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A review of ITS standards for the development of electric roads

vti

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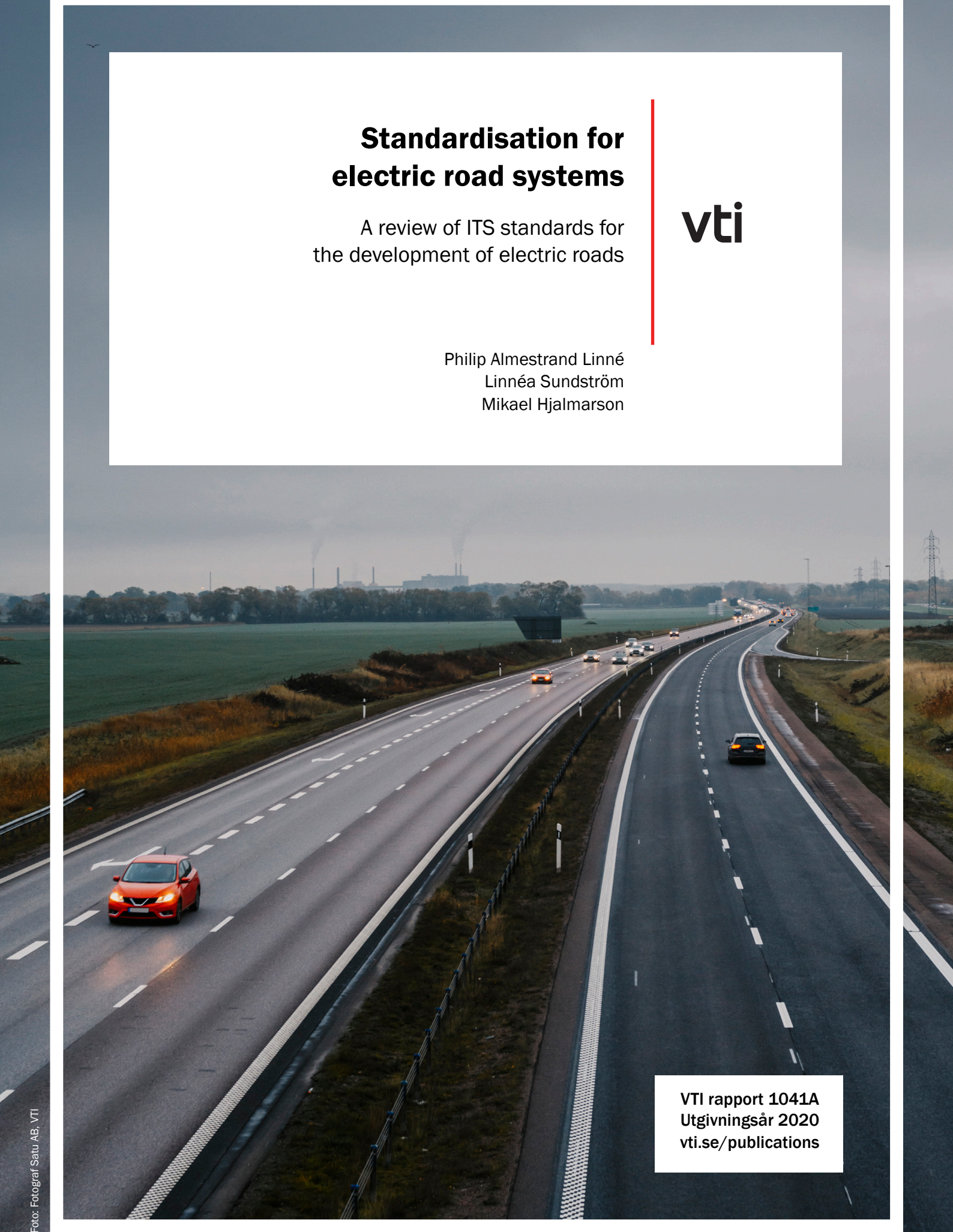

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Abstract

As electric road system (ERS) technologies continue to reach higher levels of maturity, the need for standardisation of the field appears comparable to many other technically oriented areas.

Standards can not only support industrial production and increase the opportunities for dissemination of innovations, they can also contribute to product safety, reliability, and a certain level of product quality. These are common arguments for standardisation of technologies, and they also apply readily to ERS. Standardisation is moreover essential for the interoperability, compatibility, and competitiveness of ERS, specifically from the perspective of facilitating a faster deployment of electric road systems as a promising future solution to replace the dominant position of fossil powered freight transport. Although currently under discussion, standardisation for ERS is however still only at the initial drafting phase.

The purpose of this study was to increase knowledge of standardisation to promote the development of electric road systems. During the project a mapping was carried out to create an overview of standards that are directly or indirectly central for ERS in the area of intelligent transport systems (ITS). The study employed a combination of methods including an examination of ERS literature and ITS standards, a stakeholder workshop, and expert reviews of a tentative listing of ITS standards that are potentially applicable to ERS. The main result is a preliminary inventory of 111 ITS standards, including standards for electronic fee collection (EFC), where 99 standards have been deemed as potentially applicable to ERS.

Title:	Standardisation for electric road systems. A review of key standards for the development of electric roads.
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Referat

Allteftersom tekniker för elvägssystem (ERS) fortsätter att nå högre nivåer av mognad framstår behovet av standardisering inom fältet som jämförligt med många andra tekniskt inriktade områden.

Standarder kan inte bara stödja industriell produktion och öka möjligheterna till spridning av innovationer, de kan också bidra till produktsäkerhet, tillförlitlighet och en viss produktkvalitetsnivå. Dessa är vanliga argument för standardisering av teknik och de gäller också för ERS. Standardisering är dessutom väsentligt för ERS interoperabilitet, kompatibilitet och konkurrenskraft, särskilt med tanke på att underlätta en snabbare spridning av elvägssystem som en lovande framtida lösning för att ersätta fossildrivna godstransporters dominerande position. Även om standardisering för närvarande diskuteras, är standardisering för ERS dock fortfarande bara på det inledande utarbetningsstadiet.

