.3.1 Identifying potential gaps between intended and perceived openness

From the analysis of the intended openness, specifically looking at the OSRs (see Figure 18), and the perceived openness related to the *Openness model* (see Table 13), the subsequent connection points could be made and have been illustrated below (see Figure 23).

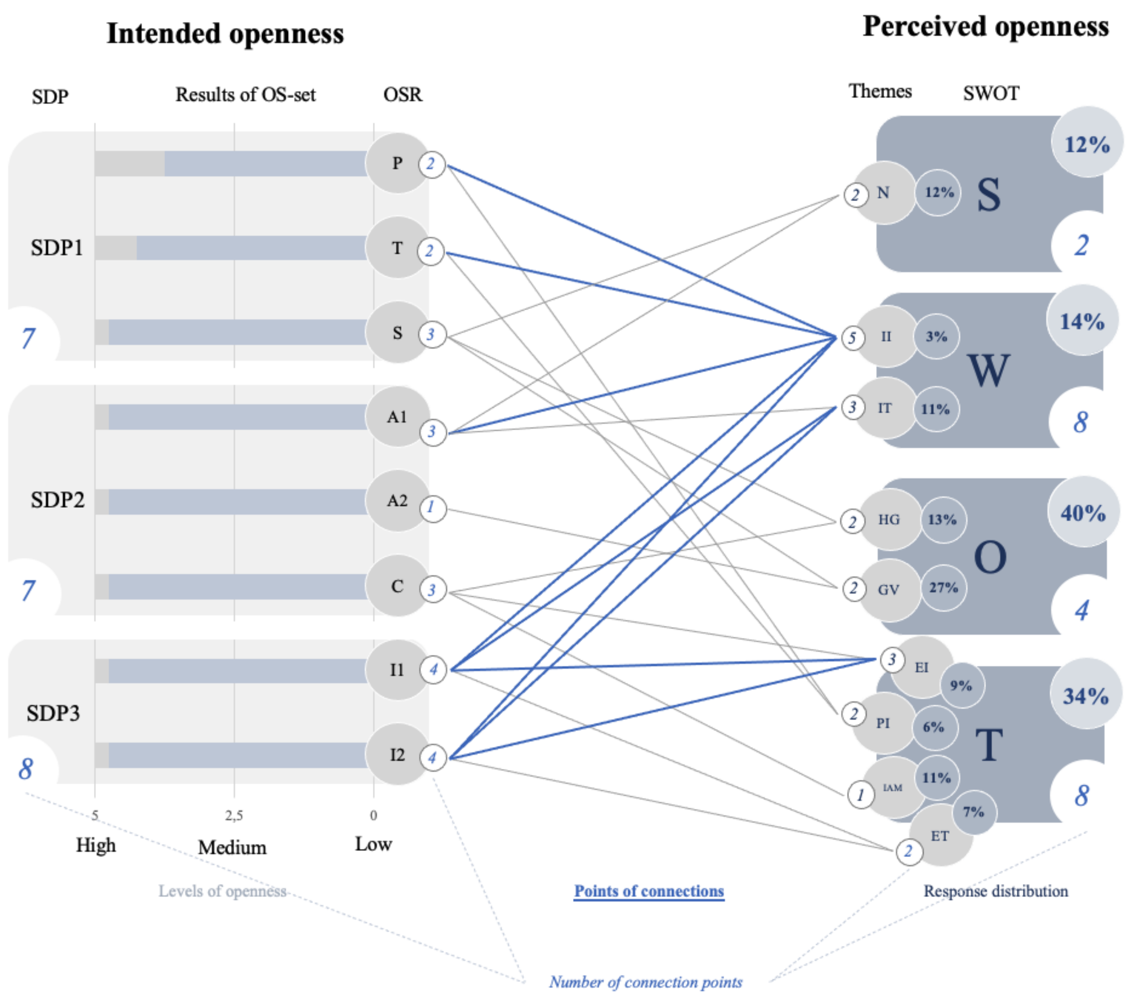

Figure 23. Connection points between intended openness and perceived openness

In Figure 23 the resulting connection points have been distributed over all of the OSRs/themes (in *grey circles*). Some with more or less accumulation of connections. The numbers in *blue cursive* in the *white circles* represent the number of connections for each OSR/Theme. The *bold dark blue numbers* in the *blue circles* represent the previous analysis of theme distribution in the responses.

The connection points of Figure 23 indicate whether there are areas where the themes may be relevant for the improvement of the OSRs, and thus the open innovation strategy. The number of connection points may allure at areas in need of prioritization, since a higher number of connections may generate a greater effect on the open innovation strategy, through its broader targeting of ORSs/themes. The effect is a measure of how much impact each effort could generate, by having the potential of addressing multiple areas. The number of connection points follows the reasoning of the analysis from the previous section (see section 5.2.4). The range goes from 1-5 connection points for each OSR/Theme, with the combined sum of connection points ranging from 2-9. Thus, the average sum of connection points is 6. To indicate the strongest connections, any *sum of connection points* above the average (7 and larger) has been given a *thicker* connection line. Resulting in a total of 9 *marked thicker lines* with the combinations; P-II (7), T-II (7), A1-II (8), I1-II (9), I1-IT (7), I1-EI (7), I2-II (9), I2-IT (7), and I2-EI (7). Here follows the analysis of the connection points for each of the; *SDPs*, *OSRs*, *themes*, and *SWOT categories*.

5.3.1.1 The connection points of the SDPs

From the perspective of SDP, they all had a similar number of connections, ranging from 7-8 connection points (see Figure 23).

The SDP3 seemed to have a higher sum of strong connections (sum of connections higher than average of 6), compared to the other SPDs. When observing the overall openness of the OS-set from the intended openness analysis, there is an indication that the SDP1 would have a lower level of openness, as previously described in section 5.1.2. However, there was not any obvious correlation between the number of OSRs and/or their *intended openness* level and the total number of connections, of each SDP.

5.3.1.2 The connection points of the OSRs

For the OSRs, the number of connection points varied between a range of 1-4 connection points. The OSR with the lowest number of connection points were *complements* (A1), at 1 connection point, and the highest number of connection points were of both the sub-requirements of *interoperability* (I), at 4 connection points respectively (see Figure 23).

The *complements* (A2) may therefore be less prioritized if the aim is to generate an overall improvement of the open innovation strategy for the OSs of the EV charging ecosystem. While interoperability can be interpreted to be of higher priority for the overall goal. The connection point between the *complements* (A2) and the opportunities of the recognized need for *higher governance structures* (HG). The complements received the lowest score but did connect to the most discussed theme from the response distribution (27%). This could indicate that even if A2 is not as effectful as the other OSRs (with its lesser number of connection points) it is of great interest to the industry and should not be overlooked. On the other hand, addressing the challenges of interoperability in regards to *buyer's constraint* (I1) and *between standards* (I2) seems to be related to more challenges, and has a generally larger effect according to the perception of the actors. The OSRs of I1 and I2 connected to themes of medium to lower number of connection points (3%-11%). Displaying that it is not overlooked, however, it might not be a priority of the industry.

5.3.1.3 The connection points of the themes

The number of connection points of each of the themes was also distributed between a range of 1-5 connection points. The lower number of connections was that of the *intellectual asset management* (IAM)**,** at 1 connection point. The highest number of connections belonged to the *internal* and *external interoperability* (II & ET), at 5 and 3 connection points, as well as the internal timing through the lagging in *industry application* (IT), at a 3. As can be viewed in Figure 23.

The theme of *intellectual asset management* (IAM) seemed to be one of the medium-discussed themes (11%), but it was not recognized to be directly connected to any OSR but the *claims* (C). The reason it had been of interest to the industry actors might have to do with the business impacts of the threats that accompany IP risks. As mentioned in the theory section (see section 2.1.2), *intellectual asset management* (IAM) can be a sensitive topic for firms as it is heavily connected to the potential value creation of knowledge assets.

A higher number of connections of the themes were made towards interoperability OSRs (I1 & I2). Aligning with previous research pointing out the importance of interoperability for OSs to work effectively. However, with their sum of connection points (at a 9 for the respective case of I1-II and I2-II), they connected to the least discussed theme from the response distribution of the interviews (3%). This can be seen as a potential gap between the intended and perceived openness. It is interesting to note that the most connected OSRs of SDP3, and the themes were connected to weaknesses. Indicating that this potential gap between the intended level of openness for the SDP3 of OSs in the EV charging ecosystem, and their relation to the perceived weaknesses of openness of the industry are still in need of further development. This can be seen as a high indication that the levels of openness for interoperability, should be seen as a priority.

5.3.1.4 The connection points of the SWOT categories

In Figure 23 the number of connection points divided over the SWOT categories seemed to be less evenly distributed than that of the SPDs. With the lesser number of connections being to that of the positive SWOT aspects; 2 connections to the *strengths* (S), and 4 connection points to *opportunities* (O). And the higher number of connections points to the negative aspects of the SWOT; 8 connection points of *weaknesses* (W), and 8 connection points to *threats* (T). Displaying a potential need for prioritization of the negative SWOT categories and addressing their respective themes to improve the adaptation of EVs.

5.3.2 Summary of the potential gaps

By connecting the SWOT back to the OSRS of the *Openness model* in Figure 23, there is a potential for understanding not only the *business perspective* but also connecting it to theory to be able to focus the effort according to the desired effect. Having as many (8) connection points linked to both of the negative aspects of the SWOT can be seen as an indication that the efforts should be focused there. Turning the weaknesses into strengths, and threats into opportunities. As is the purpose of utilizing the SWOT analysis in a business setting. Here, there is a distinction to be made of the number of connections between the Weaknesses and Threats that relate to the initial and last phase of the standard development process. Specifically, the I1 and I2, but also the P, and T. Which can be visualized by the thicker blue lines in figure Figure 23.

5.4 Answers to research questions

In this section, the analysis of the studies attempts at answering the research questions posted in section 1.5. Research questions 1- 4 are posted in order to be able to address the main research question.

5.4.1 Research question 1

The first research question posed was;

Which OSs within the EV charging ecosystem are relevant for the facilitation of sustainable transport solutions?

Through the initial literature review and initial interviews with experts, it became clear that OSs hold the potential for facilitating innovation in the EV charging ecosystem. The context of the EV ecosystem had already been identified to be a key challenge for the EV adaptation, which in turn was part of the efforts of achieving sustainable transportation solutions. Thus, the connection of OSs as facilitators for the adaptation of sustainable transportation solutions had been established. Addressing the later part of research question one.

