Factors influencing the success within multi-mode standardization for selecting the Vehicle-to-Grid (V2G) charging standards

Thesis Report

By

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in the partial fulfillment of the requirements for the degree of

Master of Science

in Management of Technology

at the Delft University of Technology,

to be defended publicly on Monday, August 24, 2020.

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Executive summary

The transportation sector is considered to be one of the significant contributors of carbon emissions around the world. With the rise in carbon emissions, electric vehicles are increasingly becoming popular globally. Most of the developed countries are moving towards the electrification of the transportation sector at a faster pace. Although the concept of electrification is novel and environmentally friendly, the electricity demand is predicted to rise exponentially in the next decade. Concerning this demand, Vehicle-to-grid (V2G) technology is considered to be one of the best solutions by experts to incorporate future electricity demand. Even though the technology was introduced in the late 20th century, it is yet to be commercialized for public use on a large scale. There are various pilot projects under development around the world, especially in the European continent. A few private clients in Denmark have already commercialized the technology for private usage, but certainly, it is not available for the general public. Hence, Europe was considered to be an ideal choice for geographical focus. The most important barrier to the adoption of V2G technology is related to the adoption of electric vehicles (EVs) in the market. While the demand for EVs is gradually increasing, the large scale adoption of V2G technology will eventually grow. The charging equipment that is used to charge the electric cars at the charging stations is another critical barrier. Three different standards are competing against each other to dominate the market (i.e., CHAdeMO, CCS Combo, and Tesla). Most of the charging stations in Europe consists of either or all the three types of charging equipment. A few private charging infrastructure companies have also established charging stations locally or nationally in Europe. As there is an equal distribution of CHAdeMO and CCS Combo charging stations around Europe, standardization of the charging equipment could become a necessity for the implementation of V2G technology in the future.

According to the literature, there are three different modes of standardization processes, namely: committee-based, market-based, and government-based standardization. Based on the involvement of various actors in the standardization processes, the concept of multi-mode standardization was introduced in the literature. The case of charging standards related to V2G technology involves actors from various domains indicating the potential case of multi-mode standardization. While the three charging standards are still in the early phases of the battle, it is imperative to analyze the factors that could influence the standardization of charging standards. Hence, the main research question for this research was framed: *"What are the factors that influence the success of charging standards in the context of multi-mode standardization in the European market for the implementation of V2G technology?".* The factors influencing success within the case of multi-mode standardization were recently introduced into the literature. A thorough literature review was carried out to identify a total of 39 influential factors within various case studies of multi-mode standardization. And it resulted in the proposition of a new framework for further analysis in this research. With the combination of a literature review and interview with the experts, 35 factors were found to be relevant. Further, a Multi-criteria Decision Making (MCDM) tool known as the 'Best Worst Method (BWM)' approach was used to rank the factors based on expert's preferences. A total of seven interviews were conducted to allocate weights for each factor using the BWM approach to rank the factors. The experts belonged to academic as well as industrial

backgrounds. The results of the analysis showed that the factors ‘brand reputation and credibility’, ‘compatibility’, ‘financial strength’, ‘bandwagon effect’, and ‘lobbying’ ended up being the top five influential factors in this research. While there were two groups of interviewees, a set of two different statistical tests were performed to analyze the significant differences between the results obtained from the two groups of experts. The weight of the factor ‘delay in the standardization process’ was found to be significantly different among the two groups. Hence, this factor was not considered for listing the influential factors.

Compared to the previous framework in the literature, a set of ten factors were added to the framework constructed during this research. The new factors were found to be indeed relevant in the standardization of charging standards. It was also observed for the first time in the BWM literature that a total of 35 factors were found to be relevant. Researchers can use the new framework for analyzing the factors influencing standards battle in different domains. Also, the BWM approach was used for the first time to identify success factors in the selection of charging standards for the implementation of V2G technology. Additionally, the articles that discussed success factors previously in literature from the market perspective were re-analyzed to explore the concept of multi-mode standardization for the first time. Out of ten reviewed articles, eight articles were recategorized to a relevant combination of multi-mode standardization. Moreover, empirical evidence was found for the factors that were considered to be relevant in the third phase of technology dominance. Additionally, it was also found for the first time that a few factors believed to be crucial in the fourth phase of technology dominance were found to be essential already in the third phase of standards battle between charging standards. The statistical analysis tests used in this research can also be used where there are more than two experts involved in the application of the BWM. Finally, the results obtained in this research provide empirical evidence to assign weights to the relevant factors and analyze the importance of those weights to explain their influence in the standardization using the BWM approach.

From a managerial point of view, a few practical contributions were also made during this research. The technology managers can use the proposed framework for the selection of charging standards globally in the future. The combination of the proposed framework and the BWM approach can be used to analyze technologies within similar domains in a situation of multi-mode standardization. The identified factors in the framework can be used to define strategies by the technological managers in the market to gain an edge over competitors in the market. Furthermore, the newly introduced factors in the proposed framework influence the members of the committees and help them to arrive at a consensus in standard development organizations. These factors can not only be validated by the technology managers but also by the committee members representing other aspects in the process of technology standardization. The proposed framework can be modified by the addition of new factors based on the relevance in the technology battle. With the increasing number of startups in the market, the framework can act as a guidance tool for entrepreneurs to analyze, validate and evaluate various factors that could influence the standardization of their product in the market.

Acknowledgment

Firstly, I would like to thank my first supervisor Geerten van de Kaa for supervising me during my master thesis. Notably, at the beginning, where valuable insights were given about the possible scenarios of the research. Also, the discussions during the feedback meetings were very helpful in narrowing down the scope of this research. Furthermore, the constant push to do better in terms of argumentation helped to improve the overall analysis during this research. I would also like to thank my second supervisor Rob Stikkelman. Even though there were no meetings conducted after the official kickoff meeting, the insights given during the kickoff meeting helped to analyze things from a different perspective. Therefore, it has indeed helped me during the writing part of this research. I am very thankful to the experts who helped me to gain more insights about the real situation in the market. A few interviews ended up being more like discussions, and the learning was mutual during such interviews. Finally, I would like to thank my family (especially my mother 'Sunita Fulari') and friends for providing unconditional support during the entire course. I would also like to thank my late father 'Chandrakant Fulari' for always motivating me to achieve bigger things in life.

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List of acronyms

Advanced Research Projects Agency (ARPA)
Alternating Current (AC)
American Society for Microbiology (ASM)
American Society for Testing and Materials (ASTM)
Analytic Hierarchy Process (AHP)
Battery Electric Vehicles (BEVs)
Best Worst Method (BWM)
British Retailers Consortium (BRC)
CHArge de Move (CHAdeMO)
Combined Charging System (CCS)
Compact Disc (CD)
Consultative Committee on International Telegraphy and Telephony (CCITT)
DC fast charging (DCFC)
Digital Video Disc (DVD)
Direct Current (DC)
Electric Power Research Institute (EPRI)
Electric Vehicle Supply Equipment (EVSE)
Electric Vehicles (EVs)
Electronic Data Interchange for Administration, Commerce, and Transport (EDIFACT)
elimination ET choix traduisant la realite (ELECTRE)
European Committee for Electrotechnical Standardization (CENELEC)
European Technology Standards Institute (ETSI)
European Union (EU)
eXtensible Business Reporting Language (XBRL)
Federal Communications Commission (FCC)
Food and Agricultural Organisation (FAO)
Fuel-Cell Electric Vehicle (FCEVs)
Fuzzy Delphi Method (FDM)
Fuzzy Analytic Hierarchy Process (FAHP)
Good Agricultural Practices (GAPs)
Hazard Analysis of Critical Control Points (HACCP)
High Definition (HD)
Information and communications technology (ICT)
Institute of Electrical and Electronics Engineers (IEEE)
International Electrotechnical Commission (IEC)
International Standards Organization (ISO)
Management of Technology (MOT)
Multi-Criteria Decision Making (MCDM)
National Cash Register (NCR)
National Television Systems Committee (NTSC)
Netherlands (NL)
Original Equipment Manufacturers (OEMs)
Photo-Voltaic (PV)
Plug-in Hybrid Vehicles (PHEVs)
Radio Corporation of America (RCA)
Society of Automotive Engineers (SAE)

Standards Development Organizations (SDOs)
Statistical Package For The Social Sciences (SPSS)
Systems Network Architecture (SNA)
Television (TV)
Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)
Transmission Control Protocol/Internet Protocol (TCP/IP)
United Kingdom (UK)
United Nations (UN)
United States of America (USA)
Wireless Ethernet Compatibility Alliance (WECA)
World Health Organisation (WHO)

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1. Introduction

Electricity has been considered to be one of the essential sources of energy in the modern world. It has been used in countless applications, especially in the field of transportation, that use electric power as a primary source of energy to function. Electric vehicles (EVs) were introduced into the market as early as the 1900s, and since its introduction, the industry saw significant developments in the field of manufacturing EVs. With the rise in the impact of global warming around the world, most of the developed nations are determined to become more sustainable by switching towards renewable sources of energy and taking measures to reduce the further effects. Concerning this issue, European Union (EU) is encouraging its state members to discontinue the usage of fossil fuel-based vehicles and promote electric vehicles as a solution to increase efficiency, decrease CO2 emissions as well as air pollution from the transportation sector (Beltramo et al., 2017).

EVs are categorized into three major types, namely: 1.) Plug-in Hybrid Vehicles (PHEVs), which use both gasoline and charged batteries as fuel, 2.) Fuel-Cell Electric Vehicle (FCEVs), which uses hydrogen as a fuel to run electric motor and 3.) Battery Electric Vehicles (BEVs), which only use charged batteries as a fuel, and PHEVs, as well as BEVs, are together known as Plug-in Electric Vehicles (PEVs) (Sovacool et al., 2017). The batteries used in the PEVs act as electricity storage devices that need to be recharged using charging stations (wherein the electricity grids supply power to these stations). Based on the usage of individual users, the charging frequency varies. Recent studies show that 95% of the EVs remain parked during peak hours, and only 5% of the EVs are being driven on the road. Therefore the energy stored in the batteries is being underutilized (Sahu et al., 2018). Researchers came up with a concept of utilizing this energy by sharing it back to the electricity grid. The process of sharing the power to the grid is carried out using the same charging stations (with bi-directional capacity). Therefore, this concept eventually was named as “Vehicle-to-Grid (V2G)” technology (Lauinger et al., 2017). Even though the technology was introduced in the year 1997 (Kempton & Letendre, 1997), the first V2G capable EVs were developed only ten years later by the University of Delaware in 2007 (Noel et al., 2019).

While the V2G technology is still in the early stages of testing and implementation, the deployment has not been on a large scale around the globe. Hence, there are very few potential countries participating in the testing and implementation projects of V2G technology. As per the report by EVConsult (2018), the major EV manufacturers engaging in global V2G projects are Japanese companies such as Mitsubishi Motors & Nissan Motor Co., Ltd, and a French company called Groupe Renault. These companies account for more than 50% of the total number of companies participating in the V2G projects around the world. Most of the Asian countries contribute to the V2G projects by representing themselves as manufacturing companies and not as deployment hubs. With half of the V2G projects undergoing in Europe, the North European countries such as the Netherlands, United Kingdom, Germany & Denmark dominate in the European market (EVConsult, 2018). The charging infrastructure company ‘NUVVE’ originating from the USA is already providing V2G compatible charging stations in both Europe and the USA (NUUVE, 2020). Also, in the year 2017, the European charging infrastructure company 'VIRTA' installed the first V2G charging station in Finland (Virta Global, 2017). There are only a few EVs such as Nissan e-NV200 vans that are compatible with V2G technology in the market that use CHAdeMO as the charging standard (PV Magazine, 2019). The "EV-PV project" was carried out at the Delft University of Technology (Netherlands) to experiment on the V2G concept. During the project, a solar V2G charger was developed that was capable of charging EVs directly from the DC power generated from solar panels without converting it to AC. The solar V2G charger was also capable of bi-directional charging and is compatible with both CHAdeMO and CCS Combo charging standards (Ram & Bauer, 2020). Recently, the Dutch government also decided to invest in V2G technology by providing a grant of five million euros to a total of 21 municipalities in the Netherlands. The grant is expected to support the installation of the infrastructure for 472 V2G enabled charging stations around the country, and is expected to be operational in the year 2020 (Randall, 2019). A total of 18 V2G projects were initiated in Europe, and the UK was part of one of the projects (European Union, 2018). A few projects are still under development, and some projects have already concluded. Considering the vast potential of the EV market in Europe, the continent has been recognized as a geographic focal point during this research.

A study conducted by Turton & Moura (2008), showed that the benefits of V2G technology could only be realized with specific requirements. These requirements include aspects such as combined infrastructure, regulation, metering and wiring in buildings, electric-drive vehicles, and fuel production and distribution systems. To analyze the benefits and issues related to V2G technology among its stakeholders, the installation of public charging infrastructure could prove to be the first step towards implementation. Such a step will not only increase the range of EVs but also increase the value of the technology to the users (Dimitropoulos et al., 2013). Evidently, with the increase in the number of EVs in the European market, the need to install the number of bidirectional charging stations will also increase exponentially. Establishing a large scale charging infrastructure not only requires substantial construction investments but also requires land for building the charging stations around the European continent. Such a requirement can prove to be one of the significant challenges during the implementation of V2G technology. Although concerns regarding investments and land availability pose to be a pertinent challenge, failing to standardize charging infrastructure could become a significant threat to the implementation of V2G technology in Europe in the future.

1.1 Research Problem

The EU published a draft Directive in January 2013 that was amended later in March 2014. The draft provided clarity on the plug designs and charging systems, which were expected to eventually become the new standard in Europe (Bakker & Trip, 2015; European Parliament and Council, 2013). But since 2013, there have been significant changes in the types of plug designs and charging systems in the European market, allowing multiple charging standards to be prevalent all over the continent. Few countries in the European continent are yet to choose a common charging standard for easing the EV drivers to charge across the country. In contrast, other European countries are trying to take initiatives to realize the European Directive legislation by creating a network of charging stations that are compatible with the new design of plugs and corresponding charging standards. Logically, all the European countries should work towards encompassing a common international standard. However, different countries across Europe have chosen their own standards rather than defining a common standard in the whole continent. According to Bakker & Trip (2015), if a local stakeholder is reluctant to accept the emerging international standards, then the optimal solution for EV drivers is to carry multiple charging plugs to ensure the abundance of charge during their trip. Indeed, this solution could be prevalent in the present day, but the idea of implementing the same solution on a larger scale is surrounded by uncertainty in the future (Bakker & Trip, 2015). Notwithstanding the temporary proposed solution for conventional charging systems, Landisgyr (2020) mentions that a fast-charging system is a key for V2G technology to diffuse the market at a faster pace. Additionally, Bakker & Trip (2015) also foresees the proposed solution as a failure for fast charging systems, which is supposed to be the potential solution for the implementation of V2G technology in the future.

While bi-directional charging is one of the critical characteristics of V2G technology, Mouli et al. (2016) propose CHAdeMO and Combined Charging Standards (CCS) as potential candidates for V2G technology implementation in the future. Currently, CHAdeMO is the only charging standard capable of V2G, whereas a German charging infrastructure company CharIN e.V. is determined to work with CCS standard to offer V2G by 2025 (Kane, 2019). Although Tesla's charging standard is also a fast-charging standard, some sources show that the company's CEO considered the idea of V2G and rejected it (Hanley, 2020). Alternatively, a few sources indicate that Tesla's CEO wants to revisit working on V2G in future projects (Lambert, 2018). Hence, Tesla charging standards can be considered as an additional candidate along with CHAdeMO and CCS in the standards battle. From the literature, there are only a few studies that are working towards standardizing the charging standards, especially in the European continent. Hence there is an impinging need to analyze the factors that play a significant role in the research of standardizing the charging standards.

1.2 Research Objective

From the brief literature analysis, the research objective can be divided into two parts. The first part pertains to the development of a conceptual framework that consists of various factors influencing the success in the selection of charging standards within the multi-mode standardization process. This framework will be built upon the framework by Van de Kaa et al. (2011, 2020) from the perspective of multi-mode standardization. The second part focuses on the identification of relevant factors within the multi-mode standardization process that can contribute to the selection of a common charging standard in Europe. The importance of the essential factors will be determined by conducting interviews from experts belonging to academic and industrial backgrounds in the field of charging standards. Further, the BWM approach will be used to analyze the relevance and importance of the essential factors.

1.3 Research question and sub-research questions

Based on the nature of the research problem and the objective of the research, the main research question is as follows:

> ***"What are the factors that influence the success of charging standards in the context of multi-mode standardization in the European market for the implementation of V2G technology?"***

Few sub-research questions that can help to answer the main research question are as follows:

- *What are the success factors that influence the selection of dominant standards in a situation of multi-mode standardization?*
- *To what extent does the concept of multi-mode standardization discussed implicitly in the literature?*
- *What are the relevant factors for the selection of charging standards in implementing V2G technology according to the literature and experts?*
- *What is the importance of the success factors in the selection of charging standards according to the experts?*

1.4 Research approach

The research approach consists of five phases, namely: identification of factors within multi-mode standardization, analyzing of literature from the perspective of multi-mode standardization, identification of factors from literature and experts, deriving weights of factors using the MCDM method, and interpretation of the results. The purpose of this research approach is to answer the sub-research questions in each phase and eventually answer the main research question.

1.4.1 Phase 1 – Identification of factors within multi-mode standardization

The first phase focuses on answering the first sub-research question "*What are the success factors that influence the selection of dominant standards in a situation of multi-mode standardization?*" by considering the existing literature about multi-mode standardization by (Wiegmann et al., 2017) as a starting point of gathering the data on success factors. Wiegmann et al. (2017) and Van de Kaa et al. (2020) provide citations on success factors within the individual as well as multi-modes of standardization. Hence, these articles will be used to explore the relevant factors. An additional set of articles will be reviewed in order to identify new factors in the literature wherever necessary. The existing framework by Van de Kaa et al. (2011, 2020) will be used for categorizing the factors to the relevant group of categories. The framework may also be modified by adding new categories and factors based on the literature review.

1.4.2 Phase 2 – Analyzing of literature from the perspective of multi-mode standardization

The second sub-research question, "*To what extent does the concept of multi-mode standardization discussed implicitly in the literature?"* will be answered by identifying the literature sources provided in the framework by Van de Kaa et al. (2011), which focuses on the success factors from the perspective of standard battles. While these sources haven't been re-analyzed further from the multi-mode standardization perspective in the literature until now, this analysis further contributes to the framework of Van de Kaa et al. (2020) by adding support from the previous literature.

1.4.3 Phase 3 - Identification of factors from literature and experts

Once the factors within multi-mode standardization have been identified, the next step is to answer the third sub-research question "*What are the relevant factors according to the literature and experts in the field of charging standards?*". This question will be answered by gathering factors from the literature that might influence the success of charging standards in the European continent in the first part. The second part will be answered by interviewing the industrial and academic experts in the field of charging standards to verify the relevance of identified factors in the literature and also add any new factors if suggested by the experts. The factors are considered to be relevant only if they are mentioned in the secondary sources and/or if the interviewees specify its relevance (Van de Kaa et al., 2011, 2017).

1.4.4 Phase 4 – Deriving weights of the factors using the MCDM method

As there are multiple factors under consideration during the analysis, Multi-criteria Decision Making (MCDM) method is an ideal choice to select the best alternatives (Rezaei, 2015). A study by (Sabaei et al., 2015) reviewed a various number of publications to show that Analytic Hierarchy Process (AHP), ELECTRE (elimination ET choix traduisant la realite) and PROMOTHEE are the most widely used MCDM methods for a particular case study. Compared to ELECTRE and PROMOTHEE method, the study also portrays the AHP method as a more robust solution for decision-makers (DM), as it focuses on giving priority to the preference for making decisions. Sabaei et al. (2015) explicitly mention that ELECTRE and PROMOTHEE are not suitable for cases where DM express their preferences. AHP method uses n(n-1)/2 number of comparisons (where 'n' is the number of criteria) to provide appropriate weights to different criteria (Sadjadi & Karimi, 2018). At the same time, the process is cumbersome if there are a large number of criteria under consideration (Sadjadi & Karimi, 2018). Considering the issues related to a large number of criteria, a modified and more efficient version of the AHP method was introduced by (Rezaei, 2015) known as Best-Worst Method (BWM), which uses only the best & worst criteria resulting in the reduction of the number of pairwise comparisons. BWM approach has various advantages over AHP method: a) it produces highly reliable as well as consistent results, b) it can be used independently and can also be combined with other MCDM methods, c) it uses only integers and no fractions while using a comparison matrix making it easy to use for DM, and d) it uses only (2n-3) number of comparisons which is lesser compared to AHP (Rezaei, 2015). While there have been various studies associated with the implementation of BWM since 2016, Sadjadi & Karimi (2018) lists some of the authors and their case studies in different scientific domains implying the popularity of the BWM approach. BWM has also been applied in many real-time applications such as supplier segregations, supplier selection, evaluation of barriers and promoting factors of technological innovation, and further various applications (Van de Kaa et al., 2017). Considering all the advantages, the

BWM approach will be used during this research to determine the weights of the individual factors, their influence in the standards battles, and predicting the potential dominant charging standard in the market. The BWM approach consists of five steps in deriving the weights of individual factors, and the detailed steps will be discussed later in the "Methodology" section.

1.4.5 Phase 5 – Interpretation of results

Once the results are obtained using the BWM approach, the fourth sub-research question "*What is the importance of each relevant factor in the selection of charging standards according to the experts?*" will be answered by identifying the top five factors with the highest scores and consider them as the most relevant. Based on the weights of those factors, the potential dominant charging standard can be derived. The derived standard will be considered as a potential winner in the standard battle during this research. Further, the validation of results will be performed by conducting interviews, which in turn will help in the interpretation of the results.

1.5 Thesis structure

In total, there are seven chapters in this research. Chapter 1 focuses on the introduction of the thesis along with research questions to be answered in the study. Chapter 2 focuses on the introduction to the single modes of standardization and then analyzes the concept of multi-mode standardization using the case studies found in the literature. Chapter 3 focuses on the relevant research methodology that will be used in this research to obtain the results. Chapter 4 focuses on the identification of success factors within a situation of multi-mode standardization. These factors will be used to construct a framework for further analysis. Chapter 5 focuses on the selection of relevant factors and the application of BWM to obtain the results for each relevant factor. Chapter 6 focuses on the interpretation of the obtained results and discusses other aspects of the research. Finally, Chapter 7 discusses the conclusion and recommendations.

1.6 Conclusion

In this chapter, the concept of V2G technology was introduced initially, and the promotion of technology in the European continent was discussed briefly. Further, the research problem was analyzed from the present literature on charging standards, and a research objective was set. Based on the research objective, the main research question and a few sub-research questions were framed accordingly. Also, a research approach was designed to answer the research questions, and it consisted of a set of five phases. A thesis structure was also designed to give a brief overview of the chapters in this research. A few critical concepts will be used in the later stages of the study, and these concepts will be discussed in the next chapter 'Theoretical background'.

2. Theoretical background

Since the advent of scientific technologies in the world, scholars in the technology management field were the first to study the effect of benefits involved in selecting a dominant technology in the industry (Suarez, 2004). Whenever a new technology or product is introduced into the mainstream market, it poses as an attack to displace the current design of established markets (Fernández & Valle, 2019), to become a new dominant design. Hence, the concept of dominant design came into existence to avoid having numerous technologies providing a similar solution for a particular problem. If there are two or more technologies in the market that are comparable in delivering similar solutions for a specific problem, then they end up in setting a market standard by competing against each other. Many authors in the literature have studied technology battles under the label “standard battles” in a network of industries (Suarez, 2004). The terms dominant design and standards are mostly considered as synonymous, whereas the process of selecting a dominant design is termed as the ‘battle’ between the standards (Fernández & Valle, 2019). While the technologies in the modern world change at a rapid pace, the corresponding technical standards need to be monitored and updated regularly to avoid risks of monopoly and issues related to technology lock-ins. Such lock-ins will eventually impact the advancement of a particular technology (Ho & O'Sullivan, 2018; Swann, 2010). The history of technical standards can be traced back to the end of the 19th century during the American Civil war, where the soldiers had issues with cannibalizing the rifles that were damaged (Kaplinsky, 2010). During the same period, the American railroad system had compatibility issues related to rail gauges, breaks, and block signal systems. These issues lead the government to form a committee consisting of railroad department professionals to decide upon the railroad integrated standards all over the country (Schmidt & Werle, 1998). From the examples, it is evident that a market with many sets of standards has created issues for the relevant set of stakeholders, and a common standard was able to avoid such problems in the history of standards battle.

Literature from late 20th century show that the technical standards were classified into four major categories: 1.) "Units" to measure physical qualities (e.g. length), 2.) "Similarity" to check the repeatability within a set of similar entities (e.g. paint color), 3.) "Compatibility" to check the interworking between two or more mating elements (e.g. a plug and a socket); and 4.) "Etiquette" to check the expandability within a communication network (Krechmer, 1996). Since the beginning of the 21st century, significant technological advancements have led to the categorization of modern technical standards based on their roles and functions. Based on the four categories of technical standards (Swann, 2010), Ho & O'Sullivan (2018) modified the types of technical standards an additional category. In total the five broad categories are: 1.) Terminology and semantic standards, 2.) Measurement and characterization standards, 3.) Quality and reliability standards, 4.) Compatibility and interface standards, and 5.) Variety-reduction standards. In this research, three different charging plug designs are competing against each other. Based on the list of standards, the most appropriate type of standard in case of charging standards pertains to "Compatibility and interface standards," which focuses on specifications between two or more interfaces (Dan, 2019; Krechmer, 1996; Van de Kaa et al., 2011).

The selection of a dominant standard is an intricate process that involves various factors that influence the outcome of the standard battles in the market (Suarez, 2004; Van De Kaa et al., 2014). Existing literature shows some essential frameworks that analyze the importance of success factors influencing the standard battles from a market perspective (Van de Kaa et al., 2011). Further, the process of determining the importance of success factors was studied by Van de Kaa et al. (2011, 2017). The authors incorporated a well-known Multi-Criteria Decision Making (MCDM) method in their study, known as the Best-Worst Method (BWM) introduced by (Rezaei, 2015; 2016). Standard battles usually lead to a war of attrition during which individual actors supporting either of the standards tries to block agreements with the other actors, unless the other actors concede (Farrell & Saloner, 1988; Farrell & Simcoe, 2012; Wiegmann et al., 2017). While there are various actors involved in a standard battle, the process of developing technical standards based on the consensus of all the actors is known as the Standardization process (Xie et al., 2016). While the literature discusses three different modes of standardization (Wiegmann et al., 2017), however, it also shows that the success of standard battles is dependent on the multi-mode standardization process rather than individual modes. Hence this chapter will discuss in detail the individual modes of standardization in Section 2.1 and possible combinations between individual modes of standardization in Section 2.2 which is popularly known as multi-mode standardization in the literature.

2.1 Modes of standardization

Based on Section 1.1, the literature introduces the concept of a multi-mode standardization process for developing common solutions around three different modes, i.e., committee, market, and government-based standardization. The first mode is known as *Committee-based* standardization, which usually takes place during the development of a standard. This mode involves cooperation between all the stakeholders in a committee and the standards can only be diffused if all the members agree upon a common solution to a problem (Wiegmann et al., 2017). *Committee-based* standards are also known as *de jure* standards (Simcoe, 2003). They are mostly developed by committees that include Standards Development Organizations (SDOs), trade associations, professional associations, consortia, and initiatives taken by open-source organizations (Wiegmann et al., 2017). As the technical rules for a standard are increasingly being set in the SDO's, explicit coordination among the committee members significantly decreases the risk for firms to introduce new technology (Cargill, 1996; as cited in Jain, 2012). SDOs also serve as a platform where the committee members can share their knowledge about emerging technologies and further help in settling the disputes within the committee (Jain, 2012). Few examples of international SDOs include International Standards Organization (ISO), International Electrotechnical Commission (IEC), and the European Committee for Electrotechnical Standardization (CENELEC) (Büthe & Mattli, 2010; Ping, 2011). In contrast, the American Society for Testing and Materials (ASTM), American Society for Microbiology (ASM), and Institute of Electrical and Electronics Engineers (IEEE) are well-known examples of national SDOs (Ping, 2011).

The second mode is known as *Market-based standardization,* which takes place during the diffusion of a standard. It involves competition between different solutions proposed by various actors in the market, leading to the emergence of a dominant standard (also known as the *de facto* standard in the literature) (den Uijl, 2015; Wiegmann et al., 2017). The competing firms in the market-based standardization are predominantly driven by private autonomous actors (Büthe & Mattli, 2010). Therefore, it usually results in a lack of inclusiveness among competitors during the development of market standards (Botzem & Dobusch, 2012). However, the competition in the market-based standards takes place on two levels. The first level of competition takes place among groups of firms supporting a specific technical standard (Keil, 2002). For instance, firms supporting mobile operating systems such as Android developed by Google, against the firms supporting operating systems such as Symbian developed by Nokia. The second level of competition is within the group of firms supporting a specific technical standard (i.e the competition is within a standard) (Keil, 2002). For example, firms supporting a particular standard such as Bluetooth 5.0, but firms might compete to gain a dominant position to shape the future specifications of the Bluetooth standard itself. A classic example of a market-based standards battle is the dominance of the VHS videocassette recorder over the Betamax recorder (Besen & Farrell, 1994). Another example of the market-based standards battle took place during the late 19th century between low voltage Direct current (DC) competing against the single-phase Alternating Current (AC) for the incandescent lighting market (Schmidt et al., 1998, pp. 28).

The third mode is known as *Government-based standardization,* where the government uses its hierarchical position to intervene in the development of a standard. Based on the available options of developed standards in the market, the government imposes standards for implementation (Wiegmann et al., 2017). Government intervention takes place usually in the form of a regulation, which may be enacted to reduce excessive competition between the standards that act as a threat to the country's economy (Khemani & Shapiro, 1993). Sometimes standard regulations can be negatively used by the incumbent firms in their favor (Khemani & Shapiro, 1993). This situation eventually leads to a possible scenario of monopoly. Hence, on the one hand, government regulations can restrict a firm's freedom to innovate (Palmer et al., 2018), and sometimes a well-designed regulation can force them to invest in innovative processes to produce innovative products (Porter & Van Der Linde, 2017). Such situations tend to question the role of government in the standardization process. Blind et al. (2017) conducted a study on the impact of the government's intervention in the form of regulations on the firm's innovation efficiency. They concluded that the degree of technological uncertainty in the market affects the innovation efficacy of a firm. For instance, lower uncertainty in the market leads to positive effects on a firm's innovation efficacy. And higher uncertainty in the market leads to a highly unstable and rapidly changing technical environment resulting in competition between the firms in the market. Nevertheless, the government can always intervene and coordinate in both phases of standardization, i.e., during the development phase as well as the diffusion phase of standards (Wiegmann et al., 2017).