Syftet med denna studie var att öka kunskapen om standardisering för att främja utvecklingen av elvägssystem. Under projektet genomfördes en kartläggning för att skapa en översikt över standarder som är direkt eller indirekt centrala för ERS inom området intelligenta transportsystem (ITS). I studien användes en kombination av metoder inklusive en undersökning av ERS-litteratur och ITS-standarder, en intressentworkshop och expertbedömningar av en tentativ lista över ITS-standarder som är potentiellt tillämpliga på ERS. Huvudresultatet är en preliminär inventering av 111 ITS-standarder, inklusive standarder för elektronisk avgiftsinsamling (EFC), där 99 standarder har bedömts vara potentiellt tillämpliga på ERS.

Titel:	Standardisering för elvägssystem. En översyn av ITS-standarder för elvägars utveckling.
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Preface

This study has been carried out by the Swedish National Road and Transport Research Institute (VTI), and the Swedish Institute for Standards (SIS). The authors would like to acknowledge Sweden's innovation agency, Vinnova, for funding the study. Moreover, the authors would like to acknowledge Anders Bülund, the Swedish Transport Administration, and Anders Bylund, Siemens, for valuable discussions about standardisation for ERS. The authors would also like to express their gratitude and appreciation for the work with and review of standards performed by Yamen Kadoura (SIS), Peter Claeson (SIS), and Johan Hedin (Hybris Konsult AB). Finally, the authors want to express their appreciation for the participation of, and valuable input from, the wide variety of stakeholders that were present during the stakeholder workshop on standardisation held at SIS in Stockholm, 12 December 2019.

Gothenburg, April 2020

Philip Almestrand Linné
Project leader

Quality review

A review seminar was held on 15 April 2020 with Björn Kalman as the reviewer. Philip Almestrand Linné has made alterations to the final manuscript of the report. Research director Mattias Haraldsson examined and approved the report for publication on 23 April 2020. The conclusions and recommendations in the report are those of are the authors' and do not necessarily reflect the views of VTI's opinion as a government agency.

Kvalitetsgranskning

Granskningsseminarium har genomförts 15 april 2020 där Björn Kalman var lektör. Philip Almestrand Linné har genomfört justeringar av slutligt rapportmanus. Forskningschef Mattias Haraldsson har därefter granskat och godkänt publikationen för publicering 23 april 2020. De slutsatser och rekommendationer som uttrycks är författarnas egna och speglar inte nödvändigtvis myndigheten VTI:s uppfattning.

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List of Abbreviations

CEN	Comité Européen de Normalisation (European Committee for Standardization)
ETSI	European Telecommunications Standards Institute
ERS	Electric Road Systems
CLC	Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical Standardization – CENELEC)
EFC	Electronic Fee Collection
ITS	Intelligent Transport Systems
NGO	Non-Governmental Organisation
PDCA	Plan-Do-Check-Act
ISO	International Organization for Standardization
SDG	Sustainable Development Goal
SDO	Standard Developing Organisation
SSO	Standard Setting Organisation
IEC	International Electrotechnical Commission
MaaS	Mobility as a Service
ERSC2020	Electric Road Systems Conference 2020
SIS	Swedish Institute for Standards
TC	Technical Committee
TS	Technical Specification
VTI	Swedish National Road and Transport Research Institute

Summary

Standardisation for electric road systems. A review of its standards for the development of electric roads

by Philip Almestrand Linné (VTI), Linnéa Sundström (SIS) and Mikael Hjalmarson (SIS)

This study emerges from the practical problem of making technology work. To make technology work for users, in society, and even across borders, a range of factors must be considered: Is a technology safe and reliable to use? Is it guaranteed a certain quality? Is it interoperable between countries, and compatible with other technologies within a certain country?

Such questions are common in relation to developing technologies but also continue to be relevant as technologies mature. The creation and use of standards can reduce many obstacles related to a new technology. Electric road systems (ERS) are a set of promising technologies currently predicted to have an important role in a future decarbonised sustainable transport system, and the need for standardisation of the field appears comparable to many other technically oriented areas. Although currently under discussion, standardisation for ERS is so far only at an initial drafting phase.

The broadly formulated purpose of this study is to increase the knowledge of standardisation to promote the development of ERS. During the project a mapping was carried out to create an overview of standards that are directly or indirectly central for ERS in the area of intelligent transport systems (ITS). Generally, the benefits of ITS among other things are more efficient management of the transport network for both passengers and business, lowering of impacts of traffic on the environment, reducing congestion and optimising the use of existing infrastructure and increase of traffic safety and security. More specifically, it is expected that ITS could be a vital part of ERS as it also includes such basic functions as the possibility to collect road tolls electronically and could be an important part of access control. Furthermore, ITS could potentially support a future where ERS technologies are combined with the concept of Mobility as a Service (Maas).

This study employs a combination of methods including an examination of ERS literature and ITS standards, a stakeholder workshop, and expert reviews of a tentative listing of ITS standards that are potentially applicable to ERS.

The main result is a preliminary inventory of 111 ITS standards, including standards for electronic fee collection (EFC), where 99 standards have been deemed as potentially applicable to ERS. The results fill a knowledge gap in relation to standardisation of ERS in the area of ITS. This knowledge is expected to be relevant for the further development of standardisation for ERS and is at the same time an addition to the growing body of ongoing ERS research. Finally, the results could potentially have a positive impact on transport and environment related sustainable development goals, including the export and import of sustainable ERS technologies between Sweden and other economies.

Sammanfattning

Standardisering för elvägssystem. En översyn av ITS-standarder för elvägars utveckling

av Philip Almestrand Linné (VTI), Linnéa Sundström (SIS) och Mikael Hjalmarson (SIS)

Denna studie uppstår från det praktiska problemet att få teknik att fungera. För att få teknik att fungera för användare, i samhället och även över gränser, måste en rad faktorer beaktas: Är en teknik säker och pålitlig att använda? Är en viss kvalitet garanterad? Är den interoperabel mellan länder och kompatibel med andra tekniker i ett visst land?