The matter of identifying the set of OSs which were relevant took the turn of utilizing the inputs from the initial interviews and verifying them through literature and documentation. The insights from the initial interviews were described in section 4.1.1.1. The initial interviews resulted in the following four OSs being seen as most relevant by the experts; *ISO 15118, IEC 61851, OCPP,* and *OpenADR.* These OSs had, according to previous literature (Neaimeh & Andersen, 2020a), been depicted to be some of the most utilized in the EV charging ecosystem. Through investigation of the characteristics and attributes of the mentioned OSs, the results depicted (see Table 2), showed that the OS-set had a broad span of variations. According to the inputs from the experts, such variations in; nature of origin (authors), information flow profile, and scope of specification, could be considered to be of interest for the aim of this study. Additionally, the attributes of publication year and development (version history) were also considered. The comparison of the OS in the set was summarized in section 4.1.1.2.

The results presented in section 4.1.1, showed that together the identified OS-set represents a broad perspective of OS with differences in organizational nature of origin (see section 2.1.3.1), information flow in the EV charging ecosystem (See section 2.2.2), and position in the open communication protocol landscape (see section 2.2.3). All in all, the OS-set is providing a nuanced perspective on openness in OSs utilized in the EV charging ecosystem. Thus, making them relevant for the adaptation of sustainable transportation solutions, which answers the first part of research question one.

5.4.2 Research question 2

The second research question was;

Which OSRs are relevant for the facilitation of sustainable transport solutions?

To answer this research question, a second literature review of previous research was conducted. This review looked at different frameworks of OSRs and compared the requirements of them to each other.

From the initial literature review, the framework of Mutkoski (2011) had been identified as a combination of previous frameworks (see section 2.1.3.3), thus it had been selected as a basis for forming an *Openness model* for the study. The results of the secondary literature review confirmed this selection. The second part of the second literature included an investigation of previous applications of OSR framework within the context of the EV charging ecosystem. The results of the investigation of previous OSR frameworks were described in Section 4.1.2. After this, two applications of OSR frameworks within the EV charging ecosystem were investigated. This included; Deniz (2015) that applied West's (2005) framework of OSRs on the OS of the OCPP, and Neaimeh and Andersen (2020a) that applied Krechmer's (2006) framework of OSRs on all of the four OS of the OS-set (see Section 4.1.3.1 – Section 4.1.3.2). From the two parts of the second literature review, a timeline was constructed (see Figure 13) to visualize the development of the OS-set, OSR frameworks, and applications of OSR frameworks within the EV charging ecosystem that had been considered. The combination of insights from previous applications and the timeline depicted that the recent development and utilization of OSR frameworks could be seen as most relevant for the EV adaptation and thus, the development of sustainable transport solutions. Thus, answering the second part of research question two.

The insights of the applications of OSR frameworks with the EV charging ecosystem were two folded. First, there was the insight of dividing some requirements into sub-requirements, which according to the arguments of Deniz (2017) creates potential for investigation of nuances in openness levels. The second was that the OSR of Mutkoski regarding *market success* could be overlooked in the context of this study. These insights came from both Deniz (2017) and Neaimeh and Andersen (2020a), which expressed that the market adaptation in this area could be considered to be low. Thus, indicating that it could be of less interest to investigate. The insights of the investigation of the applications, combined with the Mutkoski (2011) OSR as a basis, lead to the generation of the *Openness model* (see Table 5). This model included the three SDPs of West (2005) (see section 2.1.3.2), the OSRs of Mutkoski (2011) (see 2.1.3.3), with alterations from the insights of the previous applications of Deniz (2015) and Neaimeh and Andersen (2020a) (see section 4.1.3). The *Openness model* contained a total of nine requirements (including two sub-recruitments), which were as follows. For SDP1; *permeability* (P), *transparency* (T), and *structural attributes* (S). For SDP2; *availability – complete specification* (A1), *availability – encourage complements* (A2), and *claims* (C). For SDP3; *interoperability – buyer's constraints* (I1), and *interoperability – between standards* (I2). Which gives answers to the first part of research question two.

5.4.3 Research question 3

The third research question read;

How are the identified OSRs of the OS-set, mapped out according to their intended levels of openness?

The relevant OSRs and set of OS were already determined from the answering of research questions one and two. To address the third research question the findings of the second literature were utilized, along with a data collection from official documents and protocols.
was
The intended level of openness represents the level at which each of the OSRs of the OSs was intended to have, according to their official documents and protocols. Since prior research had already been performed (Neaimeh and Andersen, 2020a), evaluating the levels of openness, to a larger extent than that possible in this study, these results were utilized through

the *Openness model* (see Table 5), as generated from the results of research question two. The translation of the different OSR frameworks used to depict the openness were explained in section 4.2. The results of the investigation of the openness levels for the OSRs of the *Openness model* were depicted in Table 7 - Table 9.

The results of the intended openness were then analyzed using weighted scales (converting the previous scale of low-high, into a numeric scale of 1-5) (see Table 10). The analysis then looked at the different perspectives of openness levels comparing the; OS in the set (See Figure 16), SDPs (see Figure 17), and OSRs (Figure 18). Finally, an overall visualization of the intended openness was generated (Figure 19).

The analysis showed that most of the OSRs for each of the OS in the set were intended to be on the higher range of the openness levels. The OCPP scored lower than average than the other OS in the set. ISO 15118 and IEC 61851 scored the highest. In terms of SDPs, the SDP1 scored lower than that of the SDP2 and SDP3. This in alignment with the statements of Deniz (2015), could be rooted in the early adaptation of the standards, and could potentially change as the standards develop. As a consequence of the SDP1 having a lower score, the first two OSRs in the *Openness model* (Permeability (P) and Transparency (T)) scored the lowest out of the OSRs. The slight variations in the scores can be seen as an indication that Mutkoski's (2011) recognition of the importance of depicting nuances in the ORSs is valid. As well as Deniz's (2015) realization that sub-requirements could be used for this type of categorization of openness. However, none of the OS in the set achieved an overall high openness level for all OSRs. Aligning with the desire for openness to be utopian, as described by West in the early sections of this study (see section 2.1.3.3). Thus, this study answered the third research question of the intended openness.

5.4.4 Research question 4

The fourth research question was;

What is the Swedish EMBE's perception of the openness of OS within the EV charging ecosystem, and the relevance of OS as facilitators for sustainable transportation solutions?

For the perceived openness, the data was collected through the main interviews with actors in the Swedish EMBE. The interview questions were based on insights from the initial literature review. The specific questions asked were summarized in Table 15 (see Appendix .B).

To better understand the results of the actors' perspectives, a mapping of the interviewees according to the EMBE framework of Giesecke (2014) (see section 2.2.1), was performed (see Figure 14). A description of the companies and participation can be viewed in Table 14 (see Appendix .A). From the resulting responses of the interviews a word cloud was constructed (see Figure 15), to get a visual representation of the keywords discussed.
The first part of the analysis was to separate the 98 quotes of interest from of the main interview responses and connect them to their respective SWOT category (see Table 16 in Appendix .C). The responses were then analyzed by; SWOT category (see section 5.2.1.1), Internal vs external focus (see section 5.2.1.2), Positive vs negative aspects (see section 5.2.1.3), and the standard deviation was calculated (see section 5.2.1.4).

For the SWOT categories, the distribution showed that there was an underrepresentation of responses relating to the perceived *strengths* (S), at 12%, followed by the *weaknesses* (W), at

14%. The most talked about SWOT category was the *opportunities* (O), at 40%, followed by the *threats* (T), at 34%. Most of the interviewee's responses, 75%, related to an external focus. While the internal focus received only 25% of the response distribution. However, the positive and negative aspects were balanced, at 52% for positive and 48% for negative. Showing that the participants provided perspectives that were not leaning too far into either optimistic or pessimistic points of view. The analysis of the standard deviation showed slight variations in the interviewee's individual contribution to each of the SWOT categories. However, it was not interpreted to have a large impact on the results.

When looking at potential themes in the responses, the keywords from the word cloud, along with a word frequency count (see Table 17 in Appendix .D) were used as a guide (see section 5.2.2). Along with additional insights from the interviews, where some keywords could be interpreted even if not explicitly stated in the quoted responses. This led to the identification of the themes (with related SWOT categories) within the perceived openness (see Table 12). The themes identified for each of the SWOT categories were as follows. For *strengths* (S): a perceived *need for openness and standardization* (N). For *weaknesses* (W): a *lagging industry application* (IT), and *lack of internal interoperability* (II). For *opportunities* (O): a desire for *higher governance structure* (HG), and a realization of potential for *greater common values* (GV). Lastly, for *threats* (T): lacking *external interoperability* (EI), perceived *power imbalances* (PI), Risks of poor *intellectual asset management* (IAM), and *external time aspects* (ET) of timing and pace of developments.

The themes were then related to the responses by analyzing the quotes c and statistically depending on the theme's connection to the SWOT categories. The distribution of the themes amongst the responses showed the following representation; 12% (N), 3% (II), 11% (IT), 13% (HG), 27% (GV), 9% (II), 6% (PI), 11% (IAM), and 7% (ET). The insights of the analysis of the relation between the themes and responses were as follows. There was a perceived positive attitude towards OSs and open innovation as a beneficial tool for adapting to shifting infrastructure and industries, and for finding sustainable transportation solutions. The EMBE perceives the internal and external interoperability to be lacking, impeding knowledge transfer, and hindering the implementation of OSs and open innovation. This lack of interoperability could have implications for other industries beyond automotive. The analysis identified that both internal and external time challenges are perceived to be existing in the EV charging ecosystem. Internally, automotive companies in the Swedish EMBE were perceived as slow to adapt to changes. Externally, the industry as a whole was seen as lagging in maturity, making collaborations difficult for companies at different stages of innovation. OSs were seen as an opportunity to bridge the gap between different actors and reach a common consensus for solutions, as described in section 2.1.3. Time aspects were related to *intellectual asset management* (IAM), with a depicted hesitance to share knowledge early on due to concerns of losing control and missing out on value-creation opportunities. There was a strong intention for collaboration, but hesitance to initiate due to uncertainties about the nature of openness and who controls it. The industry actors were perceived to be hesitant to make the first movers. The common perception was that clearer definitions of openness, especially in relation to OSs and open innovation, are desired, along with coordination for common goals and joint efforts, even down to the detailed levels of *intellectual asset management* (IAM), as described in section 2.1.2.

The last step of the analysis of the perceived openness was relating the themes (see Table 12), to the OSRs of the Openness model (see Table 5). Also including considerations of the positioning of the interviewees in the EMBE, in relation to the SDPs (See Figure 14). This resulted in 22 relations that were then displayed in Table 13. Key takeaways from this analysis in section 5.2.4 were that the SDP 1 and SDP 3 were mainly related to themes connecting to the negative aspects of the SWOT. There was also a minimal focus on the encouragement of complements (A2) OSR, with only one relation identified.

From the analyses of section 5.2, the relevance of OS has been confirmed and was related to the OSs ability to bridge actors in working toward the SDGs of finding sustainable transportation solutions. The Swedish EMBE's perception was determined to be positive towards the need for openness of OSs in the EV charging ecosystem, as long as there are clear directions of the scope, excellent management of IAs, and a leading organ driving the joint efforts. The actors were perceived to be hesitant to be the first movers. However, they realized the eminent shift of the EV industry, and that OSs could be utilized in managing this effectively. Thus, having answered the fourth research question.