One such example of pure government-based standards includes the Milk safety standards established by the government in Argentina and Brazil (Farina et al., 2005).

2.2 Multi-mode standardization

While there are many stakeholders involved in the large scale deployment and commercialization of the V2G technology, aspects such as mutual understanding between standardization organizations, energy utility companies, lawmakers, and governments (Shinzaki et al., 2015), are essential to enable standardization of charging standards in Europe. Usually, if more stakeholders are participating in the standards battle, the potential adopters of any particular standard consider them as a sign of establishing legitimacy (Brunsson et al., 2012). On the contrary, an increase in the number of participants may result in a large number of solutions (Wiegmann et al., 2017), resulting in the delay of the standardization process itself. Moreover, some difficulties arise in a group of stakeholders during the standardization process. Difficulties such as lack of willingness to support, belief in different standardization schemes, and strongly diversified interests, eventually reduce the efficiency of the process, making it difficult to reach consensus (Tamm Hallström, 2008). Such issues can be avoided by the incorporation of stakeholders with common interests who rely on single standardization schemes. However, many practical standards such as GSM communication services (P. Gao et al., 2014), JAVA programming language (Garud et al., 2002), or Ethernet (Von Burg, 2001) emerged by collaboration between multiple modes of standardization that involved diversified stakeholders from various backgrounds. Wiegmann et al. (2017) reviewed different modes of standardization in the existing literature and introduced the concept of multi-mode standardization. Based on the available literature, they categorized the modes into three individual modes of standardization, namely: 1.) Committee-based standardization (e.g., Jain, 2012; Leiponen, 2008; Narayanan & Chen, 2012); 2.) Market-based standardization (Schilling, 2002; Suarez, 2004; Van de Kaa & Greeven, 2017); and 3.) Government-based standardization (e.g., Büthe & Mattli, 2010; Farina et al., 2005). Although the authors focus predominantly on individual modes of standardization and provide fundamental insights into the interactions between each mode, it lacks a full-fledged theoretical base for various actors within these modes to interact across multiple-modes. In the standardization process, various stakeholders come from different backgrounds and specialties, and they bring their diversified interests, knowledge, culture, and strategies, along with their experience in the field of their expertise to the table. Therefore, multiple modes of standardization are preferred in the market lately. According to Wiegmann et al. (2017), the concept of multi-mode standardization is expected to shape the dynamics of the standardization process in future technological developments.

Furthermore, the literature shows various examples of standards being established through individual modes of standardization. But there are very few examples that focus on multi-mode standardization. During the analysis of a few case studies identified by Wiegmann et al. (2017), it was observed that there was an influence of an additional mode of standardization. The authors considered it as an external influence, rather than viewing it as a part of the multi-mode standardization. Other examples tend to mention the entities of standardization modes (e.g., ISO) but fail to identify the corresponding standardization modes (e.g., committee-based mode). Also, a few examples lack the perspective of the interaction between the modes in achieving success in the standardization process. Hence, a few case studies for each combination are discussed in the next section to understand different paired combinations of standardization modes from the perspective of the multi-mode standardization process.

2.2.1 Combination of Committee-and Market-based standardization

A classical case of standards battle between Wifi and HomeRF can be used for analyzing the combination of committee-and market-based standardization modes. The standards battle was a result of a ruling offered by the Federal Communications Commission (FCC) in the year 1985. The verdict was related to the commercialization possibilities of wireless data communication in the US. In the same year, a renowned computer networking company, National Cash Register (NCR), took the verdict as an opportunity to explore the feasibility of developing wireless communication systems for cash registers. The cash register's performance was comparable with the wired communication systems. In the year 1990, NCR wanted to explore the relevant protocols for the standard and established a committee with the help of IEEE. The standard was officially named IEEE 802.11. A few computer manufacturing companies such as IBM and other networking companies similar to NCR were the only active members in the committee until the first version of Wifi got released in the year 1997. In the year 1999, an alliance was established in the name of Wireless Ethernet Compatibility Alliance (WECA), to promote the Wifi standard to certify the relevant market products. Although the Wifi standard was gaining support from new members, it was only focused on data transmission and was weak in the transmission of telephone signals. Intel (a semiconductor manufacturing company) took the opportunity to develop a standard to transmit the data and the telephone signals simultaneously by targeting the home telephone applications industry in the US. Soon in the same year, a working group known as 'Home Radio Frequency Group' was established to attract participants representing various electronic product based industries such as Microsoft, Compaq, Philips, and telecommunication industries such as Ericson. The first version of HomeRF was released in the year 1998 and showed good potential for the future. However, due to diverse interests from big companies in the group, the latter group meetings resulted in various disagreements. While many participants in the group were looking for high bandwidth capacity standard, HomeRF was not able to perform as per their expectations. Therefore, the participants like Microsoft and Philips left the working group, followed by Intel, eventually forcing other participants to follow, and the group was entirely dissolved by 2003. Up until then, Wifi had incorporated many desired specifications such as high bandwidth and security in the standard. Such incorporation attracted new members to the committee, such as Breezecom (a telecom industry), Philips, Microsoft, and Boeing (aircraft industry). Eventually, Wifi was successful in winning the battle with the support from the diversified network of stakeholders (Van De Kaa & De Bruijn, 2015; van den Ende et al., 2012).

From the above case study, it is evident that the Intel company developed the HomeRF as a market-based standard all by itself and later formed an alliance to gain more support from other market players in the battle against Wifi. Nevertheless, HomeRF lost the battle due to the inflexibility of the standard. In comparison to Intel, NCR also developed Wifi autonomously. However, due to technical inexperience in the field, it approached the IEEE organization, which focused on technical expertise and assisting in the formation of a technical committee as an SDO. With the relevant knowledge in the field, Wifi started gaining the needed support from the market. Many more members joined the WECA alliance and made the network grow stronger. The alliance helped in attracting various companies, including the ones that supported the HomeRF standard in the battle initially. Therefore, the Wifi standardization process can undoubtedly be considered as a combination of both committee- and market-based standardization.

2.2.2 Combination of Committee-and Government-based standardization

The emergence of Transmission Control Protocol/Internet Protocol (TCP/IP) is considered to be the foundation of the present-day internet, and Wiegmann et al. (2017) identified this case as an example for the committee-and government based standardization mode. The idea behind the internet started in 1960 as a project in universities and research institutions to solve the problems related to the communication issues between two networks. Later, the US and European based computer scientists joined the project under the US department of defense organization known as the Advanced Research Projects Agency (ARPA). And the project was named as ARPANET. As the project started as a military-based initiative, there were many speculations around the project. In this context, Townes (2012) argues that ARPANET began only due to the sheer interest of academic personnel from various universities across the US and Europe. Companies such as IBM and Xerox developed their proprietary protocols that were known as 'Systems Network Architecture' (SNA) against the TCP/IP standard. Out of commercial interests, companies such as Xerox Network Services, and other companies followed in the same path. In the meantime, the 'Consultative Committee on International Telegraphy and Telephony (CCITT)' (a private international standard-setting organization) proposed an official standard known as X.25 against the SNA standard (produced by IBM). During the committee meetings, US representatives agreed upon TCP/IP as a possible standard. Nevertheless, TCP/IP was flatly rejected as a standard by CCITT. But they allowed some networks to use TCP/IP work over X.25 links. Members of ISO also worked on a competitive standard known as OSI, and with the international influence of ISO, the standard was incorporated as an official standard in many countries. Initially, ISO also rejected the TCP/IP proposal fearing the dominance of US-based standards on a global scale. But later, due to technical deficiency in the OSI standard, TCP/IP was considered to be a predominantly faster and open-source protocol standard. Therefore, the TCP/IP standard was eventually accepted globally. While ARPA was a US government agency Townes (2012) argues that the role of the US government was significant in laying the foundation for the technology. Further, the technology was offered to the technical and academic experts to develop the technology. In the standardization of TCP/IP standards, committees such as ISO and CCITT were involved. Also, the US government and governments from various countries participated in the standardization process. Therefore, a combination of committee-and government based standardization emerges.

2.2.3 Combination of Market-and Government-based standardization

While there were very few examples discussing the combination of the market- and government-based standardization in the literature, Wiegmann et al. (2017) identified the emergence of the mobile telecommunication system as one of the examples to describe the combination. The standards battle for the mobile telecommunication system took place during the late 20th century and continued for almost two decades. There were many standards introduced by various countries, and the battles took place sequentially for three different generations of standards. There were new winners in each generation of standards. The first standard 'NMT' started as an open market-based standard in 1981 in the Scandinavian market. The NMT standard was produced by an alliance of more than 20 companies in and around the Scandinavian region. The adoption of one single standard in the Scandinavian area resulted in the strong growth of subscribers. Therefore, many European countries were expected to follow the NMT standard. In the meantime, the US government allocated the FCC agency and Judicial system to introduce another standard locally. The new standard was known as AMPS, and it was accepted by countries like Canada, Korea, and Great Britain. At this point in history, many countries were under the belief that the standards chosen by the US government will eventually become dominant in the market. On the contrary, few other countries such as Japan, France, and Germany decided to stick with the development of their local standards. At the end of the first-generation battle, the NMT standard remained dominant in Europe. Similarly, the AMPS standard was dominant in the US.

The second-generation battle was predominantly in favor of the GSM standard. The GSM standard was introduced by the European Technology Standards Institute (ETSI), which consisted of various governments, manufacturers, and network carrier representatives from European countries. At the time, there were three different standards in the US, the IS95 CDMA standard developed by Qualcomm (a semiconductor company), the DAMPS standard (modified from AMPS). The GSM standard also made its way to the US eventually. While there was no dominant standard internationally, the third-generation battle began with a new standard 'W-CDMA', introduced by NTT Docomo (a Japanse telecommunication company). The Japenese government primarily funded the development of the 'W-CDMA' standard. Mobile handset manufacturers like Nokia and Ericson convinced NTT Docomo to adopt the GSM network interface for the 'W-CDMA' standard. The adoption of the GSM network interfaces in the 'W-CDMA' standard lead the governments and manufacturers of many European countries to support the 'W-CDMA' standard eventually. With additional support from Asian countries, the 'W-CDMA' standard won the standards battle. Therefore, NTT Docomo was responsible to release the third-generation 'W-CDMA' standard globally (Funk & Methe, 2001; Gandal et al., 2003). The involvement of governments from various countries in the development of the W-CDMA standard makes it a government-based standard. However, the involvement of mobile handset manufacturers and a few independent companies that introduced proprietary standards make 'W-CDMA' a market-based standard. Hence, the emergence of the market- and government based standardization can be observed in the case of global telecommunication standards.

2.2.4 Combination of Committee-based, Market-based and Government-based standardization

As per the literature, one of the case studies that fouses on all three modes of standardization is related to global food quality and safety standards. Although there were various standards and systems developed to adhere to the stringent food quality and safety requirements during the last century, there hasn't been one dominant standard on a global scale. But instead, there were many standards developed by various countries locally that incorporate the essence of standards established in the light of food quality and safety requirements globally. Therefore, a few standards are considered for analyzing the combination of committee-market and government based standardization mode.

Due to the increased number of international food exports from various countries, a major concern for many countries is to ensure food quality and safety requirements on a global scale. In this regard, governments from various nations came up with new regulatory standards known as the Codex Alimentarius. The new standards were established by the United Nations (UN) organizations such as the Food and Agricultural Organisation (FAO) and the World Health Organisation (WHO) in the year 1962. At the end of the 20th century, two major quality assurance systems came into existence, namely: 'Good Agricultural Practices' (GAPs) and 'Hazard Analysis of Critical Control Points' (HACCP). GAP systems majorly focused on guidelines for agricultural practices, and HACCP was a systematic approach for identifying, evaluating, and controlling steps involved in food manufacturing practices. At the same time, three major standards were established by Europe, the United Kingdom, and Australia. The first standard 'Eure-Gap' was established by Eurep organization consisting of more than 20 retailers and purchase organizations of European origin. A group of British retailers established the second standard BRC in a consortium focusing on norms that were converging with HACCP systems. The third standard SQF was established in Australia, and the norms were based on HACCP systems, ISO 9000 series, and Quality Management Systems. Further, the International Organization for Standardization (ISO) established the ISO 22000 standards aiming to establish safety requirements for food manufacturing industries. Hence, these standards were considered as a benchmark to develop standards on the national level in their respective countries. According to Trienekens & Zuurbier (2008), the standardization of food quality and safety standards allows buyers to distinguish suppliers based on the conformity of their standards. It also encourages the existing stakeholders to develop, specify, and refine the norms to include them in the certification schemes. In an intergovernmental organization such as the UN, various government representatives decide and agree upon solutions for common global issues. And these standards can be considered as government-based standards. However, the presence of SDOs such as ISO, and the involvement of consortium of British retailers and retailers from 'Eurep' organization points towards a case of a committee- and market- based standards. Hence, the emergence of global food quality and safety standards can be categorized into the combination of all three modes of standardization, i.e. Committee- Market- and Government modes.

2.2.5 Success within the modes of standardization

While many authors and researchers in the literature explain the concept of success clearly concerning individual modes of standardization, they fail to define the success within multi-mode standardization. By reviewing the analysis of case studies in the previous section, a basic understanding of the concept of success within multi-mode standardization is given below.

- Committee- and Market modes: When there is a successful consensus about a standard in the committee and market alliances are supporting the same standard, it results in a dominant market standard.
- Committee- and Government modes: When there is a deployment of a particular standard by successful consensus in a committee with the help of the government agencies, it results in a dominant market standard.
- Market- and Government modes: When a particular standard emerges as a dominant standard in a battle with the support from government agencies, it emerges as a successful standard in the market.
- Committee-, Market- and Government modes: When there is a successful consensus about a standard in the committee and market alliances are supporting the same standard in a battle, the government can help it to reach dominance in the market.

Therefore, to avoid any misinterpretations during the research further, the definitions will be used to distinguish the literature in the identification of success factors within multi-mode standardization.

2.3 Success factors in standard battles using different MCDM methods

Before moving further with the identification of success factors, it is essential to understand the role of various factors in the selection of standards in a battle. A few examples of standard battles with their most influential factors are discussed in this section. The first example is related to the study on exploring the factors in the selection of smart grid communication protocols used to communicate between the smart meter and the meter data collecting point using the BWM approach (G. van de Kaa et al., 2019). Smart meters are the devices used to measure the electricity consumption of a user, and such information is provided to the energy supplying companies. Electricity consumption data is used to track the variations in the user's energy consumption that allow the user to reduce the consumption based on the previous data. While there are three competing standards in the battle, namely: Power line communication, Mobile telephony, and Radio frequency, the study focuses on selecting one dominant standard to allow successful implementation of smart meters along with the smart grids. From the set of 23 factors, only nine factors were considered to be relevant, and out of nine relevant factors, the results of BWM show 'technological superiority', 'flexibility' and 'compatibility' as the most influential factors in the study. The authors argue that the factor 'technological superiority' was considered to be the most critical factor in the battle because the smart meters are an essential part of the complex infrastructure of smart grids and are regarded as a pre-requisite for a speedy adoption in the market. The factors ‘flexibility’ and ‘compatibility’ resulted in second and third positions, respectively. The authors argue that smart meters need to be flexible enough to incorporate rapid changes in technology and should also be compatible with various embedded technologies within them. From the obtained results, the authors conclude that technology buyers are more influential in this battle compared to the suppliers of the technology. While the study is focused only on the Netherlands, the authors also indicate that the results might vary based on geographic locations across Europe, which is one of the limitations in the study.

The next example pertains to the selection of a mobile-based health monitoring application system (also known as mHealth app) using a combination of fuzzy TOPSIS and AHP approach (Rajak & Shaw, 2019). The AHP approach is slightly similar to the BWM approach but requires more number of comparisons and cumbersome calculations for analysis. The fuzzy TOPSIS approach is additionally used to avoid cumbersome calculations and handle uncertainties in decision making by using different fuzzy membership functions. While there are a large number of mHealth apps on various app stores based on different mobile operating systems, it is difficult for customers to choose the best app. Ten apps are competing against each other in this study known as ‘Cody’, ‘Hot5 Fitness’, ‘Pact’, ‘Carrot fit’, ‘Human’, ‘Moves’, ‘LoseIt’, ‘Noom Weight Loss Coach’, ‘Healthy Out’, and ‘Zipongo’. In total, nine criteria and 32 sub-criteria (factors) were determined for comparison between the different apps. From the set of 32 factors, the top four factors ‘user satisfaction’, ‘functionality’, ‘ease to learn and use’, and ‘information quality’ ended up being the top four influential factors in the study. The analysis was done based on the opinion of three experts from both academic and industrial backgrounds. The authors have not discussed the actual influence of the top four factors in the study. Nevertheless, the app ‘Healthy Out’ has been found to be the best app among ten mHealth apps. The authors also suggest that the framework can be used by mHealth app developers and doctors to rank the best mHealth apps.

Another study by van de Kaa et al. (2018) focuses on identifying the success factors in the selection of business to government (B2G) data reporting solutions using the BWM approach. The term ‘B2G data reporting’ in this study mainly deals with the exchange of sharing business information related to annual reports from the perspective of fiscal and statistical domains. The battle in this study is between two B2G data reporting solutions known as EDIFACT (Electronic Data Interchange for Administration, Commerce, and Transport) and XBRL (eXtensible Business Reporting Language). Out of 15 relevant factors, the results of BWM show that the most influential factors in the selection of B2G data reporting solutions are: ‘commitment’, ‘timing of entry’, ‘compatibility’, and ‘complementary goods’. Even though the EDIFACT standard entered the market earlier than the competitor, the results show XBLR as a potential winner in the battle. With the factor ‘timing of entry’ resulting as the 2nd most influential factor, EDIFACT had an advantage of pre-emption of the installed base. But the results are in favor of XBLR mainly because of the more substantial influence of the factors, ‘commitment’, ‘the regulator’, ‘flexibility’, and ‘compatibility’. Since XBLR was superior in terms of extendability and flexibility compared to the EDIFACT, another factor that would have been significantly important in the list is ‘technological superiority’. The authors argue that technological superiority was not in the top list of factors because both technologies have already diffused in the market and are in the later stages of adoption. While the government (the regulator) is a major stakeholder in the battle, the ‘commitment’ of the government is considered to be more important than the technological differences between XBLR and EDIFACT. Therefore, it is evident that technological superiority doesn’t always decide the winner in the standards battle. While the application of BWM in this study involved seven interviews, the authors consider the number of interviews as a limitation and recommend conducting more interviews in the scope of future research. Finally, it is also mentioned that the results of the study might vary depending on the geographic location. Therefore the authors recommend conducting cross-country research for more accurate results.

Hsu et al. (2010) studied different factors that influence the selection of lubricant oil recycling technology in Taiwan by applying a combination of the fuzzy Delphi method (FDM) and the fuzzy AHP (FAHP) approach. There are eight different types of recycling technologies: ‘acid/clay process’, ‘distillation process’, ‘solvent de-asphalting process’, ‘TFE + hydro-finishing’, ‘TFE + clay finishing’, ‘TFE + solvent finishing’, ‘solvent extraction hydro-finishing’, and ‘TDA + clay finishing and TDA + hydro-finishing’. The FDM approach was used for determining the relevant factors for technology selection by interviewing nine experts from academic, industrial, and government backgrounds. The FAHP approach was used to find the importance of various factors for the selection of competing recycling technologies by interviewing 17 experts via questionnaires. A total of 12 factors were determined by the experts and categorized into three different aspects known as ‘technology’, ‘economy’, and ‘environmental protection’. While there were three different sets of experts interviewed during the analysis using the FDM approach, there was a variable focus on each aspect based on the backgrounds of various experts. For example, academic and government experts think a lot about the ‘environmental aspects’ of technology. Similarly, a few experts had variable opinions during the analysis of the importance of the factors using the FAHP approach. From the results of FAHP, the ‘technology’ aspect was found to be the most critical aspect. In this context, the authors argue that the experts from the industrial and academic domains emphasized more towards technical aspects compared to the other two aspects. Also, three out of four factors from the technology aspect ended up in the list of top four influential factors. Further, the top three influential factors were ‘proper scale’, ‘development stage’, and ‘recovery rate’. The factor ‘proper scale’ refers to the annual recycling capacity of particular recycling technology. The factor ‘development stage’ refers to the stage where the technology is under experimentation or ready for production. The factor ‘recovery rate’ refers to the amount of lubricant oil that could be extracted from the waste lubricant oil. While the amount of lubricant oil waste generated is on the higher side in Taiwan, there are very few numbers of recycling units in the country. Therefore, the authors argue that a ‘proper scale’ has to be analyzed before selecting the type of recycling technology.

A recent study by G. van de Kaa et al. (2020) discusses the factors influencing the selection of wind turbines using the BWM approach. There are two types of wind turbines battling against each other in this study, namely: the gearbox wind turbine and the direct-drive wind turbine. The fundamental difference between the two wind turbines is the presence of gearbox within the turbines to run the induction generator that generates power. The first type consisted of a gearbox between the rotor and the generator. Due to the transmission losses and failures in the gearbox, the second type of wind turbines was introduced later, which doesn't include a gearbox but consists of many magnetic poles that control the speeds of the rotor and generator. From a set of 23 firm-level factors, only eight factors were deemed to be relevant in the study. The eight factors also included three new factors from the wind turbine technological perspective, namely: 'total energy yield', 'cost of energy', and 'reliability'. The results of BWM show that the factors 'cost of energy', and 'reliability' have ended up being the most influential factors in the battle. The 'cost of energy' refers to the price of the wind energy that's generated using the wind turbine. While the turbines are located remotely outside the cities, 'reliability' on their constant operation is inevitable. Even though the gearbox wind turbine had almost 83% of market share compared to the 17% share of the second type of wind turbine in 2011, the results in the study show that the gearbox wind turbine has more edge over the direct-drive wind turbine in the battle. There were many opinions on the results of the battle between the two types of wind turbines. Nevertheless, both the types of wind turbines have comparable scores, and hence the authors conclude with two perspectives. Firstly, the battle is still under process, and either of the types has equal chances to win the battle in the future. Secondly, both types of wind turbines can co-exist in the market without one possible winner. The authors conclude that if both the technologies continue to co-exist with each other, there is a possibility of a new technology emerging in the future with superior performance characteristics. One of the limitations mentioned by the authors is related to the fact that the opinions of the experts might vary in the future. Hence, they recommend doing the same research in the future to understand the effects of the present influential factors in the future.

From the above examples, it is evident that different MCDM approaches have been used in the identification of success factors in the selection of standards or technologies. The technologies belong to various domains such as smart communication technologies, mHealth app selection, digital reporting solutions, lubricant recycling technology, and Wind turbine technologies. Based on the technologies battling against each other in the examples, a few observations can be considered to be unique as follows:

- It can be observed that both the relevant and the most influential factors discussed in the examples vary based on the technologies battling against each other.
- In the second and fourth example, approaches other than BWM have been used with good results. Therefore, different types of MCDM can also be explored based on the various kinds of studies.
- In the second, third, and fourth example, a set of new factors have emerged outside the framework in the battle. These new factors vary as per the technology under analysis.
- In the third example, it can be observed that it is not always crucial for technology to be superior to the competing technology for winning the battle.

- The factor 'compatibility' has ended up in the top influential factors for the first and third examples, which could also be the case in many studies in the literature.
- Also, the limitations mentioned in the examples could be considered as quite critical in those battles. Similar limitations could be eliminated with proper steps in future case studies based on the technologies battling against each other.

The above observations will undoubtedly vary with technologies and have different views. The essential observations in this research will be explained in the Discussion section (i.e., section 6). It is also necessary to have a brief understanding of the emergence of charging standards and actors involved in the battle before moving further with the construction of the framework. Thus, the next section will focus on the brief history of charging standards, the current status of the charging standards in Europe, and eventually identify the standardization modes that are relevant for further analysis.

2.4 V2G Charging standards

The working principle of V2G technology requires successful bi-directional communication and power flow between the EVs and the grid. To enable the connection between the grid and EVs, Tomić & Kempton (2007) defines three essential elements in their framework: (a) Connection to the grid for the flow of electricity; (b) Communication devices to connect with the grid operators, and (c) Energy meters to measure the on-board power accurately in the vehicle. Equipment that supplies electricity to the on-board charger in EV is called Electric Vehicle Supply Equipment (EVSE) or, in simple terms, is known as "Charging equipment or chargers." For both alternating current (AC) and direct currents (DC), different types of chargers are categorized into different levels. The Society of Automotive Engineers (SAE) and The Electric Power Research Institute (EPRI), have classified AC charging levels three levels. Level 1, Level 2, and DC fast charging (DCFC) Level 3 that includes the relevant functional and safety requirements (Shareef et al., 2016) as cited in (Schey, 2009). According to Noel et al. (2019), Level 1 chargers use the lowest power AC outlets that lead to low capacity power, i.e., 1-2 kilowatts (kW). Level 2 chargers use high power capacities that range from 4-20 kW. And Level 3 DC chargers use significantly higher capacities above 50 kW and are known as fast/quick chargers. V2G technology is generally compatible with all the three-level of chargers, but mostly Level 2 and Level 3 are the more recommended ones (Noel et al., 2019). Level 2 chargers provide a sufficient balance between power capacity and cost, which makes it affordable to regular consumers, and Level 3 chargers are costly and high capacity chargers (Noel et al., 2019). Later, SAE collaborated with European automotive experts and came up with a new version of the standard. In this standard, they classify DCFC further into DC Level 1 and Level 2 charging system having maximum power capacities of 38kW and 96kW, respectively (Massachusetts Department of Energy Resources, 2014).

Based on the charging speeds and complexity of the charging systems, the International Electrotechnical Commission (IEC) has defined four different modes of charging (Bakker & Trip, 2015; as cited in IEC, 2014a, 2014b; Van Den Bossche et al., 2012). The four charging modes are: *Mode 1* is based on charging from regular mains sockets without any safety or communication features; *Mode 2* is similar in the specification in comparison to Mode 1, however, provides additional functionality to control power and protect the user as well as the vehicle; *Mode 3* uses dedicated charging equipment focusing on safety and communication between the EVSE and EV; and *Mode 4* is used for fast charging (higher than 50kW capacity) and requires an additional AC/DC converter in the EVSE to deliver DC power to the EV (Bakker & Trip, 2015). As Mode 3 & 4 are the ideal choices for V2G technology, Mode 3 charging system is categorized into three types of plugs: Type 1 (*Yazaki*) is a type of plug that is used specifically to connect to a car with a compatible inlet and is mostly used in US and Japan; Type 2 (*Mennekes*) plug is a new European standard, used on a loose cable to connect the EVSE where the cable on the car's end can be any type of plug (mostly Type 1 plug) and are used for semi-fast charging by using three-phase charger; Type 3 (*Scame*) is used mainly in southern Europe (i.e., Italy and France) and has similar features as Type 2 plug (however incompatible with each other). It also has an additional feature of safety shutter on power outlets (Bakker & Trip, 2015; as cited in IEC, 2011). Type 4 plugs are used for fast DC charging, where CHAdeMO is the only standard that specifies both plug design and vehicle inlet along with respective standards (Bakker & Trip, 2015). To challenge and compete with CHAdeMO, a consortium of automotive manufacturers agreed on a new standard known as Combo 1 & 2 and are together known as Combined Charging System (CCS) Combo. CCS Combo standard has features of both the Type 1 & 2 plugs (to match the respective vehicle inlets for AC power) combined with additional two pins to accommodate DC power which can be considered as an enhanced version of Type 2 plug (Bakker & Trip, 2015; The Mobility House, 2018). A similar design of combo plugs has been used by Tesla superchargers that allows one of their Electric car "Model S" to recharge up to 80% in just 30 minutes (The Mobility House, 2018).

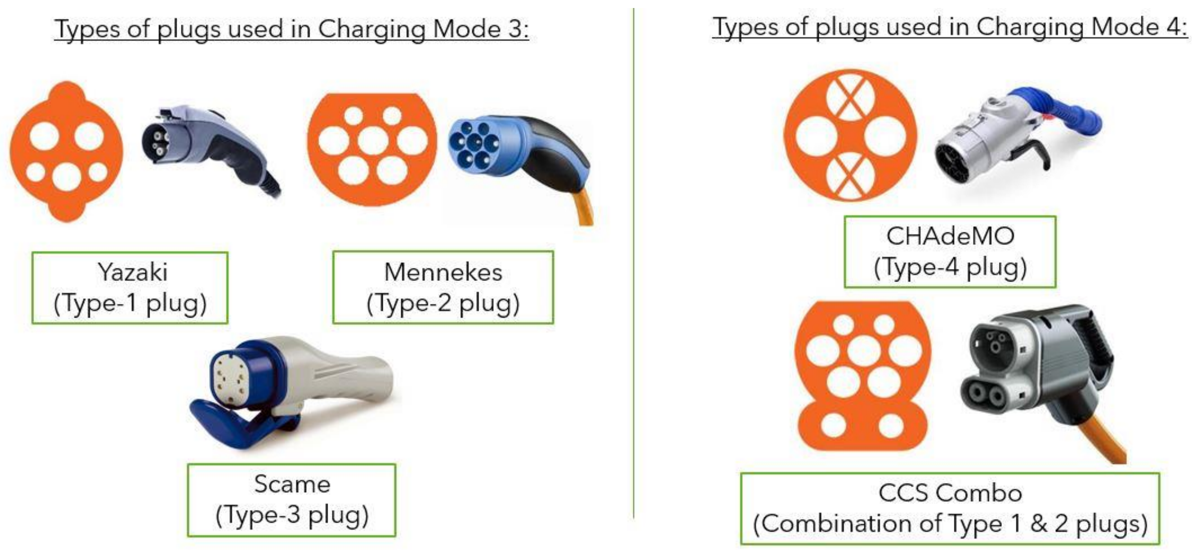

Figure 1: Overview of the type of charging modes and the corresponding type of plugs

Considering the diversification of charging standards around Europe, a recent study on Charging infrastructure for electric road vehicles in Europe found three potential DC charging standards that are dominantly used in the European market: 1.) *CCS Combo* standard is used by the US as well as German car manufacturers including BMW, Daimler, Ford, General Motors, and Volkswagen/Audi; 2.) *CHAdeMO* standard is predominantly favored by French and Japanese car companies, including Peugeot, Nissan, and Mitsubishi; and 3.) Tesla Supercharger has its own standard with charging stations that apply only to Tesla BEVs (Spöttle et al., 2018). Based on the analysis of "The Alternative Fuels Directive 2014" legislation by EU, Miles (2019) mentions that CCS Combo could likely be a dominant standard in Europe, mainly because the EV manufacturers in Europe favor it. According to Kane (2020), there are presently 8000 CCS unidirectional charging stations around Europe. Alternatively, there are 9200 CHAdeMO unidirectional charging stations all over Europe (CHAdeMO, 2019), amounting to approximately more than 15% compared to the number of CCS charging systems.