Sådana frågor är vanliga när det gäller att utveckla teknik men fortsätter också att vara relevanta när tekniker mognar. Standarders skapande och användning kan minska många hinder relaterade till en ny teknik. Elvägssystem (ERS) är en uppsättning lovande tekniker som för närvarande förutsägs ha en viktig roll i ett framtida hållbart transportsystem med minskade koldioxidutsläpp och behovet av standardisering inom fältet verkar vara jämförligt med många andra tekniskt orienterade områden. Även om standardisering för närvarande diskuteras, är standardisering för ERS dock fortfarande bara på det inledande utarbetningsstadiet.

Det brett formulerade syftet med denna studie är att öka kunskapen om standardisering för att främja utvecklingen av ERS. Under projektet genomfördes en kartläggning för att skapa en översikt över standarder som är direkt eller indirekt centrala för ERS inom området intelligenta transportsystem (ITS). Generellt sett är fördelarna med ITS bland annat en effektivare hantering av transportnätet för både passagerare och företag, minskning av trafikpåverkan på miljön, minskning av trängsel och optimering av befintlig infrastruktur samt ökad trafiksäkerhet och säkerhet. Mer specifikt förväntas det att ITS skulle kunna bli en viktig del av ERS, eftersom det också innehåller sådana grundläggande funktioner som möjligheten att samla in vägavgifter elektroniskt och vara en viktig del av tillträdes-kontroll. Dessutom kan ITS potentiellt stödja en framtid där ERS-teknik kombineras med begreppet mobilitet som tjänst (Maas).

I denna studie används en kombination av metoder inklusive en undersökning av ERS-litteratur och ITS-standarder, en intressentworkshop och expertbedömningar av en tentativ lista över ITS-standarder som är potentiellt tillämpliga på ERS. Huvudresultatet är en preliminär inventering av 111 ITS-standarder, inklusive standarder för elektronisk avgiftsinsamling (EFC), där 99 standarder har bedömts vara potentiellt tillämpliga på ERS. Resultaten fyller en kunskapslucka i förhållande till standardi-sering av ERS inom området ITS. Denna kunskap förväntas vara relevant för vidareutvecklingen av standardisering för ERS och är samtidigt ett tillägg till den växande massan av pågående ERS-forskning. Slutligen kan resultaten potentiellt ha en positiv inverkan på transport- och miljörelaterade mål för hållbar utveckling, inklusive export och import av hållbar ERS-teknik mellan Sverige och andra ekonomier.

1. Introduction

1.1. Standardisation of electric road systems – an overview

Electric Road Systems (ERS) are based on the idea that a vehicle can be supplied with electric energy both for propulsion and battery charging while in motion. For ERS, standardisation is still in an early phase, and there are yet no dedicated *published* standards either at the Swedish, European, or global standardisation level. However, the drafting of standards is under way.

Existing draft standardisation work for ERS has as to yet been performed in CLC/TC 9X, the technical committee “Electrical and electronic applications for railways” [1]. More specifically, two draft technical specifications (TS) covering aspects of ERS are being prepared [2, 3].

As ERS technologies continue to reach higher levels of maturity, the need for standardisation has grown clearer, and the arguments for standardisation of the field appear to be the same as for many other technically oriented areas: Standardisation facilitates industrial production and increases the opportunities for dissemination of innovations. Standards can contribute to product safety, reliability, environmental performance, and a certain level of product quality [4]; factors that also are of high relevance in public procurement, for instance in the context of transport infrastructure projects. Standardisation is furthermore essential for the interoperability, compatibility, and competitiveness of technologies. This is particularly significant for the facilitation of a faster deployment of ERS as promising future solutions to replace the dominant position of fossil powered freight transport [5].

The title of the mentioned CLC/TC 9X committee, Electrical and electronic applications for railways [1], depicts the current thematic point of departure for the relatively recent (2018) start of ERS standardisation discussions within CENELEC, namely the railway standardisation setting. From a broader forward-looking view however, it is not merely possible to imagine that standards for rail- and tramway operations could potentially be relevant as inspiration for future ERS standardisation efforts because of their related substance. There are also other standards that have been originally created for adjacent purposes, that could likewise become relevant to consider for ERS applications.
It is from this position that the current study begins.

1.2. Aim and purpose of the study

ERS, which has been described as a system of systems [6], could likely benefit from a range of published standards and standards under development in various technical areas. Such standards could serve as a useful foundation both in the case when existing standards are adapted to the needs of ERS, or when entirely new and dedicated ERS standards are drafted.

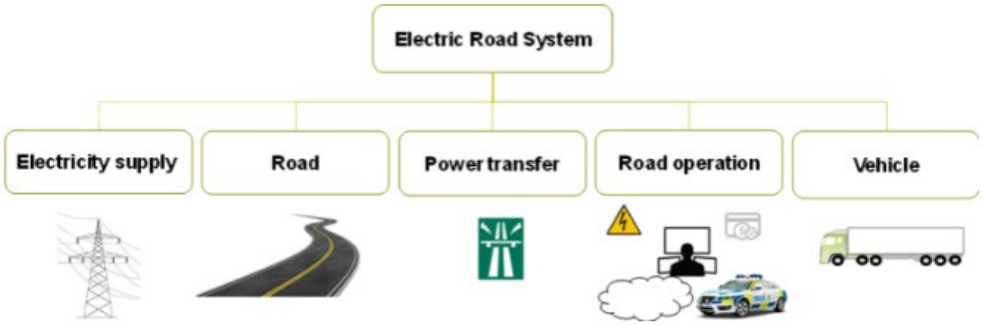

Figure 1 Overall system layout of ERS with five subsystems [7]. Picture source: www.electricroads.org.