5.4.5 Main research question

By answering research questions 1- 4 the answer for the main research question could be generated. The potential gaps between the intended openness and perceived openness were identified using the openness model (see Table 5), the analysis was described in section 5.3.1. With Figure 23 illustrating the connection points between the intended openness and perceived openness, the analysis of various perspectives; SDPs, OSRs, themes, and SWOT categories, were conducted (see section 5.3.1.1 – section 5.3.1.4). The analysis showed that the strongest connections (above the average number of connection points compared to the other OSRs and themes) were linked to the negative aspects of the SWOT. Indicating that this is where efforts might need to be prioritized. The connections were mainly to that of SDP1 and SDP3, specifically the OSRs of; I1, I2, P, and T. This analysis, have generated an answer for the main research questions of;

Are there potential gaps between the intended openness and perceived openness of OSs within the EV charging ecosystem, that would be relevant for the facilitation of sustainable transportation solutions?

The results and analysis of this study display that there are potential gaps between the indented openness and the perceived openness. This could potentially be the cause or consequence of the dissonance in the openness of the OSs of the EV charging ecosystem. Thus, affecting the OSs ability to facilitate the development of sustainable transportation solutions.

6 Conclusion

The prior identification of the existence of a knowledge gap in how to apply OSs to improve interoperability (Klotz et al., 2018) (Karpenko et al., 2018), has through this study been confirmed. The findings of this research study have in addition, further explored the correlations of the gaps between the intended and perceived openness of OSs in the context of the Swedish EV charging ecosystem. In doing so, the study found the results to be relevant for the EV adaptation of sustainable transportation solutions.

6.1 The correlations of the gaps between the intended and perceive openness

Within the SDPs of OSs in the EV charging ecosystem, the study found there to be potential gaps within phases of SDP1 and especially SPD3. According to the analysis, the specific OSRs that could be considered a priority for effective improvement of the utilization of the OS in the context, included; usage interoperability (looking at *buyer's constraint* (I1) and *between standards* (I2)), and specifications within the *permeability* (P) and *transparency* (T) of the SDOs. The most correlated themes were that related to both internal and external interoperability (IT, discussed in 3% of the total responses, and ET, discussed in 9% of the total responses) and time (IT, discussed in 11% of the total responses, and ET, discussed in 7% of the total responses) respectively. They were the ones to correlate to the SDP1 and SDP3. Thus, showing that the strongest correlations were made to the weaknesses and threats of the SWOT analysis. Although the SDP3 was evaluated to have a higher intended level of openness, the connections made to the negative SWOT categories could be hinting at them not being perceived to achieve an optimal level of openness for the application. The study displayed areas in need of improvement, and that could potentially have a greater effect on the overall open innovation strategy. The lack of a common definition of the concept of OSs could be seen as having directly correlated with the internal and external lack of interoperability due to its creation of barriers to knowledge sharing. Aligning with the importance of interoperability for the enablement of true openness (Aliprandi, 2011). As well as the dynamic nature of standards in relation to time (Fukawa et. Al, 2021).

6.2 Correlations to the innovation paradox

From the main interviews of the perceived openness, the Swedish EMBE actors were portrayed to be positive towards the need for open standards, discussed in 12% of total responses, but hesitant to make the first move, mostly due to risks of intellectual asset management, discussed in 11% of total responses. The identified need for open standards could be the result of a common perception that the complexity of the emerging technologies within EVs calls for new forms of open innovation management. Among the theme identified from the data, one of particular interest were that of the industry's interest in a governing organ, relating to the higher governance structure (HG) discussed in 13% of total responses. The interviews showed that the actors were not only looking for an organization that manages the specifications of OS, but the operational functions of the joint open innovation efforts. Call it what you want, but almost like a teacher watching over the kids playing, ensuring all is fair. The distant relationship of the higher administrations needs a buffer to be the direct connection with the kids. Someone to interrupt the perceived David vs Goliath perspective of power imbalances (discussed in 6% of total responses), since such fighting does not foster collaboration. Collaborations in innovation may increase the firm's success, by showing that the path forward is together (Moore, 1996). Thus, for actors to come together and play fair, there needs to be someone there to hold their hands. Facilitating the operations when using open innovation tools (specifically the intellectual assets of the open standards) to enable the acceleration of eco-innovations.

The balancing act of the innovation paradox (sustainability vs profitability) can be observed through the lens perspective of *value vs control*. Where the responses from the main interviews indicated that the emerging themes of; generating *greater common values* (GV), at 27% of total responses, and risks of poor *intellectual asset management* (IAM), could be seen as related to this scale. The interviews displayed a high desire to partake in the sustainability and innovation identity of Sweden's business ecosystem. The increasing network effect of end-users' awareness and willingness to pay for environmental alternatives could be seen as a shift of the innovation paradox, moving sustainability and profitability toward an equilibrium. The *value* for the companies could therefore be seen as coming from the potential value within maintaining Sweden's image of sustainability and innovation, and the *control* could be correlated to the risks of losing out on the potential profits of the knowledge assets. With the high knowledge intensity of firms in the automotive industry, this balancing is perceived as highly relevant for the acceleration of innovation. The perceived hesitance towards openness from the slowly adapting car manufacturers would need to be addressed by improved IAM strategies and realistic SDGs. As a potential way of mending the gaps, a *higher governance structure* (HG) could have the potential of generating a stable environment for the collaborations to grow within. While also facilitating the widespread adaptation of EVs.

6.3 Expanding the border of the EV charging ecosystem

The cross-sectional aspects of the shift in the E-mobility industry, call for a deeper understanding of the interactions of the SoS and different cases of the EV interoperability layers. Which could lead to increased comprehension of how the openness can be diffusing knowledge at the various levels. The nuances of the framework of OSRs in this study could be one step in the right direction, in seeing collaborative efforts may affect the various areas of the openness. With the industry actor's reluctance towards over-sharing, providing a clearer cause and affect scheme of the open standards could aid in the loose coupling of the open innovation network for the EV adaptation. Allowing for the actors in the fast-changing pace of ICT to move forward and share parts of their knowledge stock, through collectively driven actions (Deniz, 2015). Thus, strategically enabling the adaptation of the open standards to achieve the approaching SDGs targets.

The context of the EV charging ecosystem proved to be a current area of great interest for standard development. Where the evaluations of the success of OSs could be further investigated through their expansion of implementations (Walli, n.d.). The emerging shifts in the industry, and across industries, related to the ICT developments within automotive, call for new technology innovations to be developed. The study showed that there was a perceived need and interest for OSs as a tool. Displaying the OSs potential to produce broad advantages for actors involved in the ICT market (Aliprandi, 2011). Although there are SDOs in the form of both established international standard organizations and consortia, in this context, there was a perception that the landscape was lacking clear recipients and responsible roles. Hence, increasing the desire for operational leadership managing the function throughout the open innovation ecosystem.

On the larger perspective of openness and knowledge sharing, the forces moving the EV adaptation may lead to great insights to be adapted to other areas where open standards are not yet mature. The globalized and technologically intense context of the automotive industry contributes to the complex dynamics of today's challenges (Aliprandi, 2011). Even if the E-mobility industry was perceived to have a low market adaptation as of 2020 (Neaimeh & Andersen, 2020a), the changes that are happening currently will generate new perspectives for other complex SoSs. This could aid the innovation of other areas, by not having to follow in the wrong footsteps. It was commonly agreed upon amongst the participants that we are heading towards an infrastructure shift, affecting our industries and society at large. Whether the car as we know it will be the future of transportation or not, the ICTs that is being developed in the e-mobility industry will have spillover effects on other industries, and thus change the way we are living our lives in the, hopefully, more sustainable, future.

7 Discussion

This chapter discusses the contribution to research, the research limitations, and some future suggestions, that can be drawn from this study.

7.1 Contribution to research

This study aimed at exploring openness from two different cases of the EV interoperability layers, by providing a broad and nuanced investigation of a model for openness in an area that was perceived to be in great need of adaptation – the EV charging ecosystem. The findings of the different phases of the study could be used separately, or together to produce an overview of the potential gaps in the openness of the context of the EV charging ecosystem.

7.2 Research limitations

Although the OS-set of this study was limited to four OSs, the set displayed a broad range of characteristics and attributes. This could in turn inspire future research to be conducted on specific categories of OS characteristics and/or attributes.

The Openness model for the OSRs was depicted to be a sweet spot with a nuanced set of requirements, but still keeping it simple enough to be applied in real-life. The optimal OSR framework is still in need of future development, applying insights from the applications of the rapidly developing markets, such as the EV market. Not including the *market success* requirement might have led to a potential missing out on relations. Since the market was shown to be an identified theme later on in the main interview.

It is worth noting that none of the interviewees explicitly state their company's participation in the development of the specific OSs of the OS-set. Thus, the findings cannot be used to directly correlate with the specific open standards set. However, with the OS-set depicting some of the most used open standards in the EV charging ecosystem, and the interviewees describing OSs and open innovation in the EV charging ecosystem, this link could be used to indicate potential connections and correlations.

The roles of the interviewed actors may have had an additional effect on the results. Positioning them was, a useful tool for identifying implications from the main interview responses. However, since one actor may have multiple roles in the EMBE (According to Giesecke, 2014), the full extent of the actors' implications could be further investigated.

Having only actors from the Swedish EMBE was a way of creating a manageable study within the given timeframe. Still, with the international environment of the EV market, Open standards, and SDGs, this limit might need to be stretched to not elude the research of the full potential of open standards as a facilitator for the EV adaptation of sustainable transportation solutions.

7.3 Suggestions for future research

Future research may be interested in re-evaluating the industry actor's perception (with a larger sample of interviewees and companies participating), to improve upon the general perception of the EMBE. Even go as far as to expand across the Swedish border to include other EMBE actors (eg. France, Germany, India, US, etc).

Another perspective to explore is if there are more nuances to the OSR framework that could be of interest for this, and or other areas, of innovation ecosystems. The implications of the nuances and their potential connections may lead to the identification of future areas of improvement and prioritizations depending on the goal.

On a different note, the findings of this study could potentially be applied in other areas of innovation ecosystems, to aid in the exploration of potential gaps in intended and perceived openness. This could be an angle that could generate effectful results in industries that are in the same, or even greater need, of an acceleration of eco-innovation.

Looking forward, the quest for sustainability and innovation will most likely lead to new ways of collaboration. If entered into with an open mind and effective tools for asset management, these efforts may become the next knowledge shift of our generation.