Although CHAdeMO has a more significant number of charging stations, it appears that the automakers around Europe do not want to decide on one single connector as a de facto standard. To maximize the utilization from PEVs, the new DC fast-charging stations have opted for dual-cord stations that are capable of providing both CHAdeMO as well as CCS charging wires. Indeed, this solution could be considered as more cost-efficient compared to the deployment of two independent charging stations (Spöttle et al., 2018). Therefore, Spöttle et al. (2018) argue that the lack of one common single standard doesn't pose a significant barrier to the use of DC charging systems on a global scale. However, Tomoko Blech (a representing person for CHAdeMO charging standards in Europe) believes that the automotive manufactures should fight it out with their products in the market rather than battling for future prevailing standards (Steitz, 2018). Recently, Tesla company announced that they would release the version of their "Model 3" car fleet with CCS chargers in the European market, showing their support for CCS charging standards in Europe (EVANNEX, 2018). There have many attempts to harmonize different charging standards related to EVs since the 1900s (Peter & Gaston, 2002), and yet there has been no consensus over a dominant standard. Although the charging standards competing against each other in this research have a common purpose, they have been manufactured and promoted by various companies all over the world. Depending on multiple geographic locations, the charging standards possess a different set of specifications and follow a different set of standards. Hence, there is a lot of uncertainty around the idea of choosing one dominant standard in the European continent. There are a few V2G enabled charging stations already installed across Europe by various private charging infrastructure companies for pilot projects. And the commercialization of the V2G technology has already taken place in Denmark with a few operational private clients (PV Magazine, 2019). Hence, as per the framework of Suarez (2004), the deployment o V2G technology is in the third phase of technology dominance.

After analyzing the current status of the charging standards in the European continent, there are three essential entities involved in the charging standards battle. The first entity is the European Committee for Electrotechnical Standardization (CENELEC), which is responsible for choosing a common standard in Europe. CENELEC is also involved in the adoption of international standards through its close collaboration with the International

Electrotechnical Commission (IEC) (CENELEC, 2020). The second entity pertains to various EV manufacturing companies that are supporting the V2G technology and the charging standards across Europe. The third entity is the EU, which consists of government representatives of all its member states. The EU interacts with all the members of the EU and is responsible for giving mandates all over the European continent (e.g., the mandate for using Type 2 plugs in 2014). It is evident that there is a specific European committee for standardization. And there are market alliances that are supported by firms in the market. Therefore, the committee- and market-based modes of standardization are a possible combination in this scenario. However, the presence of the EU makes the government an essential part of the standardization process. Hence, the process can be classified under multi-mode standardization consisting of all the three modes.

Now that the modes of standardization have been identified, it is essential to collect, analyze, and model the factors (Fernández & Valle, 2019), that will eventually help in the identification of an acceptable charging standard during the research. Building on the literature on factors influencing the single-mode standardization process, Wiegmann et al. (2017) suggests focusing on success factors within multi-mode standardization as a possible research area. The latest study by Van de Kaa et al. (2020) focuses on analyzing the case of multi-mode standardization for the first time in the literature by identifying the success factors in the area of water treatment. Furthermore, the study suggests working on more cases to validate the success factors identified during their research and also add more possible factors within multi-mode standardization wherever necessary. With the limited research in the area of standardization process for charging standards, there is more scope towards finding success factors for selecting a common charging standard within the multi-mode standardization process for the successful implementation of V2G technology in the European continent.

2.5 Conclusion

In this chapter, an introduction to three different modes of standardization was given. Also, various combinations of multi-mode standardization were discussed in detail with the help of various case studies from the literature. Further, the definition of success among different combinations of multi-mode standardization was explained briefly. Moreover, the factors that influence the success within standard battles were reviewed from the literature to analyze the similarities and differences between various standard battles using different MCDM approaches. While there are three crucial requirements for the implementation of V2G technology, the charging plug was considered to be the focal point in this research. Also, the three competing charging standards, i.e., CHAdeMO, CCS Combo, and Tesla supercharger were discussed in detail. Based on the analysis of the actors involved in the development of charging standards in the European continent, a combination of all three modes of standardization was found to be relevant. The next chapter focuses on the sequential steps involved in framing the research methodology.

3. Methodology

3.1 Conceptual Framework

To date, there have been very few frameworks designed to understand the various factors that contribute to the success of a dominant standard. From a market perspective, the first framework was introduced by Suarez (2004), which identifies eight essential factors to influence the outcome of a technology battle. The factors are classified under two broad categories known as *Firm-level factors* and *Environmental level factors,* each consisting of four factors, depending on their relevance. These groups of factors were analyzed further in detail by Van de Kaa et al. (2011). They identified 29 factors including the previously identified factors by (Suarez, 2004) and classified them under the following five categories of format interface: (i) Characteristics of the format supporter; (ii) Characteristics of the format; (iii) Format support strategy; (iv) Other stakeholders; and (v) Market characteristics. While the focus of the research is based on multi-mode standardization, the recent framework by Van de Kaa et al. (2020) will be considered for analyzing the success factors to select the dominant charging standard (as mentioned in section 1.3). Based on the identification of new factors in the literature, the framework will be modified accordingly by classifying them under relevant categories.

The literature review for the success factors and their description will consist of the various sources that represent the concepts of multi-mode standardization, as enlisted in the article by Wiegmann et al. (2017). Further, additional literature was reviewed based on the suggestion by Wiegmann et al. (2017) for the future scope of research in the field of success factors. The framework by Van de Kaa et al. (2020) was used further to expand the literature study for the identification of success factors within the multi-mode standardization. The articles selected for the forward research was done based on the sources of literature mentioned in Wiegmann et al. (2017) and Van de Kaa et al. (2020). The forward search for additional articles ended after the framework was clear, and there were no new factors identified. Based on the title of the research, other articles were reviewed to decide whether they can help to expand the framework. The literature review approach used in research is similar to the approach used by Van de Kaa et al. (2011, 2020) in their frameworks. Eventually, a total of 64 articles were identified to construct a new framework.

3.2 Process of data collection

While the first step in the BWM involves the identification of relevant criteria, the relevant factors were chosen from the 39 factors identified in the constructed framework. Relevant factors were listed by content analysis of the literature and interviews with three experts in the field of charging standards. The two experts (I1 & I2) belonged to the industrial background, and the third expert (I3) belonged to academic background. Before moving on to the identification of relevant factors, few questions regarding the charging standards were asked to the interviewees as follows:

- What is the potential of V2G technology in the European continent?
- What is the role of charging standards in the implementation of V2G technology?

- What are the potential candidates for charging standards that are/will be capable of V2G technology? And Why?
- Are there any specific requirements for choosing a charging standard to enable V2G technology?
- Is there a need to find a common charging standard to realize the V2G technology at a faster pace?
- According to you, what are the barriers inhibiting the standardization process?
- As an expert, are you playing any role in choosing a common standard in the market?
- According to you, which charging standard is/would be already dominant in the market?

Further, the factors from the constructed framework were discussed individually with the interviewees to identify the relevant factors. If a particular factor was selected to be relevant, the interviewees were further asked to justify the relevance behind the selection. These justifications are discussed briefly in Appendix C. All the interviews were conducted in the English language on skype and audio recorded. The transcripts of these interviews are available if needed for reference (links for audio files and transcripts are given at the end of Appendix D). As mentioned earlier in section 1.5.2, the factors were considered relevant only if they were mentioned by the interviewees or found in the literature. An overview of the information on the interviewees is given in Table 1.

Interviewee	Background	Organization	Function	Expertise
I1	Industry	EV test (Denmark)	V2G expert	Specialist in Electric Vehicles and Vehicle-to-Grid deployment.
I2	Industry	ElaadNL (Netherlands)	Project Manager Innovation	Innovation projects related to EV Smart Charging and Vehicle-to-Grid technology.
I3	Academia	Delft University of Technology (Netherlands)	Senior Research Fellow	Economics of Infrastructures, energy market developments, ongoing de/re-regulation of energy markets, policymaking on market design and its impact on the organization and operation of energy companies, co-evolution of technology and institutional arrangements.

Table 1: Information about the first round of interviewees used for identification of relevant factors

3.3 Best Worst Method

For the quantitative part of this research, the BWM approach was used to rank the relevant factors based on the interviews conducted with the experts. Before applying the BWM to an MCDM problem, a typical MCDM problem can be seen in the matrix below:

$$P = \begin{matrix} & c_1 & c_2 & \dots & c_n \\ a_1 & p_{11} & p_{12} & \dots & p_{1n} \\ a_2 & p_{21} & p_{22} & \dots & p_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_m & p_{m1} & p_{m2} & \dots & p_{mn} \end{matrix}$$

In the above matrix, $\{a_1, a_2, ..., a_m\}$ represent the alternatives of solutions, and $\{c_1, c_2, \dots, c_n\}$ represents a set of decision criteria. The values inside the matrix represent the performance of solution 'i' with respect to the criterion 'j' in the form of p_{ij}. Once the weights w_{ij} for all j are determined, the values of p_{ij} are obtained by evaluating the alternative 'i' compared to the criterion 'j'. The performance scores for p_{ij} will be obtained based on the literature review and interviews. Further, the value of p_{ij} will be multiplied with the weight of each criterion to gain a final score.

The value of p_{ij} is scored 0,3,5,7 according to a certain criterion. The score of '0' represents that the alternatives have no performance according to the criterion; '3' represents that the alternatives have poor performance according to the criterion; '5' represents that the alternatives have good performance according to the criterion; '7' represents that the alternatives have excellent performance according to the criterion. The overall score of V_i is calculated as follows:

$$V_i = \sum_{j=1}^{n} w_j p_{ij}$$

$$w_j \geq 0, \sum w_j = 1$$

The overall scores of the alternatives undergo a comparison analysis and the alternative is considered to be the best if it has the highest overall value.

BWM implementation consists of five important steps (Rezaei, 2015; 2016), and they are as follows:

Step 1 – A set of 7 criteria in the form of $(c_1, c_2, \dots, c_n)$ were determined, namely: 'characteristics of standard supporter', 'characteristics of the standard', 'standard support strategy', 'factors influencing committee consensus', 'other stakeholders', 'market characteristics', and 'factors influencing the committee composition'.

Step 2 – During the second round of interviews, the experts were asked to select the best and the worst criteria with their expertise.

Step 3 – After determining the best criteria, the experts were further asked to compare the best criteria to other criteria. The experts expressed their preferences by assigning a range of scores from 1-9 (where a score of 1 represents "i" being equally important to "j" and score of 9 represents "i" is extremely more important compared to "j") to each criterion. The results obtained from this step were considered to be Best-to-Others vector in the form of $A_B = (a_{B1}, a_{B2}, a_{B3}, \dots, a_{Bn})$, where a_{Bj} is the preference of best criterion B compared to criterion j.

Step 4 – Similarly, the experts were asked to compare the other criteria to the worst criterion with a similar range of scores 1-9, as explained in Step 3. The results obtained in this step were considered to be Others-to-Worst vector in the form of $A_W = (a_{1W}, a_{2W}, a_{3W}, \ldots, a_{nW})^T$, where a_{jW} is the preference of criterion j to the worst criterion W.

Step 5 – The final step focuses on obtaining the optimal weights for the criteria in the form of $(w_1^*; w_2^*; \ldots; w_n^*)$. A condition needs to be satisfied to get the optimal weights of the criteria. According to the condition, for each pair of w_B/w_j and w_j/w_W there should be $w_B/w_j = a_{Bj}$ and $w_j/w_W = a_{jW}$. To satisfy the condition, the solution needs to be found in such a scenario where the maximum absolute differences $|\frac{w_B}{w_j} - a_{Bj}|$ and $|\frac{w_j}{w_W} - a_{jW}|$ for all j will be minimized. Thus it results in the following problem:

$$\min \max_j \left\{ \left|\frac{w_B}{w_j} - a_{Bj}\right|, \left|\frac{w_j}{w_W} - a_{jW}\right| \right\}$$

$$\text{s.t.}$$

$$\sum_j w_j = 1$$

$$w_j \geq 0, \text{ for all } j$$

The problem can be converted into a linear problem as follows:

$$\min \xi$$

$$\text{s.t.}$$

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi, \text{ for all } j$$

$$\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi, \text{ for all } j$$

$$\sum_j w_j = 1$$

$$w_j \geq 0, \text{ for all } j$$

By solving this problem, the weights of each criterion j, i.e., 'w_j', is optimized, and a consistency ratio 'ξ^L' is obtained. When the consistency ratio is closer to zero, it shows higher consistency of the weights. Therefore, the reliability of the results is higher. For example, in one of the previous research cases that used the BWM approach (Van de Kaa et al., 2017), the consistency ratio was within the value of 0.24. Another research case shows the value of consistency ratio to be within 0.20 (Van De Kaa et al., 2017 a). Hence, it is evident that if the value of the consistency ratio is nearer to zero, the results are more accurate and reliable.

Furthermore, a recent study by Liang et al. (2020) studied the potential issues related to the consistency ratios obtained from the BWM approach and suggested threshold values for different combinations of criteria and scales. For instance, a combination of 4-criteria with a combination of 5-scale will have a threshold value of 0.2848. If the value of the obtained consistency ratio is lower than or equal to the threshold value, then that particular consistency ratio is acceptable. If the value of the obtained consistency ratio is higher than the threshold value, then it is unacceptable. The threshold values for all the combinations of criteria and scales ranging from 3 to 9 are mentioned in Table 2.

Scale	Criteria						
	3	4	5	6	7	8	9
3	0.2087	0.2087	0.2087	0.2087	0.2087	0.2087	0.2087
4	0.1581	0.2352	0.2738	0.2928	0.3102	0.3154	0.3273
5	0.2111	0.2848	0.3019	0.3309	0.3479	0.3611	0.3741
6	0.2164	0.2922	0.3565	0.3924	0.4061	0.4168	0.4225
7	0.2090	0.3313	0.3734	0.3931	0.4035	0.4108	0.4298
8	0.2267	0.3409	0.4029	0.4230	0.4379	0.4543	0.4599
9	0.2122	0.3653	0.4055	0.4225	0.4445	0.4587	0.4747

Table 2: Threshold values for a different combination of criteria and scales

[Source: (Liang et al., 2020)]

As discussed above in Steps 3 & 4, the allowable ranking scale for the experts to express their preferences ranges from 1-9. However, in a few cases, there could be fewer criteria in a group for comparison. And if most of the criteria are essential in that group, the experts might use a 3-scale (for 3-criteria) or 5-scale (for 3-criteria). While the maximum allowable range of the scale is 1-9, experts can restrict the scale to a 3-scale or a 5-scale, based on the importance of the criteria in the group. In such cases, the scale will remain the same for both the 'best to worst' and 'other to worst' criteria. Nevertheless, the consistency ratios obtained from the BWM approach in this research will be tested for acceptance as per the threshold values in Table 2.

3.4 Local and Global weights

Based on the literature analysis and expert interviews, the final list of relevant factors was listed, and hence the first step in the BWM approach was performed. During the second round of interviews, the experts were asked to perform a pairwise comparison between the categories. Thus the weight of each category was obtained, which is known as 'category weight'. A similar pairwise was performed by the experts to compare the factors in individual categories and were known as 'local weights'. Finally, global weights are calculated by multiplying both the category and local weights. A similar approach can be found in previous research using BWM (Van de Kaa et al., 2017). The information about the second round of interviewees is shown in Table 3.

Interviewee	Background	Organization	Function	Expertise
I3	Academia	Delft University of Technology (Netherlands)	Senior Research Fellow	Economics of Infrastructures, energy market developments, ongoing de/re-regulation of energy markets, policymaking on market design and its impact on the organization and operation of energy companies, co-evolution of technology and institutional arrangements.
I4	Academia	Delft University of Technology (Netherlands)	Researcher	Bi-directional charging of Fuel cell-based car to the microgrid, working on a project called Power parking, which uses the CHAdeMO standard for sharing electricity from parked cars in the airport.
I5	Academia	Delft University of Technology (Netherlands)	Professor	Electric vehicles, EV charging, PV systems, power electronics and demand-side management; solar-powered V2G electric vehicle charger compatible with CHAdeMO, CCS/COMBO and designed smart charging algorithms; power converters for EV charging, smart charging of EVs and trolley busses.
I6	Industry	ElaadNL (Netherlands)	ICT Architect	EV related communication protocols and Smart Charging related projects.
I7	Industry	EV test (Denmark)	V2G expert	Specialist in Electric Vehicles (EV) and Vehicle-to-Grid deployment.
I8	Industry	ElaadNL (Netherlands)	Project Manager Innovation	Innovative projects related to EV Smart Charging and Vehicle-to-Grid technology.
I9	Industry	Anonymous organization (Belgium)	Project Management in V2G	Projects concerning DC charging and grid integration of electrical vehicles.

Table 3: Information about the second round of interviewees used for performing BWM on the relevant factors

3.5 Ranking of alternatives

During the second round of interviews, the experts were asked to give performance scores for all the relevant factors relating to individual charging standards in the battle. The experts gave the performance scores to each factor ranging from 0 (not relevant), 3 (least relevant), 5 (relevant), and 7 (highly relevant). The relevant scores were multiplied with the individual average global weights of the factors to determine a weight of the scores. These scores were added to get a value for each charging standard. The charging standard that represents the highest value was considered as a dominant design.

During the third round of the interview, the interviewees were asked a few questions for interpretation of BWM results, as follows:

- Why do you think the top five have ended up being more important than others, do elaborate your answers?
- Why do you think the bottom five have ended up being least important than others, do elaborate your answers?
- Ideally, in any standard battles, the current installed base and technological superiority are significant factors for dominance. Still, here they ended up being essential but not in the top set of factors. Why do you think it is?
- As the EU gave the mandate for Type 2 connectors in 2014, the regulator should have been an essential influencing factor but has ended up being of less importance compared to others. Why do you think it is?
- Incentives also play a key role in getting more support in the market but have ended up being of less importance. Why do you think it could be?
- Usually, the factor Network externalities are also a quiet influencing factor, but in this scenario, it has ended up being less critical. Why do you think it is?
- Even though CHAdeMO entered early in the market, the timing of entry ended up being of less importance, Why do you think it is?
- Other than lobbying and appropriability strategy, most of the factors from standard support strategy have ended up being of less importance, why do you think it is?
- Some factors related to the committee have also ended up being quite significant; why do you think it is?
- Why do you think the Big Fish has ended up being of less importance compared to others even though their support is very important during any standards battle?
- Do you have any other comments on other factors?

During each round of interviews, it was made sure that the interviewees were aware of the factor’s description at all times, to avoid misinterpretation. There were a total of seven interviewees contacted during the research. A few among the seven interviewees were contacted multiple times for the second and third round of interviews. If the interviewees remained the same during multiple rounds, their names were changed. For example, I1 to I7, although both the interviewees are the same. These changes were incorporated because the interviews were conducted at different schedules (i.e., held on different days at different times). For clarification, the list of interviewees involved in all the three stages of interviews is shown in Table 12 (under Chapter 9). Also, the information about the third round of interviewees is mentioned in Table 4.

Interviewee	Background	Organization	Function	Expertise
I10	Academia	Delft University of Technology (Netherlands)	Senior Research Fellow	Economics of Infrastructures, energy market developments, ongoing de/re-regulation of energy markets, policymaking on market design and its impact on the organization and operation of energy companies, co-evolution of technology and institutional arrangements.
I11	Academia	Delft University of Technology (Netherlands)	Researcher	Bi-directional charging of Fuel cell-based car to the microgrid, working on a project called Power parking, which uses the CHAdeMO standard for sharing electricity from parked cars in the airport.
I12 & I12a	Industry	ElaadNL (Netherlands)	ICT Architect	EV related communication protocols and Smart Charging related projects.

Table 4: Information about the third round of interviewees used for interpretation of BWM results

3.6 Comparison of BWM results obtained from experts with different backgrounds

There were only seven interviews conducted to obtain the global weights of the factors using the BWM approach in this research. Out of seven interviews, three interviewees were from Academic background, and the remaining four experts were from an Industrial background. Therefore, to evaluate the similarities and differences between their preferences, an independent sample T-Test or Man-Whitney U test was employed to analyze whether the obtained weights were significantly different for experts from both the backgrounds. An independent sample T-Test was used if the obtained global weights of the factors were normally distributed (Julious & Freeman, 2006). Alternatively, if the global weights of the factors were not found to be normally distributed, the Mann-Whitney U test was employed (Nachar, 2008). While the number of interviews conducted for the application of BWM was minimal, the sample size used for the statistical analysis was small. However, both tests are capable of testing data from small sample sizes (Julious & Freeman, 2006; Nachar, 2008) without any issues. The statistical tests were performed using IBM SPSS 26 statistical analysis software. To determine the significant difference between the two groups of experts, the following three steps were used:

Step 1

The global weights of all the factors were evaluated to be distributed normally using the Kolmogorov-Smirnov test. The hypotheses that were assumed during the analysis are:

H_o: The global weights are normally distributed

H_1: The global weights are not normally distributed

If the p-value was found to be less than 0.05, then the null hypothesis 'H_o' would be rejected (Berg, 2020). Alternatively, if the p-value was found to be higher than 0.05, then the hypothesis 'H_1' would be rejected.

Step 2

Based on the results from the previous step, an independent sample T-Test or Mann-Whitney U test was employed to evaluate whether the global weights of the factor resulting from two different groups of experts were significantly different or not. If the global weights of the factors obtained from two groups by applying BWM were found to be normally distributed, then an independent sample T-Test was performed. During the analysis, if the p-value was found to be less than 0.05, then the global weights were found to be significantly different between both the groups (Laerd Statistics, 2020).

The analysis also shows the results for Leven's test to analyze the homogeneity of variances in the IBM SPSS software. For analyzing the results of Leven's test, the following hypotheses were assumed:

H_o: The variance is equal among the two groups

H_1: The variance is unequal among the two groups

It can be concluded that if the p-value is less than 0.05, then the null hypothesis 'H_o' would be rejected (Kent State University, 2020). If the variance is found to be unequal for any factor, then the software shows p-values in the next line by adjusting the difference in the variances between the two groups. Here the p-values were again checked for significant differences. If the p-value is less than 0.05, then there is a significant difference in means between the two groups.

Step 3

Alternatively, if the global weights of the factors obtained were not normally distributed, then the Mann-Whitney U test was used for the analysis. If the p-value was found to be less than 0.05, then it is concluded that there is a significant difference between both the groups (Nachar, 2008).

3.7 Conclusion

In this chapter, the four sequential steps were discussed to design the research methodology in the study. First, a conceptual framework was framed to identify success factors within multi-mode standardization based on the literature review of a total of 64 articles. Second, a set of questions was designed based on V2G technology to understand the opinion of the interviewees. Further, a literature review on charging standards and expert interviews would be conducted to identify the relevant factors. Third, the BWM approach was chosen for the quantitive part of the analysis and explained in detail. Finally, a set of three statistical tests to analyze the significant differences of mean global weights between the two groups of experts. The next chapter focuses on a brief description of the success factors within multi-mode standardization found in the literature and classifying them into different categories.

4. Factors for success within multi-mode standardization

A total of 64 articles were reviewed for identification of success factors within multi-mode standardization during the literature study, as mentioned in Section 3.1. In those 64 articles, a total of 10 articles were focused on standard battles from the market perspective in the literature. The ten articles were further studied to explore the concept of multi-mode standardization implicitly. Based on the implicit discussion, they were categorized under different combinations of multi-mode standardization. The resulting list of factors reconstructed the framework of Van de Kaa et al. (2011, 2020) with a total of 39 factors. Based on the relevance to the categories, the factors were categorized as well as recategorized into seven broad categories: 1.) Characteristics of standard supporter; 2.) Characteristics of the standard; 3.) Standard support strategy; 4.) Factors influencing committee consensus; 5.) Other stakeholders; 6.) Market characteristics and 7.) Factors influencing the committee composition. The following section will focus on giving a brief explanation about the individual categories and the factors that belong to them. Further, the influence of individual factors on the standardization process will be explained in Appendix A. Appendix B shows the sources in the literature study categorized into four different combinations of multi-mode standardization.

4.1 Characteristics of standard supporter

The first category of factors signifies the strength of the standard supporter or a group supporting a particular standard. In the standardization process, the higher strength of the standard supporter increases the chances of the supported standard reaching dominance. As the cost of developing a standard requires investments until it reaches dominance, firms with higher 'financial strength' can afford to be involved in the standardization process for an extended period. Such firms can focus on various strategies to use their finances to increase their bargaining power in the standardization process and to further enhance the chances of setting a dominant standard (Blind & Mangelsdorf, 2016; Van de Kaa et al., 2011). While the 'brand reputation and credibility' plays a critical role in attracting new customers in the market, it is based on the past performances of a firm or group of standard supporters in the market. It helps to create legitimacy and attract more stakeholders to the group, eventually resulting in the increased installed base (T. Egyedi & Spirco, 2011; Van de Kaa et al., 2011; van den Ende et al., 2012). When a firm or group of firms can exploit their resources more efficiently compared to their competition in the standardization process, they obtain 'operational supremacy,' which enhances the chances of the supporting standard achieving dominance (Van de Kaa et al., 2011; Wakke et al., 2015). 'Learning orientation' also plays a crucial role in establishing a knowledge base for a firm or group of firms that allows them to avoid repeating mistakes from previous experiences. It also increases the absorptive capacity, which in turn helps to enhance the chances of reaching dominance (Funk & Methe, 2001; Markard & Erlinghagen, 2017; Van de Kaa et al., 2011).

4.2 Characteristics of the standard

The second category of factors pertains to the superiority of the standard itself compared to the other standards, allowing it to gain higher chances of becoming dominant in a standardization process. Most of the thriving technologies in history show that 'technological superiority' of a standard allows them to have a competitive advantage over the other competing standards. Thus it increases the chances of that standard to become dominant. Nevertheless, it is not entirely necessary to have superior technology to reach dominance (Van de Kaa et al., 2011). With the changes in technology, newer versions of standards are introduced frequently with better performances. However, if the latest standard lacks backward 'compatibility' with the immediate previous versions of the technology, then it has fewer chances of reaching dominance (Fukami & Shimizu, 2018; Van de Kaa et al., 2011). Whenever a new product is launched based on a particular technology, 'complementary goods' play an essential role in the commercialization of that technology. Hence, with the increase in the number of complementary goods supporting a particular standard helps increase the chances of that standard becoming dominant (Van de Kaa et al., 2011; van den Ende et al., 2012). Similar to the 'compatibility' factor, the 'flexibility' of a standard is equally important that needs attention with the new developments in the technology. 'Flexibility' of a standard refers to the ability to incorporate the desired changes in the customer needs along with the technological improvements. And such incorporation entails the firm representing a standard with incremental costs and time required to adapt to new developments (Van de Kaa et al., 2011). Higher flexibility of a standard increases the chances of reaching dominance (van den Ende et al., 2012).

4.3 Standard support strategy

The third category of factors refers to the various strategies developed and used by the firms or groups of firms in promoting a standard to reach dominance in a standardization process successfully. One of the essential strategies used by the firms pertains to the pricing of a standard. The 'pricing strategy' is used by firms to increase their market share by reducing the prices temporarily to block new entrants or competitors, and it also helps to attract new stakeholders to support the standard to reach dominance (Pelkmans, 2001; Van de Kaa et al., 2011). While on the one hand, some firms use strategies to protect their standards from being imitated by other firms (Van de Kaa et al., 2011). And on the other hand, some firms use open systems as a strategy to allow other firms to develop the standard as a collective group. Such an approach is known as the 'Appropirablity strategy.' However, open systems are positively related to attracting supporting stakeholders, which in turn increases the chances of achieving a dominant standard (Dan, 2019; Garud et al., 2002). Another vital strategy pertains to the point in time when the standard is developed and diffused in the market. Early 'timing of entry' increases the installed base and is considered to contribute positively to achieve the dominant standard (Van de Kaa et al., 2011; Vercoulen & van Wegberg, 1998). Early timing also allows the firms to 'pre-empt scarce assets,' and provides a competitive advantage against the rivals to gain a dominant position in the market (Van de Kaa et al., 2011). Obtaining scarce assets also helps in gaining more support from other stakeholders, which in turn increases the chances of achieving success in selecting a dominant standard (Blind & Gauch, 2008). The next strategy revolves around the role played by the customers and helps the firm to gain a dominant position in the market and is known as 'market communications'. It is used by firms to pre-announce the developments of their standards before the market release. Customers tend to form expectations about the standards before they get introduced into the market. Hence, market communications strategy helps the firm to gain more customer support and increase the chances of achieving a dominant standard (Van de Kaa et al., 2011). During the diffusion of a standard, a good 'distribution strategy' increases the strength of a firm's distribution system, eventually allowing that standard to dominate in the market (Van de Kaa et al., 2011). For a particular standard to become dominant, 'commitment' from all the relevant stakeholders in a standardization process is an essential factor in achieving success (Markard & Erlinghagen, 2017). 'Lobbying' is used as a strategy by firms or a group of firms to gain support from various stakeholders (especially government representatives) in the standardization process to increase the chances of the supporting standard to gain dominance (De Vries & Verhagen, 2016; Mattli & Büthe, 2003; Meyer, 2012).