In an imagined overall system layout of ERS, five principal subsystems have been identified: electricity supply, road, power transfer, road operation, and vehicle [7]. Each of the subsystems consist of further components and connections, and a first detailed overview of a whole ERS system architecture was presented in 2019 [8]. Currently, critical interfaces of ERS that need to be standardised are still under identification.

Previously, some authors[1] of this study have examined standards relating to important ERS system components such as “vehicle”, “energy supply”, and “road infrastructure” [9,10]. In the current study, the authors turn to examine standards that are expected to be important both for *communication within and between the different subsystems*. For instance, for purposes of road operations to control system energy management, user information, access control, and payment and billing or fee collection [11].

The aim of this study was to carry out a survey and analysis of central standards that directly or indirectly affect ERS on a national, European, and global level. More specifically, this study focuses on the relation between ERS and standards in the area of intelligent transport systems (ITS).

The overall purpose of this study is to increase the knowledge about standardisation to further promote the establishment and expansion of electric road systems.

[1] Linnéa Sundström and Philip Almestrand Linné. Note that the author Linnéa Sundström was formerly known as Linnéa Casselbrant.

1.3. Research questions

In order to create an overview and analyse standards that are directly or indirectly central for ERS in the area of ITS, the present work aims to answer the following research question:

Which standards in the area of intelligent transport systems (ITS), including electronic fee collection (EFC), can be considered to have central direct or indirect significance for the establishment and expansion of electric road systems?

1.4. Scope and delimitations

A general delimitation for this study is that focus is put on ITS standards, including EFC standards, in relation to commercial (heavy goods) vehicles on electric roads, since ERS have been underlined as especially important in the heavy vehicle context [5, 12]. Additionally, for reasons of time and budget constraints, ITS standards applicable to urban and public transport are excluded in this work although these could also potentially be interesting to examine in an ERS context. Hence, standards developed by the International Organization for Standardization (ISO) in ISO/TC 204 or CEN/TC 278 which focus on public transports or urban ITS have been intentionally excluded. Moreover, the starting point of this work is from a Swedish perspective on standards for ERS as an innovation area, but with a deliberate view also pointed towards European and in some cases global standardisation work.

For all purposes, the standards in this study that are mapped, analysed, and possibly later become subject for new standardisation work are examined in the light of today's three main areas for electric road system technologies: conductive overhead, conductive rail, and inductive (wireless) [5]. The examined standards belong both to existing published standards and standards that are expected to be published in final versions at different levels (national, European, global). Which standards that are of central direct or indirect importance is chiefly determined with guidance from the project participants' previous work regarding standardisation for ERS in the theme areas of “vehicle”, “power supply”, and “infrastructure” [9, 10].

1.5. Previous research, contribution of the present study, and target audience

As far as the authors of this study are aware of, no similar work has been performed before, except for the previously mentioned work regarding standardisation of ERS involving some of the same authors of the current report [9, 10].

All in all, the current study is expected to be a welcome contribution to broaden and deepen the current state of knowledge in the area of standardisation for ERS with a specific focus on ITS standards. In the long term, this study may contribute to possible follow-up in the form of standardisation work related to ERS. With regards to the main target audience, it is expected that this includes stakeholders with an interest in ERS representing public authorities, private entities, NGOs like standardisation organisations, and research environments such as academia and research institutes.

1.6. Methods and materials

This study employed a combination of methods including an examination of ERS literature and ITS standards, a stakeholder workshop, and expert reviews of a tentative listing of ITS standards that are potentially applicable to ERS.

The examination of ERS literature and ITS standards provided the foundation for gaining new knowledge in the area of ITS standardisation for ERS. Specifically, the examination of these sources contributed to the drafting of a standard inventory, and an analysis to broaden and deepen available knowledge in the research area of standardisation for ERS. The stakeholder workshop among other things generated new data about the current state of knowledge, as well as opinions of, and challenges

for stakeholders regarding standardisation of ERS. Finally, the expert reviews of the listed ITS and EFC standards secured a peer-review of gathered data and aids the creation of a more refined tentative list of standards potentially applicable to ERS.[2]

As a matter of overarching work process, this study has applied a flexible and cyclical working method, which is based on the idea that constant feedback and improvement can take place during the different project phases according to the steps of plan, execute, follow up, and act (PDCA: plan-do-check-act). This has more concretely resulted in some changes of the study along the way. One example is a change of initial study focus from standards in telecommunication to ITS standards [13]. Such a change of focus has been possible by applying the PDCA method for macro and micromanagement during the different project phases at regular information and planning meetings via web conference and routine e-mail correspondence regarding project status.

Finally, as an outline description, this project has been performed in three consecutive phases:

Phase 1 - Mapping, where a survey of standards in the ITS area considered to have central direct or indirect significance for the establishment and expansion of electric roads has been performed, as well as a generally focused survey of standardisation committees where work relating to ERS has begun.

Phase 2 - Analysis, vision formulation, where an analysis of ITS standards that are directly or indirectly central to electric road systems has been performed, partly based on the project partners' previous work and the standardisation mapping in Phase 1, in order to formulate a vision of future scenarios where new standardisation work can be initiated that increases the conditions for new Swedish market entries in the area of ERS technologies.

Phase 3 - Recommendation formulation, formulation of concrete recommendations based on Phase 1 and 2 for how new standardisation work for ERS can be initiated in different forums for standardisation, and to contribute with conclusions on any increased theoretical understanding of how the area of standardisation for electric roads can be systematised.

[2] For further details regarding the standardisation mapping and expert review, see also section 2.2 below.

2. Standardisation mapping

2.1. Standardisation of intelligent transport systems (ITS) – an overview

In Sweden, it is the technical committee "Vägtrafikinformatik" (SIS/TK 255 "Road traffic informatics"), that monitors and participates in the international standardisation work in the area of Intelligent Transport Systems (ITS) (CEN/TC 278 and ISO/TC 204). Figure 2 below illustrates where the main standardisation work of relevance for ERS is developed. The Swedish mirror committee is participating actively in all mentioned working groups.

