The interaction between standardization, technology and market: the early development of the electric vehicle as an example

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Abstract

Standardization is an inevitable part of our contemporary life: in many areas we come in contact with technical standards. The genesis of these standards is an aspect that is covered usually only marginally in the study of industrial history. By studying the activity of standards committees however, one can gain insights into the technical, social and economic developments in a given domain. This article sets out a typical example: the early battery-electric vehicle, which in the first quarter of the 20th century knew a very strong development.

A considerable part of the early standardization work in the field can clearly be considered as successful, particularly considering dimensional standards.

The introduction of performance standards and ratings proved more difficult, mainly due to the different operation environment of electrical equipment in a vehicle compared to a stationary industrial setting. Furthermore, the performances of the vehicles proved to be strongly dependent on the application, which hampered the drafting of universally applicable standards.

Some attempts of standardization were botched however. It was not feasible for example to standardize the speed of the vehicles, despite that there were strong technological arguments for this issue, facing the commercial rush for high speeds.

The study of the early standardization work, for which extensive archive material such as meeting minutes is still accessible, and its comparison with the actual work in the field, where the author is active in several intenational standardization committees, has shown that there are significant constants in the standardization scene. The technology may have evolved, the same problems and the same arguments always come back in the discussions. Standardization committees thus become a mirror of society and its technological, economical and social developments, and the study of standardization history can be considered a key element of the general study of technological and industrial heritage.

1 Introduction

The introduction of electric vehicles in the early twentieth century has seen a development of specific standardization activities. Although the history of electric vehicles has been thoroughly documented in a number of recent works, [1], [2], the aspects of standardization however have been covered only marginally. This paper, gives an overview of the development of early electric vehicle standardization and its impacts.

2 Actors in standardization

2.1 The Electric Vehicle Association of America

One of the first actors to get involved in specific standardization work concerning electric vehicles was the *Electric Vehicle Association of America* (EVAA) which was active from 1910 to 1916, and which should not be confounded with its near namesake EVAA (*Electric Vehicle Association of the Americas*) which has been promoting the electrically driven vehicle in recent years, until late 2002 it changed its name in *Electric Drive Transportation Association* (EDTA). The EVAA was incepted June 8, 1910 , on a meeting assembling "*one of the most representative bodies of men comprising the allied interests of the central stations and the electric vehicle and storage battery manufacturers of the country* [3]. It was considered of such importance that Thomas Alva Edison attended in person; he was much interested in the incorporation of a nationwide association for the advancement of the electric vehicle.
The association was quite successful, its membership growing steadily, and local sections being founded in a number of cities. It set up a number of technical Committees to deal with several aspects of electric vehicles, among which *Standardization*.

One characteristic of the association is the fact that its policies were mainly determined by the interests of the central stations (as electric power plants were known then), particularly those in big cities. Their interest in electric vehicles concerned on one hand their own vehicle fleets, on the other hand the selling of electric energy and the use of electric vehicles to level the station's load. For this reason, large commercial fleets in big cities received the most interest, rather than individual vehicles.

2.2 The Society of Automobile Engineers

In its early days, the automobile industry was characterized by the activity of a large number of manufacturers each working on themselves, and it was perceived that technical progress was retarded through the lack of exchange of knowledge and ideas.
With no concerted action being performed between different manufacturers, and with consequently no standardization of components or materials in place, there was a heavy burden for economical efficiency of the whole automobile [4].
The need arising to have a technical society dealing specifically with the nascent automobile industry, allowing exchange of ideas and expanding of the knowledge base, including the development of engineering standards, was expressed in the early years of past century, leading to the inception of the *Society of Automobile Engineers* in 1905.
One of the first standardization issues covered concerned the screw-thread standard, meeting an urgent need and being a success from the start. The next great stride was to decrease the number of unnecessary sizes of products, allowing simplification of manufacture, less stock problems, lower prices and better products [4].
SAE activities, particularly in the field of standardization were however to expand to other sectors. Representatives from other sectors, like the electric vehicle, but also the (agricultural) tractors, and the emerging aeronautic industry, made a pitch to SAE for oversight of the development for technical standards in the respective fields of business. In 1916 the *Society of*

Automobile Engineers thus became the *Society for Automotive Engineers*, representing engineers in a wide array of vehicle- and mobility-related activities. Standards development became a vital part of SAE's service to the industry and to society.
The procedure for adoption of standards by the early SAE reflects the same sound and safe principles that are still used in today's standardization work, and that are key elements in its success [4]:

- There is no forcing of any kind in the formulation of standards.
- No subject is considered for standardization except in answer to a normal, spontaneous demand.
- There is a specific procedure for approving new subjects and for preparing reports through the work of the divisions in charge of standardization in a specific field.
- Acceptation of standards is done by voting.
- Standards are published and made available to all interested parties.