4.4 Factors influencing committee consensus

The fourth category is mainly related to the factors that influence building consensus within a committee in a standardization process. The first factor within this category is 'voting rights'. It refers to the rights possessed by the members to vote committee, which in turn influences the final consensus in the standardization process. Usually, when the committee is unable to reach an agreement from all the relevant stakeholders voting is considered a last resort to avoid a deadlock (Schmidt & Werle, 1998). Hence, voting rights play a crucial role in such a standard-setting. As per the literature, the lesser the number of personnel possessing voting rights, it is faster to reach consensus. Further, stakeholders are reluctant to invest their time and money to support a particular standard without motivation to participate in a committee (Blind & Mangelsdorf, 2016). Therefore, 'incentives for consensus-building' serves as an important factor, and providing sufficient incentives can attract more stakeholders to support a standard (Van De Kaa & De Bruijn, 2015). Therefore, higher incentives will increase the chances of selecting a dominant standard. Furthermore, the 'consensus rules in a standardization process' govern consensus-building in a committee. These rules are pre-determined, and a set of stringent rules could hinder the process of reaching consensus (Garud et al., 2002; Leiponen, 2008). Hence, the stringent rules might create conflicting interests within stakeholders and reduce the likelihood of choosing a dominant standard. Conflicting interests also lead to the 'dealy in the standardization process' making it a costly process and results in frustration among stakeholders. Such a delay leads to loss of incentives or sunk costs for many members (Van De Kaa & De Bruijn, 2015). Therefore, long-term delays reduce the possibility of arriving at a consensus to select a dominant standard. The next factor is related to the 'number of standard proposals and revisions' being submitted by various stakeholders in the committee that usually results in the delay of the standardization process (Simcoe, 2003). Hence, the higher the number of standard proposals in the committee, the longer it takes to arrive at a consensus. The last factor in the category is 'agenda-setting efforts,' which is used as a tool by any member in the standardization process to align the interests and increase the awareness about possible standards among stakeholders (Meyer, 2012; Van de Kaa et al., 2020). Therefore, increase in the agenda setting efforts could leads to increased collaboration, eventually helping to reach a successful consensus.

4.5 Other stakeholders

The fifth category of factors signifies the support from stakeholders other than the standard supporters. The first two factors in the category are related to the customer base supporting a particular standard known as 'current installed base' and 'previous installed base'. The term 'current installed base' refers to the number of users of a technology that is implemented already, and is being used currently in the market (Van de Kaa et al., 2011). And 'previous installed base' refers to the number of users that followed a particular technology representing a firm in the past, and they could become potential customers for new standards developed by the same firm (Van de Kaa et al., 2011). In both cases, the increase in the installed base increases the chances of achieving a dominant standard. The third factor is known as the 'Big fish,' which refers to the size and power of a firm participating in the standardization process. Usually, the 'big fish' exercises its influence by promoting a standard or supporting it with financial resources (Van de Kaa et al., 2011). Hence, a 'big fish' is positively related to obtaining a higher bargaining position and increasing the chances of a standard to become dominant in a standardization process (Blind & Mangelsdorf, 2016; de Vries et al., 2011). The next factor,'Anti-trust laws' is used by the government judiciaries to impose regulations against a standard to prohibit its dominance in the market. Such regulations help to reduce the dependency on one single standard in the market (Cabral & Kretschmer, 2006; Van de Kaa et al., 2011). However, such interventions can hinder the growth of standards in a standardization process. Therefore, fewer interventions can allow firms to produce their standards and achieve success. The government also plays a role of 'regulator' in a standardization process, where it prescribes a standard of its own or sometimes enforce a privately developed standard all over the country (Borraz, 2007; de Vries et al., 2011). Government acknowledgment also plays a crucial role in creating legitimacy among customers and helps in the adoption of standards successfully (T. Egyedi & Spirco, 2011). The last factor in the category is the 'suppliers'. They produce complementary goods and services based on the dominant standard in the market. Firms can influence suppliers by incentives to support their standards, and such support can increase the chances of that standard reaching dominance (Van de Kaa et al., 2011).

4.6 Market characteristics

The sixth category pertains to the factors that cannot be influenced by any firm or group of firms. Nevertheless, such factors are capable of indirectly influencing the outcome in a standardization process. When a standard has been chosen by few firms to solve a particular problem in the market, other market players tend to follow the same standards as the solution that is readily available for implementation, and this process is known as the 'Bandwagon effect' (Van de Kaa et al., 2011). An increase in the Bandwagon effect leads to higher chances of success in achieving a dominant standard. The next factor is the 'network externality'. This factor refers to the rise in the utility of a product to one customer with every new customer using the same product (Van de Kaa et al., 2011). Hence, higher network externality increases the installed base of a particular standard and is positively related to enhancing the chances of achieving a dominant standard. During a standardization process, the number of standards competing against each other has a significant role to play in acquiring a market share (Van de Kaa et al., 2011). When there is a lesser 'number of options available' in a standardization process, it increases the likelihood of choosing a common standard. On the contrary, the increase in the number of competing standards leads to higher 'uncertainty in the market', which eventually reduces the chances of selecting a dominant standard (Ranganathan et al., 2018). While technology changes rapidly in the market, the 'rate of change' can affect the standardization process negatively as the stakeholders cannot commit to one particular standard due to a rise in risk and uncertainty (Van de Kaa et al., 2011). And if some stakeholders are committed to one specific standard in the market, the 'switching costs' involved can be significant if the standard turns out to be on the losings side in the standardization process (van Wegberg, 2004; Vercoulen & van Wegberg, 1998). Hence, higher switching costs can reduce the chances of adopting a common standard (Van de Kaa et al., 2011). A relatively new factor known as 'community development' in the literature refers to the formation of a coalition with communities with similar interests in a particular standard. And such coalitions nurture the development of communities in society (Fukami & Shimizu, 2018; Garud et al., 2002). Hence, higher community development can help the growth of a standard and eventually increase the likelihood of selecting a dominant standard.

4.7 Factors influencing the committee composition

The final category refers to the factors that influence the composition of a committee. While the factors in this category focus on the composition of a committee, the term committee is redefined here. To avoid misinterpretations, it is defined as the firms or groups of firms participating in a consortium, alliance, or committee under one group. The first factor in this category is 'cost to participate' in a committee, which can take up two different forms in terms of financial constraints for firms or a group of firms participating in the committee. Firstly, firms need to pay membership fees to the committee for the services rendered during the standardization process, and high membership fees could be a hurdle for small firms to participate in the committee (Leiponen, 2008). Secondly, firms need to invest their time and money in collaboration for each consecutive meeting to support their interest in the committee. And excessive delays during the process of reaching consensus could result in sunk costs (Van De Kaa & De Bruijn, 2015). Hence, the lesser the cost for participation in the standardization process, the more number of stakeholders can participate and increase the chances of achieving a common standard. The second factor is the 'size of the committee' that refers to the number of firms or groups of firms supporting one particular standard in a committee. Therefore, an increase in the size of the committee leads to a higher probability of developing the standards successfully (Axelrod et al., 1995; Dan, 2019; Hail et al., 2010). The third factor pertains to the diversity of the 'network of stakeholders' supporting a particular standard in a committee. Diversity in the stakeholders brings various technology experts to the table, allowing them to consider all the possible scenarios in the standardization process from a technical perspective. Therefore, the higher diversity of the network of stakeholders in a committee increases the chances of selecting a common standard (De Vries & Verhagen, 2016; Van de Kaa et al., 2011). The final factor in the category is the 'number of firm-specific representatives in the committee' that refers to the number of representatives from a particular firm (for example including individual employees and engineers) in a committee supporting one specific standard (Fukami & Shimizu, 2018). These representatives add significant weightage during the discussions based on their skillsets in the committee, which collectively gives a strong position to the firm in the standardization process. Hence, higher firm representatives enhance the status of a stakeholder in the committee and help them in the selection of a dominant standard.

4.8 Conclusion

In this chapter, a total of 39 factors were found to essential within multi-mode standardization. These factors were classified into seven different categories. The factors were briefly discussed to understand their influence in the standard battle from a measurable perspective. The next chapter focuses on addressing the results obtained from the experts by applying the BWM approach.

5. Results

5.1 Selection of relevant factors

The case of standardizing the charging standards for the implementation of V2G technology during this research was further studied by using the BWM approach. While the first step in BWM pertains to the identification of relevant factors (as mentioned in Section 3.3), the constructed framework in section 4 was used to determine the relevant factors by a combination of literature review and interviews with the experts. From a total 39 factors in the framework, 35 factors were found to be relevant, namely: 'financial strength', 'brand reputation and credibility', 'operational supremacy', 'learning orientation', 'technological superiority', 'compatibility', 'flexibility', 'pricing strategy', 'appropriability strategy', 'market communications', 'pre-emption of scarce assets', 'distribution strategy ', 'commitment', 'lobbying', 'voting rights', 'incentives for consensus-building', 'consensus rules in the standardization process', 'delay in standardization process', 'number of standard proposals & revisions', 'agenda-setting effort', 'current installed base', 'previous installed base', 'big fish', 'suppliers', 'regulator', 'bandwagon effect', 'network externalities', 'uncertainty in the market', 'rate of change', 'switching costs', 'community development', 'size of the committee', 'network of stakeholders', and 'number of firm-specific representatives in the committee'. The relevance of each factor has been discussed briefly in Appendix C. Figure 2 shows the list of relevant factors along with their categories.

5.2 Strength of relevant factors

Further, the remaining BWM steps from 2 to 5 (as mentioned in Section 3.3) were applied to determine the strength of the relevant factors, along with the values of consistency ratios. First, the experts were asked to make pairwise comparisons between the seven categories to obtain the category weights. Secondly, a similar comparison was made by the experts to determine the local weights of the factors within each category. Then the global weights of all the factors were determined by multiplying the local weights of each factor with the category weights of the respective factor category. The global weights of individual factors were considered to be the strength of those factors corresponding to an individual interviewee. Further, the average of the global weights was calculated for all the seven interviews, which resulted in determining the overall strength of individual factors (known as Average global weights). Based on these global weights, the results show that the top five factors with the highest weights were 'brand reputation and credibility', 'compatibility', 'financial strength', 'bandwagon effect', and 'lobbying'. The application of the final step of BWM resulted in obtaining the consistency ratio (ξ^L), which corresponds to the consistency of the scores recorded from the interviews. After comparing the consistency ratios of all the categories in each interview with the threshold values (as discussed in Table 2), it was found that all the consistency ratios were within the range of respective threshold values. Therefore, all the consistency ratios were accepted during the analysis and are shown in Table 5. Table 6 shows the values of local and global weights for all the factors along with their categories. The comparison results are shown in Appendix E.

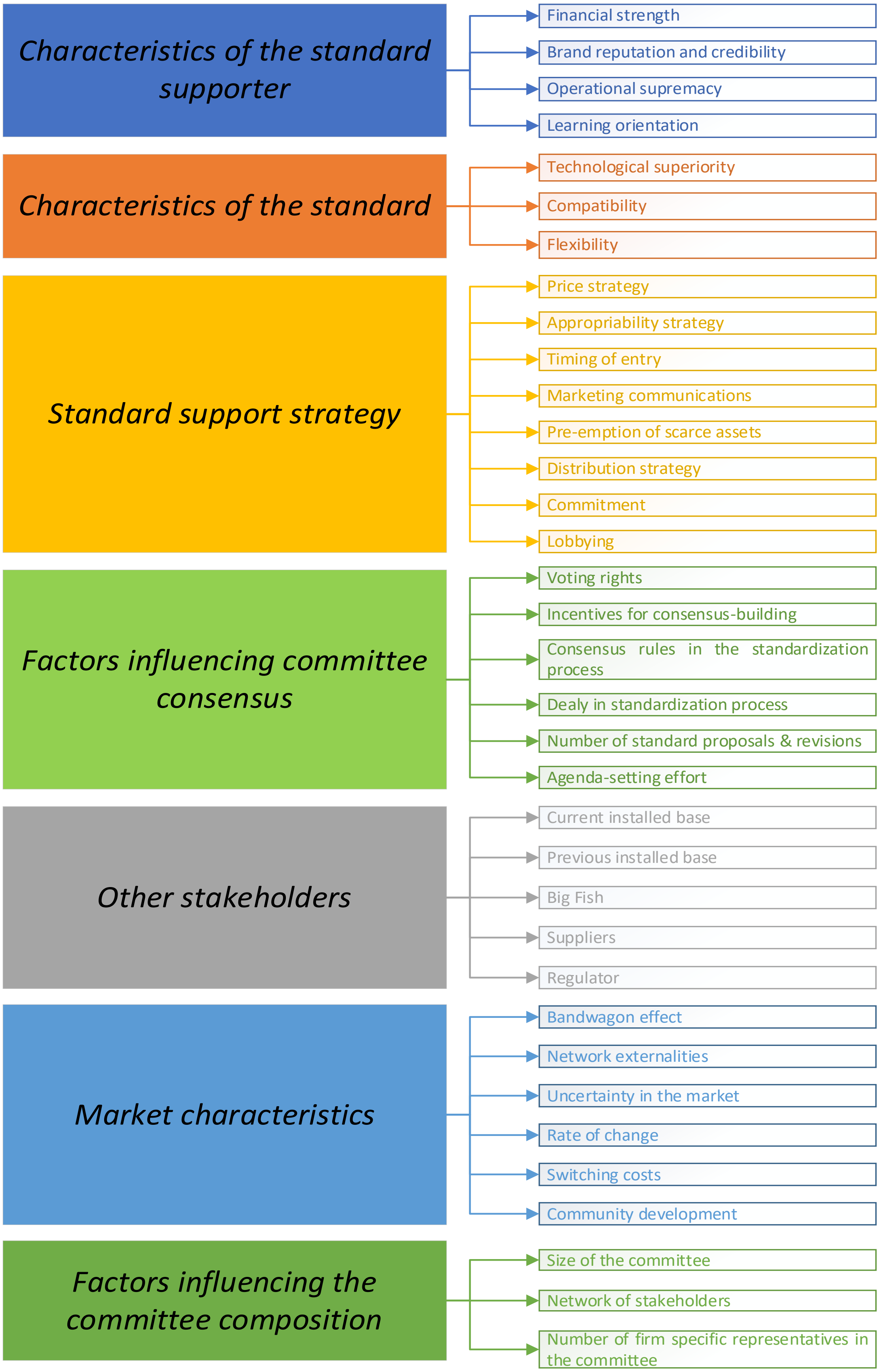

Figure 2: Overview of the 35 relevant factors with their categories

Categories	ξ^{L*} Experts							Average ξ^{L*} value
	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	
Characteristics of standard supporter	0.0916	0.1071	0.0786	0.1049	0.0714	0.0916	0.1215	0.1142
Characteristics of the standard	0.0417	0.0750	0.0417	0.1524	0.1091	0.0417	0.1319	0.0899
Standard support strategy	0.0628	0.0664	0.0684	0.1348	0.0664	0.0664	0.0567	0.0757
Factors influencing committee consensus	0.0805	0.961	0.0819	0.0846	0.0999	0.0829	0.0865	0.0891
Other stakeholders	0.669	0.0768	0.0641	0.1536	0.0853	0.0573	0.0904	0.0898
Market characteristics	0.0705	0.1226	0.0820	0.0979	0.1004	0.0829	0.0787	0.0925
Factors influencing the committee composition	0.0417	0.0833	0.1250	0.1524	0.0889	0.0893	0.0889	0.0993

Table 5: BWM results of Consistency ratio (ξ^{L}) for individual categories

Categories & Factors	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Local average weight	Global average weight
Characteristics of standard supporter	**0.0784**	**0.1486**	**0.3030**	**0.3492**	**0.3506**	**0.1460**	**0.2013**		**0.2253**
Financial strength	0.0168	0.0283	0.0905	0.1809	0.1002	0.0234	0.1162	0.3246	0.0795
Brand reputation and credibility	0.0431	0.0425	0.1572	0.1088	0.1753	0.0802	0.0469	0.4197	0.0934
Operational supremacy	0.0060	0.0690	0.0362	0.0435	0.0501	0.0312	0.0281	0.1765	0.0377
Learning orientation	0.0126	0.0088	0.0191	0.0160	0.0250	0.0111	0.0102	0.0792	0.0147
Characteristics of the standard	**0.1944**	**0.0743**	**0.1136**	**0.0856**	**0.0854**	**0.3504**	**0.0805**		**0.1406**
Technological superiority	0.0567	0.0427	0.0189	0.0155	0.0217	0.0584	0.0062	0.2419	0.0315
Compatibility	0.1053	0.0242	0.0616	0.0644	0.0559	0.1898	0.0602	0.5875	0.0802
Flexibility	0.0324	0.0074	0.0331	0.0057	0.0078	0.1022	0.0142	0.1706	0.0290
Standard support strategy	**0.0273**	**0.3616**	**0.0379**	**0.2140**	**0.2134**	**0.2190**	**0.1342**		**0.1725**
Pricing strategy	0.0030	0.0240	0.0029	0.0166	0.0142	0.0073	0.0219	0.0850	0.0128
Appropriability strategy	0.0045	0.1201	0.0036	0.0166	0.0213	0.0436	0.0219	0.1621	0.0331
Timing of entry	0.0074	0.0120	0.0119	0.0145	0.0425	0.0291	0.0032	0.1479	0.0172
Marketing communications	0.0007	0.0360	0.0010	0.0290	0.0283	0.0145	0.0146	0.0855	0.0178
Pre-emption of scarce assets	0.0023	0.0206	0.0073	0.0065	0.0121	0.0125	0.0073	0.0758	0.0098
Distribution strategy	0.0018	0.0288	0.0018	0.0145	0.0170	0.0175	0.0073	0.0680	0.0127
Commitment	0.0045	0.0480	0.0021	0.0290	0.0071	0.0218	0.0219	0.1124	0.0192
Lobbying	0.0030	0.0721	0.0073	0.0873	0.0709	0.0727	0.0362	0.2634	0.0499
Factors influencing committee consensus	**0.1177**	**0.2229**	**0.0909**	**0.1427**	**0.1067**	**0.0328**	**0.0336**		**0.1068**
Voting rights	0.0182	0.0837	0.0372	0.0464	0.0102	0.0029	0.0035	0.2207	0.0289
Incentives for consensus-building	0.0452	0.0263	0.0037	0.0292	0.0123	0.0035	0.0145	0.2002	0.0192
Consensus rules in the standardization process	0.0109	0.0350	0.0064	0.0292	0.0088	0.0043	0.0025	0.1164	0.0139
Delay in standardization process	0.0273	0.0175	0.0223	0.0195	0.0044	0.0058	0.0058	0.1549	0.0147
Number of standard proposals & revisions	0.0051	0.0526	0.0149	0.0146	0.0506	0.0146	0.0058	0.2344	0.0226
Agenda-setting effort	0.0109	0.0078	0.0064	0.0038	0.0204	0.0017	0.0015	0.0734	0.0075
Other stakeholders	**0.1569**	**0.0637**	**0.2273**	**0.0300**	**0.0711**	**0.0876**	**0.1342**		**0.1101**
Current installed base	0.0665	0.0289	0.0291	0.0062	0.0052	0.0364	0.0558	0.2994	0.0326
Previous installed base	0.0385	0.0169	0.0583	0.0010	0.0032	0.0207	0.0226	0.1799	0.0230
Big Fish	0.0192	0.0085	0.1020	0.0062	0.0352	0.0138	0.0170	0.2418	0.0288
Suppliers	0.0070	0.0027	0.0146	0.0027	0.0069	0.0063	0.0049	0.0642	0.0064
Regulator	0.0257	0.0068	0.0233	0.0140	0.0206	0.0104	0.0340	0.2147	0.0192
Market characteristics	**0.3581**	**0.0396**	**0.0758**	**0.1070**	**0.0305**	**0.1095**	**0.3356**		**0.1509**
Bandwagon effect	0.1357	0.0190	0.0310	0.0262	0.0122	0.0488	0.0793	0.3699	0.0503
Network externalities	0.0322	0.0079	0.0093	0.0175	0.0077	0.0057	0.0317	0.1394	0.0160
Uncertainty in the market	0.0805	0.0030	0.0075	0.0105	0.0038	0.0193	0.0264	0.1253	0.0216
Rate of change	0.0402	0.0048	0.0124	0.0035	0.0026	0.0145	0.0132	0.0979	0.0130
Switching costs	0.0537	0.0034	0.0124	0.0419	0.0011	0.0096	0.0528	0.1536	0.0250
Community development	0.0158	0.0016	0.0031	0.0075	0.0031	0.0116	0.1321	0.1139	0.0250
Factors influencing the committee composition	**0.0672**	**0.0892**	**0.1515**	**0.0713**	**0.1423**	**0.0547**	**0.0805**		**0.0938**
Size of the committee	0.0196	0.0081	0.0126	0.0129	0.0917	0.0039	0.0089	0.2105	0.0225
Network of stakeholders	0.0364	0.0227	0.1073	0.0537	0.0348	0.0323	0.0519	0.5336	0.0484
Number of firm-specific representatives in the committee	0.0112	0.0584	0.0316	0.0048	0.0158	0.0186	0.0197	0.2559	0.0229

Table 6: BWM results for Local and Global weights of factors and categories

5.3 Statistical analysis of the BWM results

The global weights obtained from the BWM approach were compared between two groups of experts, i.e., Academic and Industrial experts. The comparison study was performed to evaluate the significant differences between their preferences. For example, it was tested whether the mean global weight for the factor ‘delay in the standardization process’ obtained from Academic experts is significantly different compared to one obtained from Industrial experts. The tests used to analyze the significant differences are ‘Independent sample T-Test’ or ‘Mann-Whitney U test’. To determine the type of test for analysis, the normal distribution of global weights was evaluated using the Kolmogorov-Smirnov test (as mentioned in section 3.6). If the global weights were found to be normally distributed, then ‘Independent sample T-Test’ was used for the analysis. Alternatively, if the global weights were not found to be normally distributed, then the ‘Mann-Whitney U test’ was used for the analysis. Out of 35 relevant factors, the global weights of 9 factors were not found to be normally distributed, and hence the ‘Mann-Whitney U test’ was used for analysis. For the remaining 26 factors, ‘Independent sample T-Test’ was used for analysis. The corresponding type of tests used for analyzing the significant difference for each factor is shown in Table 7. The final results obtained from the IBM SPSS software are shown in Appendix D. The results from the ‘Independent T-Test’ show that ‘dealy in the standardization process’ (with a p-value of $0.037<0.05$) was the only factor that was found to be significantly different. Hence, the factor ‘dealy in the standardization process’ was not considered for naming the top, medium, and least influencing factors. Moreover, the results of Leven’s test show that the factors ‘appropriability strategy’, ‘timing of entry’, ‘marketing communications’, ‘distribution strategy’, ‘big fish’, ‘uncertainty in the market’, and ‘network of stakeholders’ had unequal variances between the two groups (i.e, p-value < 0.05). However, the adjusted p-values for these corresponding factors were higher than 0.05. Therefore, these factors were considered for naming the top, medium, and least influential factors. Finally, none of the factors were found to be significantly different between the academic and industrial experts based on the results of the ‘Mann-Whitney U test’.

5.4 Conclusion

In this chapter, a total of 35 factors out of 39 factors were found to be relevant as per the literature review and expert’s interview. Further, the top five influential factors in the charging standards battle were obtained using the BWM results, namely: ‘brand reputation and credibility’, ‘compatibility’, ‘financial strength’, ‘bandwagon effect’, and ‘lobbying’. Finally, the relevant statistical tests were performed to analyze the significant differences between the two groups of experts. The results showed that the factor ‘dealy in the standardization process’ was the only factor that was found to be significantly different. Therefore, it was not considered for naming the influential factors in this research. The next chapter focuses on analyzing the results obtained using the BWM approach.

Factors	Normally distributed	Type of test used for analysis
Brand reputation and credibility	Yes	Independent Sample T-Test
Compatibility	No	Mann-Whitney U Test
Financial strength	Yes	Independent Sample T-Test
Bandwagon effect	Yes	Independent Sample T-Test
Lobbying	Yes	Independent Sample T-Test
Network of stakeholders	Yes	Independent Sample T-Test
Operational supremacy	Yes	Independent Sample T-Test
Appropriability strategy	No	Mann-Whitney U Test
Current installed base	Yes	Independent Sample T-Test
Technological superiority	Yes	Independent Sample T-Test
Flexibility	No	Mann-Whitney U Test
Big Fish	No	Mann-Whitney U Test
Voting rights	Yes	Independent Sample T-Test
Switching costs	Yes	Independent Sample T-Test
Community development	No	Mann-Whitney U Test
Previous installed base	Yes	Independent Sample T-Test
Number of firm-specific representatives in the committee	Yes	Independent Sample T-Test
Number of standard proposals & revisions	No	Mann-Whitney U Test
Size of the committee	No	Mann-Whitney U Test
Uncertainty in the market	Yes	Independent Sample T-Test
Regulator	Yes	Independent Sample T-Test
Incentives for consensus-building	Yes	Independent Sample T-Test
Commitment	Yes	Independent Sample T-Test
Marketing communications	Yes	Independent Sample T-Test
Timing of entry	Yes	Independent Sample T-Test
Network externalities	Yes	Independent Sample T-Test
Learning orientation	Yes	Independent Sample T-Test
Delay in standardization process	Yes	Independent Sample T-Test
Consensus rules in the standardization process	No	Mann-Whitney U Test
Rate of change	No	Mann-Whitney U Test
Pricing strategy	Yes	Independent Sample T-Test
Distribution strategy	Yes	Independent Sample T-Test
Pre-emption of scarce assets	Yes	Independent Sample T-Test
Agenda-setting effort	Yes	Independent Sample T-Test
Suppliers	Yes	Independent Sample T-Test

Table 7: Type of test used for analyzing the global weights of the factors

6. Discussion

6.1 Identification of factors in a situation of multi-mode standardization

The first step towards answering the main research question in this thesis was to divide it into three sub-research questions. To answer the first sub-research question, *"What are the success factors that influence the selection of dominant standards in a situation of multi-mode standardization?"*; a refined framework was constructed as an extension to the previous framework by Van de Kaa et al. (2020). The initial step in constructing the framework focused on reviewing the literature and identifying relevant articles related to multi-mode standardization. While the concept of multi-mode standardization was first introduced by Wiegmann et al. (2017), they have briefly discussed case studies related to standardization (with corresponding citations) from the previous literature and categorized them into four combinations of multi-mode standardization in their article. Therefore, these case studies were reviewed extensively along with additional literature sources, to identify the success factors based on the four combinations of multi-mode standardization. The process of identification of the success factors was more straightforward when the reviewed literature clearly discussed the concept of the multi-mode standardization process. In some cases, the authors did not precisely discuss the mode of standardization. Therefore there was a need to analyze such cases thoroughly before considering them for identifying the success factors. Similar issues were found during the identification of success factors. Some authors particularly mentioned the name of the factors in their case studies making it easier to identify those factors. And some authors indirectly implied the name of the factors which needed some efforts to analyze properly. Nevertheless, the first sub-research question was answered by identification of 39 factors that influence the success of selecting dominant standards in a situation of multi-mode standardization.

The framework of Van de Kaa et al. (2011, 2020) was expanded to a total of 39 factors and categorized into seven categories. In the proposed framework, some factors were recategorized based on their relevance in those categories. There were no addition or deletion of factors in the first two categories, i.e., 'characteristics of the standard supporter' and the 'characteristics of the standard'. Therefore both these categories consist of four factors each, as per the framework of Van de Kaa et al. (2011). In the third category 'standard support strategy', there was an addition of one factor known as 'lobbying'. The fourth category 'market characteristics' had an addition of a new factor known as 'community development'. As the factor 'community development' pertains to the collaboration of the firms with the developers in the market/society, it was added in the category of 'market characteristics'. A significant modification was done within the next category known as 'other stakeholders'. In this category, one of the factors 'effectiveness of the format development process', describes that the standards are usually developed by either one single firm, a group of firms, or by official SDOs in the standardization process. Further, the standardization process can be affected by differences in aspects such as decision rules, process management, and stakeholder involvement in the groups (Van de Kaa et al., 2011). This particular factor was removed and expanded into two new categories known as ‘factors influencing committee consensus’ and ‘factors influencing committee composition’ (Van de Kaa et al., 2020). The expansion of the categories was made to explore the new set of factors affecting the effectiveness of standard development processes in the literature. The new factors were then classified under new categories based on their influence in the standardization process. The category ‘factors influencing committee consensus’ represents the factors responsible for arriving at a consensus in the committee, whereas the other category ‘factors influencing committee composition’ represents the factors accountable for the involvement of members in the committee. While the factor ‘network of stakeholders’ is more influential within a committee rather than in the category ‘other stakeholders’, it was recategorized into the category ‘factors influencing committee composition’. Another reason revolves around the fact that ‘other stakeholders’ category influences the standardization process without any direct involvement, however participating in the committee allows to have a larger influence. After the reduction of two factors in the category ‘other stakeholders’, the remaining six factors were used to form the fifth category in the proposed framework. The sixth category ‘factors influencing committee consensus’ consists of five new factors from the literature, and one of the factors ‘agenda-setting efforts’ was derived from the framework of Van de Kaa et al. (2020). While the agendas are set inside the committees to align interests among the members to reach consensus, the factor ‘agenda-setting effort’ was categorized into the category ‘factors influencing committee consensus’. The last category ‘factors influencing committee composition’ consists of four new factors from the literature.

6.2 Discussion of multi-mode standardization in the previous literature

The second step in this research was focused on re-analyzing the previous literature to check whether the concept of multi-mode standardization was discussed in them. To answer the second sub-research question, *“To what extent does the concept of multi-mode standardization discussed implicitly in the literature?”*, a further literature study was extended with the sources that discuss success factors within the framework of Van de Kaa et al. (2011). Previously, the suggested sources discussed the success factors within standard battles from the market-based perspective along with the framework itself. A total of 10 articles were re-analyzed individually to find whether they are purely market-based or they implicitly discuss the concept of multi-mode standardization.