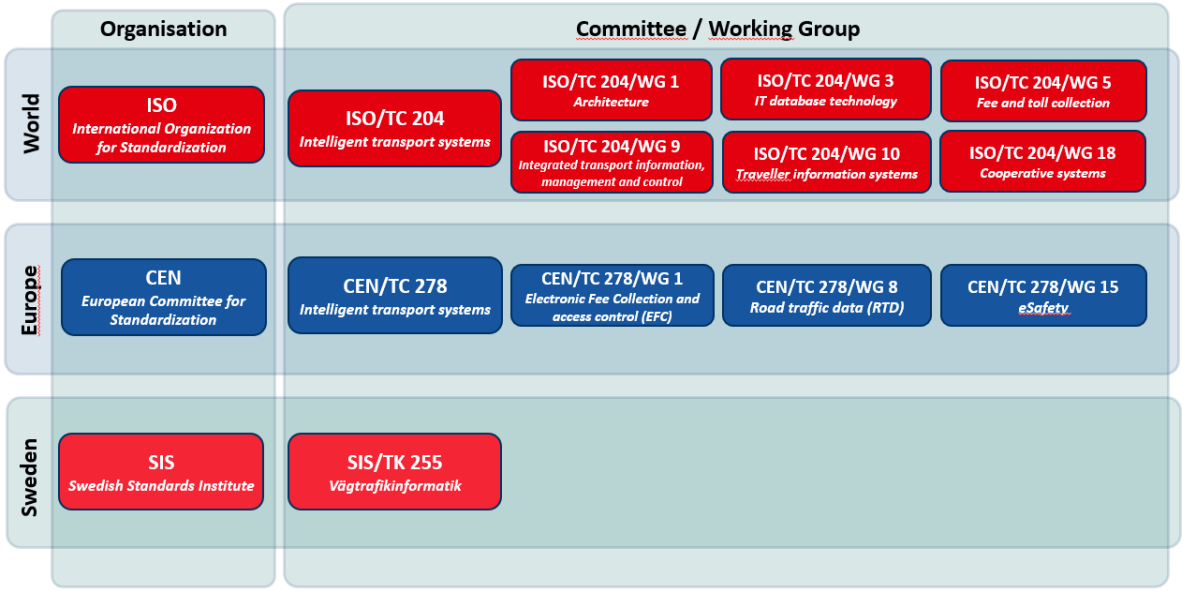

Figure 2 Scheme of how the main ITS standardisation work of relevance for ERS on the global and European level is mirrored in Sweden.

The term ITS refers to the efforts to manage real-time traffic information in transport systems to increase efficiency, safety, and reliability by applying and using electronics, information, and telecommunication technologies in infrastructure, vehicles, and goods.

ITS can contribute to a cleaner, safer, and more efficient transport system. This has led the European Commission to request the European Standards Organisations (CEN, CENELEC and ETSI) to develop and adopt European standards to support the EU's legal framework in the same area.

From an EU perspective, to be effective and feasibly implemented, the roll-out of ITS needs to be coherent and properly coordinated across Europe. For this purpose, standardisation can support legislation [14, 15]

The benefits of ITS are:

- more efficient management of the transport network for passengers and business
- improvement of journeys and operations on specific and combined modes of transport
- lower impact of traffic on the environment
- reduction of congestion and optimisation of the use of existing infrastructure
- increase of traffic safety and security [14].

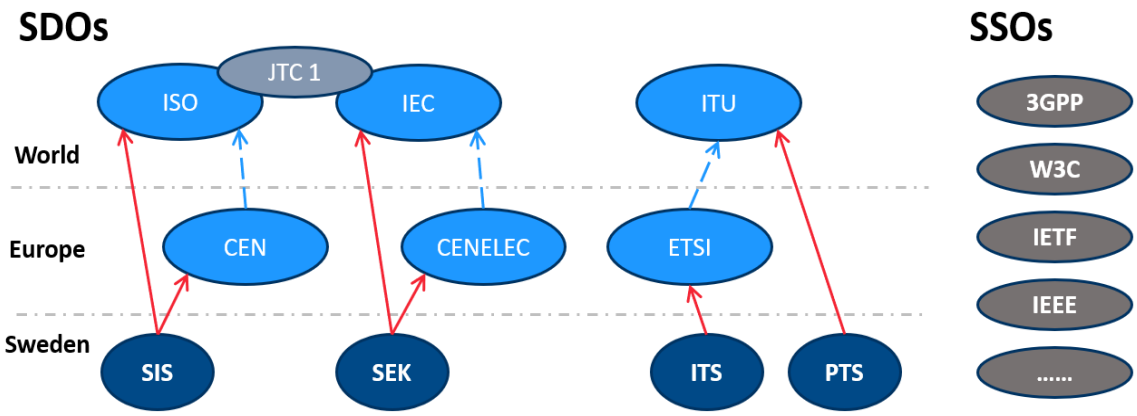

Figure 3 Overview of Standard Developing Organisations (SDOs) and Standard Setting Organisations (SSOs) monitoring and developing standardisation of ITS.

Figure 3 shows an overview of the organisations monitoring and developing standards in the area of ITS. The shaded content represents linked areas/topics that are needed for ITS to be fully operational, but which are managed by other groups.

Within ITS standardisation, there are multiple areas that could be useful for ERS such as Electronic Fee Collection (EFC), Traffic Data, and Cooperative ITS. This also includes adapting useful functions that already exist, for instance toll roads, instead of specifically reinventing them for ERS.