8 References

ABB E-mobility. (2022). *Standards and interoperability: Scaling EV charging infrastructure*. ABB E-mobility Inc. Retrieved May 3, 2023, from https://library.e.abb.com/public/eb9346be60a74ca6a6f42d559e2d102f/ABB_E-mobility_Interoperability_WhitePaper_B.pdf

Adner R. (2006). Match your innovation strategy to your innovation ecosystem. *Harvard business review*, *84*(4), 98–148.

Ahlgren, B., Hidell, M., & Ngai, E. C.-H. . (2016). Internet of Things for Smart Cities: Interoperability and Open Data. *IEEE Internet Computing*, *20*(6), 52–56. https://doi.org/10.1109/mic.2016.124

Ahmad, A., Alam, M. S., & Chabaan, R. (2018). A Comprehensive Review of Wireless Charging Technologies for Electric Vehicles. *IEEE Transactions on Transportation Electrification*, *4*(1), 38–63. https://doi.org/10.1109/tte.2017.2771619

Albert, C. L., Rubio, F., & Valero, F. (2021). Impact of digital transformation on the automotive industry. *Technological Forecasting and Social Change*, *162*, 120343. Ncbi. https://doi.org/10.1016/j.techfore.2020.120343

Aliprandi, S. (2011). Interoperability and open standards: the key to a real openness. *International Free and Open Source Software Law Review*, *3*(1), 5–24. https://doi.org/10.5033/ifosslr.v3i1.53

Andersen, P., Christensen, B. E., Zecchino, A., Høj, J., Sørensen, T. J., & Toghroljerdi, S. H. (2019). *The Parker Project: Final Report*. https://backend.orbit.dtu.dk/ws/portalfiles/portal/201164295/Parker_Final_report_v1.1_2019.pdf

Andreeva, T., & Kianto, A. (2011). Knowledge processes, knowledge-intensity and innovation: a moderated mediation analysis. *Journal of Knowledge Management*, *15*(6), 1016–1034. https://doi.org/10.1108/13673271111179343

Arcese, G., Flammini, S., Lucchetti, M., & Martucci, O. (2015). Evidence and Experience of Open Sustainability Innovation Practices in the Food Sector. *Sustainability*, *7*(7), 8067–8090. https://doi.org/10.3390/su7078067

Bell, E., Bryman, A., & Harley, B. (2019-a). *Business Research Methods* (5th ed.). Oxford University Press.

Bell, E., Bryman, A., & Harley, B. (2019-b). *Business Research Methods* (5th ed.), 3. Oxford University Press.

Bharadwaj, A., Devaiah, V. H., & Gupta, I. (2020). *Complications and Quandaries in the ICT Sector*. Saint Philip Street Press.

Blind, K., & Gauch, S. (2008). Trends in ICT standards: The relationship between European standardisation bodies and standards consortia. *Telecommunications Policy*, *32*(7), 503–513. https://doi.org/10.1016/j.telpol.2008.05.004

Bogers, M. (2011). The open innovation paradox: knowledge sharing and protection in R&D collaborations. *European Journal of Innovation Management*, *14*(1), 93–117. https://doi.org/10.1108/14601061111104715

Bogers, M. (2012). Knowledge Sharing in Open Innovation. *Open Innovation in Firms and Public Administrations*, 1–14. https://doi.org/10.4018/978-1-61350-341-6.ch001

Bogers, M., Zobel, A.-K., Afuah, A., Almirall, E., Brunswicker, S., Dahlander, L., Frederiksen, L., Gawer, A., Gruber, M., Haefliger, S., Hagedoorn, J., Hilgers, D., Laursen, K., Magnusson, M. G., Majchrzak, A., McCarthy, I. P., Moeslein, K. M., Nambisan, S., Piller, F. T., & Radziwon, A. (2016). The open innovation research landscape: established perspectives and emerging themes across different levels of analysis. *Industry and Innovation*, *24*(1). https://doi.org/10.1080/13662716.2016.1240068

Bowen, D. J., Kreuter, M., Spring, B., Cofta-Woerpel, L., Linnan, L., Weiner, D., Bakken, S., Kaplan, C. P., Squiers, L., Fabrizio, C., & Fernandez, M. (2009). How We Design Feasibility Studies. *American Journal of Preventive Medicine*, *36*(5), 452–457. https://doi.org/10.1016/j.amepre.2009.02.002

Bryman, A. (2012). *Social Research Methods* (4th ed.). Oxford University Press.

Cancela, B. L., Coelho, A., & Duarte Neves, M. E. (2022). Greening the business: How ambidextrous companies succeed in green innovation through to sustainable development. *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3287

CEN-CENELEC-ETSI Smart Grid Coordination Group. (2012). CEN-CENELEC-ETSI Smart Grid Coordination Group Smart Grid Information Security. In *cencenelec.eu*. https://www.cencenelec.eu/media/CEN-CENELEC/AreasOfWork/CEN-CENELEC_Topics/Smart%20Grids%20and%20Meters/Smart%20Grids/security_smartgrids.pdf

Chesbrough, H. W. (2003). *Open Innovation: the New Imperative for Creating and Profiting from Technology*. Harvard Business School Press.

Chesbrough, H. W. (2006a). *Open Innovation : Researching a New Paradigm*. Oxford University Press.

Chesbrough, H. W. (2006b). *Open Innovation : Researching a New Paradigm* (p. 2). Oxford University Press.

Chesbrough, H., & Spohrer, J. (2006). A research manifesto for services science. *Communications of the ACM*, *49*(7), 35. https://doi.org/10.1145/1139922.1139945

Chesbrough, H., Vanhaverbeke, W., & West, J. (2006). *Open Innovation : Researching a New Paradigm*. Oup Oxford.

CIE. (2006). *Standards and the economy* (p. 5). Centre for international economics. https://www.pc.gov.au/inquiries/completed/standards/submissions/standards_australia_cie/subdr133.pdf

Cohen, W., & Levinthal, D. A. (2000). Absorptive Capacity: A New Perspective on Learning and Innovation. *Strategic Learning in a Knowledge Economy*, *35*(1), 39–67. https://doi.org/10.1016/b978-0-7506-7223-8.50005-8

Coppersmith, G., & Kelly, E. (2014). Dynamic Wordclouds and Vennclouds for Exploratory Data Analysis. *Proceedings of the Workshop on Interactive Language Learning, Visualization, and Interfaces*. https://doi.org/10.3115/v1/w14-3103

Costa, J., & Matias, J. C. O. (2020). Open Innovation 4.0 as an Enhancer of Sustainable Innovation Ecosystems. *Sustainability*, *12*(19), 8112. https://doi.org/10.3390/su12198112

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (4th ed.). Sage Publications Ltd.

Crotty, M. (1998). *The Foundations of Social research: Meaning and Perspective in the Research Process*. Sage Publications.

Curley, M., & Salmelin, B. (2013). Open Innovation 2.O: A New Paradigm . In *European Union* . https://ec.europa.eu/futurium/en/system/files/ged/24-oispgopeninnovation20anewparadigm-whitepaper.pdf

Deniz, S. (2015). *An empirical analysis of the openness dimension of OCPP standard*. Fourth European Battery, Hybrid and Fuel Cell Electric Vehicle Congress, Brussels, Belgium. https://portal.research.lu.se/en/publications/an-empirical-analysis-of-the-openness-dimension-of-ocpp-standard

Díaz-Marta, V. Z., & Ferrandis, C. M. (2020). Open standards and open source: characterization and typologies. *Journal of Intellectual Property Law & Practice*, *15*(9), 700–710. https://doi.org/10.1093/jiplp/jpaa101

Drive Sweden. (n.d.). *About*. Www.drivesweden.net. Retrieved February 22, 2023, from https://www.drivesweden.net/en/about-us

Drucker, P. F. (1985). *Innovation and entrepreneurship practice and principles.* London Heinemann.

Drucker, P. F. (1992). *The age of discontinuity : guidelines to our changing society*. Transaction Publishers.

Drucker, P. F. (1994). *Post-Capitalist Society.*

Druedahl, L. C., Minssen, T., & Nicholson Price, W. (2021). Collaboration in Times of Crisis: A Study on COVID-19 Vaccine R&D Partnerships. *Vaccine*, *39*(42). https://doi.org/10.1016/j.vaccine.2021.08.101

EEI. (2019). *Interoperability of Public Electric Vehicle Charging Infrastructure*. https://www.eei.org/-/media/Project/EEI/Documents/Issues-and-Policy/Electric-Transportation/Final-Joint-Interoperability-Paper.pdf

El Sheikh, S. (2022, November 9). *CO2 emissions from buildings and construction hit new high, leaving sector off track to decarbonize by 2050: UN*. UN Environment. https://www.unep.org/news-and-stories/press-release/co2-emissions-buildings-and-construction-hit-new-high-leaving-sector

ElaadNL. (2017). *EV related protocol study*. ElaadNL. https://www.researchgate.net/publication/317265159_EV_Related_Protocol_Study

Elg, L. (2014). *Innovations and new technology - what is the role of research? Implications for public policy*. Vinnova. https://www.vinnova.se/contentassets/e5fe05cb13604be7b221f3ddbecb41c3/va_14_05.pdf

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Enel X. (2021). *A look at open standards in the EV industry | Enel X Way*. Enel X. https://evcharging.enelx.com/resources/blog/808-a-look-at-open-standards-in-the-ev-industry

Enkel, E., & Gassmann, O. (2010). Creative imitation: exploring the case of cross-industry innovation. *R&D Management*, *40*(3), 256–270. https://doi.org/10.1111/j.1467-9310.2010.00591.x

EPRI. (2019). *The Integrated Grid: Realizing the Full Value of Central and Distributed Energy Resources*. Www.epri.com; Electric Power Research Institute (EPRI). https://www.epri.com/research/products/3002014379/the-integrated-grid-realizing-the-full-value-of-central-and-distributed-energy-resources

Erlandson, D. A. (1993-a). *Doing naturalistic inquiry: a guide to methods*. Sage.

Erlandson, D. A. (1993-b). *Doing naturalistic inquiry: a guide to methods*. 132. Sage.

ETSI. (2023). *Intellectual Property Rights (IPRs)*. ETSI. Retrieved March 22, 2023, from https://www.etsi.org/intellectual-property-rights?jjj=1680204340801

European Commission. (2022, September 29). *Regulatory framework on AI | Shaping Europe's digital future*. Digital-Strategy.ec.europa.eu. https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai

Farrell, J., & Saloner, G. (1992). Converters, Compatibility, and the Control of Interfaces. *The Journal of Industrial Economics*, *40*(1), 9. https://doi.org/10.2307/2950625

Fransman, M. (2010). *The New ICT Ecosystem: Implications for Policy and Regulation*. Cambridge University Press.