Anderson & Tushman (1990) proposed a cyclical model that explains the evolution of technology before it emerges as a ‘dominant design’ in the market. The technological cycle is divided into two eras of technological change known as ‘Era of ferment’ and ‘Era of incremental change’. The ‘Era of ferment’ further refers to the two types of competition between the competing technologies, namely: ‘competition between technological regimes’ and ‘competition within technological regimes’. And the ‘Era of incremental change’ refers to the incremental evolution of technology after it has emerged as the dominant design in the market. Even though there is no discussion on the process of standardization, the term ‘dominant design’ has been coupled with the term ‘industrial standard’ throughout the article. Furthermore, the competition between different technologies in the ‘Era of ferment’ results in the selection of dominant design or an industrial standard, which is comparable with the concept of selecting standards within a standards battle. The authors also discuss the emergence of dominant designs in different ways, which indirectly pertains to multiple modes of standardization. For example, the emergence of computer protocols has been discussed as a committee-based standard. However, the same example has been considered as a case of the committee-and market-based standard by Farrell & Saloner (1988). Another example pertains to the emergence of Television (TV) standards in the USA as a government-based standard. The same example has been discussed from a market-based perspective by Besen & Farrell (1994), where he focuses on the strategies that can be incorporated by individual companies to outperform in the standards battle. However, there were many important actors involved in the standardization of color TV in the USA such as the National Television Systems Committee (NTSC), the US government agency Federal Communications Commission (FCC) and also the broadcasting networks such as Radio Corporation of America (RCA) (a leading manufacturer of black and white TV sets) along with its competitor CBS corporation (a leading manufacturer of color TV sets) in the standardization (Shapiro & Varian, 1999a). Hence, the articles by Anderson & Tushman (1990), and Shapiro & Varian (1999) are considered under the multi-mode standardization category.

Besen & Farrell (1994) propose different types of strategies that could be used by individual firms when competing in a standardization process. These strategies vary with the three types of competition that take place in standards battle. The first type of competition is known as ‘Tweedledum and Tweedledee’, where different firms compete against each other to select the industry standard in the standards battle between two incompatible standards. The second type of competition is known as the ‘Battle of Sexes’, where the two competing firms compete within a compatible standard and have different preferences of technology. In the third type of competition, a more prominent firm prefers to maintain a proprietary standard, and the competing smaller firm wishes to join the rival’s network to have a better position in the competition. Here the smaller firm is known as ‘pesky little brother’. Even though Besen & Farrell (1994) have not explicitly mentioned anything regarding the committee- and market-based standards, they have suggested a strategy for a sponsor to attract rivals to its network by allowing a neutral third party to decide on the selection of dominant standards. The neutral third party in this scenario could be considered as a committee. For example, the Open Software Foundation (an industry-sponsored software developing association) was established to remove control from a single software developer over the development of Unix-based software and increase support from other market players (Besen & Farrell, 1994). Hence, the article by Besen & Farrell (1994), is categorized under multi-mode standardization.

Suárez & Utterback (1995) discusses the effect of technology evolution on the survival of the industries in the market. The authors focus on determining how the entry of a firm into the market pre- and post dominant design affects them in their survival. While the article is purely related to the survival of individual firms from the market perspective, it also mentions about external influencing entities that can affect the selection of dominant designs. Furthermore, it discusses a similar example as discussed above, where RCA had an advantage from the FCC to establish a dominant design in the US TV industry. Even though the role of NTSC has been ignored in this article, it was undoubtedly involved in the standardization of TV sets (as discussed above). The authors also argue that the role of government is not restricted as a regulating body alone in the emergence of dominant design. It can extend further towards purchasing products in the early stages of an industry, making those products more favorable in the industry, which will eventually gain more support from other players in the market. Therefore, this example is considered to be a combination of committee-market and government-based standardization. Hence, the article by Suárez & Utterback (1995) is related to multi-mode standardization.

Suarez (2004) discusses the various phases that a technology goes through to achieve dominance in the battle. These phases are divided into five sequential milestones ranging from 'R&D buildup' to the 'post dominance' of the technology once it emerges as dominant in the battle. The author also focuses on identifying critical success factors that influence the outcomes of technology battles. A total of eight factors are equally categorized into firm-level and environmental factors based on the capabilities of individual firms and the performance of different firms in the market. One of the factors known as 'regulators' in the category of environmental factors, explains the role of actors such as government and institutions in the technology battles. The examples used to describe their influence in the standards battle are related to the emergence of dominant design for TV in the USA and 3G telecommunication standards in Europe. The example of TV has been discussed in the previous paragraph and the example of telecommunication standards in section 2.2.3. Both of these examples are discussed under the category of standard battles within multi-mode standardization. Hence, Suarez (2004) implicitly discusses the concept of multi-mode standardization. Furthermore, the framework of eight key factors was further studied and modified by Van de Kaa et al. (2011), who proposed a new framework with 29 success factors for standard battles. In addition, Van de Kaa et al. (2011) explain briefly about the distinction between committee- and market-based standards individually. However, the authors mention that the other stakeholders such as regulating agencies and standardization committees are often considered as the influencing actors in the standards battle. While all the factors in the framework of Van de Kaa et al. (2011) have been considered as influential factors within various examples of multi-mode standardization, this article by Van de Kaa et al. (2011) indeed discusses the concept of multi-mode standardization implicitly.

Lee et al. (1995) focus on the various categories of factors that might be responsible for the emergence of dominant design in the market, and these factors could be used to plan different strategies for selecting the dominant design. The four crucial groups of factors are 'technological forces', 'non-technological forces', 'external conditions', and 'complementary assets'. The category 'non-technological forces' has been further divided into 'organizational forces', 'socio-political forces', and 'economic forces'. While 'organization forces' pertains to the influencing forces within the organization as well as among different organizations, 'economic forces' (also called incentives) relates to incentives to be generated on the demand side (buyers) and supply side (suppliers) to influence the acceptance of a dominant design. Apart from these market-based forces, 'socio-political forces' relates to players other than the firms participating in the process of standardization. These influencing players include customers, suppliers, and governments (national, regional, and local) who have interests in a particular design. It is also specified that the standards might be influenced by dominant producers, powerful user groups, industries, and governments. There are four examples used by the authors to explain the framework. One of the examples pertains to the advent of the concept of credit cards in the USA. As per the article, the important actors involved in the standardization of the credit card system include The significant competitors in this battle were Master Card, and Visa Card supported individually by various companies. While Bank of America backed the Visa card, the opposing banks created a Master card by establishing an association known as 'Interbank Card association' as an alliance. Although other important actors in the standardization haven't been mentioned in the article, the US Commission on Consumer Finance (a government financial agency for consumers) played a quite significant role in the standardization of credit cards by imposing regulations and deregulations (Montgomerie, 2006). Hence, the article discusses indirectly regarding the influence of government- and market-based modes of standardization in this particular example. Therefore, the article by Lee et al. (1995) is related to multi-mode standardization.

Schilling (2002) explores the impact of three important factors that influence the success of technology in the market. The three factors are learning orientation, the timing of entry, and network externalities. These factors are considered to have a predictable and robust effect on the adoption of technologies in the market. However, the factors can also be influenced by random and idiosyncratic effects such as government legislation and bundling partnerships. While government legislation can be considered as the influence of government agencies in the standard battles, this implicitly points towards the concept of the market- and government-based standardization. Regardless of these random influences, the author indicates that the adoption of technology could be modeled to achieve success in the market. Even though the article focuses predominantly on the factors affecting market players from the perspective of market-based standardization, the random influence by the government helps in categorizing the article by Schilling (2002) in multi-mode standardization implicitly.

Gallagher & Park (2002) explores the history of the US home video game industry and examines the influence of five factors in the selection of the dominant video game technology over six generations in a network-based industrial sector. Each generation consists of definite market players, eventually leading to a change in market leadership in each generation. The five influential factors include 'technological superiority', 'switching costs', 'installed base', 'backward compatibility', and ' complementary goods'. The results in the study show that 'technological superiority' does not guarantee success in the battle but is a strategic factor to enter the battle. The other factors such as increasing the network of 'complementary goods' leading to increased 'installed base', which in turn is dependent on strategizing the 'switching costs' are more valuable in the video game industry battle. While there are only market players involved in the standardization of the video game consoles in each generation, a purely market-based standardization process emerges without any influence from other modes.

Srinivasan et al. (2006) propose an estimation model for finding the probability and time of emergence of dominant design in the market using six product-market characteristics (also known as success factors in the literature). The product-market characteristics include, 'appropriability', 'network effects', 'number of firms in the value net', 'type of standard-setting process', 'radicalness', and ' R&D intensity'. The authors explicitly discuss the role of committee-based and market-based standardization modes individually in the description of the product-market characteristic 'type of standard-setting process'. Further, market-based standardization is considered to be a quicker way to select a dominant design in the market compared to the committee-based standardization process. Similar to the previous article, the effect of the product-market characteristics is focused only on individual firms in the market without any external influences. Therefore, the article by Srinivasan et al. (2006) is categorized into a purely market-based standardization process.

Out of 10 articles analyzed from previous literature, a total of 8 articles discussed the concept of multi-mode standardization implicitly.

6.3 Identification of relevant factors for selection of charging standards to implement V2G technology

The third step in this research pertains to the identification of relevant factors from the list of factors identified in the proposed framework in a situation of multi-mode standardization. To answer the third sub-research question, *"What are the relevant factors according to the literature and experts in the field of charging standards?";* the factors were identified through a literature review and thorough interviews with academic and industrial experts. The second sub-research question was answered with a total of 35 relevant factors (as discussed in section 5.1). Out of 35 relevant factors, there were ten new factors added in the proposed framework, namely: 'lobbying', 'voting rights', 'incentives for consensus-building', 'consensus rules in the standardization process', 'delay in standardization process', 'number of standard proposals & revisions', 'agenda-setting effort', 'community development', 'size of the committee', and 'number of firm-specific representatives in the committee'.

6.4 Strength of relevant factors

The fourth step in this research pertains to the analysis of the importance of the relevant factors by applying BWM. To answer the fourth sub-research question, "*What is the importance of the success factors in the selection of charging standards according to the experts?";* interviews were conducted with the experts, and they were asked to perform BWM. A total of seven interviewees were involved in the application of the BWM. And their results were used to calculate the local and global weights of the factors. After determining the global average weights of all the relevant factors, the factors were ranked corresponding to their global average weights. Hence, the factors with higher ranks were considered to be significantly important compared to the others with the lower ranks.

6.5 Top influencing factors

Compared to the previous studies in the literature, the number of relevant factors is high in this research. Therefore, a new approach was used to identify the top factors. The mean between the highest and the lowest score was calculated to analyze the distribution of scores (global weights). As per Table 8, the highest score is found to be '0.0934' and, the lowest score is '0.0650'. Therefore, the mean value between these scores was calculated to be '0.0500'. However, there were only five factors with global weights higher than the calculated mean value, which signifies the accumulation of 50% of scores within the top five positions. Hence, the top five factors were considered to be highly influential in this research. Also, the experts had similar expectations and were not surprised by the results. The top five factors with the higher scores are: 'brand reputation and credibility', 'compatibility', 'financial strength', bandwagon effect', and 'lobbying'.

Factor Rank	Score	Top 5 factors	Categories
1	0.0934	Brand reputation and credibility	Charateristics of standard supporter
2	0.0802	Compatibility	Characteristics of the standard
3	0.0795	Financial strength	Charateristics of standard supporter
4	0.0503	Bandwagon effect	Market characteristics
5	0.0499	Lobbying	Standard support strategy
6	0.0484	Network of stakeholders	Factors influencing the committee composition
7	0.0377	Operational supremacy	Charateristics of standard supporter
8	0.0331	Appropriability strategy	Standard support strategy
9	0.0326	Current installed base	Other stakeholders
10	0.0315	Technological superiority	Characteristics of the standard
11	0.0290	Flexibility	Characteristics of the standard
12	0.0289	Voting rights	Factors influencing committee consensus
13	0.0288	Big Fish	Other stakeholders
14	0.0250	Switching costs	Market characteristics
15	0.0250	Community development	Market characteristics
16	0.0230	Previous installed base	Other stakeholders
17	0.0229	Number of firm specific representatives in the committee	Factors influencing the committee composition
18	0.0226	Number of standard proposals & revisions	Factors influencing committee consensus
19	0.0225	Size of the committee	Factors influencing the committee composition
20	0.0216	Uncertainty in the market	Market characteristics
21	0.0192	Regulator	Other stakeholders
22	0.0192	Incentives for consensus-building	Factors influencing committee consensus
23	0.0192	Commitment	Standard support strategy
24	0.0178	Marketing communications	Standard support strategy
25	0.0172	Timing of entry	Standard support strategy
26	0.0160	Network externalities	Market characteristics
27	0.0147	Learning orientation	Charateristics of standard supporter
28	0.0147	Delay in standardization process	Factors influencing committee consensus
29	0.0139	Consensus rules in the standardization process	Factors influencing committee consensus
30	0.0130	Rate of change	Market characteristics
31	0.0128	Pricing strategy	Standard support strategy
32	0.0127	Distribution strategy	Standard support strategy
33	0.0098	Pre-emption of scarce assets	Standard support strategy
34	0.0075	Agenda-setting effort	Factors influencing committee consensus
35	0.0064	Suppliers	Other stakeholders

Table 8: Factor rankings with their corresponding global weights and categories (green color represents the most crucial factors, orange color represents factors with medium importance, and the red color represents the least important factors)

6.5.1 Brand reputation and credibility

The factor 'brand reputation and credibility' has attained a top position in the list of 35 factors based on the fact that it was given a higher score by 57% of interviewees within the category. And the corresponding category 'characteristics of the standard supporter' has attained a top position in the list of category ranks with the highest global average weight of '0.2253'. Therefore, it is evident that the factor 'brand reputation and credibility' ended up being at the top of the list with a global average weight of '0.0934'. While the V2G technology is yet to be commercialized on a large scale, the general public has limited knowledge concerning the future potential of the technology. Also, the charging standards to implement V2G technology are being developed and supported by groups of well-known automobile companies in the market. According to Sweeney & Swait (2008), 'brand reputation and credibility' primarily impact customer satisfaction and loyalty in the market. While the customers do not have enough experience to judge the quality of new technology in the market, they are heavily dependent on the 'brand reputation' of the companies in the service sectors (Hem et al., 2003). Hence, the 'brand reputation' of energy utility providers and charging infrastructure companies is very crucial in the implementation of V2G technology. Furthermore, the strong brand reputation of the charging infrastructure companies provides an edge over competitors to negotiate the cost of energy with energy utility providing companies (Bhatti & Broadwater, 2019).

Moreover, achieving a more substantial reputation in the automobile industry sector involves continuous efforts to succeed in a competing market. Once a strong brand reputation has been achieved in the market, the company can have higher sales with increased prices, which in turn can help to gain a dominant position over the competitors in the market (Loureiro et al., 2017). According to Chen et al. (2020), V2G technology has environmental benefits and could be the tipping point to adopt EVs at a faster rate. While the adoption of the charging standards is dependant on the adoption of EVs in the market, the automobile companies involved in the development of charging standards to implement V2G technology have a significant role in attracting the customers to their buy electric cars. From the perspective of the adoption of charging standards, I10 (2020) mentioned that: "reputation and credibility also become more important as it's not the plug that differentiates which car I would buy". Also, customers tend to rely upon the brand reputation of the EV manufacturers for safer and reliable EVs in the market (Li et al., 2019). Therefore, it can be inferred that customer preferences are significantly dependent on the attributes of the EVs (Chen et al., 2020), and their brand reputation in such type of markets.

According to Nguyen (2018), brand reputation allows the company to have a competitive advantage in the market. He further mentions that the implementation of an environmentally friendly technology can not only differentiate the company from the competitors but also increase social performance in the market. Also, I1 (2020) states that: "Brand value and credibility is also important because if other companies go to the vehicle-to-grid and your car cannot do it, the brand is slowly losing value. And also, when people realize how much more green vehicle-to-grid is, compared to a car that's just charging. I think this is also something that will influence the brand absolutely”. Presently, the Nissan Leaf is the only electric car capable of bi-directional charging using the CHAdeMO standard in the market (Virta Global, 2020). Therefore, Nissan and CHAdeMO have been involved in various V2G pilot projects around the world and have gained massive ‘brand reputation and credibility’ in the V2G forums. In addition to Nissan, the Mitsubishi Motors company has also started pilot V2G projects using the Mitsubishi Outlander PHEV teaming with the largest EV charge point providers ‘NewMotion’, along with network operators such as TenneT and Nuvve (Clear Technology, 2017). Therefore, it is very likely that the brand reputation of the companies involved in the development of V2G technology is gradually increasing in the market.

Similarly, CCS Combo standard has been backed by many automobile companies such as BMW, Daimler, Ford, General Motors, and Volkswagen/Audi (as per section 2.3). Only the Tesla company supports its own Tesla supercharging standard, which is yet to participate in the V2G pilot projects. Nevertheless, Tesla has managed to create a huge brand reputation in terms of producing the best EV engines and selling the top EVs in the market (I3, 2020). Furthermore, I8 (2020) mentions that: “Tesla is using a CCS standard. So I don't think they will use their own standard for vehicle-to-grid, but I think they will follow the CCS standard”. Since the renowned automobile companies in the European market have been supporting the CCS standards in Europe, the ‘brand reputation and credibility’ of these companies will play a critical role in gathering more support from other players in the market to choose CCS as a dominant charging standard for implementing V2G in the future.

Suarez & Lanzolla (2005) mention that the factor ‘brand reputation and credibility’ plays a crucial role in a situation where both technology development and its adoption are moving slowly in the market. A similar situation can be observed in the case of the adoption of V2G technology. On the one hand, V2G technology is being developed at a slower pace in the market, which in turn is dependent on the rate of adoption of EVs. On the other hand, the rate of adoption of EVs in the market is slower as well. According to Shapiro & Varian (1999b), brand reputation is a precious asset in the network markets. The authors also mention that firms cannot convince their customers with their best products in the market alone. But instead, the firms will have to satisfy the customers of their potential to be victorious in the market battle, which in turn allows the firm to gain credibility in the market. Certainly, the brand reputation of the EV manufacturers involved in the development of V2G technology and charging standards have a significant role to play in attracting EV owners to adopt their standards, by showing the poteintal of their technology and gaining more credibility in the market. Therefore, ‘brand reputation and credibility’ has been considered as the most crucial factor as per the experts.

6.5.2 Compatibility

The factor ‘compatibility’ has attained a second position in the list of 35 factors based on the fact that it was given a higher score by 86% of interviewees within the category. And the corresponding category ‘characteristics of the standard’ has attained a fourth position in the list of category ranks with the global average weight of ‘0.1406’. It can also be observed that; even though the category ‘characteristics of the standard’ scored the fourth rank in the list of categories, the factor ‘compatibility was able to secure the second position in the list. It can be explained with the fact that there are only three sets of factors in this category, and therefore the factor ‘compatibility’ resulted in higher local average weight (0.5863). Nevertheless, the factor ‘compatibility’ ended up being at the second position of the list with a global average weight of ‘0.0802’. Also, if the global average weight of the ‘characteristics of the standard’ category was slightly higher, then the factor ‘compatibility’ would have been at the top position in the list. Nevertheless, most of the experts chose compatibility without taking much time as compared to the others within this category.

Recent studies by Van De Kaa et al. (2019; 2020) on identifying success factors for the standardization of technologies using BWM show that ‘compatibility’ attained a second position in the list of top influencing factors in the standardization process. According to Shapiro & Varian (1999b), ‘compatibility’ can help in increasing the installed base in the market but also, on the contrary, decrease the technological superiority of the technology, eventually affecting the chances of achieving success. Also, if the market is bound together with the benefits of compatibility, it is difficult to move towards a better standard in the market (Farrell & Saloner, 1985). Hence, compatibility needs to be continuously monitored by technology producers to avoid losing the quality of the standards. While there are various EVs manufactured by multiple companies, the competing charging standards will not only have to be compatible with the latest generation of EVs in the market but also have to be backward compatible with the previous generation of EVs. Such compatibility will help to obtain a better position among the competitors and increase the chances to succeed in the market. Therefore, ‘compatibility’ has a critical role to play in this battle.

As discussed in the above section 6.4.1, there are many electric cars manufactured by various EV automobile manufacturers that support either of the charging standards in the battle. The concept of ‘compatibility’ in this research can be discussed from six different perspectives. First, the charging equipment should be compatible with the electric car itself. Second, the charging equipment also needs to be compatible with the specific sockets at the charging stations. For example, if a consumer owns a Tesla car that came with a particular Tesla supercharger, other chargers such as CCS or CHAdeMO cannot be used to charge the Tesla car. Likewise, if there are no Tesla sockets available at the charging stations, the Tesla cars cannot be plugged in for charging. Also, if the charging equipment is made compatible across different countries, it helps to gain a dominant position in the market (Choi et al., 1999). One of the interviewees mentioned that: “I went to a supercharger to charge up my car, which usually can travel up to 500 kilometers, and I can do only 450. So, I had to charge it up on the way. And then you could see three different types of chargers. There you see a Combo; you see a CHAdeMO or a Tesla supercharger. And you see all these, and still, you can use the same plugs” (I10, 2020).

Therefore, it can be concluded that most of the charging stations have incorporated all three types of charging sockets in the present scenario.

Third, depending on the type of current (i.e., AC or DC) that a car and the charging equipment is compatible with, the consumers need to go to those particular charging stations to charge their vehicles for more efficiency. Fourth, the charging equipment also needs to be made backward compatible with the previous version of the standard (Van de Kaa et al., 2011). For example, if a consumer owns a Nissan Leaf car that came with compatible charging equipment and the consumer decides to buy a newer version of Nissan Leaf; the older charger should be compatible with the new car as well. As "the charging equipment is seen as a piece of add-on equipment to the electric cars" (I11, 2020), the most compatible charging standard will open the possibility of that particular standard being adopted by consumers and EV manufacturers.

Fifth, the charging standards should be able to perform bi-directional charging for the implementation of V2G technology (as per section 2.3). Therefore, the sooner a specific charging standard becomes capable of performing bi-directional charging with most of the EVs in the market; it will gain more support from other stakeholders in the domain. Compatibility also acts as a useful tool in reducing the switching costs and facilitating a smoother transition towards the new technology (den Uijl, 2015 p. 233). In some cases of compatibility standards, Kristiansen (1998) mentions that competing firms can gain combined incentives by agreeing for mutual compatibility to reduce the R&D expenditures. Moreover, he also indicates that 'compatibility' is a possibility only when competing firms enter the market simultaneously. However, if the firms enter sequentially, incompatibility is the plausible outcome in the market. A similar scenario is evident in the case of charging standards, where CHAdeMO entered the market earlier than CCS in Europe. Hence, both the standards are incompatible with each other. Finally, the factor 'compatibility' can be considered from the perspective of V2G technology itself. According to Turton & Moura (2008), the amount of energy shared by each EV to the grid might have compatibility issues with the existing systems that produce large units of energy. For example, replacing a small wind turbine with 100 MW capacity would require 30,000 EVs capable of supplying 6.6 kW energy 50% vehicle availability. Therefore, such a compatibility issue needs further research in the area of replacing the existing energy-producing systems. Considering all the perspectives discussed above, the factor 'compatibility' has many significant roles to play to gain dominance in the battle between the charging standards.

6.5.3 Financial Strength

The factor 'financial strength' has attained a third position in the list of 35 factors based on the fact that it was chosen as the most important factor by 29% of interviewees and as the second important factor by 43% of interviewees within the category. And the corresponding category 'characteristics of the standard supporter' has attained the highest position, as mentioned in section 6.4.1. Therefore, the factor 'financial strength' ended up being at the third position of the list with a global average weight of '0.0795'. We can easily see that the global average weight of 'financial strength' is comparable with the global average weight of the factor ‘compatibility’ (as discussed in section 6.4.2). Hence, if two more experts would have given a higher score for ‘financial strength’ within the category, it would have ended up in the second position. It is also quite surprising to see that the factor ‘financial strength’ has gained the third position in the results because none of the previous studies show ‘financial strength’ in the top influencing factors. Although in one study by Van De Kaa et al. (2017a), it shows that the ‘financial strength’ scored the fourth position, but only the top three were considered for discussion as the total number of relevant factors were less. Nevertheless, the financial resources for a particular firm are very crucial in any technology battles to sustain in the market.

Usually, the development of a standard consumes enough time and effort before the successful diffusion in the market. But without financial resources, the time and effort involved in the standard development will not provide any significant results. Although financial investments involve substantial risks, companies cannot sustain themselves for a more extended period in the market without adequate financial resources (Nolan et al., 1998; van de Kaa, 2009). Therefore, it is inevitable for the relevant stakeholders to offer continuous investments for the development and implementation of the standard in the market. For example, even though CHAdeMO first developed the standard protocols for V2G in the year 2014 (CHAdeMO, 2020), the standards are being tested and continuously developed for newer versions that involve constant investments by CHAdeMO and their network of stakeholders. Additionally, a huge financial strength is needed to establish the infrastructure for a particular charging standard. Under the same context, one of the interviewees argued: “You need deep pockets to provide these services” (I10, 2020), which implicitly points towards providing charging services to the consumers in the market. The financial strength is also an essential tool for lobbying, to gain more support from the relevant stakeholders in the market (Nicoll Victor, 2007).

Recently it is known that Nissan was unable to develop its electric cars in the last couple of years due to the lack of investments and, one of the interviewees mentioned: “I worked a lot with Nissan. And I don't know if you agree with me, but Nissan is having a rough time with the EVs. Now, it also had it before the COVID-19. But they have it now because they haven't developed the electric vehicle very much in this over the last years. So for them, it should be a very obvious move that they took to go a lot more in vehicle-to-grid. But I think, as I said before, I'm sure that it's going to be a competitive value at some point with vehicle-to-grid and the factor of how much you can charge or discharge will be a killer. So, the financial strength is absolutely important when we get a bit of competition in this field” (I1, 2020). Additionally, the financial resources are essential marketing tools, which in turn increases the adoption rate of the technology in the market (Schilling, 1999). In the case of charging standards, financial resources have played a critical role for CHAdeMO in promoting the V2G capability in the market. Therefore, the lack of investments can hinder the development of competing charging standards for the successful implementation of V2G technology in the market. Hence, the higher financial strength for a particular charging standard will help the relevant stakeholders to gain an advantage over the other competing standards.

6.5.4 Bandwagon effect

The factor ‘bandwagon effect’ has attained the fourth position in the list of 35 factors based on the fact that it was given a higher score by 86% of interviewees within the category. And the corresponding category ‘market characteristics’ has attained a third position in the list of category ranks with the global average weight of ‘0.1509’. Therefore, the factor ‘bandwagon effect’ ended up being at the fourth position of the list with a global average weight of ‘0.0503’. A significant gap can be observed in the global average weight of the previous ranking factor ‘financial strength’ compared to the global average weight of the factor ‘bandwagon effect’. Two reasons explain the gap; first, because of the position of the category in the fourth place, and second, because there are a total of six number of factors present in the category ‘market characteristics’ allowing the factor bandwagon effect’, to obtain lesser local average weight (0.3709).

Previous studies show that the factor ‘bandwagon effect’ was never considered to be in the list of relevant factors. In this particular research, it has not only attained the title of a relevant factor but also has ended up among the top influencing factors. A significant reason behind the fact is that the big core companies (i.e., Original Equipment Manufacturers, usually known as OEMs) that are involved in the development of V2G charging standards affect each other in many ways. For example, I1 (2020) said: “even though the OEMs are really really big. They look a lot on each other. I'm very sure this had an effect on the others already, even though we don't see the vehicle-to-grid as much on the other one, so I'm sure this will have an effect on the others, that's for sure”. As mentioned in the above section 6.4.4, CCS combo has plans to develop V2G capable standard by 2025 because it wants to compete with CHAdeMO to gain dominance in Europe. Similarly, many market players have joined forces with CHAdeMO or CCS combo to acquire incentives in the process of developing successful charging standards (as mentioned in section 6.4.1). Also, I11 (2020) indicated that: “The ‘bandwagon effect’ has been seen in the market already. A bunch of automobile manufacturers have chosen one of the charging standards, just because the majority has chosen one of the standards in the battle”. Therefore, the ‘bandwagon effect’ has already started in the market just because the major players have chosen to support a particular charging standard. The ‘bandwagon effect’ will continue to affect other players in the market until a dominant standard arises in the charging standards battle.

Moreover, the ‘bandwagon effect’ can also be considered from the perspective of the adoption of EVs in the market. As discussed earlier, the adoption of V2G technology and charging standards are dependent on the adoption of EVs. From the year 2010 until 2019, approximately 1.93 million units of electric cars have been sold in the European continent (IEA, 2020). The sales figure shows a significant step towards the electrification of vehicles in Europe. However, considering the market share of gasoline-based cars in Europe, the market share of electric cars is considerably meager. Nevertheless, the EV market share is projected to grow with the increasing awareness of the benefits that EVs provide over the gasoline-based vehicles (Tsakalidis & Thiel, 2018). A recent study shows that around 76% of consumers have shown interest in buying EVs but are hesitant to buy them. The consumers believe that the EV industry is not ready yet and will gain mass-market share only in the next five years (Boilard & Confais, 2019), providing the potential for the bandwagon effect in the future. Therefore, the 'bandwagon effect' has a crucial role to play in the adoption of EVs, which in turn will help to adopt the V2G technology and the charging standards.

6.5.5 Lobbying

The factor 'lobbying' has attained the fifth position in the list of 35 factors based on the fact that it was given a higher score by 57% of interviewees within the category. And the corresponding category 'standard support strategy' has attained a second position in the list of category ranks with the global average weight of '0.1725'. Therefore, the factor 'lobbying' ended up being at the fifth position on the list with a global average weight of '0.0499'. We can easily see the similarity between the global average weight of 'lobbying bandwagon effect' and the global average weight of the factor 'bandwagon effect' (as discussed in section 6.4.4).

As 'lobbying' is a relatively new factor in the proposed framework, the relevance of 'lobbying' was nonexistent in the previous studies that focused on the standardization of technologies using BWM. In the battle between the charging standards, lobbying has a critical role to play within a committee. In this context, I2 (2020) argues that: "Lobbying, for specific decisions or specific technologies within a standard, I think that's just very important. Because I think every car manufacturer will have its own ideas on how, for example, vehicle-to-grid should take place and how safety devices should be implemented in a standard. So for those specific decisions, lobbying is very important". Apart from car manufacturers, other stakeholders also participate in the standardization of charging standards. Each stakeholder within the committee propose their ideas and recommend them to be incorporated in the standard. However, the decision for incorporation depends upon the consensus among the stakeholders. Therefore, lobbying is used by technology producers to gain support from other stakeholders to reach an agreement, which in turn helps them to obtain a dominant position within the committee.