The danger of overstandardization, which could hamper technical progress [5], and the key value of international collaboration in standardization, was clearly recognized [6].
The SAE standards were made available in the comprehensive *SAE Handbook*, the aim of which was to be "*the textbook of automobile engineering*" [7]. It is published yearly up to this day, and grew from a pocket-size booklet to today's DVD with thousands of files.

2.3 Collaboration EVAA—SAE and transfer of standardization activities to SAE.

Through the efforts of the Standardization Committee of the EVAA, a cordial relationship had been established with the SAE, which had appointed an Electric Vehicle Committee, to give careful consideration to electric vehicle conditions in the automobile world [8].
In June 1914, the EVAA requested the establishment of a collaboration with the SAE in standardization matters [9]. The Standardization Committee of the EVAA was to remain active, "*insofar it could be of assistance in supplementing the efforts of the SAE Standardization Committee, and also for the purpose of acting upon matters of peculiar significance to the electric vehicle industry*".
The further standardization actions concerning electric vehicles were gradually transferred to SAE, withthe EVAA Standardization Committee was relegated to the role of an advisory or consulting committee [10], [11], with all work being performed by the SAE Electric Vehicle Division, which had sub-divisions devoted to *Motors and Controllers*, *Batteries, Wiring and Charging, Speed and Mileage Ratings* and *Tires* [12].

3 The call for the need of electric vehicle standardization

The utility of standardization for the development of the electric vehicle had been recognized as early as 1900. Battery tray sizes and charging infrastructure had been cited as suitable subjects for standardization [1].
It took however ten years, and the creation of the EVAA, for concrete actions to be performed in this domain.
On the first convention of the EVAA, in October 1910, the need for standardization was directly addressed in the address of President William H. Blood, Jr., who deplored the fact that up to that moment, manufacturers were working independently in perfecting their machines, and who mentioned charging plugs, motor voltage, battery size, chassis size and tires as areas where standardization would be of a benefit [13].

These statements already deal with several key standardization issues, such as:

- Adding convenience to the user and manufacturer,
- Simplifying manufacturing,
- Reduce the cost of manufacturing.

Co-operation between the different actors involved was considered the base for standardization, ”*one of the most important things that our association has to do with*” [14].

4 Standardization of charging plugs

4.1 The introduction of a standard plug

The first item to be addressed was the standardization of the charging plug.
It did frequently happen in fact that electric pleasure cars (as passenger automobiles were then called) or, also, commercial trucks were operating some distance from their home garage and needed access to some other garage or charging station. The absence of a fitting charging plug became a troublesome problem, only to be resolved easily, with some pieces of wire and some moments work, by the ”*practical electrician or the skilled driver that we sometimes find*” [15]. It was clear however that this knowledge was not often present with the average driver or garage man, and the presence of charging stations with suitable charging plugs was considered a key to successful deployment of electric vehicles.
At that time, about eight different patterns of charging plugs were in use, the concentric design being the most popular, adopted by practically all builders of commercial vehicles and at least one of the pleasure type. Concentric plugs designed for electric vehicle charging had already been introduced to the market in 1902 [2]. However, the plugs being offered on the market often were of poor quality, defective in strength and thus condemned by fire underwriters.
The introduction of standardized charging plugs was supported by all large manufacturers of electric vehicles at the time [15].
One of the first standardization tasks to be performed by the newly formed Electric Vehicle Association of America would thus be the appointment of a *Committee on Design and Adoption of a Universal Charging Plug*, that would work in harmony with the National Board of Fire Underwriters as to secure the adoption of a standard and safe plug.
This committee, consisting of representatives of both vehicle and battery manufacturers, started its activities from early 1911. After a number of meetings [16], specifications for the proposed concentric plug were presented on the Second Annual Convention of the EVAA in 1911 by its chairman Alexander Churchward, the electric vehicle expert of General Electric Company, and the Chairman of the EVAA Standardization Committee:
”*As you no doubt know, every company - especially the pleasure vehicle manufacturers - have their own type of charging plug which is not interchangeable. We have been able to get a charging plug which, I believe, will be acceptable to at least ninety-five per cent. of the manufacturers, although the price is higher than they have been making their own, yet they are willing to pay something for standardization. (...)*
The plug which I now present to you has been laid out to carry one hundred amperes continuously and one hundred and fifty amperes overload.
I have interviewed most of the leading pleasure vehicle manufacturers and they have agreed to use this type of plug, and in this connection you must remember that there are at least four or five pleasure vehicles for every commercial vehicle made. Therefore, in presenting this plug to you, I believe we have made a step in the right direction.” [17]
The design of the plug was voted upon in the standardization committee [18], and adopted as standard by the Electric Vehicle Association.
The original standard sheet was promptly adopted as a standard by several vehicle manufacturers. The EVAA's directors passed a resolution [18], that a standard set of connectors had to be sent to all manufacturers, still facing the difficulty of non-matching connections, and stating: ”*It seems such a small matter to have a standard plug for charging vehicles*”.