Fukawa, N., Zhang, Y., & Erevelles, S. (2021). Dynamic Capability and Open-Source Strategy in the Age of Digital Transformation. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(3), 175. https://doi.org/10.3390/joitmc7030175

Gallagher, S. (2007). The Complementary Role of Dominant Designs and Industry Standards. *IEEE Transactions on Engineering Management*, *54*(2), 371–379. https://doi.org/10.1109/tem.2007.893991

Gartner. (2023). *Electro Mobility (e-mobility)*. Gartner. Retrieved February 20, 2023, from https://www.gartner.com/en/information-technology/glossary/electro-mobility-e-mobility

Gassmann, O., Enkel, E., & Chesbrough, H. (2010). The Future of Open Innovation. *R&D Management*, *40*(3), 213–221. https://doi.org/10.1111/j.1467-9310.2010.00605.x

Giesecke, R. (2014, June 26). The electric mobility business ecosystem. *International Conference on Ecological Vehicles and Renewable Energies*. https://doi.org/10.1109/ever.2014.6844046

Global EV Outlook 2022. (2023). In *iea.org*. IEA. https://www.iea.org/reports/global-ev-outlook-2022

Grant, R. M. (1996). Toward a Knowledge-Based Theory of the Firm. *Strategic Management Journal*, *17*(S2), 109–122. https://doi.org/10.1002/smj.4250171110

Grassman, O., & Enkel, E. (2004, July 9). *Towards a theory of open innovation: Three core process archetypes*. RADMA RandD Management conference, Lisbon.

Grauers, A., Karlström, M., & Sarasini, S. (2013). *Why electromobility and what is it*. 10–21.

Greenberg, M., Isenhour, C., McDonogh, G., & Checker, M. (2014). “The Sustainability Edge”: Competition, Crisis, and the Rise of Green Urban Branding. *Sustainability in the Global City*, 105–130. https://doi.org/10.1017/cbo9781139923316.008

Gregoris Mentzas, Apostolou, D., Abecker, A., & Young, R. (2012). *Knowledge Asset Management*. Springer Science & Business Media.

Guba, E. G., & Lincoln, Y. S. (1994). Competing Paradigms in Qualitative Research. In *Handbook of qualitative research* (pp. 105–117). SAGE.

Guterres, A. (2022). *Secretary-General’s remarks to the General Assembly on his Priorities for 2022 | United Nations Secretary-General*. Www.un.org. https://www.un.org/sg/en/content/sg/speeches/2022-01-21/remarks-general-assembly-his-priorities-for-2022

Hafner, K., & Lyon, M. (1996). *Where Wizards Stay up Late: The Origins of the Internet* (10th ed.). McGraw-Hill.

Hawkins, R. (1999). The rise of consortia in the information and communication technology industries: emerging implications for policy. *Telecommunications Policy*, *23*(2), 159–173. https://doi.org/10.1016/s0308-5961(98)00085-8

Hawkins, R., Knut Blind, & Page, R. (2017). *Handbook of innovation and standards*. Edward Elgar Publishing.

Huang, K. T. (1998). Capitalizing on intellectual assets. *IBM Systems Journal*, *37*(4), 570–583. https://doi.org/10.1147/sj.374.0570

Hughes, T. P. (1986). The evolution of large technological systems. In *The Social Construction of Technological Systems* (Vol. 89). Berlin Wzb.

IEA. (n.d.-a). *Clean energy technology innovation and the vital role of governments – Clean Energy Innovation – Analysis*. IEA. https://www.iea.org/reports/clean-energy-innovation/clean-energy-technology-innovation-and-the-vital-role-of-governments

IEA. (n.d.-b). *Transport – Innovation Gaps – Analysis*. IEA. https://www.iea.org/reports/innovation-gaps/transport

IEA. (2020). *EPO and IEA team up to shed light on trends in sustainable energy technologies - News*. IEA. https://www.iea.org/news/epo-and-iea-team-up-to-shed-light-on-trends-in-sustainable-energy-technologies

IEA. (2021). Global EV Outlook 2021. In *iea.org*. https://iea.blob.core.windows.net/assets/ad8fb04c-4f75-42fc-973a-6e54c8a4449a/GlobalElectricVehicleOutlook2022.pdf

IEC. (2023). *About us*. Iec.ch; https://iec.ch/about-us. Retrieved February 23, 2023, from https://iec.ch/about-us

IEEE. (2014, January 24). *Market-Driven Standards Seen as Necessary and Beneficial to Society*. OpenStand. https://open-stand.org/market-driven-standards-seen-as-necessary-and-beneficial-to-society/

IETF. (n.d.). *Introduction to the IETF*. IETF. Retrieved February 10, 2023, from https://www.ietf.org/about/introduction/

ISO. (n.d.-a). *About us*. International Organization for Standardization (ISO). Retrieved January 20, 2023, from https://www.iso.org/about-us.html

ISO. (n.d.-b). *Standards*. ISO. Retrieved February 5, 2023, from https://www.iso.org/standards.html

ISO. (2015). *Sustainable Development Goals*. ISO. https://www.iso.org/sdgs.html

ISO. (2021). Standards & economic growth: ISO members' research on the impact of standards on their national economies. In *iso.org*. International Organization for Standardization. https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100456.pdf

ITU. (2019). *About ITU*. Itu.int. https://www.itu.int/en/about/Pages/default.aspx

Janssen, M., Charalabidis, Y., & Zuiderwijk, A. (2012). Benefits, Adoption Barriers and Myths of Open Data and Open Government. *Information Systems Management*, *29*(4), 258–268. https://doi.org/10.1080/10580530.2012.716740

Krechmer, K. (2008). *Open standards: A call for action*. https://doi.org/10.1109/kingn.2008.4542244

Karpenko, A., Kinnunen, T., Madhikermi, M., Robert, J., Främling, K., Dave, B., & Nurminen, A. (2018). Data Exchange Interoperability in IoT Ecosystem for Smart Parking and EV Charging. *Sensors*, *18*(12), 4404. https://doi.org/10.3390/s18124404

Kianto, A., Ritala, P., Spender, J.-C., & Vanhala, M. (2014). The interaction of intellectual capital assets and knowledge management practices in organizational value creation. *Journal of Intellectual Capital*, *15*(3), 362–375. https://doi.org/10.1108/jic-05-2014-0059

Kirpes, B., Danner, P., Basmadjian, R., Meer, H. de, & Becker, C. (2019). E-Mobility Systems Architecture: a model-based framework for managing complexity and interoperability. *Energy Informatics*, *2*(1). https://doi.org/10.1186/s42162-019-0072-4

Klotz, B., Datta, S. K., Wilms, D., Troncy, R., & Bonnet, C. (2018, June 1). *A Car as a Semantic Web Thing: Motivation and Demonstration*. IEEE Xplore. https://doi.org/10.1109/GIOTS.2018.8534533

Krechmer, K. (2006). Open Standards Requirements. *Advanced Topics in Information Technology Standards and Standardization Research*, *1*. https://doi.org/10.4018/9781591409380.ch002

Krippendorff, K. (2004). Reliability in Content Analysis: Some Common Misconceptions and Recommendations. *Human Communication Research*, *30*(3), 411–433. https://doi.org/10.1093/hcr/30.3.411

KSC. (n.d.). *Kista Science City*. Kista Science City. Retrieved May 22, 2023, from https://kista.com/about-ksc-ab/

Lakhani, K. R., & von Hippel, E. (2003). How open source software works: “free” user-to-user assistance. *Research Policy*, *32*(6), 923–943. https://doi.org/10.1016/s0048-7333(02)00095-1

Lozano, R. (2007). Collaboration as a pathway for sustainability. *Sustainable Development*, *15*(6), 370–381. https://doi.org/10.1002/sd.322

Luborsky, M. (1994). The identification and analysis of themes and patterns. In *Qualitative methods in aging research* (pp. 189–210). Sage Publications Inc.

Lurie, N., Saville, M., Hatchett, R., & Halton, J. (2020). Developing Covid-19 Vaccines at Pandemic Speed. *New England Journal of Medicine*, *382*(21), 1969–1973. https://doi.org/10.1056/nejmp2005630

Maier, M. W. (1998). Architecting principles for systems-of-systems. *Systems Engineering*, *1*(4), 267–284. https://doi.org/10.1002/(sici)1520-6858(1998)1:4%3C267::aid-sys3%3E3.0.co;2-d

Maxwell, E. (2006). Open Standards, Open Source, and Open Innovation: Harnessing the Benefits of Openness. *Innovations: Technology, Governance, Globalization*, *1*(3), 119–176. https://doi.org/10.1162/itgg.2006.1.3.119

Mehlman, S. K., Uribe-Saucedo, S., Taylor, R. P., Slowinski, G., Carreras, E., & Arena, C. (2010). Better Practices for Managing Intellectual Assets in Collaborations. *Research-Technology Management*, *53*(1), 55–66. https://doi.org/10.1080/08956308.2010.11657612

Miller, J. G. (1978). *Living systems*. McGraw-Hill.

MobilityXLab. (n.d.). Www.mobilityxlab.com. Retrieved May 2, 2023, from https://www.mobilityxlab.com/about

Moore, J. F. (1993). *Predators and Prey: A New Ecology of Competition Harvard Business Review*. http://blogs.harvard.edu/jim/files/2010/04/Predators-and-Prey.pdf

Moore, J. F. (1996). *The death of competition: Leadership and strategy in the age of business ecosystems*. Harperbusiness.

Mutkoski, S. (2011). Defining Open Standards: A comparison of policy and practice. *SSRN Electronic Journal*, *7th*. https://doi.org/10.1109/siit.2011.6083616

Neaimeh, M., & Andersen, P. B. (2020a). Mind the gap- open communication protocols for vehicle grid integration. *Energy Informatics*, *3*(1). https://doi.org/10.1186/s42162-020-0103-1

Neaimeh, M., & Andersen, P. B. (2020b). Mind the gap- open communication protocols for vehicle grid integration. *Energy Informatics*, *3*(1), 3. https://doi.org/10.1186/s42162-020-0103-1

Neaimeh, M., Wardle, R., Jenkins, A. M., Yi, J., Hill, G., Lyons, P. F., Hübner, Y., Blythe, P. T., & Taylor, P. C. (2017). A probabilistic approach to combining smart meter and electric vehicle charging data to investigate distribution network impacts. *Applied Energy*, *157*, 688–698. https://doi.org/10.1016/j.apenergy.2015.01.144

EU Commission (2022) *New approach to enable global leadership of EU standards promoting values and a resilient, green and digital Single Market*. (2022, February 2). European Commission - European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_661

Nicholas, M., & Hall, D. (2018). Lessons learned on early electric vehicle fast-charging deployments. In *theicct.org*. International Council on Clean Transport (ICCT). https://theicct.org/publication/lessons-learned-on-early-electric-vehicle-fast-charging-deployments/

NIST. (1993). *Integration definition for function modeling (IDEF0)*. National Institute of Standards and Technology (NIST). https://nvlpubs.nist.gov/nistpubs/Legacy/FIPS/fipspub183.pdf

Nonaka, I., & von Krogh, G. (2009). Perspective—Tacit Knowledge and Knowledge Conversion: Controversy and Advancement in Organizational Knowledge Creation Theory. *Organization Science*, *20*(3), 635–652. https://doi.org/10.1287/orsc.1080.0412

Norzalila Jamaludin, Ahmad, H., & Thurasamy Ramayah. (2012). Profitability vs Sustainability: Preliminary Findings on Green Innovation Adoption in Information Technology Usage. *Nternational Conference on Technology and Operations Management*, *3*.