Lobbying can also be used as a strategic tool by the alliances of charging standards to negotiate with the government to regulate their standards to avoid competing against other standards in the market. For example, the CCS alliance has had great success in lobbying with the EU because CCS had compatibility with Type 2 plug, which was a mandated standard plug by the EU back in the year 2014. Hence, I8 (2020) mentions that: "CCS is lobbying more because they will have a stronger network". Also, I1 (2020) argued that: "Lobbying is very important because the automotive industry is a very slow-moving industry, but the energy side is also very slow-moving. And they have a number of good reasons not to give the controls to any kind of aggregator. And then there is a very important and very complicated thing with taxation. So, there needs to be a lot of lobbying in vehicle-to-grid". Therefore, lobbying can also play a critical role in harmonizing the interest with aggregators.

While the adoption of EVs is equally important for the adoption of V2G technology, the car companies involved in the standardization of charging standards can use lobbying strategies to persuade policymakers in the EU to provide incentives for buying EVs. Apart from car companies, other actors such as renewable energy producers, SDOs such as ISO, and NGOs are also involved in the development of V2G technology (Noel et al., 2019). The renewable energy producers focus on lobbying with the government for the development of energy storage markets. Whereas ISO focus on setting agreements for V2G standards, and NGOs focus on proposing pro-environmental legislation to the government. Therefore, lobbying can play a significant role not only in the adoption of EVs but also in the development of V2G technology and charging standards.

6.6 Least influencing factors

The least influencing factors include 'suppliers', 'agenda-setting efforts', 'pre-emption of scarce assets', 'distribution strategy', and 'pricing strategy'. These factors will be discussed very briefly to understand why they ended up being at the bottom of the list.

1. *Suppliers* – In this research, suppliers can be interpreted as the hardware manufacturers for the charging equipment, and the hardware within the charging equipment remains mostly the same (I10, 2020). Hence, there is a minimal role for suppliers in the charging standards battle.
2. *Agenda-setting efforts* – Agenda-setting effort happens within the boundaries of the adopted standards (or a committee). Therefore, the factor has the least influence on the adoption of a particular charging standard among the market stakeholders or the end-users (I11, 2020).
3. *Pre-emption of scarce assets* – The scarce assets in this battle could be the charging stations, and it is evident that none of the charging standards have dominated in establishing their charging stations over the other. For example, all the DC fast-charging stations have both CHAdeMO and CCS charging points made available parallelly. Hence, there is much cooperation in this scenario rather than competition between the charging standards (I11, 2020).
4. *Distribution strategy* – As both the charging standards get their equipment manufactured by a similar pool of suppliers, distribution strategy also doesn't have much influence in the battle (I11, 2020). The manufacturers have already established the supply chain of the distributing channels of charging equipment, and they tend to remain the same until there is a significant need to change (I10, 2020). Hence, the distribution strategy has a minimal role to play in the battle between charging standards.
5. *Pricing strategy* – In this research, the pricing strategy of the charging equipment makes less impact on the battle as opposed to the pricing strategy of the cars that prove to be more significant. For example, the Nissan Leaf EV car had a more prominent role to play in the adoption of CHAdeMO charging equipment and not the other way round (I11, 2020). Furthermore, the consumer does not tend to buy a new car just because the charging equipment is costlier (I10 & I12, 2020). Hence, the pricing of the charging equipment has the least influence in the battle.

6.7 Other influencing factors

During the third round of interviews conducted for interpretation of BWM results, the interviewees were asked about their opinion on other potentially influential factors and also on the position of a few factors that were unusual in comparison with the previous studies. A brief explanation about such factors is discussed below:

1. *Technological superiority* – The factor 'technological superiority' usually ends up at the top 3 positions, as mentioned in the previous studies (van de Kaa et al., 2019; Van de Kaa et al., 2017a, 2020; Van De Kaa et al., 2017). But in this research, the factor ended up being at the 10th position in the list, which was quite surprising. The interviewees were asked for an explanation of this unusual result, and they weren't that surprised. One of the interviewees explained that the charging equipment is considered to be just a piece of add-on equipment to the EVs, and the 'technological superiority' of the EVs is more important compared to that of charging equipment in this scenario. For example, Tesla has gained more popularity only because of their superior EVs sold in the market. Hence, technological superiority has not ended up in the top five factors in the list (I10, 2020). Another interviewee mentioned that it is not always the superior technology that wins the battles, but the ones that are backed by more prominent companies with high financial strength in this scenario (I12, 2020).
2. *Current installed base* – The 'current installed base' has a significant role to play in the adoption of standards but has ended up at 9th position in the list. One of the interviewees mentioned that in this particular case, the 'current installed base' is more concerned with the adoption of EVs rather than the location of charging stations or the charging standards itself. The interviewee further added that the market is still early into the electrification process around the European continent, and the installed base for EVs is significantly lower. Hence, the current installed base is not in the top five factors (I10, 2020).
3. *Regulator* – In the European countries, the EU has a critical role to play in regulating the standards around the continent. But the factor 'regulator' ended up in the 21st position and was undoubtedly surprising. An interviewee mentioned that the EU has given both CHAdeMO and CCS combo recognition, and it hasn't played any significant role as a 'regulator' in this scenario. Further, the interviewee explained that the EU also encourages fair competition between the market players, which is not the case in individual countries around Europe. And when the EU gave a mandate for Type 2 plugs in the year 2014, it was already too late for the cars that had adopted other standards. A similar case is predictable in the case of choosing one particular charging standard concerning V2G technology (I10, 2020). Hence, the factor has a relatively minimal role in the battle.
4. *Incentives for consensus-building* – Incentives play a crucial role in motivating the technology producers to join the committee and enforce their company-specific standards, which will prevent incompatible or conflicting standards (Blind & Mangelsdorf, 2016). But the factor ended up in the 22nd position in the list. The interviewee explained that: There are huge incentives on its own for joining the most significant group supporting either of the charging standards. For example, if the CCS

combo standard is winning at the moment and CHAdeMO offers some sort of incentive to gain more support, it is difficult to convince the CCS supporters to switch sides from CCS to CHAdeMO. Hence, such incentives cannot relatively be considered to be more meaningful in this scenario (I10, 2020).

5. *Timing of entry* – While CHAdeMO entered the market early in the development of V2G capable standards, it certainly should have had the edge over the other charging standards in the market. But the factor has attained 25th position in the list. One of the experts mentioned that: 'Timing of entry' could be considered to be quite significant, but it has been overshadowed by the adoption of EV fleet and tax benefits provided to the EV owners. For example, the sudden increase in the adoption of Tesla EVs in the Netherlands was mainly due to the tax benefits offered to the various companies and the EV owners. Even though the Nissan Leaf car entered early in the market and was more affordable, the financial incentives and tax benefits allowed other EVs to be adopted on a large scale in the market. Therefore, 'timing of entry' has been overcome by the other factors enabling it to be less significant compared to the other top factors (I10, 2020).

6.8 Factors influencing the stages of standard dominance in the market

As discussed in section 6.2, Suarez (2004) proposes a framework consisting of the five sequential phases that define the milestones for technology to achieve dominance in the market. The five phases are: 1.) Phase-1 (*R&D Buildup*) determines the state of the technological field based on the developments of R&D; 2.) Phase-2 (*technical feasibility*) marks the first appearance of the technological prototype in the market; 3.) Phase-3 (*creating the market*) determines the launching of the first commercial product entering the market; 4.) Phase-4 (*the decisive battle*) analyzes the competition in the market, and 5.) Phase-5 (*post-dominance*) determines the emergence of dominant technology in the market. As mentioned in section 2.4, the V2G technology has been commercialized with CHAdeMO charging standard in the market for pilot projects, and there are a few commercial clients that are available only in Denmark (PV Magazine, 2019). Therefore, the standards battle between charging standards can be placed in the third phase (i.e., 'Creating the market') of technology dominance. Further, Suarez (2004) elaborates on the eight key success factors (divided into firm-level factors and environmental factors) that are essential in each phase for technology dominance. Table 9 shows the list of factors and their importance in each phase.

Factor type	Dominance factor	Phase I	Phase II	Phase III	Phase IV	Phase V
Firm level	Technological superiority		***			
	Credibility / complementary assets	***			***	
	Installed base				***	***
	Strategic manoeuvering			***		
Environmental level	Regulation		***			
	Network effects and switching cost				***	***
	Regime of appropriability	***				
	Characteristics of the technological field	***				

Table 9: Success factors at each phase of technology dominance

[Source: (Suarez, 2004)]

A few factors in the above table are similar to the factors listed in the constructed framework, such as ‘technological superiority’, ‘installed base’, and ‘switching costs’. Over time a few factors such as ‘regulation’, ‘network effects and switching costs’, ‘regime of appropriability’ were modified in the literature to ‘regulator’, ‘network externalities’, ‘switching costs’, and ‘appropriability strategy’, respectively. The factor ‘strategic manoeuvering’ refers to various strategies that are used by firms to gain a dominant position in the market. These strategies include a sub-set of factors such as ‘timing of entry’, ‘pricing strategy’, ‘type of licensing policy’, and ‘marketing and public relations resources’. While the factors ‘timing of entry’, and ‘pricing strategy’ have similar names and meaning in the constructed framework, one of the factors ‘marketing and public relations resources’ has been modified in the literature to ‘marketing communications’. Although the factor ‘type of licensing policy’ has been separately defined by Suarez (2004), it is included under the factor ‘appropriability strategy’ in the framework by Van de Kaa et al. (2011). Another factor ‘credibility/complementary assets’ comprises of a sub-set of factors, which define firm-specific aspects such as ‘reputation and credibility’, ‘manufacturing capability’, ‘financial support’, and ‘prior experience’. These factors are similar to ‘brand reputation and credibility’, ‘operational supremacy’, ‘financial strength’, and ‘learning orientation’, respectively, in the framework by Van de Kaa et al. (2011). The definitions of all these factors are similar to the ones defined in Appendix A.

As per Table 9, the most influencing factor in the third phase is ‘strategic manoeuvering’ which comprises of the sub-set of factors as mentioned above. Even though the factors such as ‘timing of entry’, ‘pricing strategy’, ‘appropriability strategy’, and ‘marketing communications’ in Phase-3 are deemed to be crucial by Suarez (2004), these factors have ended up being relevant but not critical in this research. It is argued by Cusumano et al (1992) and Suárez & Utterback (1995) that ‘bandwagon effect’ is the main driving force for ‘strategic manoeuvering’ for the emergence of dominant design in the market. Therefore, the factor ‘bandwagon effect’ has emerged as a top influencing factor compared to the other sub-set of factors concerning ‘strategic manoeuvering’ in this research. It can also be observed that the essential factors in Phase-4, such as ‘brand reputation and credibility', and 'financial strength' have ended up being in the top five influential factors during the battle between the charging standards (as discussed in section 6.5). Another factor 'operational supremacy' from the fourth phase has also ended up being of medium importance (as shown in table 6). Also, the factors 'installed base', 'network externalities', and 'switching costs' from Phase-4 have been found to be relevant in Phase-3. Therefore, it is evident that most of the factors in Phase-4 are already crucial in Phase-3 of technology dominance. While the CCS Combo standard has been found to be a potential winner in the charging standards battle (as discussed in section 7.3.3), it is yet to develop V2G capability. On the contrary, CHAdeMO already has its commercial product enabled with V2G technology. Even though the battle is not official due to the absence of CCS Combo enabled V2G charging standard in the market, most of the European electric car manufacturers could be bidding for CCS to win the battle eventually. It can be argued that the charging standards battle could be in transit between Phases 3 & 4. Therefore, the factors in Phase-4 have found to be of more importance compared to the factors in Phase-3 of technology dominance.

Further, the phases of technology dominance were studied by den Uijl (2015), and based on a thorough literature review, a total of 36 factors were identified to build the framework. These factors were divided into three categories, namely: 'firm', 'technology', and 'market/industry'. Few factors were also categorized multiple times in these categories because they were found to be influential to the end customers in multiple categories. For example, the factor 'installed base' is present in both the categories 'firm' and 'technology' (shown in Table 10). The newly proposed factors were analyzed for relevance using three different case studies at each phase of technology dominance. The three case studies pertained to technology battles such as 'HD-DVD vs. Blu-ray disc', 'MP3', and 'Super Audio CD vs. DVD-Audio'. After the analysis of the case studies, many factors were found to be relevant in individual or multiple phases of technology dominance. The relevant factors were compared with the success factors in the framework of Van de Kaa et al. (2011) to analyze the similarities in the description of the factors. Few factors were not comparable and hence were not considered to be necessary. In a few cases, multiple factors in the framework of den Uijl (2015) were described under one single factor in the framework of Van de Kaa et al. (2011). For example, both the factors 'backward compatibility' and 'adapters and gateways', were described under one single factor 'compatibility'.

Category	Factors (den Uijl, 2015)	Factors (Van de kaa et. al, 2011)	Phase-III	Phase-IV
Firm	Reputation and credibility	Brand reputation and credibility	X	
	Installed base	Current installed base & Previous installed base		
	Pricing	Pricing strategy	X	X
	Entry timing	Timing of entry	X	
	Marketing and pre-announcements	Marketing communications	X	X
	Availability of products	Distribution strategy	X	X
	Availability of complementary goods	Complementary goods	X	X
	Killer application	-	X	X
	Firm Size	Financial strength (the number of industries and geographical markets are missing)	X	X
	Complementary assets	Operational supremacy	X	X
	Technological superiority	Technological superiority	X	
	Technological knowledge and skill base	Learning orientation	X	
	Absorptive capacity	Learning orientation		X
	Pre-empting scarce assets	Pre-emption of scarce assets		
	Level of collaborative development	-		X
	Organizational community of supporters	Network of stakeholders	X	X
	Strategic partnerships	-	X	X
	Product proliferation	-	X	X
	Appropriability	Appropriability strategy	X	
	Chance	-	X	
Technology	Technological superiority	Technological superiority	X	X
	Installed base	Current installed base & Previous installed base	X	X
	Network effects	Network externalities	X	X
	Switching and homing cost	Switching costs (without homing cost)	X	X
	Backward compatibility	Compatibility	X	X
	Increasing returns of adoption	-		
	Technological breakthroughs in subsystems	-	X	X
	Type of technological innovation	-		
	Adapters and gateways	Compatibility	X	X
	Chance	-		
Market/Industry	Market and industry characteristics	-	X	X
	Level of competition	Number of options available	X	X
	Rate and type of technological change	Rate of change		X
	Network effects	Network externalities	X	X
	Availability of products	-	X	X
	Availability of complementary goods	Complementary goods	X	X
	Killer application	-		X
	Government intervention and industry regulation	Regulator		X
	Product proliferation	-		
	Appropriability	Appropriability strategy	X	X
	Chance	-	X	

Table 10: Relevant factors for technology dominance in Phase-3 & 4 (analyzed from three case studies) [Source: (den Uijl, 2015)]

Furthermore, a few factors from Phase-4 were also found to be important (as discussed in the previous paragraph). Therefore, the analysis is focused mainly on the Phase-3 and Phase-4 of technology dominance. The relevant factors in the corresponding phases are shown in Table 10. In total, out of 21 factors (by Van de Kaa et al. in Table 10) that were found to be relevant in three case studies, 18 factors were considered to be relevant in the Phase-3. And, out of those 18 relevant factors, 16 factors have been found to be relevant in the battle between charging standards as well (as shown in Table 6). Also, other factors such as 'regulator', and 'rate of change' were found to be irrelevant in Phase-3 but were relevant in Phase-4. However, 'regulator', and 'rate of change' have been found to be relevant in Phase-3 already in this research (shown in Table 6). It can be observed from Table 10 that multiple factors have been found to be relevant in both phases. However, den Uijl (2015) identifies only a few factors that are most influential in each phase. There are a total of 6 factors found to be essential in Phase-3, but only three are being considered. The description of the other three factors was not comparable with the framework of Van de Kaa et al. (2011). The three essential factors in Phase-3 are: 'timing of entry', 'pricing strategy', and 'marketing communications', which are similar to the ones found by Suarez (2004). However, Suarez (2004) also identified the factor 'appropriability strategy' to be crucial in Phase-3. But den Uijl (2015) places the importance of the factor 'appropriability strategy' in the final phase of technology dominance (i.e., Post dominance phase, based on the cross-case analysis of three case studies). According to den Uijl (2015), if companies that specialize in low-cost production can imitate the new technology, then they will reap more benefits in the market. Therefore, the factor 'appropriability strategy' helps to avoid imitation of the technology both on firm and industry level. He also suggests that there is a better chance for achieving success in Phase-3 if a company: has 'entered' first in the market with a good 'brand reputation and credibility' and 'marketing communications', uses the 'installed base' to gain more support in the market, enables 'complementary goods', and makes the new technology 'backward compatible' with the incumbent standard. While the factors 'brand reputation and credibility' and 'compatibility' have ended up in the top five influencial factors, the other factors 'timing of entry', 'current installed base', 'previous installed base', and 'marketing communications' have also found to be relevant in the charging standards battle. However, the factor 'complementary goods' was not found to be relevant because there weren't any siginifant complementary goods available for the charging equipments as per the expert interviews in the first round (I1; I2; I3, 2020).

One of the analyzed case studies by den Uijl (2015) pertains to the technology battle between HD-DVD and Bluray Disc. In Phase-4 of technology dominance (i.e., the decisive battle), the author discusses an incident where Toshiba provided financial incentives to one of the leading mass media company owners 'Paramount', to gain support for HD-DVD format in the battle and the reports acknowledge the fact. This incident defines the factor 'lobbying' implicitly. However, during the first round of expert interviews, lobbying was not particularly paired with financial incentives. Nevertheless, the factor 'lobbying' has ended up in the top five influential factors. While 'lobbying' is mentioned in Phase-4, it can be observed that it is already essential in the Phase-3 of technology dominance. Therefore, it can be concluded that most of the factors relevant in the Phase-4 are indeed relevant in the Phase-3 of technology dominance.

6.9 Multi-mode standardization

The final step in this research was to answer the main research question, "*What are the factors that influence the success of charging standards in the context of multi-mode standardization in the European market for the implementation of V2G technology?"* using the answers from three sub-research questions (as per the section 1.4). Out of 35 relevant factors, only five factors were identified to be the top influential factors, namely: 'brand reputation and credibility', 'compatibility', 'financial strength', 'bandwagon effect', and 'lobbying'. The next five factors in the list were considered to be of medium importance, namely: 'network of stakeholders', 'operational supremacy', 'appropriability strategy', 'current installed base', and 'technological superiority'. The last five ranking factors in the list were considered to be of least influencing factors, namely: 'suppliers', agenda-setting efforts', pre-emption of scarce assets', 'distribution strategy', and 'pricing strategy'. The rankings of each factor have been shown in Table 7. In the initial analysis of the possible modes of standardization in section 2.3, it was predicted that standardization of charging standards involved all three modes of standardization. Indeed, the results show that the top 60% of the factors are related to all three modes of standardization. Therefore, the standardization of charging standards has ended up being a case of multi-mode standardization, which includes all the three modes with equal importance. While CHAdeMO is the only standard in the battle capable of performing V2G in the market, the top five factors in the list have found to be most influential not only from the perspective of the present situation but also considering the future outlook in the development of V2G capable standards.

6.10 Conclusion

In this chapter, all the research questions were answered by discussing the results obtained from BWM. Initially, the discussion focuses on the reasons behind the recategorization of the factors in this research. Further, a set of 10 articles that discussed standard battles from a market perspective were reanalyzed from the perspective of the multi-mode standardization. Out of 10 articles, eight were recategorized into a suitable combination of multi-mode standardization. The remaining two articles indeed discussed success factors from the perspective of market-based standardization. The influence of the top five factors in the charging standards battle was discussed in detail. Moreover, the factors with the least influence were also discussed briefly. Based on the previous studies, a few factors that were usually considered to be essential in any standards battle had ended up being of medium or least importance. Such factors were also discussed under the title 'other influencing factors'. Also, the relevant factors found in this research were also compared with the frameworks that examined the success factors within each stage of technology dominance. The analysis showed that the success factors that were considered to be relevant in the fourth stage were found to be already essential in the third stage itself. The next chapter focuses on discussing the conclusion of all the chapters. Further, it highlights the contributions made during this research and addresses the potential winner in the charging standard battle.

7. Conclusion and Recommendation

7.1 Conclusion

The main goal of this research was to identify the relevant factors and analyze the importance of those factors within a situation of multi-mode standardization for selecting the charging standards for implementation of V2G technology. Based on the main goal, the main research question was formed: "*What are the factors that influence the success of charging standards in the context of multi-mode standardization in the European market for the implementation of V2G technology?".* To answer the main research question, a set of four sub-research questions were proposed. The first sub-research question in this research was: "*What are the success factors that influence the selection of dominant standards in a situation of multi-mode standardization?"*. To answer this question, an extensive literature review was performed. To identify the success factors, a framework was constructed by extending the previous frameworks by Van de Kaa et al. (2011, 2020). A total of 39 factors were determined with the identification of 11 new factors in the literature. Further, two factors were redefined from the previous framework and were recategorized. To answer the second sub-research question, "*To what extent does the concept of multi-mode standardization was discussed implicitly in the literature?",* a set of ten articles were identified which focused on standard battles from the perspective of market-based standardization. And out of ten articles, eight were recategorized into relevant combinations of multi-mode standardization. To answer the third sub-research question, "*What are the relevant factors for the selection of charing standards in implementing V2G technology according to the literature and experts?",* relevant factors were identified by performing a literature review and conducting interviews with the experts. A total of 35 factors were identified as relevant factors from a total of 39 factors (as discussed in section 5.1). To answer the fourth sub-research question, *"What is the importance of the success factors in the selection of charging standards according to the experts?",* a BWM approach was used. The BWM approach involved conducting interviews with the experts to obtain local and global average weights of individual factors and rank them accordingly. Therefore the main research question was answered by identifying the factors with the top five global average weights, namely: 'brand reputation and credibility', 'compatibility', 'financial strength', 'bandwagon effect', and 'lobbying'.

7.2 Theoretical and practical contributions

7.2.1 Theoretical contributions

This research has contributed to the previous literature on multi-mode standardization in addition to the concept of selecting charging standards for the implementation of V2G technology in significant ways. First, the research builds upon the previous framework of Van de Kaa et al. (2011, 2020) that focuses on the identification of relevant factors within standard battles and also within multi-mode standardization, respectively. A similar framework for success factors within multi-mode standardization was recently proposed for the first time by Van de Kaa et al. (2020), and the framework has been applied for the first time in this research with a slight modification. The modification involves the addition of 11 new factors into the new framework. And, out of 11 newly introduced factors, one of the factors 'agenda-setting effort' was introduced for the first time in the framework of Van de Kaa et al. (2020). The remaining ten factors have been introduced for the first time in the literature, and all the ten factors were found to be indeed relevant by the experts in the case of charging standards battle. The factor 'lobbying' was found to be among the ten factors that ended up being on the list of the top five influential factors. Therefore, the newly introduced factors can be used to analyze the standard battles in a situation of multi-mode standardization in future case studies. Also, the maximum number of relevant factors in the previous literature amounted to 20 factors in the case of selecting complex systems to build automation systems (van de Kaa et al., 2014). Recent studies show that, on an average, only 13 factors were considered to be relevant among various standard battles (G. van de Kaa et al., 2019; van de Kaa et al., 2018, 2020; Van de Kaa et al., 2017, 2020; Geerten Van De Kaa et al., 2017; van de Kaa, Fens, et al., 2019; van de Kaa, Papachristos, et al., 2019). For the first time in this research, it is observed that a total of 35 factors have been considered to be relevant in a standards battle. However, considering the early phase of charging standards battle, the experts believe that all the relevant factors could become important in the later stages of the battle. Therefore, the list of relevant factors might get narrowed down with future developments in the battle. Nevertheless, all the relevant factors found in this research can be used for analyzing the factors influencing standards battle in different domains in the future.

Second, the BWM approach was used for the first time to identify success factors in the selection of charging standards for the implementation of V2G technology. The literature on V2G charging standards was mostly found to be from a technological perspective (Haddadian et al., 2015; Jar et al., 2016; Mouli et al., 2016; Rajagopalan et al., 2014), and it lacked insights about the influence of success factors in the standards battle. However, they implicitly suggested a few success factors which were found to be relevant by the experts as well. Hence, these factors can be used to study standard battles related to V2G technology in the future. Additionally, two articles discussed briefly about the potential competition between the DC fast charging standards CHAdeMO and CCS Combo (Bakker et al., 2014, 2015). They also give the empirical evidence of the involvement of the actors such as the European Commission (government), the European Committee for Electrotechnical Standardization (CENELEC) (committee), and various car manufacturers supporting either CCS Combo or CHAdeMO (market) in the standardization of charging standards (also predicted in section 2.3). Also, almost all the factors (35 out of 39 total factors) identified in the literature of multi-mode standardization were found to be relevant by the experts. Hence, the standardization of chargings standards can indeed be considered as a case of a multi-mode standardization process. The global weights of all the relevant factors discovered during this research can also be used for comparison with similar studies related to V2G technology in the future.

Third, the articles that discussed success factors previously in literature from the market perspective were re-analyzed to explore the concept of multi-mode standardization for the first time. During the analysis, 8 out of 10 articles were recategorized from a market-based perspective to relevant combinations of multi-mode standardization. Also, empirical evidence was found for the remaining two articles to be categorized into market-based standardization. Therefore, these articles can be viewed from different modes of multi-mode standardization in the future.

Fourth, another empirical evidence was found for the factors that were considered to be relevant in the third phase of technology dominance (as mentioned in the framework by Suarez (2004) and den Uijl (2015)). Initially, the relevant factors found in this research were compared with the factors in the framework of Suarez (2004). It was found that a subset of factors such as 'timing of entry', 'pricing strategy', 'appropriability strategy', and 'marketing communications' were discussed under one single factor known as 'strategic manoeuvering', and it was considered to be an essential factor in the third phase. These factors were indeed found to be relevant in the case of charging standards battle. Further, the relevant factors were compared with the factors in the fourth phase of technology dominance. And for the first time, it was found that the factors which were considered to be essential in the fourth phase of technology dominance ended up being important already in the third phase within the charging standards battle. The factors in the fourth phase consisted of 'brand reputation and credibility', 'financial strength', 'operational supremacy', 'installed base', 'network externalities', and 'switching costs'. It was also observed that the factors such as 'brand reputation and credibility', and 'financial strength' had ended up being more influencial than the factors found to be important in the third phase. Moreover, the relevant factors were also compared with the list of factors in the framework by den Uijl (2015). In his framework, three out of four factors were comparable with the ones in the framework of Suarez (2004) in the third phase. However, den Uijl (2015) placed the factor 'appropriability strategy' in the final phase of technology dominance. Nevertheless, the factor 'appropriability strategy' has been found to be relevant in the third phase itself. Therefore, the factors in the fourth phase of technology dominance can be considered to be essential in the third phase already in future case studies.

Fifth, the statistical tests used in this research contribute to the existing BWM literature, which uses only global and local weights for analysis. As there were two different groups of experts involved in the application of BWM in this research, statistical analysis tests such as 'Independent samples T-Test', 'Leven's test', and 'Mann-Whitney U test' were used for the first time. These tests were used to analyze the significant differences in global weights between the two groups. While these tests are capable of analyzing data from a smaller set of samples, they can be used in similar research studies in the future. Further, these tests can also be used in studies where the BWM approach is applied with the help of more than two types of experts.

Finally, the results provide empirical evidence to assign weights to the relevant factors and analyze the importance of those weights to explain their influence in the process of standardization using the BWM approach.

7.2.2 Practical contributions

Some practical contributions were made in this research in addition to the theoretical contributions discussed in the previous section 7.2.1. The first practical contribution in this research pertains to the possibility of using this framework for the selection of charging standards in the future before the large-scale commercialization of V2G technology. Technology managers in the filed of charging standards can use the top five factors obtained during the analysis of results in this research to decide which charging standards are more suitable for investments to commercialize V2G technology on a large-scale in the future. Secondly, the proposed framework with the BWM approach in this research can also be used to analyze technologies within similar domains in a situation of multi-mode standardization. Finally, the identified factors in the framework can be used to define strategies by the vital technological players in the market to gain advantages before the other entrants in the market.

7.3 Limitations and recommendations

7.3.1 Constructed Framework

Although the new framework consists of most of the relevant factors, further testing of this framework needs to be carried out for standard battles within a multi-mode standardization scenario. The proposed framework along with the BWM approach needs to be used in the identification of success factors instead of the previous framework by Van de Kaa et al. (2011) to validate the relevance of identified factors for future technology battles. As the new framework is constructed around 39 factors, scrutinizing the relevant factors in the early stages can help to gain prominent results during the analysis part.

While the concept of success factors within multi-mode standardization was studied for the second time, there is much scope for the identification of new case studies in the literature. Such case studies can help to find empirical evidence for the influence of success factors proposed in the constructed framework. Also, there is further scope for the identification of new factors in the literature, which in turn can enhance the proposed framework in the future. During the BWM interviews, the experts proposed an additional two factors. The first factor 'geographical area' refers to the particular geographic location where the battle between the standards takes place. This factor could be included in the category 'market characteristics'. And the second-factor 'security' pertains to the security of consumer data when the EV is communicating with the smart grid. This factor could be added in the category 'characteristics of the standard'. The additional two factors were not incorporated in the proposed framework because they were identified in the later stages of the research. It is also further recommended to evaluate the literature research and validate the proposed framework in the future.

During the literature review of the success factors, a few factors were found to be correlated with each other. For example, 'brand reputation and credibility' helps increase the 'installed base' (Van de Kaa et al., 2011). Another example shows that the adoption rate of new 'compatible' technologies is affected by the 'current installed base' and existing 'network externalities' for the current defacto standard in the market (Farrell & Saloner, 1986). During the BWM interviews, the experts also discussed the existence of a correlation between the success factors implicitly. For example, in the case of charging standards, the 'big fish' is undoubtedly backed by high 'financial strength' and technological resources in the market (I11, 2020). Also, technologies with high 'compatibility' and right 'brand reputation and credibility' help in inducing the 'bandwagon effect' in the market (I10, 2020). Therefore, it is evident that a correlation exists between the success factors, according to the literature and experts. However, the correlation aspect was not considered for ranking the factors using the BWM approach. Nevertheless, it is recommended to examine the correlation between success factors in future studies.

7.3.2 Local and Global weights

As discussed in section 6.2, there were a few instances where the ranks of the top factors varied because of one major reason. If a particular category consisted of more number of factors it resulted in the lesser corresponding local weights for all the factors. On the contrary, if a particular category consisted of fewer factors it resulted in the higher corresponding local weights for all the factors within that category. Hence, all the categories under analysis need to have an equal number of factors to obtain the best results. There is also a possibility where results could end up being inconsistent if there is a difference of opinion between interviewees. Hence, more number of interviews can help to gain consistent results using the BWM approach.