2.2. Creating and reviewing the ITS standardisation inventory

The ITS standardisation inventory in this study was created by experts at SIS in collaboration with external expertise. First, a preliminary list of central directly or indirectly significant ITS standards for ERS and heavy transports was drafted. The idea was to include standards with specific enough substance to possibly apply to ERS. Therefore, standards that were too general in nature, and would be applicable to a very wide variety of cases were left out of the inventory, as their inclusion would risk shifting the focus of the list. For example, a standard that was excluded was ISO 17267:2009 "Intelligent transport systems – Navigation systems – Application programming interface (API)" because it was deemed as too general, although possibly applicable to ERS. On the contrary, a standard that was included was ISO/TS 19082:2020 "Intelligent transport systems – Definition of data elements and data frames between roadside modules and signal controllers for cooperative signal control" since this was specific enough to possibly apply to ERS on a more detailed level.

It can be noted that standards in the inventory regarding EFC was included in this study by virtue of being within the area of ITS in accordance with mandate M/338 - EN Standardisation mandate to CEN, CENELEC, and ETSI in support of operability of electronic road toll systems in the EU.

The preliminary draft of EFC standards was analysed more deeply and checked for relevance with the external support from Hybris Konsult AB, an expert on standardisation for EFC or toll roads. These standards were included in the list even when they were classified as “not applicable” to ERS.

Upon receiving the reviewed inventory from Hybris Konsult AB, it was once again refined by the experts at SIS by further analysis of factors such as relevance, duplicates, and outdated and updated standards. Furthermore, a final review and sorting of the standards was made according to the categories

“Standard number”, “Standard title”, and colour coding to mark potential applicability to ERS (green = yes, red = no).

99	CEN/TS 16702-1:2020	Electronic fee collection - Secure monitoring for autonomous toll systems - Part 1: Compliance checking
100	CEN/TS 16331:2012	Electronic fee collection - Interoperable application profiles for autonomous systems
101	SIS-CEN ISO/TS 17444-1:2017	Electronic fee collection - Charging performance - Part 1: Metrics (ISO/TS 17444-1:2017)
102	SS-EN ISO 13141:2016/A1:2017	Electronic fee collection - Localisation augmentation communication for autonomous systems - Amendment 1 (ISO 13141:2015/Amd 1:2017)

Figure 4 Sample of standards listed in final inventory categorised according to standard number, standard title, and colour coded for ERS applicability marking (green = yes, red = no).

Marking a standard as “applicable” (green) in the inventory indicates that the standard has been deemed to have a potential central direct or indirect significance for the establishment and expansion of ERS. By this token, the substance of the standard has been judged as central for ERS according to the criteria explained in the beginning of this section. Moreover, the standard could potentially be revised to apply to ERS in the future.

The status of the standards of each project or standard listed in the final inventory corresponds with an examination of standards between April 2019 and March 2020. The list includes published, drafts, and new work items.[3] Complementary information regarding the standards are available on the websites of the following standardisation organisations: ISO, IEC, CEN, and CENELEC.

[3] This is not specifically indicated in the final list in the appendix of the current study, but can be derived from checking if a certain standard has a year indicated in the title. If so, the standard has been published, and if not, it is either in a draft stage or a new work item.

3. Stakeholder participation

3.1. Stakeholder workshop - remarks and input

As a part of the current study, a breakfast workshop was arranged in December 2019 [16, 17] with the purpose to spread the knowledge about standardisation, ERS, and in particular the importance of ITS standards for interoperable ERS. Around 40 persons from different stakeholder categories including representatives from the vehicle industry, energy sector, transport sector, and road infrastructure sector joined the workshop.

After an introduction by VTI, five presentations were held: the Swedish Transport Administration presented the national time plan for introducing ERS in Sweden, the haulier Ernsts Express shared their experiences from three years of trafficking the first public electric road in Sweden, Scania highlighted the importance of standards for profitable development of future vehicles, Hybris Konsult AB shared their knowledge in standardisation of systems for EFC, and ElectReon gave a presentation on their wireless solution for ERS which is now installed in Gotland: Sweden´s fourth demonstration of ERS. The talks were followed by a debate which was moderated by SIS and included all the presenters, and an expert from SEK Svensk Elstandard, the organisation responsible for standardisation in Sweden in the field of electricity. The workshop also included an interactive part where the stakeholder participants could answer questions via an online tool. Among other things, the following was noted during the interactive session:

- a majority (~65%) of the participants stated that they worked with electric roads today
- around 54% of the participants stated that they believed that electric roads would be an important part of the Swedish transport infrastructure in 2030, while about 29% did not think so, and around 17% answered they did not know
- regarding ERS and its potential in relation to ITS and digitalisation, automatisation and autonomous vehicles, and sharing and mobility as a service (MaaS), attitudes were mostly positive, and opportunity focused among the workshop participants
- roughly 78% answered that they “agreed to some extent” or “fully agreed” that the possibilities to create working standards for electric roads today are good
- finally, some 64% of the participants answered that they were interested in actively engaging in standardisation work to promote the establishment of electric roads.

4. Results

4.1. Main results of the study

The aim of this study has been to carry out a survey and analysis of central standards that directly or indirectly affect electric road systems on a national, European, and global level. More specifically, this study has focused on the relation between ERS and standards in the area of ITS by aiming to answer the following:

Which standards in the area of intelligent transport systems (ITS), including electronic fee collection (EFC), can be considered to have central direct or indirect significance for the establishment and expansion of electric road systems?

It can be concluded that this study has yielded three main results. A first immediate result from attempting to answer the above research question is that an examination of 250 ITS standards has resulted in a preliminary inventory of a total of 111 standards categorised broadly as ITS standards. These 111 standards are also sorted according to standard number, standard title, and potential ERS applicability (green = yes or red = no) [Appendix]. Specifically, 44 of the 111 standards categorised as ITS standards could also simultaneously be categorised as EFC standards. Of the latter standards, 32 out of 44 standards were marked as "applicable" to ERS. Adding up the numbers, this means that 99 of 111 or around 89% of the ITS/ERS standards were marked as "applicable" to ERS, while the remaining 12 standards or around 11% were marked as not "applicable".