OASIS. (2009). *Rules of Procedure for the OASIS eGovernment Member Section*. OASIS eGovernment Member Section. https://www.oasis-open.org/committees/download.php/41843/eGov%20ROP%202011-3-1%20draft.pdf

OASIS. (2010). *Transformational Government Framework Version 2.0*. Docs.oasis-Open.org. http://docs.oasis-open.org/tgf/TGF/v2.0/cs01/TGF-v2.0-cs01.html

OASIS. (2022). *About Us*. OASIS Open. Retrieved January 20, 2023, from https://www.oasis-open.org/org/

OCA. (n.d.). *About us*. Www.openchargealliance.org. Retrieved February 23, 2023, from https://www.openchargealliance.org/about-us/

Open-stand. (n.d.). *The Modern Standards Paradigm - Five Key Principles*. OpenStand. Retrieved February 5, 2023, from https://open-stand.org/about-us/principles/

OpenADR Alliance. (n.d.). *About OpenADR*. Www.openadr.org. Retrieved February 23, 2023, from https://www.openadr.org/about-us

Opensource. (2023). *What are open standards?* Opensource.com. Retrieved January 5, 2023, from https://opensource.com/resources/what-are-open-standards

Pahl, N., Richter, A., & Berlin., S. (2018). *SWOT analysis : idea, methodology and a practical approach*. Grin Verlag.

Pant, H. A., Rupp, A. A., Tiffin-Richards, S. P., & Köller, O. (2009). Validity issues in standard-setting studies. *Studies in Educational Evaluation*, *35*(2-3), 95–101. https://doi.org/10.1016/j.stueduc.2009.10.008

Patton, M. Q., Guba, E. G., & Lincoln, Y. S. (1983). Effective Evaluation: Improving the Usefulness of Evaluation Results Through Responsive and Naturalistic Approaches. *The Journal of Higher Education*, *54*(3), 339. https://doi.org/10.2307/1981810

Petrusson, U. (2004). *Intellectual property & entrepreneurship : creating wealth in an intellectual value chain*. Chalmers University of Technology - Center For Intellectual Property Studies.

Pohl, H. (2017). *The automative industry in Sweden - A cluster study*. Vinnova.

Pohlmann, T. (2014). The Evolution of ICT Standards Consortia. *Digiworld Economic Journal*, *1*(95), 17–40.

Regeringskansliet, R. och. (2009, March 17). *En sammanhållen klimat- och energipolitik - Klimat*. Regeringskansliet. https://www.regeringen.se/rattsliga-dokument/proposition/2009/03/prop.-200809162#:~:text=Regeringen%20presenterar%20en%20sammanh

Regeringskansliet, R. och. (2021, March 11). *Sweden's climate policy framework*. Regeringskansliet. https://www.government.se/articles/2021/03/swedens-climate-policy-framework/

Rennings, K. (2000). Redefining innovation — eco-innovation research and the contribution from ecological economics. *Ecological Economics*, *32*(2), 319–332. https://doi.org/10.1016/s0921-8009(99)00112-3

RISE. (n.d.). *Sweden's production clusters contribute to sustainable production*. RISE. Retrieved March 22, 2023, from https://www.ri.se/en/our-stories/swedens-production-clusters-contribute-to-sustainable-production

Russell, A. L. (2014-a). *Open standards and the digital age : history, ideology, and networks* (p. 3). Cambridge University Press.

Russell, A. L. (2014-b). *Open standards and the digital age : history, ideology, and networks*. Cambridge University Press.

Saunders, M., Lewis, P., & Thornhill, A. (2019). Ontological and epistemological considerations. In *Research Methods for Business Students* (8th ed.). Pearson.

Schlagwein, D., Conboy, K., Feller, J., Leimeister, J. M., & Morgan, L. (2017). "Openness" with and without Information Technology: A Framework and a Brief History. *Journal of Information Technology*, *32*(4), 297–305. https://doi.org/10.1057/s41265-017-0049-3

Schmidt, M. (2022, July 21). *Industry Standards – How They Differ From Regulations, Why They're Important, and How Manufacturers Can Make Their Voices Heard*. Aem.org. https://www.aem.org/news/industry-standards-how-they-differ-from-regulations-why-theyre-important-and-how-manufacturers-can

Schwab, K. (2016). *The Fourth Industrial Revolution*. Penguin Random House.

Shen, C.-L., Wang, R. L., Wu, T.-C., & Hsiao, W. W.-W. (2021). A concise framework to facilitate open COVID pledge of non-disclosed technologies: In terms of non-disclosed patent applications and trade secrets. *Elsevier*, *121*(8), 1425–1430. https://doi.org/10.1016/j.jfma.2021.10.004

SIS. (n.d.-a). *About SIS*. Svenska Institutet För Standarder (SIS). Retrieved February 23, 2023, from https://www.sis.se/en/about_sis/

SIS. (n.d.-b). *What is a standard?* Svenska Institutet För Standarder, SIS. Retrieved February 5, 2023, from https://www.sis.se/en/standards/what-is-a-standard/

Stark, D., & Castells, M. (1997). The Rise of the Network Society. *Contemporary Sociology*, *26*(6), 725. https://doi.org/10.2307/2654643

Tansley, A. G. (1935). The Use and Abuse of Vegetational Concepts and Terms. *Ecology*, *16*(3), 284–307. https://doi.org/10.2307/1930070

Trudell , C., & Davis, R. (2022, June 1). *Bloomberg - Are you a robot?* Www.bloomberg.com. https://www.bloomberg.com/news/articles/2022-06-01/will-electric-cars-take-over-they-must-sell-faster-to-reach-net-zero

Tsvetkova, A., Hellström, M., & Ringbom, H. (2021). Creating value through product-service-software systems in institutionalized ecosystems – The case of autonomous ships. *Industrial Marketing Management*, *99*, 16–27. https://doi.org/10.1016/j.indmarman.2021.09.007

Vanhaverbeke, W., & Cloodt, M. (2006). Open innovation in value networks. *Oxford University Press*, 258–281.

Venturelli, A., Caputo, A., Pizzi, S., & Valenza, G. (2022). A dynamic framework for sustainable open innovation in the food industry. *British Food Journal*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/bfj-03-2021-0293

Vogel, C. A. (2018). Externalism and Conceptual Analysis. *Metaphilosophy*, *49*(5), 730–765. https://doi.org/10.1111/meta.12339

Walli, S. (n.d.). *Understanding Technology Standardization Efforts* (p. 1). Retrieved March 20, 2023, from https://stephesblog.blogs.com/papers/stdsprimer.pdf

Werther, B., & Hoch, N. (2012). E-Mobility as a Challenge for New ICT Solutions in the Car Industry. *Trustworthy Global Computing*, *7173*, 46–57. https://doi.org/10.1007/978-3-642-30065-3_3

West, J. (2005). The economic realities of open standards: black, white, and many shades of gray. *Standards and Public Policy*, 87–122. https://doi.org/10.1017/cbo9780511493249.004

West, J., & Gallagher, S. (2006). Challenges of open innovation: the paradox of firm investment in open-source software. *R and D Management*, *36*(3), 319–331. https://doi.org/10.1111/j.1467-9310.2006.00436.x

West, J., & Lakhani, K. R. (2008). Getting Clear About Communities in Open Innovation. *Industry and Innovation*, *15*(2), 223–231. https://doi.org/10.1080/13662710802033734

West, J., Salter, A., Vanhaverbeke, W., & Chesbrough, H. (2014). Open innovation: The next decade. *Research Policy*, *43*(5), 805–811. https://doi.org/10.1016/j.respol.2014.03.001

Wiegmann, P. M., Eggers, F., de Vries, H. J., & Blind, K. (2022). Competing Standard-Setting Organizations: A Choice Experiment. *Research Policy*, *51*(2), 104427. https://doi.org/10.1016/j.respol.2021.104427

Yilmaz, K. (2013). Comparison of Quantitative and Qualitative Research traditions: Epistemological, theoretical, and Methodological Differences. *European Journal of Education*, *48*(2), 311–325.

Zhang, Y., Huang, T., & Bompard, E. F. (2018). Big data analytics in smart grids: a review. *Energy Informatics*, *1*(1). https://doi.org/10.1186/s42162-018-0007-5

9 Appendix

A. List of interviewees

The participants in the various phases of the interviews have been positioned according to the EMBE framework (see Table 1). Here follows a short description of the actors (see Table 14). Some actors may hold multiple roles in the EMBE, this is the interpretation of their main role in the EMBE. The roles of the interviewees are mapped out in Figure 14.

Table 14. Interviewee Descriptions

Actor ID	Description	Role/s in EMBE	Interview phase participation (nr of interviews)
A	Large vehicle manufacturing company	Aggregator	Main (1) Expert (1)
B	National innovation network within mobility	Governor	Main (1)
C	Large vehicle manufacturing company	Aggregator	Main (1)
D	Government research council (within sustainability and innovation)	Input provider	Expert (1)
E	NGO (within sustainability and innovation)	Governor	Expert (1)
F	University (with expertise within e-mobility)	Enabler	Initial (2) Expert (1)

B. Interview guide

The questions asked in the main interviews are stated below (see Table 15). The aim of the questions was to open up to open-ended questions discussion OSs and open innovation within EV adaptation. The results (responses) of the interview questions can be seen Appendix C. The analysis of the responses is found in Section 5.2.

Table 15. Interview Questions

Question ID	Questions	Focus
Q1	How does your organization currently approach OSs and how do you see this evolving in the future?	Internal
Q2	What opportunities do you see for your organization in leveraging open innovation strategies to drive sustainability?	Internal
Q3	How do you envision the role of collaboration and partnerships in driving open innovation and sustainability within the e-mobility industry?	External
Q4	How do you think the e-mobility industry can best collaborate and coordinate efforts to drive open innovation and sustainability at a larger scale?	External
Q5	Are there any specific challenges or opportunities that you think are unique to the e-mobility industry when it comes to leveraging open innovation strategies for sustainability?	External
Q6	How do you envision the e-mobility industry evolving in terms of sustainability and innovation over the next 5-10 years?	External

C. Main interview responses

The responses were; collected through the main interviews, transcribed, separated into quotes, and randomized Quote ID to keep the anonymity of the responses (see Table 16). The quotation numbers are referenced throughout the analysis in Section 5.2.3. The quotes are presented below, in numeric order, with corresponding *Question ID*, *SWOT categorization*, and *Theme*, which are discussed in Section 5.2.1- Section 5.2.3.