7.3.3 Potential winner in the standards battle

To identify the winner in the charging standards battle, the global average weights of individual relevant factors obtained from the BWM approach needed to be tested on each of the competing standards. Initially, a pairwise comparison is made with the help of experts to allocate scores ranging from 0,3,5 and 7 to each relevant factor for all the competing standards. Once the scores have been allotted, the global average weights of individual factors are multiplied by the allocated scores to obtain a unique value for each factor. Finally, these values are added to obtain a final score for each competing standard. The charging standard with the highest score wins the battle. In this research, CCS combo is the potential winner with a score of '5.32', and CHAdeMO stands in the second position with a score of '4.97'. Even though Tesla is supporting CCS combo in Europe, few experts allocated scores for Tesla based on the future potential of the standard. Nevertheless, Tesla gained the least score in the battle, i.e., '1.87'. The relevant factors with the highest scores that differentiate CCS combo from other competing standards are: 'financial strength', 'compatibility', 'pricing strategy', 'big fish', 'regulator', and 'network of stakeholders'. Table 11 shows the scores for all the relevant factors for individual charging standards.

Categories & Factors	CHAdeMO		CCS Combo		Tesla	
	Performance score	Weighted score	Performance score	Weighted score	Performance score	Weighted score
Characteristics of standard supporter						
Financial strength	5.00	0.40	7.00	0.56	3.00	0.24
Brand reputation and credibility	5.00	0.47	5.00	0.47	3.00	0.28
Operational supremacy	7.00	0.26	5.00	0.18	3.00	0.11
Learning orientation	5.00	0.08	5.00	0.08	3.00	0.05
Characteristics of the standard		-		-		-
Technological superiority	7.00	0.22	7.00	0.22	3.00	0.09
Compatibility	5.00	0.40	7.00	0.56	3.00	0.24
Flexibility	5.00	0.15	5.00	0.15	3.00	0.09
Standard support strategy		-		-		-
Pricing strategy	5.00	0.06	7.00	0.09	3.00	0.04
Appropriability strategy	5.00	0.17	5.00	0.17	3.00	0.10
Timing of entry	7.00	0.12	5.00	0.09	-	-
Marketing communications	5.00	0.09	5.00	0.09	-	-
Pre-emption of scarce assets	5.00	0.05	5.00	0.05	-	-
Distribution strategy	5.00	0.06	5.00	0.06	-	-
Commitment	7.00	0.13	5.00	0.10	-	-
Lobbying	5.00	0.25	5.00	0.25	-	-
Factors influencing committee consensus		-		-		-
Voting rights	3.00	0.09	3.00	0.09	-	-
Incentives for consensus-building	3.00	0.06	3.00	0.06	-	-
Consensus rules in the standardization process	3.00	0.04	3.00	0.04	-	-
Delay in standardization process	3.00	0.04	5.00	0.07	3.00	0.04
Number of standard proposals & revisions	5.00	0.11	3.00	0.07	-	-
Agenda-setting effort	3.00	0.02	5.00	0.04	-	-
Other stakeholders		-		-		-
Current installed base	5.00	0.16	5.00	0.16	3.00	0.10
Previous installed base	7.00	0.16	5.00	0.12	3.00	0.07
Big Fish	5.00	0.14	7.00	0.20	3.00	0.09
Suppliers	5.00	0.03	5.00	0.03	-	-
Regulator	3.00	0.06	7.00	0.14	-	-
Market characteristics		-		-		-
Bandwagon effect	5.00	0.25	5.00	0.25	-	-
Network externalities	3.00	0.05	5.00	0.08	3.00	0.05
Uncertainty in the market	5.00	0.11	5.00	0.11	3.00	0.06
Rate of change	5.00	0.07	5.00	0.07	3.00	0.04
Switching costs	5.00	0.13	5.00	0.13	3.00	0.08
Community development	5.00	0.12	5.00	0.12	3.00	0.07
Factors influencing the committee composition		-		-		-
Size of the committee	5.00	0.11	5.00	0.11	-	-
Network of stakeholders	5.00	0.24	7.00	0.34	-	-
Number of firm-specific representatives in the committee	3.00	0.07	5.00		-	-
Total		**4.97**		**5.32**		**1.83**

Table 11: Ranking of alternatives based on the performance scores for all factors within each charging standard

7.4 Reflection

The most challenging aspect before the start of my master thesis was to find a suitable topic related to Vehicle-to-grid (V2G) technology. However, a few assignments from different courses such as 'Integration Moment' and 'Technology battles' made me interested in V2G technology. Initially, I was interested in the topic of sustainable transition towards V2G technology in the Netherlands. However, when I contacted Geerten van de Kaa with my proposal, he immediately remembered me from his course 'Technology battles' and asked me if I was interested in standard battle related to V2G technology. As I was very eager to work on topics related to V2G technology, I accepted the proposal and started working on it immediately. With the experience of assignments in the course 'Technology battles', it was easier to define the scope of my research. However, I had some difficulty in reading all the articles thoroughly to identify the factors within multi-mode standardization. While a similar approach was used in one of the assignments for the analysis of success factors for a different aspect of V2G technology, it was easy to understand the application of the methodology in this research. Even though I had attended the course 'Research Methods' in one of my previous quarters, I had minimal awareness about the application part of the various statistical tools during an actual case study. Hence, during this research, I was able to understand the importance of the tests, and this will be helpful for me in the future. Another challenge was about finding experts in the field of V2G technology. While I had worked on a previous assignment related to V2G technology, I could find the academic experts easily. However, finding industrial experts was a real challenge. I had to attend webinars related to the technology and then was able to find some contacts through it. With the limited number of interviews, statistical tests were used to analyze the results obtained from the interviews.

From the perspective of an academic researcher, the research performed during my thesis has given me insights about the technology battles in detail. The knowledge gained during this research has helped me to understand the perspective of technology managers where they need to decide on selecting technology for investments. As a student of Management of Technology (MOT), it is inevitable to come across the process of standardization of technologies, this research has given me a deeper understanding of the potential actors involved and their expectations in the standardization process. The literature review allowed me to explore different case studies (which I was unaware of prior to this research) and know about various technologies around the world.

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9. Interviews

I1 2020: Consultant at EV test (Denmark). 16 May 2020 via a Skype interview about the relevance of factors.

I2 2020: Employee at ElaadNL (Netherlands). 29 May 2020 via a Skype interview about the relevance of factors.

I3 2020: Senior Research Fellow at the Delft University of Technology (Netherlands). 29 May 2020 via a Skype interview about the relevance of factors and performed BWM offline.

I4 2020: Researcher at the Delft University of Technology (Netherlands). 02 June 2020 via a Skype interview about the BWM.

I5 2020: Professor at the Delft University of Technology (Netherlands). 03 June 2020 via a Skype interview about the BWM.

I6 2020: Employee at ElaadNL (Netherlands). 04 June 2020 via a Skype interview about the BWM.

I7 2020: Consultant at EV test (Denmark). 08 June 2020 via a Skype interview about the BWM.

I8 2020: Employee at ElaadNL (Netherlands). 09 June 2020 via a Skype interview about the BWM.

I9 2020: Employee at an Anonymous organization (Belgium). 12 June 2020 via a Skype interview about the BWM.

I10 2020: Senior Research Fellow at the Delft University of Technology (Netherlands). 16 June 2020 via a Skype interview about the interpretation of the BWM results.

I11 2020: Researcher at the Delft University of Technology (Netherlands). 16 June 2020 via a Skype interview about the interpretation of the BWM results.

I12 2020: Employee at ElaadNL (Netherlands). 16 June 2020 via a Skype interview about the interpretation of the BWM results (Part-1).

I12 2020a: Employee at ElaadNL (Netherlands). 17 June 2020 via a Skype interview about the interpretation of the BWM results (Part-2).

Interviewee	Stage 1 (Identification of relevant factors)	Stage 2 (Performing BWM)	Stage 3 (Interpretation of BWM results)
I1 & I7	X	X	
I2 & I6	X	X	
I3 & I10	X	X	X
I4 & I11		X	X
I5		X	
I6, I12 & I12a		X	X
I9		X	

Table 12: Information about the interviewees involved in three stages of analysis

The link for interview audio files and corresponding transcripts are as follows:

Interview audio files:

https://drive.google.com/drive/folders/1WgVs16kcpW0VuyQXNn9ZD-JMn80cC-J8?usp=sharing

Interview transcripts:
https://drive.google.com/drive/folders/1hN_j_sGQsEQxAdJy8MUfJzn7E1xnB9Kh?usp=sharing

The link for BWM files are as follows:

https://drive.google.com/drive/folders/156a2WEPXF2mBE76R811t2BgZz0X9Nugk?usp=sharing

The link for files related to the identification of factors are as follows:

https://drive.google.com/drive/folders/1WAKqVLKsuYWa_JAeL3JzPPIX8Rhd1yqj?usp=sharing

Appendix A: List of identified factors that influence success in a situation of multi-mode standardization

This Appendix includes a broad explanation of the influence of identified success factors within multi-mode standardization.

Table 13: Overview of the factors identified that affect success in a situation of multi-mode standardization

Factors	Explanations
Characteristics of the standard supporter	The first category of factors signifies the strength of the standard supporter or a group supporting a particular standard.
1. Financial strength	Financial strength gives bargaining power for large firms in the standardization process (Blind & Mangelsdorf, 2016), which indeed gives them the advantage of spending more on the development of a standard successfully (Geerten Van de Kaa et al., 2011). Hence, the more the financial strength of a firm, there are higher chances of having a better position in the committee and gain strong voting rights in the standardization process.
2. Brand reputation and credibility	Usually, brand reputation and credibility of a firm in the market plays a crucial role in creating an installed base and helps in attracting stakeholders to support the firm. With the increase in the number of supporters, there is an increase in the size of the group representing a standard in the standardization process (Geerten Van de Kaa et al., 2011, 2020). Hence, brand reputation and credibility help creating legitimacy and provide a dominant position for the firms in the committee.
3. Operational supremacy	Operational supremacy concerns the capacity of a firm to efficiently utilize its resources better than its competitor in the market (Geerten Van de Kaa et al., 2011). Hence, it can help the firm to allocate resources for the standardization process efficiently, which will allow it to gain sufficient momentum in the committee.
4. Learning orientation	Learning orientation describes the capacity to learn from its previous experiences and gain a dominant position in the standardization process (Geerten Van de Kaa et al., 2011). Further, during the standardization process, the members tend to learn that cooperation is the only solution to reach a successful consensus, which otherwise would lead to delay in the standardization process ending up as a lose-lose situation (Geerten Van De Kaa & De Bruijn, 2015). Other than cooperation, members also gain knowledge from different stakeholders in the standardization process to learn, implement, disseminate, and make use of resources efficiently. This process is popularly known as absorptive capacity (Wakke et al., 2015). It plays a crucial role in the development of an individual firm and groups in the committee for the successful standardization process.

Characteristics of the standard	The second category of factors pertains to the superiority of the standard itself compared to the other standards, allowing it to gain higher chances of becoming dominant in a standardization process.
5. Technological superiority	Ideally, the potential winners in the market are related to the firms that possess superior technological resources (Vercoulen & van Wegberg, 1998). Technological superiority refers to a dominant design with the best features which allow it to outperform in the market (Geerten Van de Kaa et al., 2011). While the technicalities of a standard have a significant role to play in the standardization process (X. Gao, 2014), it certainly helps to attract more stakeholders to gain more support towards the dominant standard eventually.
6. Compatibility	Compatibility refers to the characteristics of fitting two interrelated entities aiming to function better together, and backward compatibility is considered to be an essential aspect for a standard to reach dominance (Geerten Van de Kaa et al., 2011). Users tend to prefer a high-degree of compatibility to enjoy the benefits from a broad range of complementary products to avoid being locked-in to only one particular product or technology or standard (Markard & Erlinghagen, 2017). Hence, the higher the compatibility of a standard, the more the chances of achieving a common standard eventually.
7. Complementary goods	Complementary goods are essential goods that are needed to diffuse technology into the market successfully (Geerten Van de Kaa et al., 2011). If the proposed standard in the standardization process is gaining more momentum, the chances of attracting complementary goods producers are more, and this helps to increase the size of the committee leading to success in achieving a dominant standard.
8. Flexibility	During the development of a standard, there are various number and degree of changes that need to be incorporated since the beginning of the standardization process. This process of incorporation is known as flexibility in the standards (van den Ende et al., 2012). Such changes emerge due to the diverse interests of the stakeholders in the committee, and the adoption of these changes involves costs as well as time (Geerten Van de Kaa et al., 2011). Lower flexibility tends to create conflicts within the stakeholders in the committee, eventually delaying the process of standardization. For example, HomeRF lost support from its stakeholders due to its inflexibility, and Wifi became the dominant standard with significant support due to higher flexibility. Hence, higher flexibility tends to increase technological superiority and helps in achieving common standards successfully (Geerten Van de Kaa et al., 2011).
Standard support strategy	The third category of factors refers to the various strategies developed and used by the firms or groups of firms in promoting a standard successfully to reach dominance in a standardization process.
9. Pricing strategy	Pricing strategy is used by the firms to block new stakeholders into the standardization process and elevate their position in the committee by

	strategically pricing the standards. Lower prices tend to attract more sets of stakeholders and increase the committee size and hence, increase the chances of reaching consensus in the standardization process (Geerten Van de Kaa et al., 2011).
10. Appropriability strategy	Appropriability strategy refers to the actions taken by the firms to protect their standards from being imitated by others in the market (Geerten Van de Kaa et al., 2011). Strategies include giving variable access to valuable information about the standards to the stakeholders, which might take a significant amount of time to develop otherwise. Open access to such information by a technology sponsor allows other members to find opportunities to join the collective and create complementary assets which eventually generates momentum to support the technology (Garud et al., 2002; Ranganathan et al., 2018; van den Ende et al., 2012), which is very helpful in reaching success. While the close settings are exclusive and are protected with Intellectual Property Rights, they deter the entry for new members (Pelkmans, 2001). Hence, an open appropriability strategy tends to provide more benefits over a closed approach and helps in selecting a common standard successfully.
11. Timing of entry	The timing of entry refers to the point in time when the standards are developed and diffused in the market (Geerten Van de Kaa et al., 2011). On the one hand, imposing the standards too early can hinder the quality of the standard from a technical perspective leading to very few opportunities to innovate further. On the other hand, the late imposition of standards can reduce incentives to the market stakeholders, create market confusion, and eventually hinders further innovation of the standards (Ho & O'Sullivan, 2018). Hence, the diffusion of standards at the right time can help meet the roles and functions of the standards in the market. Although, an early entry can help large firms with the high financial strength to create an installed base for their standards (Geerten Van de Kaa et al., 2011). Hence, an early entry can be considered as an advantage for powerful firms to have a dominant standard in the market.
12. Marketing communications	Communicating with customers can help understand their requirements and gain more outstanding market share. Before the introduction of standards, pre-announcement strategies are used in the early phase of the standardization process to avoid competition from the rivals and force the customers to wait for the standards (Geerten Van de Kaa et al., 2011). Increased market communications can allow the firms to establish an installed base prior to the imposition of standards in the market.
13. Pre-emption of scarce assets	Capturing of scarce assets by firms at an early stage can help to gain a competitive advantage in the standardization process (Geerten Van de Kaa et al., 2011). For example, if a firm already has captured an asset such as an installed base for a particular product in the market, it can

	help the firm to use the same installed base as a competitive advantage before the release of new standards in the market. Hence, the higher the number of scarce assets captured by the firms, the more support it gains in a standardization process.
14. Distribution strategy	Distribution strategy refers to the various number of strategies used by the firms to increase the strength of their standards. A good distribution strategy can help increase the acceptance of the standards in the market (Geerten Van de Kaa et al., 2011).
15. Commitment	Commitment describes the process of obtaining sufficient attention and support from various stakeholders in the standardization process (Geerten Van de Kaa et al., 2011). If an essential stakeholder in the committee makes an official announcement of committing to a particular standard, then the other stakeholders will follow the lead to make their products compatible with that specific standard (Farrell & Saloner, 1988). Hence, obtaining more commitment for a particular standard from sufficient stakeholders in the committee can help increase the chances of selecting that specific standard eventually.
16. Lobbying	The process of negotiating for favorable measures directly to the concerned entity in the standardization process to increase the speed of reaching consensus. For example, lobbying can be used as a strategy by a group of firms to negotiate with the government to include their technical specifications for the development of better standards and sometimes allow them to participate in a standardization process that could threaten their local business otherwise (De Vries & Verhagen, 2016; Mattli & Büthe, 2003; Meyer, 2012). Further, on the one hand, lobbying can be used by alliances to negotiate with public actors such as parliaments and courts, against the adoption of the government regulations that do not reflect their technical and strategic preferences (Meyer, 2012). On the other hand, Government authorities also use lobbying on private firms in an international setting organization, to get their desired results in a standardization process (Mattli & Büthe, 2003). Such lobbying could harm the development of quality standards. Hence, depending on the incentives of the group of stakeholders involved in the standardization process, lobbying can help or hinder the success of a quality standard (De Vries & Verhagen, 2016; Hail et al., 2009).
Factors influencing committee consensus	The fourth category is mainly related to the factors that influence building consensus within a committee in a standardization process.
17. Voting rights	Usually, voting is considered a last resort when the committee is unable to get consensus from all the relevant stakeholders eventually leading to a deadlock (Schmidt & Werle, 1998), and hence voting rights play a crucial role in such a standard-setting. Generally, voting rights are given to major stakeholders such as the board of directors from large company stakeholders and technical committee members, while

	other stakeholders are welcome to show their support without any voting rights in the committee (den Uijl & de Vries, 2013). Voting rights are also related to the cost of membership in the consortia, where a member can gain strong voting rights by paying more membership fees, and lower membership fees are related to limited voting rights (Markus et al., 2006). Blocking or delaying the standardization process may be reflected as a deliberate voting strategy on the part of countries chairing or sharing secret services with the technical committee members in an international standard-setting (Borraz, 2007). Nevertheless, members usually would not try to use the voting rights in their favor as they would lose the rights if found guilty, and the fear of losing the rights will make them abide by the committee rules (Geerten Van De Kaa & De Bruijn, 2015). Hence, the number of voting rights needs to be given to a few personnel, which will help to reach the consensus on a common standard.
18. Incentives for consensus-building	Incentives play a crucial role to motivate the technology producers to join the committee and enforce their own company-specific standards, which will prevent incompatible or conflicting standards (Blind & Mangelsdorf, 2016). As huge investments are involved in the standardization process by the stakeholders in the committee, various forms of incentives need to consider before leaving the process entirely leading to sunk investments. Van De Kaa & De Bruijn (2015) define various forms of incentives from perspective of future gains, enduring gains, voting rules, sense of urgency, and incentive to compromise. Hence, each stakeholder needs to target at least one of the forms of incentives to gain by participating in the standardization process. Farrell & Saloner (1988) also mention that less incentive for the stakeholders in the committee can help achieve compatibility in the standards, and excessive incentives for a particular stakeholder can lead to the bandwagon effect. Nevertheless, without sufficient incentives for a stakeholder in a committee, consensus-building can be hindered significantly eventually leading to delay in the standardization process. Hence, sufficient incentives will attract more stakeholders for the support of a standard, which in turn will increase the chances of selecting a dominant standard.
19. Consensus rules in the standardization process	The consensus in a committee means that all the stakeholders have agreed upon a common solution, and no one had to give up without integrating their expectations in the proposed standard. There are rules for building consensus not only in a committee but also in alliances and consortiums as well. Various industry representatives are explicitly invited to participate in drawing up rules based on their concerns (Borraz, 2007). While these rules are pre-determined before the start of the standardization process, sometimes, these rules may hinder the process of reaching consensus. For example, Sun Microsystems was a sponsor for a coalition in the development of Java software and hence acted as an enforcer of rules. The rules were pre-

	dominantly ensured to benefit Sun Microsystems alone, which led to many members to request for open-source software and few members started working on their version of the software (Garud et al., 2002). The rules governing the standardization process must enable the contributions of marginal players as well (Leiponen, 2008). Nevertheless, the rules need to be chosen very wisely, and understanding these rules can help to refine the strategies and decisions in the standardization process. Hence, a more number of stringent rules might create conflicting interests within stakeholders and reduce the likelihood of choosing a dominant standard.
20. Delay in the standardization process	Delays emerge majorly as consequences of conflicting interests from stakeholders in a standardization process (Simcoe, 2003; Geerten Van De Kaa & De Bruijn, 2015). Delay in the standardization process can affect the stakeholders either positively or negatively. For example, whenever there is a significant delay in the standardization process, the involved stakeholders become frustrated to a level where the chairperson would have to intervene to decide autonomously, which lead to loss of incentives as well as sunk costs for many participants (Geerten Van De Kaa & De Bruijn, 2015). Voting rules can also be implemented at the final stages of the standardization process, as a means of last resort to decide on the selection of a standard (Borraz, 2007). On the one hand, delays may also force the stakeholders to come to a consensus (Schmidt & Werle, 1998), while on the other hand, sometimes costly delays can eventually help to build high-quality standards (Simcoe, 2003; Spulber, 2019), which can give long-term returns to the stakeholders. But, long-term delays reduces the likelihood of arriving at a consensus to select a dominant standard.
21. Number of standard proposals & revisions	Before reaching consensus, the committee follows a procedure of reviewing all the number of proposals submitted by the members. If there is no consensus on the current set of proposals, new revisions will be prepared by the members and proposed in consecutive meetings. This process continues until the final agreement is reached. Hence, it leads to excessive delays until the proposals are not neutral, i.e., where there are no conflicting interests (Simcoe, 2003). Therefore, the higher the number of standard proposals in the committee, the longer it takes to arrive at a consensus.
22. Agenda-setting effort	Agenda-setting can be used as a tool by any member in the standardization process to align the interests and increase the awareness about possible standards among stakeholders, which leads to increased collaboration, eventually helping to reach a successful consensus. (Meyer, 2012; Geerten Van de Kaa et al., 2020). First movers in the market are also considered as agenda setters in the international setting. In contrast, the laggards or second movers need to join the bandwagon of first-mover and switch to new standards incurring the relevant switching costs (Garud et al., 2002; Simcoe,

	2003). Increasing the agenda-setting efforts by all the stakeholders helps to reach a quality consensus in the committee.
Other Stakeholders	The fifth category of factors signifies the support from stakeholders other than the standard supporters.
23. Current installed base	Installed base refers to the total number of users for a particular technology in the market (Geerten Van de Kaa et al., 2011). While a standardization process starts with a set of technology developers, they tend to add new members to the process with the increase in the installed base for that particular technology (Dan, 2019). Hence, when a stakeholder with a strong installed base supports a specific standard, the chances of selecting that standard as a winner increases significantly.
24. Previous installed base	The previous installed base refers to the number of users already following a particular standard in the market (Geerten Van de Kaa et al., 2011). If the new standard that is under development in the standard-setting is based on the previous technology, then it certainly can achieve success as a common standard in the standardization process.
25. Big Fish	A Big fish refers to a large company in the market that can have a significant amount of influence in the standardization process by either promoting or financing a particular standard (Geerten Van de Kaa et al., 2011). van Wegberg (2004) mentions that the greater the ability of a stakeholder to influence a standard, the more likely they are to be considered as a desirable partner in the standardization process. Hence, a Big fish can significantly help a standard to achieve success.
26. Anti-trust laws	The government can impose laws against a standard to prohibit its dominance in the market (Geerten Van de Kaa et al., 2011). The government can intervene in the market and impose laws against a closed standard to reduce the dependency on one single standard and give the mandate to share the knowledge openly with the competitors. Sometimes, the government can also support the lagging standard to delay the outcome of the market battle (Cabral & Kretschmer, 2006). Such interventions can hinder the growth of standards, and hence, fewer interventions can allow firms to produce their standards and achieve success.
27. Suppliers	Suppliers are market entities that produce complementary goods based on the dominant standard in the market. To increase the chances of selecting a particular standard, stakeholders influence suppliers in the market to gain more support for that specific standard (Geerten Van de Kaa et al., 2011). Hence, support from suppliers can help increase the chances of selecting a particular standard in the standardization process.
28. Regulator	Governments can enforce regulations by using their resources in both the public and private sectors to achieve their objectives. Generally, the regulations by the government do not affect the standardization

	process entirely, but when the government itself prescribes a certain design it will have a major impact on the standardization process (de Vries et al., 2011). Governments can also regulate the market stakeholders to decide on the standard battles, which can either result in successful or sometimes failed standards, based on factors such as technological improvements (Gandal et al., 2003). Privately developed standards can also be enforced by the government to mandate similar standards all over the country, which will also help knowledge sharing among other market stakeholders (Borraz, 2007). The government also intervenes in the form of price regulation or stabilization of the market during an unbalanced supply and demand of products (Khemani & Shapiro, 1993). Government acknowledgment also plays a crucial role in the adoption of standards successfully (T. Egyedi & Spirco, 2011).
Market characteristics	The sixth category pertains to the factors that cannot be influenced by any firm or group of firms but can be influenced by other entities in the market.
29. Bandwagon effect	When a standard has been chosen by few firms to solve a particular problem in the market, many market players tend to follow the same standards as the solution is readily available for implementation, and this process is known as the Bandwagon effect (Geerten Van de Kaa et al., 2011). Sometimes a firm alone produces a de facto standards in the market and the other players in the market are forced to either follow that particular standard as a bandwagon or battle against it with a more superior standard (Mattli & Büthe, 2003). An increase in the Bandwagon effect leads to higher chances of success in achieving a dominant standard.
30. Network externalities	If there is a presence of a Network externality effect, the value of a product increases with the increase in the number of other users using it (Geerten Van de Kaa et al., 2011). Due to the network externalities effect, standards that obtain an early installed base are more likely to become dominant standards (Funk & Methe, 2001). Government support for one single standard can create positive network externalities, eventually expanding the market (Funk & Methe, 2001). Hence, the presence of network externalities increases the likelihood of a particular standard to be dominant.
31. Number of options available	The number of competing standards in the standardization process plays a significant role in the selection of dominant standards (Geerten Van de Kaa et al., 2011). The more the number of competing standards in a committee, more the uncertainty and hence it is difficult to reach consensus on selecting one dominant standard (Ranganathan et al., 2018). Hence, a lesser number of competing standards in a committee increases the likelihood of choosing a common standard.
32. Uncertainty in the market	When there is high uncertainty surrounding a standard in the committee, stakeholders tend to stop investing in that particular standard, fearing future losses, and it results in delaying the

	standardization process (Geerten Van de Kaa et al., 2011). Hence, lesser uncertainty leads to more likelihood of choosing a dominant standard.
33. Rate of change	The rate of change refers to the speed with which technology is evolving in the market (Geerten Van de Kaa et al., 2011). With the rapid shift in technology, the number of competing standards also increases, eventually creating uncertainty in the market. Hence, high uncertainty reduces the chances of reaching a consensus around one dominant standard.
34. Switching costs	When a dominant standard emerges from two competing standards in a committee, the stakeholders supporting the losing standard will incur costs to switch to the new prevailing standard (van Wegberg, 2004; Vercoulen & van Wegberg, 1998). And these costs include the costs for procurement as well as complementary goods in which the new standard has been implemented (Geerten Van de Kaa et al., 2011). Hence, higher switching costs result in the delay in the selection of dominant standards.
35. Community development	Firms are increasingly dependent on the developer communities to develop and diffuse IT-based standards, where they form a coalition with those with similar interests. Hence it is necessary to build and nurture the community of standard and application developers (Fukami & Shimizu, 2018). For example, Sun Microsystems allowed software developers to learn Java with initiatives such as development tools and courses (Garud et al., 2002). Hence, higher community development can help the growth of a standard and eventually increase the likelihood of selecting a dominant standard.
Factors influencing the committee composition	The final category refers to the factors that influence the composition of participants in a committee.
36. Cost to participate	The cost of participation can take up two forms for the participating members in the standardization process. Firstly, firms need to pay membership fees to the committee organizations for the services provided during the standardization process. It is essential to include the smaller as well as resource-constrained firms by charging reasonable membership fees (Leiponen, 2008). Secondly, firms need to invest their time and money in collaboration for each consecutive meeting they attend to support their interest in the committee organization. If there are conflicting interests within the committee, delays can become excessive, incurring more costs without any benefits in the standardization process (Geerten Van De Kaa & De Bruijn, 2015). The dilemma to further continue or leave the process entirely can undoubtedly result in sunk costs eventually. Sunk costs can be seen as a barrier to entry for new members and the exit for current members (Khemani & Shapiro, 1993). Hence, there is a risk and significant burden involved in small and resource-constrained firms to participate in the standardization process (Wakke et al., 2015). The

	lesser the cost for participation in the standardization process, the more number of stakeholders can participate eventually increasing the chances of achieving a common standard.
37. Size of the committee	The utility of standard-setting increases with the increase in the size of the committee in the standardization process, which also leads to a higher probability of developing the standards successfully (Axelrod et al., 1995; Dan, 2019; Hail et al., 2010). The large size of a committee can exert pressure on other stakeholders in the committee to cooperate in the standardization process (Bakker et al., 2014), which could help speed up the standardization process. However, with the increase in the size of the committee, sometimes it is difficult to reach consensus leading to delay in the standardization process (van den Ende et al., 2012). Nevertheless, more the size of the committee, there are more chances of reaching consensus.
38. Network of stakeholders	The diversity of the network of stakeholders supporting particular standards in the committee increases the chances of that standard to dominate in the standardization process (De Vries & Verhagen, 2016; Geerten Van de Kaa et al., 2011). Diversity in the stakeholders brings various technology experts to the table, allowing them to consider all the possible scenarios in the standardization process from a technical perspective. While diversity can take conflicting views during the process, it can either help to resolve them at a faster pace or sometimes could take a significant amount of time to arrive at a consensus. For example, the divergent set of stakeholders is positively related to the successful standardization of LED standards (Geerten Van de Kaa & Greeven, 2017). On the contrary, accommodating a large number of diverging interests slows down the decision-making process, and the stakeholders eventually end up compromising (Keil, 2002). Many SDOs encourage participation by a divergent set of stakeholders, but it poses a challenge to find suitable participants at the high cost of acquiring information or expertise (Simcoe, 2003). Hence, a higher diversity of stakeholders increases the chances of achieving a common standard. Thus higher the diversity of the network of stakeholders in a standard setting, the higher the chances of selecting a common standard.
39. Number of firm-specific representatives in the committee	The number of representatives from a particular firm in a committee adds significant weightage during the discussions. These representatives are employees of the firm that are required to handle complex processes based on their skillsets in the committee, which collectively gives a strong position to the firm in the standardization process. According to Fukami & Shimizu (2018), the committee stakeholders are not restricted only to the representatives of the firm but also involved engagement with the individual employees and engineers as well. However, if the firm size is small and has limited human resources, accommodating the travel expenses and time loss of participating personnel can be a costly process (Wakke et al., 2015).