Again, as mentioned above, marking a standard as "applicable" in the inventory indicates that the standard has been deemed to have a potential central direct or indirect significance for the establishment and expansion of ERS. By this token, the substance of the standard has been judged as central for ERS according to the criteria just explained. Moreover, the standard could potentially be revised to apply to ERS in the future.

When it comes to further details of the inventory results, the subject matter of the ITS and EFC standards marked as "applicable" to ERS in the list varied. It could be noted that there was an interesting range of standards, even within the area of ITS. For example, one relevant ITS standard, as of yet only a work item, marked as "applicable" in the inventory can be found in the CEN 16742 series, namely a work item named "Intelligent transport systems - Privacy aspects in ITS standards and systems in Europe according to GDPR 2016/679". Another example can be found in the ISO 14813-series, namely SS-ISO 14813-1:2017 "Intelligent transport systems - Reference model architecture(s) for the ITS sector - Part 1: ITS service domains, service groups and services (ISO 14813-1:2015, IDT)". Yet another example, an EFC standard, can be found in the ISO 14906-series: "Electronic fee collection - Application interface definition for dedicated short-range communication (ISO 14906:2018)" [Appendix]. Thus, the substance of the reviewed standards regarded everything from questions of personal integrity and confidentiality to more general matters of ITS architectures, and technical matters for EFC. Moreover, it could also be noted that the relevant "applicable" listed ITS standards were deemed to be applicable irrespective of ERS technology choice.

A second main result is that the stakeholder workshop arranged by VTI and SIS in Stockholm in December 2019 gathered representatives of all Swedish ERS technology manufacturers as well as a range of other stakeholders in what could be described as a "science-policy-industry" discussion about standardisation of ERS. This was positive for several reasons:

- the workshop spread knowledge about ERS generally, and standardisation of ERS in particular, to new potentially important stakeholders for current and future development of ERS
- the workshop gave a variety of stakeholders the opportunity to contribute to the current study and to future studies by voicing their opinions
- additionally, the stakeholders were invited to become engaged in actual ERS standardisation efforts via SIS.

Finally, a third main result is that this study yielded a publication accepted as an extended abstract at the global Electric Road Systems Conference 2020 (ERSC2020). Thus, the current study has also contributed concretely to and interacted with the developing scientific field of ERS and standardisation of ERS.[4]

4.2. Discussion

As a matter of relevance, some limitations, weaknesses, and uncertainties of this study ought to be mentioned.

One aspect of relevance is a methodological question that can be raised in relation to the stakeholder workshop. On the one hand, it is a fact that a part of the current study was to gather stakeholders, for example for a "science-policy-industry" discussion, to gain further knowledge about stakeholder attitudes regarding standardisation of ERS. On the other hand, based on the data gathered and analysed at the stakeholder workshop, there was no possibility to draw general conclusions about stakeholder attitudes and priorities beyond the population of the around 40 participants.[5] Such conclusions would arguably require complementary and more extensive quantitative data sets. Thus, the results from the stakeholder workshop must be treated with caution, even if they may give an indication of some attitudes and opinions among stakeholders surrounding the standardisation of ERS that could be further taken into consideration in future research. Nevertheless, a value that all the same remains is the dimension of spreading knowledge about ERS, including the current study, to new groups of stakeholders whilst also inviting them to engage in ERS standardisation discussions.

There are also some uncertainties related to the form and presentation of the standards inventory in this study. For instance, it could be argued that ITS and EFC should not necessarily be organised together, since EFC or payment systems could also be viewed as a specific function that ERS could benefit from, while ITS is more a question about connecting and communicating for other purposes such as locating services, eCalls, and traffic information (commercial and public). Another perspective is that ERS could also be a system that should be more integrated on a system level with ITS, while ERS specific basic techniques, such as electric feed and charging, could be managed separately. In relation to this, it can be noted here that from an international standardisation point of view, EFC is an integrated part of the ITS standardisation [18] which is also mirrored on the national Swedish level of standardisation [19].

[4] At the time of writing, ERSC2020, which was scheduled for May 12–13 2020 in Lund, has unfortunately been cancelled due to an ongoing COVID 19 pandemic. Currently it is unsure whether the objectives of the conference will be otherwise realised.

[5] Some participants joined late without officially registering, but the interactive stakeholder question session registered between 36 and 41 voting participants.

Yet another uncertainty of the inventory is that the forward-looking listing and analysis of possibly future applicable standards in this study is in a sense an inherently speculative activity. At present, the authors of this study argue that the "applicable" standards in the final inventory are directly or indirectly relevant for ERS. Some of these standards are likely to require modification to fit ERS, while other could potentially be applicable to ERS in a more general sense, because they are viewed as needed in an ERS as well as for other road transport systems. All the same, time will tell whether the listed standards *will eventually become relevant* for ERS in the future.

It should also be recalled that at present, there are still *no dedicated published ERS standards*, only two draft technical specifications, and these do not belong to the area of ITS or EFC. The inventory of compiled standards presented in this study is therefore merely a starting point and a work in progress that gives a snapshot picture of current standards that the authors believe could become relevant for ERS in times ahead. This list could and should subsequently be updated and refined, for instance via further studies and analyses of standards.

Finally, at a more general level of discussion, worried voices are sometimes raised about potential lock-in effects from standardisation of new innovations. This is a discussion that is too wide reaching to be dealt with extensively in this report, but a couple of words can all the same be said in relation to the standardisation of ERS. First, as has been argued, there is not necessarily an inherent conflict between innovation and standardisation [20]. In fact, there are several examples of standardisation as an innovation enabling rather than innovation impeding force, like in the development of modern audio and video digital compression standards such as MP3, MPEG-2, and MPEG-4 [21].

From the perspective of the authors of the current report, the discussion among some ERS technology manufacturers is that, rather than fearing standardisation, they instead seem to express a will to get a clearer picture, from for example national road administrations, of which technology or technologies that could possibly be used in future ERS *before* engaging further in standardisation. Standardisation tends to be "a moving target" and getting involved is a costly procedure and an investment for example for a technology manufacturer.