Table 16. Interview responses – Categorized (SWOT & Theme)

Quotation ID (randomized)	Question	Quotes	SWOT	Themes
1	Q3	A new trend has been the development of collaboration between big industry actors and start-ups. Creating communities and innovation hubs. This will probably continue to increase.	O	HG
2	Q5	This could be a key for the infrastructure development if electric vehicle manufacturers were able to work together with battery companies and actors from the electrical infrastructure industry to jointly develop technological processes and products that fit multiple industry needs. This provides a boarder picture and enables the actors to learn from each other to find optimal system solutions. The facilitation and management of such openness would also be a lot easier, compared to actors competing in the same value chain.	T	PI
5	Q2	Ex. the three-point belt – the patent was opened up. Are there other parts connected to safety or sustainability that can be used similarly?	O	GV
7	Q1	In the US, they have decided on a different path where actors on the west coast are dictated by defining what type of data that needs to be shared, in this case in the commute traffic, for the cities to be able to coordinate the traffic. This effort, or standard, has spread across to other cities in the US and Europe. This adaptation has happened due to people realizing it to be a necessity for cities to be able to develop a more sustainable society. Here, an example is of where the market drives the standard due to governance structures being too slow.	O	HG
8	Q4	If the goal in mind is to reach the same level of openness as in the pharmaceutical industry, then the automotive actors need to dare to let the guard down.	O	GV
9	Q4	It will only look stupid if companies compete on a regional, national, and even European level if the consequences are that the earth will succumb to the climate changes. This is an existential threat.	G	G
10	Q1	Open standards may grow and become more prominent.	S	N
11	Q2	There might not yet be that level of maturity in this development, but the discussion is ongoing.	T	IAM
12	Q1	Less mature companies are focused on establishing their own standards within the company.	W	IT
14	Q5	Going back to "why do commercial actors place standards on 4G or a USB cable?". It is because they have solved their own problems by doing so. Then we need to identify which problems we have that would make it beneficial for us to be part of solving the challenges.	O	GV
15	Q6	Sharing the solutions and creating values for other actors. And still being actors that can partake in the value created.	O	GV
17	Q1	The definition of a standard is also important in determining if it will be able to aid or become a barrier for companies.	O	GV
19	Q1	There is a likelihood that there will be more open standards developed as the e-mobility industry progresses in the future.	O	GV
20	Q5	The benefit of developing open standards, for example charging solutions for electric vehicles, is that the development of sustainable solutions could become increasingly faster. With less friction within interoperability, the focus could be placed on other issues.	S	N
21	Q2	If there were to be developments that affect fuel consumption or electric efficiency, there might be a greater value in opening up the knowledge to be available for others.	O	GV

22	Q2	It is worth noting that some challenges that are not directly related to sustainability – ex performance or size and weight of the vehicles, can still have an impact on the environment due to the indirect effects it has on in this example fuel consumption.	O	GV
23	Q1	Ex what tesla has done on the charging infrastructure by setting a de facto standard by taking over the market.	S	N
24	Q5	The way our electric grid is designed today, we will not be able to adhere to the adaptation of elective vehicles. Therefore, it is important for the sectors to collaboratively find solutions, or they will be limited due to each other. Ex in the levels of distribution on the electric grid. There can be a domino effect on the cities.	T	EI
25	Q2	It is difficult to achieve sustainability without incorporating the suppliers.	T	EI
27	Q1	With example car manufacturers, evolution is not clear enough since any improvement can be categorized as evolutionary. However, the revolutionary perspective is where actual movements and new trends in innovation can be looked at.	W	IT
28	Q1	It will take a stronger pan-European grip on standardization. To be able to force the market into a faster evolution.	O	HG
29	Q1	There is a David versus Goliath narrative in the automotive sphere, where smaller actors need to invent their own tools, or slingshots, to be able to compare to the strength of larger actors.	W	IT
30	Q3	It is more reasonable that we would have collaborations between manufacturers of smaller electric vehicle actors, such as scooters, and larger vehicles such as individual cars. And that this would generate a common standard, rather than having standards for different markets that limit the development as the boundaries of the various mobility markets tend to merch.	T	PI
31	Q1	This demands openness and collaborative traits if you are to be able to deliver on equal or even improved terms on services and innovation compared to the big dragons.	W	IT
32	Q3	Then there will always be a discussion of the power games that evolve from companies directly collaborating.	T	PI
33	Q3	What I believe needs to be added is standards for how this type of service could work across systems and the accessing key solutions to them. For other actors providing cross-industry services to be able to merch into ecosystems and be able to deliver their services together with other solutions. However, this would need larger actors as facilitators, since smaller companies do not hold the same capabilities to lead these ecosystems.	T	PI
37	Q2	Putting pressure on having some kind of open innovation strategy. Utilizing the IP in a non-exclusive manner.	T	IAM
39	Q2	There are multiple examples where companies, both cross-organization, and cross-industry, start to collaborate to achieve sustainability through innovation platforms. The goal of these established ecosystems is usually to span across sectors to together formulate what strategic challenges they aim to solve.	O	GV
40	Q5	There are three areas in the automotive industry where it is crazy to even compete. The first is cyber security. It does not help if one company builds the most secure car if other cars on the road can be hacked and cause potential crashes. The second is autonomously driven. If AI and sensor technology are further advanced in one type of vehicle but others are lacking and may cause a crash, that is not helpful. The third is the charging infrastructure. No automotive actors will gain from having a poor charging infrastructure.	O	GV
41	Q1	Believe that open standards are very important and will be a demand in one form or another for this industry.	S	N
44	Q5	The actors would likely want to be part of the initiatives, however, the push would need to come from above if it is to be a coordinated effort that aligns the many interests. It would be good if the politicians made the decision, in dialog with industry experts and technology developers, and then everyone could start working in the same direction. Just knowing the common direction would make a big difference in the pace of sustainable development.	O	HG
45	Q6	E-mobility opens up for a new network of interactions between various industries and actors to build an infrastructure for these solutions to be viable in our future society.	O	HG
46	Q5	The challenges lay in the question “what is in it for us?”. The commercial actors who want to drive change still need to know that there is something in the business model that gains them. Financial incentives are powerful tools.	O	GV

47	Q1	The consequences might be that there will be multiple standards developed in parallel if the EU takes a stance on one standard and then the market-driven standards develop as an alternative. Then we would be left with two competing standards. And it would become increasingly harder for vehicle manufacturers to relate and make a choice. Worst case one is forced into a decision.	W	IT
48	Q4	Even in areas where there are no standards, the technology has matured so that everyone can access it, in their version. These features of the versions become the actual value, not the technology base in itself.	T	ET
51	Q3	There is a lacking today in organizations that manage the responsibilities of asset distribution and innovation diffusion.	O	HG
52	Q3	It will not help to scale it down to a national level if the solutions need to happen worldwide. Actors tend to be more global nowadays and that elevates the level at which the solutions need to be adapted to. Looking at it from a national level will only create potential barriers with multiple competing solutions or standards.	T	EI
55	Q3	Higher levels of collaboration – national level and judiciary, are important. The industry actors try to stay up to date and are active in the current legislation shifts and politics. This is to display the opportunities for green transportation transformation and also to lobby for the conditions needed for this to be possible.	O	HG
56	Q5	It would tear down barriers and make it easier for companies to choose which path to focus on, instead of holding off due to uncertainties in markets and technology trends.	S	N
60	Q6	There will be more collaborations in the future, but if they are part of an increasing openness trend to achieve sustainability goals is hard to say.	T	ET
61	Q1	A higher governance structure is needed.	O	HG
62	Q2	Inventors are pushing for inventions that can generate a greater societal value to be open. And this can display how important these questions are at multiple levels of the organization.	O	GV
63	Q5	Going back to that there is a need for larger efforts, governmental efforts, for this to be possible.	O	HG
64	Q2	There are definitely opportunities to drive development for sustainability. Whether it will be called innovation or not. And these forms of collaboration are believed to increase over time.	T	ET
67	Q6	The battery industry is probably going to go through big transformations over the upcoming years. There is already a focus on making the batteries more sustainable. But also, on other parts such as the electrical machinery and choices in material for components are about to see a shift. Thereby, there will be a shift in the supply chain of these components. Now that a lot of vehicles are about to become electric and sustainability is such a big focus, especially but not solely in Sweden, companies will start to put stronger restrictions on suppliers to confirm that their whole supply chain is sustainable and circular*. Which is a big shift from how it has been up until now.	O	GV
68	Q3	When two product-producing actors are meant to collaborate, both of them have clear interests and IP becomes difficult to manage. In regards to who gets to own what asset, who has the right to use what, is it to be licensed to third parties, etc.	T	IAM
71	Q6	If there are actors where there is a match in interests, it will be possible to see collaborations of innovation happening there. However, identifying where the value lies in the collaborations is key for it to proceed. Actors with less overlapping interests, but complementary to each other, may find it easier to collaborate naturally.	O	GV
73	Q4	Compared to other innovation hubs where assets, of both talent and knowledge, can be shared among members. We are not yet there in the automotive industry.	O	GV
74	Q3	Partnerships between companies in the same value chain, where there is a risk of disproportionate distribution of power, will continue to find it hard to collaborate.	T	PI
75	Q1	The positive attitude may be a result of a perceived need for open standards in the electro-mobility industry. Since there is a common consensus that this path of development is necessary for the future of the industry. Therefore, it can be deemed reasonable that there is a couple of standards that everyone is dependent upon and need to become competitive in the market.	S	N
76	Q5	It would have been appreciated to have instructions/directives from above.	O	HG
77	Q3	Collaboration can be good in the sense that one plus one equals three. It can also become very complicated, especially when it comes to the IP parts.	T	IAM