	Nevertheless, higher firm representatives enhance the position of a stakeholder in the committee and help them in the selection of a dominant standard.

Appendix B: List of reviewed literature sources categorized into the relevant mode of standardization.

This Appendix includes an overview of the literature sources that were used to identify success factors within four different modes within multi-mode standardization.

*Table 14: Overview of the list of articles used for identifying the success factors in a situation of multi-mode standardization. Based on the combination of multi-mode standardization found in the literature, the articles were categorized accordingly. Articles that were studied and recategorized are marked with *.*

Multi-mode standardization				
Articles	**Committee- & Market- based Standardization**	**Committee- & Government-based Standardization**	**Market- & Government-based Standardization**	**Committee-, Market- & Government-based Standardization**
(Abbate, 2001)				X
(Axelrod et al., 1995)	X			
(Bakker et al., 2014)			X	
(Bakker & Trip, 2015)				X
(Bakker et al., 2015)				X
(Blind & Mangelsdorf, 2016)	X			
(Blind, 2011)		X		
(Blind & Gauch, 2008)		X		
(Borraz, 2007)		X		
(Dan, 2019)	X			
(de Vries et al., 2011)	X			
(De Vries & Verhagen, 2016)		X		
(den Uijl & de Vries, 2013)	X			
(Delmas & Montiel, 2008)				X
(Farrell & Saloner, 1988)	X			
(Farina et al., 2005)			X*	
(Funk & Methe, 2001)				X
(Fukami & Shimizu, 2018)	X			
(Gandal et al., 2003)			X	
(Garud et al., 2002)	X			

(Hail et al., 2009)				X
(Hail et al., 2010)				X
(Ho & O'Sullivan, 2018)				X
(Keil, 2002)	X			
(Lu et al., 2016)				X
(Markard & Erlinghagen, 2017)				X
(Mattli & Büthe, 2003)				X
(Markus et al., 2006)	X			
(Meyer, 2012)		X		
(P. Gao et al., 2014)		X		
(Pelkmans, 2001)		X		
(Puffert, 2000)			X	
(Puffert, 2002)			X	
(Ranganathan et al., 2018)	X			
(Rosen et al., 1988)			X	
(Schmidt & Werle, 1998)				X
(Spulber, 2019)	X			
(T. M. Egyedi, 2000)		X		
(T. Egyedi & Spirco, 2011)		X		
(Townes, 2012)		X		
(Trienekens & Zuurbier, 2008)				X
(van de Kaa et al., 2019)	X			
(Van De Kaa & De Bruijn, 2015)	X			
(Van de Kaa et al., 2020)				X
(van den Ende et al., 2012)	X			
(van Wegberg, 2004)	X			
(Vercoulen & van Wegberg, 1998)	X			
(Wakke et al., 2015)	X			
(Wätzold et al., 2001)				X
(X. Gao, 2014)		X		

*Table 15: Overview of the list of articles studied under single-mode standardization. Further, the articles from market-based standardization were studied to analyze whether the concept of multi-mode standardization was implicitly discussed in these articles. Articles that were studied and recategorized into multi-mode standardization are marked with *.*

Single modes of standardization			
Articles	**Committee-based standardization**	**Market-based standardization**	**Government-based standardization**
(Anderson & Tushman, 1990)		X*	
(Besen & Farrell, 1994)		X*	
(Cabral & Kretschmer, 2006)			X
(Gallagher & Park, 2002)		X	
(Lee et al., 1995)		X*	
(Leiponen, 2008)	X		
(M. A. Schilling, 2002)		X*	
(Shapiro & Varian, 1999a)		X*	
(Simcoe, 2003)	X		
(Srinivasan et al., 2006)		X	
(Suárez & Utterback, 1995)		X*	
(Suarez, 2004)		X*	
(Van de Kaa et al., 2011)		X*	

Table 16: Overview of the articles analyzed in Table 15 and recategorized into relevant combinations of multi-mode standardization

Recategorized into Multi-mode standardization				
Articles	**Committee- & Market- based Standardization**	**Committee- & Government-based Standardization**	**Market- & Government-based Standardization**	**Committee-, Market- & Government-based Standardization**
(Anderson & Tushman, 1990)				X
(Besen & Farrell, 1994)	X			
(Lee et al., 1995)			X	
(Schilling, 2002)			X	
(Shapiro & Varian, 1999a)				X
(Suárez & Utterback, 1995)		X		
(Suarez, 2004)	X	X		
(Van de Kaa et al., 2011)				X

Appendix C: List of relevant factors along with the justification of relevance in the selection of charging standards

This Appendix includes the broad reasons behind the identification of relevant factors for selecting a charging standard to implement V2G technology.

Table 17: Overview of the success factors identified by the experts with explanations for their relevance in the standardization of charging standards.

Factors	Explanation for relevance
1. Financial strength	“The development of the bi-directional charging capability in electric vehicles needs investments and hence having Financial strength in the competition is an absolutely important factor for all the EV manufacturing OEMs” (I1, 2020) “Strong financial company has more budget to develop a standard.” (I2, 2020) “This factor is certainly an important one for any company to build standards.” (I3, 2020)
2. Brand reputation and credibility	“If a particular EV manufacturing OEM is not capable of bi-directional charging, its brand reputation will decrease. And hence good brand reputation is essential for OEMs for gaining support.” (I1, 2020) “The better the reputation of a company supporting the standard, there will be more acceptance of that standard eventually.” (I2, 2020) “One of the EV car manufacturing company in the Netherlands is selling their cars for a premium price, which is comparable with the cost of Tesla cars. Indeed, Tesla is gaining more dominance in the market due to its high brand reputation, and hence this is an essential factor in the standard battles as well.” (I3, 2020)
3. Operational supremacy	“Operational supremacy is an important factor, but at present, the stakeholders are not concentrating much on this aspect. Certainly, in the long run, this can play an important role.” (I1, 2020) “The companies supporting the standards need to be working efficiently to gain a dominant position in the market.” (I3, 2020)
4. Learning orientation	“Some of the OEMs like Nissan would have supported CCS combo if they had learned sooner about the possible mandate by the EU. Nissan is losing brand value as they don't support CCS combo in Europe.” (I1, 2020)

	“Tesla company was successful in the market to introduce a new concept of cars, which predominantly was based on their learning orientation in the market.” (I3, 2020)
5. Technological superiority	“Technological superiority for EVs supporting V2G will be a game-changing aspect and certainly will help them to gain valuable support.” (I1, 2020) “Incorporation of safety protocols in the standards can make the standards superior and acceptable in the market.” (I2, 2020) “Standards battling against each other will have to perform perfectly in terms of technological perspective, which will give an added advantage for either of the standards in the standardization process.” (I3, 2020)
6. Compatibility	“While there are some intricate aspects in developing a particular standard concerning the coding of communication protocols, having compatibility of multiple cars with V2G is an added advantage. For example, Nissan had issues for making the Leaf model compatible with V2G, and eventually, it was resolved using a very minute change in the communicating software.” (I1, 2020) “The first charging standards established in the Netherlands were industrial power plugs, and later when Type 2 plugs were made mandatory by the EU, the charging stations that were already established with industrial plugs were not compatible with the technologically superior Type 2 plugs. Hence, backward compatibility plays an important in influencing the selection of charging standards.” (I2, 2020) “If particular charging equipment is not compatible with various charging standards, then it will have a disadvantage in the standardization process.” (I3, 2020)
7. Flexibility	“When there are EVs that are compatible with one particular charging standard on a broader level in Europe, the flexibity of incorportaing new developments is easier for all the stakehodlers support that particular standard.” (I1, 2020) “While there is a lot of uncertainty around the innovative developments of charing standards, CCS standard is trying to be flexible enough to support a broad range of protocols to gain dominance eventually.” (I2, 2020) “CCS combo has the flexibility of single-phase, 3 phase & DC fast charging and the same goes for Tesla. If any of the standards is

	incapable of being flexible to incorporate either of the support systems, then it would have a disadvantage." (I3, 2020)
8. Pricing strategy	"Although the charging equipment that supports either of the competing charging standards are expensive at the moment, the cost of charging equipment will vary with individual countries in Europe. Hence pricing strategy will certainly help OEMs to gain more support for a particular standard." (I1, 2020)
9. Appropriability strategy	"As the specifications for the charging standards are not available as open-source information, certainly having the data made available to other stakeholders can help gain support for that particular standard." (I1, 2020) "Providing the charging standards as an open-source system where the information is readily available for the developers can help the development of standards at a faster pace by incorporating new changes in the technology." (I2, 2020) "If any of the battling standards is made open source, developments can happen at a faster pace." (I3, 2020)
10. Timing of entry	"Getting approvals from relevant authorities and understanding the issues related to the market plays an essential role in the implementation of V2G technology, and hence the timing of entry is a crucial factor." (I1, 2020)
11. Marketing communications	"As the customers need to know about the products before it enters the market, marketing communications can help the standard developers to gain trust from the customers. Once the product is released into the market, getting feedback from the first set of customers also is an added advantage to make necessary changes before it is made available for everyone in the market." (I1, 2020) "Marketing communications is an important aspect of gaining a dominant position before a standard is diffused into the market." (I3, 2020)
12. Pre-emption of scarce assets	"Establishing of charging infrastructure early in the market can help to gain more support." (I1, 2020)
13. Distribution strategy	"Based on the type of market and available grid services, the distribution of the charing equipment varies. Hence, a distribution strategy is a bit complicated but certainly relevant." (I1, 2020) "One of the distribution strategies that can allow gaining a dominant position could be the involvement of stakeholders in a working group. Such an approach can also enable getting feedbacks from the stakeholders not only in the development

	phase but also in the implementation phase of the standards." (I2, 2020) "Different distribution channels can help gain a dominant position for companies promoting the standard." (I3, 2020)
14. Commitment	"While the commercialization of V2G technology will take a longer time, the relevant stakeholders will need a significant amount of commitment before generating any revenues." (I1, 2020) "The companies behind the development of charging standards are large companies and will certainly commit in the standardization process." (I2, 2020) "Commitment certainly is important for all the companies participating in the standardization process." (I3, 2020)
15. Lobbying	"Both the EV manufacturing industry and the energy supplying sector are very slow-moving industries. Hence, the implementation of charging standards certainly involves lobbying from both the stakeholders that are behind development and implementation." (I1, 2020) "Lobbying inside the committee plays an important role in gaining a dominant position." (I3, 2020)
16. Voting rights	"During the development of the CHAdeMO standard, providing voting rights to many stakeholders in the development has created conflicts of interest. This led to a significant delay in the development process. Hence, voting rights is an important factor." (I1, 2020) "Having more stakeholders on board of a committee with voting rights can result in a delay but could help the development of a quality standard." (I2, 2020)
17. Incentives for consensus-building	"During the development of the CHAdeMO standard, the developers were reluctant on changing the standard entirely but provided incentives to the stakeholders to have constant support for the CHAdeMO standard in the market." (I1, 2020) "Stakeholders participating in the committee certainly need to have incentives, and this helps the group to reach consensus." (I3, 2020)
18. Consensus rules in the standardization process	"While the standards are being developed constantly in this particular case, the stakeholders are not exactly sure about all the relevant aspects to be considered while deciding on the rules for consensus. But it will eventually play a significant role in building consensus." (I1, 2020)

19. Delay in the standardization process	“Many stakeholders, specifically the EV manufacturing OEMs, are waiting to decide on supporting either of the charging standards. This delay has certainly increased uncertainty around the dominance of standards.” (I1, 2020)
20. Number of standard proposals & revisions	“Indeed, all the stakeholders in the standardization process want to choose a dominant standard as soon as possible, but having quality standards revolves around the concept of numerous sets of proposals and revisions. Hence, having a balance between the pace of the standard development process and incorporating the relevant revisions is the key to have consensus.” (I1, 2020)
21. Agenda-setting effort	“Having new agendas will undoubtedly help to shape a quality standard but might sometimes end up delaying the standardization process.” (I1, 2020) “It is an essential factor as it can help developments to move in a new direction that eventually helps to build a better standard.” (I2, 2020)
22. Current installed base	“Tesla has a significant amount of installed base in the market and this can help the company to gain more support in the standardization process.” (I1, 2020) “There is already an installed base for both CCS and CHAdeMO in the market. And indeed, this factor will help in achieving a dominant standard in the future.” (I2, 2020)
23. Previous installed base	The interviewee (I3, 2020) agreed with the definition of the factor ‘precious installed base’ and hence considered this factor as important in the standardization of the charging standards.
24. Big Fish	“Nissan has been a big fish supporting CHAdeMO, and Tesla is going to be the next big fish and hence has a significant role to play in the standardization process.” (I3, 2020)
25. Suppliers	“Due to the small size and the speed with which the suppliers manufacture the charging components in the market, suppliers were not considered to be that essential in the market. But certainly, with the development of the standards, suppliers are expected to grow in size and play a significant role in supporting the standards.” (I1, 2020) “The suppliers in this particular case are concerned with providing V2G enabled charging stations and incorporating software protocols for the implementation of V2G technology. Hence the suppliers play an essential role in the standardization process.” (I2, 2020) “If there is no regulation, then it would be hard to do business for standard developers in the country and hence is considered important.” (I3, 2020)

26. Regulator	"While the EU plays a vital role in the selection of the charging equipment and communication protocols in the standardization process, regulation is an essential factor in deciding the dominant standard." (I1, 2020) "The regulators have already chosen the Type 2 connectors in the European countries and given a mandate that the V2G tests will henceforth be conducted only using the CCS connectors." (I2, 2020) "If there is no regulation then it would be hard to do business for standard developers in the country and hence is considered important." (I3, 2020)
27. Bandwagon effect	"While the participants in the standardization process are big companies, Nissan has undoubtedly made some impact on these companies supporting CHAdeMO in the implementation of V2G technology." (I1, 2020) "Bandwagon is an essential factor that can help achieve a dominant standard." (I2, 2020)
28. Network externalities	"The value that can be obtained out of V2G technology is vast in the future, and hence that would undoubtedly provide positive externality to the users and developers of the charging standards. Hence it can help to shape the technology." (I1, 2020)
29. Uncertainty in the market	"Considering the development of V2G capable standard, the slow-moving CCS standard has created high uncertainty among the supporting stakeholders, and the European EV manufacturers are still uncertain about supporting CCS completely." (I1, 2020) "There is uncertainty for the technology itself, along with the business models revolving the technology. But there is less uncertainty regarding the development of standards and hence is an important factor." (I2, 2020)
30. Rate of change	"Considering the communication protocols behind the charging standards, the rate of change is a very important factor. As the physical plugs will not have significant developments, the rate of change is relatively lower." (I1, 2020) "For example, the development of new types of batteries is changing at a rapid pace, and incorporation of these developments by the EV car manufacturing companies is significant to gain a dominant position." (I3, 2020)
31. Switching costs	"As the switching cost of plugs itself is very high at the moment, switching from one standard to another entirely can be a problematic scenario. Hence, until the switching costs are

	reduced, switching to another standard is not an option for the customers.” (I1, 2020) “If either of the standards ends up being dominant in the market, the users will have no alternatives but to switch to the prevailing standard. Hence, if the switching costs are low, users will find it easy to switch to the dominant standard.” (I2, 2020) “Switching costs are expected to high when the users of CHAdeMO switch to CCS in Europe.” (I3, 2020)
32. Community development	“For standards that are supported by smaller companies, the community development factor could be an important one for faster development. It is also true that if either of the standards supported by the more prominent companies is made open source, then it can help to develop a quality standard” (I2, 2020) “If either of the standards is made open source, then the community protocols developers can help the development of the standard at a faster pace.” (I3, 2020)
33. Size of the committee	“Finding the right size of the committee is essential in the standardization process, without which a bigger size can result in delay, and a smaller size could result in having reduced quality standards.” (I1, 2020) “The right balance of around 15-20 stakeholders could be an ideal size of the committee to conduct meetings efficiently. Hence the factor is important.” (I3, 2020)
34. Network of stakeholders	“Both CCS and CHAdeMO can be developed significantly by the inclusion of a diverse set of stakeholders and hence is an essential factor to gain more value out of the standardization process.” (I1, 2020) “Currently, the stakeholders involved in the standardization process includes EV manufacturing companies, charging equipment manufacturing companies, and IT companies. Involving a more diverse set of stakeholders can help to gain more support for a particular standard.” (I2, 2020)
35. Number of firm-specific representatives in the committee	“Having firm-specific representatives in the committee from more prominent companies like Volkswagen will have a significant impact on the standardization process.” (I1, 2020) “Such firm-specific representatives can influence the time of standard to be released and implement into the market.” (I2, 2020)

Appendix D: Results of Statistical analysis performed using IBM SPSS 26 software

Figure 3: Normality test results obtained for all the relevant factors from IBM SPSS 26 software. The data were assumed to be normally distributed if the p-value (i.e., Sig. value in the figure) is higher than 0.05.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Financial strength	0.230	7	.200*	0.903	7	0.347
Brand reputation and credibility	0.228	7	.200*	0.860	7	0.152
Operational supremacy	0.169	7	.200*	0.984	7	0.976
Learning orientation	0.215	7	.200*	0.909	7	0.391
Technological superiority	0.250	7	.200*	0.888	7	0.265
Compatibility	0.330	7	0.021	0.812	7	0.054
Flexibility	0.309	7	0.042	0.721	7	0.006
Pricing strategy	0.169	7	.200*	0.908	7	0.383
Appropriability strategy	0.323	7	0.026	0.733	7	0.008
Timing of entry	0.292	7	0.072	0.870	7	0.186
Marketing communications	0.205	7	.200*	0.904	7	0.358
Pre-emption of scarce assets	0.235	7	.200*	0.925	7	0.507
Distribution strategy	0.169	7	.200*	0.922	7	0.487
Commitment	0.200	7	.200*	0.911	7	0.405
Lobbying	0.301	7	0.055	0.849	7	0.121
Voting rights	0.213	7	.200*	0.873	7	0.199
Incentives for consensus-building	0.193	7	.200*	0.922	7	0.481
Consensus rules in the standardization process	0.305	7	0.048	0.814	7	0.056
Delay in standardization process	0.260	7	0.167	0.878	7	0.216
Number of standard proposals & revisions	0.363	7	0.006	0.759	7	0.016
Agenda-setting effort	0.197	7	.200*	0.873	7	0.197
Current installed base	0.160	7	.200*	0.928	7	0.536
Previous installed base	0.222	7	.200*	0.927	7	0.523
Big Fish	0.327	7	0.023	0.694	7	0.003
Suppliers	0.300	7	0.057	0.833	7	0.086
Regulator	0.140	7	.200*	0.973	7	0.922
Bandwagon effect	0.241	7	.200*	0.841	7	0.101
Network externalities	0.290	7	0.076	0.794	7	0.036
Uncertainty in the market	0.287	7	0.085	0.720	7	0.006
Rate of change	0.313	7	0.037	0.775	7	0.023
Switching costs	0.275	7	0.117	0.824	7	0.071
Community development	0.434	7	0.000	0.551	7	0.000
Size of the committee	0.395	7	0.001	0.603	7	0.000
Network of stakeholders	0.283	7	0.094	0.798	7	0.039
Number of firm-specific representatives in the committee	0.285	7	0.089	0.857	7	0.142

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 4: Independent Samples T-Test results obtained for normally distributed global weights of the factors from IBM SPSS 26 software. The data were assumed to be significantly different among the two groups of experts if the p-value (i.e., Sig. value in the figure) is higher than 0.05.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Financial strength	Equal variances assumed	0.298	0.608	-1.385	5.000	0.225	-0.059	0.043	-0.169	0.051
	Equal variances not assumed			-1.500	4.884	0.195	-0.059	0.039	-0.161	0.043
Brand reputation and credibility	Equal variances assumed	0.310	0.602	-0.482	5.000	0.650	-0.022	0.045	-0.139	0.095
	Equal variances not assumed			-0.467	3.889	0.666	-0.022	0.047	-0.154	0.110
Operational supremacy	Equal variances assumed	2.026	0.214	-0.189	5.000	0.857	-0.003	0.016	-0.044	0.038
	Equal variances not assumed			-0.165	2.355	0.882	-0.003	0.018	-0.071	0.065
Learning orientation	Equal variances assumed	0.594	0.476	-0.253	5.000	0.810	-0.001	0.005	-0.013	0.011
	Equal variances not assumed			-0.272	4.951	0.797	-0.001	0.004	-0.012	0.010
Technological superiority	Equal variances assumed	0.124	0.739	0.827	5.000	0.446	0.014	0.016	-0.028	0.056
	Equal variances not assumed			0.854	4.874	0.433	0.014	0.016	-0.028	0.055
Pricing strategy	Equal variances assumed	3.145	0.136	-0.726	5.000	0.500	-0.005	0.007	-0.023	0.013
	Equal variances not assumed			-0.653	2.754	0.564	-0.005	0.008	-0.031	0.021
Timing of entry	Equal variances assumed	7.081	0.045	-1.168	5.000	0.295	-0.012	0.010	-0.038	0.014
	Equal variances not assumed			-1.371	3.204	0.259	-0.012	0.009	-0.039	0.015
Marketing communications	Equal variances assumed	6.840	0.047	-0.826	5.000	0.446	-0.009	0.011	-0.037	0.019
	Equal variances not assumed			-0.728	2.490	0.529	-0.009	0.012	-0.053	0.035
Pre-emption of scarce assets	Equal variances assumed	5.126	0.073	0.089	5.000	0.932	0.000	0.005	-0.012	0.013
	Equal variances not assumed			0.077	2.334	0.944	0.000	0.006	-0.021	0.022
Distribution strategy	Equal variances assumed	8.564	0.033	-0.405	5.000	0.702	-0.003	0.008	-0.024	0.017
	Equal variances not assumed			-0.349	2.274	0.757	-0.003	0.009	-0.039	0.032
Commitment	Equal variances assumed	6.429	0.052	-0.127	5.000	0.904	-0.002	0.014	-0.037	0.033
	Equal variances not assumed			-0.111	2.386	0.920	-0.002	0.016	-0.060	0.056
Lobbying	Equal variances assumed	2.197	0.198	-1.735	5.000	0.143	-0.039	0.023	-0.098	0.019
	Equal variances not assumed			-1.583	2.943	0.213	-0.039	0.025	-0.119	0.041
Voting rights	Equal variances assumed	0.903	0.386	1.504	5.000	0.193	0.030	0.020	-0.021	0.082
	Equal variances not assumed			1.395	3.182	0.252	0.030	0.022	-0.036	0.097
Incentives for consensus-building	Equal variances assumed	1.115	0.339	0.866	5.000	0.426	0.010	0.012	-0.020	0.041
	Equal variances not assumed			0.782	2.800	0.495	0.010	0.013	-0.033	0.054

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Delay in standardization process	Equal variances assumed	0.670	0.450	2.824	5.000	0.037	0.014	0.005	0.001	0.026
	Equal variances not assumed			3.006	4.993	0.030	0.014	0.005	0.002	0.025
Agenda-setting effort	Equal variances assumed	3.423	0.124	0.308	5.000	0.771	0.002	0.006	-0.012	0.016
	Equal variances not assumed			0.357	3.486	0.742	0.002	0.005	-0.012	0.016
Current installed base	Equal variances assumed	0.775	0.419	0.835	5.000	0.442	0.015	0.017	-0.030	0.059
	Equal variances not assumed			0.866	4.921	0.427	0.015	0.017	-0.029	0.058
Previous installed base	Equal variances assumed	0.666	0.452	2.185	5.000	0.081	0.026	0.012	-0.005	0.057
	Equal variances not assumed			1.989	2.903	0.144	0.026	0.013	-0.017	0.069
Suppliers	Equal variances assumed	2.773	0.157	1.042	5.000	0.345	0.003	0.003	-0.005	0.011
	Equal variances not assumed			0.901	2.300	0.452	0.003	0.004	-0.010	0.017
Regulator	Equal variances assumed	0.015	0.908	-0.115	5.000	0.913	-0.001	0.008	-0.021	0.020
	Equal variances not assumed			-0.115	4.415	0.914	-0.001	0.008	-0.022	0.021
Bandwagon effect	Equal variances assumed	3.995	0.102	0.568	5.000	0.595	0.020	0.036	-0.071	0.112
	Equal variances not assumed			0.506	2.628	0.652	0.020	0.040	-0.118	0.158
Network externalities	Equal variances assumed	0.132	0.731	0.092	5.000	0.930	0.001	0.010	-0.024	0.026
	Equal variances not assumed			0.090	4.062	0.933	0.001	0.010	-0.026	0.028
Uncertainty in the market	Equal variances assumed	11.773	0.019	0.702	5.000	0.514	0.015	0.022	-0.041	0.071
	Equal variances not assumed			0.598	2.156	0.607	0.015	0.026	-0.088	0.118
Switching costs	Equal variances assumed	0.013	0.914	-0.164	5.000	0.876	-0.003	0.020	-0.054	0.047
	Equal variances not assumed			-0.162	4.243	0.879	-0.003	0.020	-0.057	0.051
Network of stakeholders	Equal variances assumed	9.739	0.026	0.538	5.000	0.614	0.012	0.023	-0.047	0.071
	Equal variances not assumed			0.460	2.183	0.688	0.012	0.027	-0.094	0.119
Number of firm-specific representatives in the committee	Equal variances assumed	3.221	0.133	1.568	5.000	0.178	0.019	0.012	-0.012	0.050
	Equal variances not assumed			1.350	2.252	0.297	0.019	0.014	-0.036	0.074

Figure 5: Mann-Whitney U test results obtained for non-normally distributed factors from IBM SPSS 26 software. The data were assumed to be significantly different among the two groups of experts if the p-value (i.e., Sig. value in the figure) is higher than 0.05.

Test Statistics[a]

	Compatibility	Flexibility	Appropriability strategy	Consensus rules in the standardization process	Number of standard proposals & revisions	Big Fish	Rate of change	Community development	Size of the committee
Mann-Whitney U	5.000	5.000	4.000	3.000	5.000	4.000	4.000	4.000	6.000
Wilcoxon W	11.000	15.000	10.000	13.000	15.000	14.000	14.000	10.000	16.000
Z	-0.354	-0.354	-0.707	-1.061	-0.354	-0.707	-0.707	-0.707	0.000
Asymp. Sig. (2-tailed)	0.724	0.724	0.480	0.289	0.724	0.480	0.480	0.480	1.000
Exact Sig. [2*(1-tailed Sig.)]	.857b	.857b	.629b	.400b	.857b	.629b	.629b	.629b	1.000b

a. Grouping Variable: Experts

b. Not corrected for ties.

Appendix E: Comparison of consistency ratios with the threshold values

Table 18: Overview of the comparison results between consistency ratios and corresponding threshold values (from Table 2)

Interviewee	Categories/Criteria	Maximum Scale	Number of Criteria	Consistency ratio	Threshold values
I1	Charateristics of standard supporter	6	4	0.0916	0.2922
	Characteristics of the standard	3	3	0.0417	0.2087
	Standard support strategy	8	8	0.0628	0.4543
	Factors influencing committee consensus	7	6	0.0805	0.3931
	Other stakeholders	8	6	0.0669	0.4230
	Market characteristics	7	6	0.0705	0.3931
	Factors influencing the committee composition	3	3	0.0417	0.2087
I2	Charateristics of standard supporter	6	4	0.1071	0.2922
	Characteristics of the standard	5	3	0.0750	0.2111
	Standard support strategy	8	8	0.0664	0.4543
	Factors influencing committee consensus	8	6	0.0961	0.4230
	Other stakeholders	9	6	0.0768	0.4225
	Market characteristics	9	6	0.1226	0.4225
	Factors influencing the committee composition	7	3	0.0833	0.2090
I3	Charateristics of standard supporter	7	4	0.0786	0.3313
	Characteristics of the standard	3	3	0.0417	0.2087
	Standard support strategy	9	8	0.0684	0.4587
	Factors influencing committee consensus	8	6	0.0819	0.4230
	Other stakeholders	6	6	0.0641	0.3924
	Market characteristics	8	6	0.0820	0.4230
	Factors influencing the committee composition	7	3	0.1250	0.2090
I4	Charateristics of standard supporter	9	4	0.1049	0.3653
	Characteristics of the standard	9	3	0.1524	0.2122
	Standard support strategy	9	8	0.1348	0.4587
	Factors influencing committee consensus	9	6	0.0846	0.4225
	Other stakeholders	9	6	0.1536	0.4225
	Market characteristics	9	6	0.0979	0.4225
	Factors influencing the committee composition	9	3	0.1524	0.2122
I5	Charateristics of standard supporter	6	4	0.0714	0.2922
	Characteristics of the standard	7	3	0.1091	0.2090
	Standard support strategy	8	8	0.0664	0.4543
	Factors influencing committee consensus	9	6	0.0999	0.4225
	Other stakeholders	9	6	0.0853	0.4225
	Market characteristics	8	6	0.1004	0.4230
	Factors influencing the committee composition	5	3	0.0889	0.2111
I6	Charateristics of standard supporter	6	4	0.0916	0.2922
	Characteristics of the standard	3	3	0.0417	0.2087
	Standard support strategy	8	8	0.0664	0.4543
	Factors influencing committee consensus	7	6	0.0829	0.3931
	Other stakeholders	5	6	0.0573	0.3309
	Market characteristics	7	6	0.0829	0.3931
	Factors influencing the committee composition	7	3	0.0893	0.2090
I7	Charateristics of standard supporter	9	4	0.1215	0.3653
	Characteristics of the standard	8	3	0.1319	0.2267
	Standard support strategy	9	8	0.0567	0.4587
	Factors influencing committee consensus	8	6	0.0865	0.4230
	Other stakeholders	9	6	0.0904	0.4225
	Market characteristics	8	6	0.0787	0.4230
	Factors influencing the committee composition	5	3	0.0889	0.2111