4.3. Concluding remarks, recommendations, and possible further research

This study has examined the possibilities of standardising ERS. It has done so with the overall purpose to increase the knowledge about, and the need for standardisation to further promote the establishment and expansion of electric road systems. More specifically, inspiration has been looked for among already existing central ITS standards that could potentially directly or indirectly affect the future of ERS.

To round off, this concluding section now proceeds to offer some forward-looking comments from a wider perspective.

Looking into the future, it is believed that this study could potentially contribute to the achievement of a couple of sustainability goals. Although it is presently not possible to evaluate the actual effects that the results in this study could have in times ahead, it is imagined that the following sustainable development goals in the 2030 Agenda for Sustainable Development [22] could be positively affected:

To begin with, Sustainable Development Goal (SDG) 13 "Climate action" is favoured, as ERS are deemed to be a promising way forward towards fossil-free transports. This also includes a link to target 13.2, integrating climate change measures into national policies, strategies, and planning.

Another presumably affected goal is SDG 3, to "Ensure healthy lives and promote well-being", since ERS are a way of reducing air emissions, which in turn also has bearing on target 3.9 of substantially reducing the number of deaths and illnesses from harmful pollution. Additionally, SDG 9 the sustainability goal concerned with building resilient infrastructure, sustainable industrialization, and fostering innovation is relevant to mention. In particular, target 9.1, concerning the development of quality, reliable, sustainable, and resilient infrastructure, (including regional and transborder infrastructure) as ERS are a possible way forward for working with climate challenges, but is likewise considered to be of interest for cross-border transport corridors [23].

Lastly, on the note of goal fulfilment, it can be added that one of the Swedish national objectives for transport and infrastructure is to ensure the economic efficiency and long-term sustainability of transport provision for citizens and enterprises throughout Sweden, something that standardisation of ERS could also potentially contribute to [24]. This could be the case because of the potential decrease in carbon dioxide emission, higher energy efficiency in the transport system, as well as lowered transport costs [12].

From a standardisation point of view, the result of this project is yet another piece of a gap analysis for identifying areas needed, and possibly being essential, to enable an interoperable ERS in Europe and even globally.

At the stakeholder workshop held in December 2019, several participants expressed their interest in being contacted by SIS for further discussions on how to proceed with standardisation to make ERS a reality. At the same workshop there were also strong voices from the industry that there is a need of guidance and regulatory support to achieve interoperability for harmonised implementations, especially in Europe but also globally from politicians and governmental stakeholders, to enable for the industry to continue with technical development.

Some likely next steps and future research would be to examine possible modifications of existing standards, and where new standards are needed, if any, when taking electric road systems into account. Here, SIS/TK 255 is a platform for Swedish stakeholders to meet regarding ITS standardisation.

Seen in a broader context, it would also be beneficial to include the results from the ongoing national ERS project “Research and Innovation Platform for Electric Roads” [25], and the concerned stakeholders, as it is believed that this study’s specific focus on ITS standards combined with the authors’ previous work on mapping potentially applicable standards for ERS in the theme areas of

“vehicle”, “energy supply”, and “road infrastructure” [9, 10] could be a good stepping stone for the continuation of standardisation mapping for ERS. If not, this study’s mapping of standards arguably helps increase the understanding of how the area of standardisation for electric roads can be systematised, since the current study’s inventory and analysis of standards now covers yet another thematic area (ITS), in a possible system-of-systems architecture for ERS. This can be used to update a previously created working document with ERS standards that contains macros for possible filtering of standards by criteria such as theme area and standard status.

A more immediate next step will also be to spread knowledge about the current study and its results, something that has already started during the mentioned stakeholder workshop. As equally mentioned above, an extended abstract based on this study was accepted for ERSC2020 in March 2020, but the conference has unfortunately been cancelled due to an ongoing COVID 19 pandemic, and the authors are awaiting further information following the cancellation.

Finally, based on the above, some suggestions for possible future research could also be to examine standards useful for ERS that bridge dynamic and static charging interfaces with an open mind to examining standardisation for ERS applications of vehicles in various classes (for example light, medium and heavy duty) and with different applications also including for instance public transport, maintenance services like sanitation, and personal transports with cars [7, 26]. Additionally, it would be welcome to further examine ITS standards for urban and public transports in relation to ERS, but also to involve possible end-users of ERS as a critical group that should not be overlooked in ERS standardisation discussions.

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Appendix – Inventory of ITS Standards including EFC Standards

See attached Excel file.

ABOUT VTI

The Swedish National Road and Transport Research Institute (VTI), is an independent and internationally prominent research institute in the transport sector. Our principal task is to conduct research and development related to infrastructure, traffic and transport. We are dedicated to the continuous development of knowledge pertaining to the transport sector, and in this way contribute actively to the attainment of the goals of Swedish transport policy.

Our operations cover all modes of transport, and the subjects of pavement technology, infrastructure maintenance, vehicle technology, traffic safety, traffic analysis, users of the transport system, the environment, the planning and decision making processes, transport economics and transport systems. Knowledge that the institute develops provides a basis for decisions made by stakeholders in the transport sector. In many cases our findings lead to direct applications in both national and international transport policies.

VTI conducts commissioned research in an interdisciplinary organisation. Employees also conduct investigations, provide counseling and perform various services in measurement and testing. The institute has a wide range of advanced research equipment and world-class driving simulators. There are also laboratories for road material testing and crash safety testing.

In Sweden VTI cooperates with universities engaged in related research and education. We also participate continuously in international research projects, networks and alliances.

The Institute is an assignment-based authority under the Ministry of Infrastructure. The Institute holds the quality management systems certificate ISO 9001 and the environmental management systems certificate ISO 14001. Certain test methods used in our labs for crash safety testing and road materials testing are also certified by Swedac.

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