78	Q1	One way of utilizing tools is through partnerships and ecosystems.	S	N
81	Q5	The infrastructure will also have to manage an increasing population of electric vehicles. This will have a large effect on the electric grid infrastructure.	O	GV
82	Q4	Looking at the European automotive industry today where we have multiple innovation clusters.	O	GV
85	Q4	I would love to see stronger collaboration between these clusters. Because every cluster in itself is an ecosystem. Getting these ecosystems to collaborate would generate a system of systems. This could bring a stronger levering effect.	O	GV
86	Q1	There is a difference between evolution and revolution when it comes to innovation.	W	IT
88	Q3	Everybody likes the image of Sweden being a sustainability leader. It is in everyone's interest that this image is upheld.	O	GV
89	Q1	Car manufacturers tend to become more passive about different technology choices. If there is no force toward one standard. They are less likely to invest in technology that may become obsolete. Either if it is due to legislation or the market heading in a different direction.	W	IT
90	Q4	Sooner or later certain technology will become more of a commodity. Maybe due to standards. Then the focus will shift towards other service solutions, complements, and/or improvement from the fundamental technology that become the new market for competition.	T	ET
91	Q3	It would have been appreciated to have instructions/directives from above.	O	HG
92	Q5	Standards could hold the potential of pushing the industry in a common direction.	S	N
94	Q3	Looking at other industries, collaboration comes and goes in waves. Periods of intense collaboration and others with less. Some actors feel the need to "do it themselves" instead of collaborating. A lot may have to do with the difficulties to reach agreements between parties.	T	ET
95	Q1	The connection to open standards is clear, even if they are not being directly discussed or applied in the real-world industry.	W	IT
96	Q1	Compared to computer standards and the sharing of data between mobility actors in the mobility system, there has been an established effort going on for quite some time to force the development of a common data-sharing standard. But it has been far too slow.	W	IT
97	Q5	A more prominent challenge is the perceived elevation of risks companies imagine comes from openness. They are afraid of over-sharing and want to protect their proprietary assets.	T	IAM
98	Q2	There are ongoing discussions of which technological development is perceived to have a greater value.	O	GV
100	Q2	We can see that on the supplier side, there could have been interesting ideas but there have been uncertainties about who would have an interest in purchasing these ideas. The purchasers do not specifically ask for it and therefore it remains undeveloped due to a lack of communication in demand.	T	EI
101	Q1	The answer may differ between the technology department and the innovation/IP department.	W	II
103	Q4	And for assets that are more knowhow based – ex. software, it can be even harder as there are no IPRs to rely on. Therefore, actors become even more hesitant to open up for collaboration.	T	IAM
105	Q4	A lot has to do with protecting one's territory. Don't lose opportunities or become locked in. All of this does not contribute to a very open environment for collaborative innovation.	T	IAM
106	Q5	The other opportunity is if you take the perspective of sustainability in e-mobility and start to look at not just the sustainability goals but also where the business value comes from for the actors in the industries.	O	GV
109	Q1	From my experience, the technology organization is very positive towards open standards. This in turn may have a negative effect on the IP perspective.	W	II
112	Q6	I do believe we will see innovation efforts that combine industries. These new cross-industry borders will alter how solutions need to be formulated. For example, vehicle manufacturers have previously not been as involved with steel production. Suddenly, we now see direct relationships between these actors. Due	T	EI

		to the increased resource awareness amongst vehicle manufacturers. The collaborations will go further down in the supply chain.		
114	Q4	Everyone has a big g self-interest. “what is in it for us”, “we need to be able to do this”, and “they are not allowed to do this”.	T	IAM
115	Q5	The solution to solving these challenges is to address how one can possibly generate changes in the industry. Not just looking at how the customer demand and behaviors shape the actor’s business models. But also, on the regulatory effects than can be placed on the actors from above.	O	GV
117	Q1	Have a designated teamed area that works with these important questions.	S	N
118	Q3	We need to incorporate the energy sector, suppliers, and other cross-industry actors to be able to drive and manage these sustainability challenges.	O	GV
119	Q6	If an increased amount of BEV can find ways of balancing the energy consumption avoiding the dips and spikes in the energy grid. Possibly by utilizing the cars as mobile energy storage solutions. Also, through second life application of batteries.	O	GV
121	Q3	At the same time, I believe that the concept of e-mobility is too narrow if the aim is to have a larger impact on sustainability. Part of this dilemma is the separation and gaps that form in the various approaches. Where some issues are not being addressed due to anyone knowing who must claim responsibility for it. This grey area may also hinder innovative solutions. For example, if the goal is to transport people, then dividing into smaller segments of vehicles may divert from finding a solution that would radically change the industry.	T	EI
122	Q1	Therefore, I believe there is a need for a stronger pan-European governance-driven standard.	O	HG
125	Q3	It will need more perspective to be considered, one big one is the common perception of what is our future society going to look like.	O	GV
127	Q3	The waves in collaboration efforts can also be seen as trends that periodically result in fatigue in the actors and lead to a decrease in partnerships for a period moving forward, with more “do it ourselves” mindsets again.	T	ET
128	Q4	Distinguishing between countries will not make it happen. It is the global feature of the companies that will aid in finding solutions.	T	EI
130	Q2	The problem, looking at it from a society infrastructure perspective, is that there is no clear recipient or responsible organ. Without this visionary to look at the issues on a national level, there will be issues.	T	EI
131	Q1	People have an image of a standard always being open; free and available for all. However, an organization in general may have a lack of knowledge of what a standard is and is not. Hard to navigate if a standard is opened or closed, and people take for granted that it is an open standard. Not understanding the process of access and participation.	W	II
132	Add	We should not underestimate how important the set of standards are as enablers as they are something that industry actors can trust and invest in, in order to drive technical developments around this area. Then I can also imagine there being positive and negative aspects. The ISO standard has been developed at a point in time where it is necessary. It could always have come earlier. However, we are at a point where we need it to continue developing. And it has not been the issue that the standard has been lagging, rather it has been enabling certain investment decisions.	S	N
133	Add	Something I believe can be missing in some standards is an understanding of the complexity of a certain business case. It is easy to simplify what it entails to own a car. The shift in the ecosystem of cars nowadays is still being overlooked in some standards, causing implementation issues.	W	IT
134	Q6	We aim, not to create issues, but to be part of the solution.	O	GV
135	Add	The ISO standard has been developed at a point in time where it is necessary. It could always have come earlier. However, we are at a point where we need it to continue developing. And it has not been the issue that the standard has been lagging, rather it has been enabling certain investment decisions.	W	IT
136	Q5	Opportunities for cross-industry collaboration can be far more likely, where the different interests make for a more beneficial exchange. Not one cannibalizing and pushing ahead of the others.	T	PI
137	Q5	It also avoids lock-in effects for the users if multiple solutions are implemented. As with the charging infrastructure and charge point interfaces where, if different systems were to exist, you could not be able to charge at all charging points.	S	N

		Making it difficult for the consumer to adapt to elective vehicles as a form of transportation.		
138	Q3	IP rights are always on the agenda. Creating a conflict about who gets to own what.	T	IAM
139	Q3	Big companies generally find it harder to collaborate with smaller businesses, due to the speed at which the collaboration's progress. The smaller finding the pace too slow, and the bigger finding it too fast.	T	ET
140	Q3	Organizations need to take a bigger role in the facilitation of sustainable collaborative efforts. Driving platforms that stimulate societal development. Almost like a consultant organization. Balancing the power game between small and larger actors.	O	HG
141	Q5	The beneficiary from this implantation of standards would not only be the end customer but also regions and nations as they are allowing recourse to focus on the infrastructure transformation that needs to happen.	S	N
142	Q4	It is an industry with more restrictions and closed approaches. Even if it tries to display itself to be open in many ways. Even compared to the pharmaceutical industry.	T	IAM
143	Q4	The fear of losing IP has become a blocker. Whether this is right or wrong is up for debate. IP is important and needs protection. But, it is hard to draw the line between what is ok to share and not. What can we dare to open up without risking becoming “burnt”?	T	IAM
144	Q3	By lifting the challenges above single segments, we could identify for example the cities' interest in future mobility design. Again, needing to work across sectors to find better solutions. Therefore, there is also a need for governments to rethink system platforms. Broadening and opening-up between sectors to address gaps and find more viable solutions.	T	EI

D. Word count interview responses

This displays the word count of any word used five or more times in the responses from the main interviews (see Table 17). Fill-out words have been removed. However, synonyms and potential variations of wordings are kept. Meaning that some of the words occur in different variations (synonyms and or related words) and therefore may have slightly higher representation in the responses. The number accounted for are the specific wordings of each word. The top words have been illustrated in a word cloud in Figure 15. The analysis of identifying themes is displayed in section 5.2.2.

Table 17. Word Count

Frequency	Word
48	Actors
38	Industry
33	Standards
25	Solutions
23	Need
22	Companies
21	Standard
17	Innovation
17	Open
17	Charging
17	Able
16	Car
15	Become
15	Sustainability
15	Infrastructure
14	Technology
14	Different
13	Development
13	Electric
12	Collaboration
11	Value
11	Vehicles
10	However
10	Common
10	Level
10	Vehicle
10	Cars
9	IP
9	Important
9	Automotive
9	Manufacturers
9	Charge

Frequency	Word
9	Collaborations
9	Challenges
9	Solution
8	Perspective
8	Future
8	Market
8	Compared
8	E-Mobility
8	Multiple
8	Focus
8	Believe
8	Mobility
8	Time
8	Ecosystems
7	Hard
7	Comes
7	Drive
7	Efforts
7	Hubs
7	Needs
7	Sustainable
7	Issues
7	Stronger
7	Larger
7	Energy
6	Organization
6	Effect
6	Everyone
6	System
6	Developed
6	Generate
6	Utilizing

Frequency	Word
6	Collaborate
6	Partnerships
6	National
6	Interest
6	Openness
6	Shift
6	Together
6	Organizations
6	Business
5	Knowledge
5	Battery
5	Areas
5	Greater
5	Company
5	Continue
5	Interests
5	Industries
5	Goal
5	Challenge
5	Cross-Industry
5	Key
5	Effects
5	Cities
5	Examples
5	Platforms
5	Aim
5	Changes
5	Grid
5	Services
5	Involved

E. Calculation of standard deviation

To calculate the sample standard deviation the subsequent formula has been used:

$$s^2 = \frac{\sum(x_i - \bar{x})^2}{N-1}$$

With the following variables; *standard deviation* (SD): s, input (number of quotes): x_i, average (mean) of inputs: $\bar{x}$, total sample size: $N = 3$, and the number of inputs: $i = 1,2,3$. The inputs have been applied in a randomized order for the interviewee's responses to remain anonymous. The samples are collected from each of the interviewees within each of the SWOT categories; *Strengths* (S), *Weaknesses* (W), *Opportunities* (O), and *Threats* (T). The analysis of the standard deviation below (see Table 18), has been described in section 5.2.1.4.

Table 18. Calculation of Standard Deviation

	Number of quotes	**Average (mean)**			**Variance**	**Standard deviation**
	$\mathbf{x_i}$	$\bar{\mathbf{x}}$	$\mathbf{x}_i - \bar{\mathbf{x}}$	$(\mathbf{x}_i - \bar{\mathbf{x}})^2$	$\mathbf{s^2}$	$\mathbf{s}$
S_{Total}	12	4		14	7	2,65
S_1	3		-1	1		
S_2	7		3	9		
S_3	2		-2	4		
W_{Total}	14	4,66		16,67	8.33	2,89
W_1	8		3,33	11,11		
W_2	3		-1,67	2,78		
W_3	3		-1,67	2,78		
O_{Total}	39	13		26	13	3,61
O_1	14		1	1		
O_2	16		3	9		
O_3	9		-4	16		
T_{Total}	33	11		74	37	6,08
T_1	18		7	49		
T_2	8		-3	9		
T_3	7		-4	16		

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