The plug came in two dimensions, one rated 50 A and the other 150 A. These ratings were subject to discussion however [19], particularly the rating of the smaller plug, which was 50 A for the underwriters, although it was stated by the committee that it could carry up to 100 A. The ”absolute necessity” for larger equipment was cited.
The concentric plug was also adopted as a SAE standard, and featured in the SAE Handbook.
In 1916 however a few dimensions of the receptacle were slightly changed following a suggestion by the Anderson Manufacturing Company [20], a major manufacturer of charging plugs up to this day. Some dimensions were enlarged, lengthening the sleeve and insulating members of the receptacle. The reason for this change was to obviate the present tendency towards breakage of the shell when the plug is inserted or withdrawn [21].
With these dimensions, the plug continued to feature as a SAE standard throughout the years to come.
From 1929 however, the 50 A version, was presented with a rating of 100 A, its dimensions remained unchanged [22]. The last time the concentric plug appeared in the SAE Handbook as a SAE Standard was in 1939 [23].

4.2 The standard plug enters the scene

In 1913, the number of electric vehicles in use throughout the United States reached a number of 30000 [24], which fact highlighted even more the need for standardized charging connections. The report of the Standardization Committee at the October 1913 convention of the EVAA [25] recommended the adoption of the larger size plug, to take care of heavier trucks, with a rating approved by the underwriters of 150 A, and an overload rating of 225 A.
Another issue to be tackled in this report was the polarity of the terminals in the concentric plug. Following the majority practice of manufacturers, the Committee thus recommended adopting as a standard practice ”outside terminal positive, inside terminal negative” [25].
Practical experience with the concentric plugs in use , showed alignment problems due to inaccurate manufacture; to this effect, tolerances to insure straight interchangeability were settled upon. The Committee also decided on a method on publishing information on standards: the *standard sheet* [25].
One significant remark about standardization was made by Mr. Lloyd, who warned against too fast proceeding with standardization work facing a rapidly evolving technology: ”*...that we ought to be a little cautious before going on record at this convention on something which might again next year have a definite change* [25].
This argument was refuted however, through the recognition of a need for a two sizes of plugs (a small one for pleasure vehicles, and a larger plug for heavier trucks) and the need for some immediate standardization action facing the *tremendous confusion* that was present at that time. ”*We want to have something, if it is only a temporary standard, that would be arranged for all trucks*” [25].
This discussion already put forward a most typical problem faced by standardization committees: the trade-off between having a standard ready to be used, and the fact that such standard might become obsolete due to the evolution of the technology.

4.3 Standard products for all markets

That standards are not necessarily forcing one single product on the market, or are not necessarily promoting one single manufacturer, becomes clear in the statements made at the fifth EVAA convention in October 1914.
The EVAA Standardization Committee stated explicitly that it was not to standardize any particular make of plug, but confined itself to standardizing dimensions as to ensure interchangeability. This interchangeability of accessories was considered of foremost value [26].

4.4 The standard plug goes international

The standard concentric plug found its way abroad, and more particularly to the fast growing electric vehicle industry in the United Kingdom [27]. The great importance of standardizing the plug and socket was brought to the notice of the British Engineering Standards Committee (the forerunner of the British Standards Institution known up to this day) by the Electric Vehicle Committee of the Incorporated Municipal Electrical Association in March 1914. In October of the same year, a proposed standard design based on the recommendations of the Electric Vehicle Association of America was considered.
The design was implemented in September 1917 into British Standard BS74 [28], which described the same dimensions of plug and socket as the American SAE standard specification for the 150 A plug. The smaller, 50 A size was not considered. The concentric design was retained in subsequent amendments to BS74 [29], which was finally withdrawn as late as June 1975.
This development has been one of the first occurrences of international infrastructure standardization.

5 Standardization of battery voltage

A second standardization issue that was tackled by the Electric Vehicle Association of America concerned the battery voltage, or, otherwise said, the number of cells in a battery.
The rationale behind this issue was presented in a paper by Alexander Churchward at the February 1911 meeting of the EVAA [30].
The necessity of standardizing the voltage was identified for three reasons:

- The nationwide interest shown for electric vehicles, where it could not be expected that all central stations provide charging facilities at a great variety of voltages, considering the cost of doing so;
- Proper charging facilities at public garages are much easier with standardized charging equipment;
- A vehicle usually charged at a private garage may be charged while *en tour* at any other garage or charging station.

The electric vehicle market presented a wide array of voltages; historically the voltage levels had been increasing from 20 or 24 V (10 or 12 lead-acid cells) in early vehicles to 80 or 88 V (40 or 44 cells). The tendency was all the time to increase the number of cells. The tendency to go to higher voltages allows higher power without drawing excessive currents, and improves efficiency.
Standard levels were thus proposed corresponding to respectively 30, 40 or 42 lead-acid cells or 40, 60 or 62 alkaline cells. The adoption of two charging voltages, with a small amount of regulating resistance, would simplify matters considerably; also because the maximum voltage required for the higher proposed level is close to 110 V, allowing the charge to be performed from an 110 V d.c. network with minimal losses in the regulating resistance.
The recommended voltage levels were further adapted by the SAE, which recommended the adoption of two classes of motors for electric vehicles, one for 80 to 85 V operation, the other for 60 to 66 V operation. [31]. The recommended battery voltage was defined as 42 cells (84 V) for lead-acid batteries and 60 cells (72 V) for nickel-iron alkaline batteries [32].
The aim of choosing these levels was to allow all electric vehicles to be charged from a 110-volt service [33].

The physical size of the battery also lent itself to standardization work. Standard-sized batteries could facilitate battery exchange between vehicles in fleets, limiting the number of reserve batteries to be kept available [34].

6 Standardization of speed

The speed of the electric vehicles proposed on the market did in fact increase every year; this was not being caused by technological evolution, but by marketing: ”*the salesman finds it easier to dispose of a car which will go faster than that of its nearest competitor*” [35].
This phenomenon raised safety concerns among the Standardization Committee. Electric pleasure vehicles were in fact advertised to be simple and easy to operate, and were thus popular with women and even children. This gave rise to the following concern, which could still be expressed openly in an era not yet affected by *political correctness*:

”*But when you stop to consider that one of these glass-enclosed vehicles weighs nearly one ton and a half, with passengers, and is capable in some cases of making 25 miles on good level roads, do you not think that the speed is too high for a vehicle to be properly controlled by a woman or a child. Twenty miles an hours I consider very fast, yet the braking strain is 56 per cent. greater at 25 miles than at 20 miles.*” [35]

Alexander Churchward did talk this matter over with several manufacturers, who would welcome some standard maximum speed, providing that the different companies would stand by it. This would not concretize however, the speed remaining, under influence of the (gasoline) sports car, a major marketing tool for the vehicles.

A deeper reasoning concerning standardization of speed developed however taking into account the effect of speed on the energy consumption of a vehicle. It was clearly recognized in fact that excessive speeds would dramatically increase energy consumption, this effect being caused both by tire losses and wind resistance (*windage*).
A measurement campaign [36] showed that the power required did rise very rapidly as the speed was increased over 17 to 18 miles per hour.
For really fast speed, the design of the vehicle had to be to aerodynamic so-called *Torpedo* design adapted, a typical example being Jenatzy's well-known electric *Jamais Contente*, the first vehicle ever to exceed a speed of 100 km/h. This type of vehicle was at that time not considered a good suggestion for practical use, it would however have a deep influence on future automobile design [37].

The speed/consumption problem was also analyzed from the commercial vehicle side.
The ideal speed to be selected depended on minimizing tire and windage losses; a ”critical speed” was defined, where a minimum tractive effort is necessary, this being mainly dependent on the deformation of the tires. For heavy commercial vehicles, the proposed speeds were rather low (e.g. 7,5 mph for a 3-ton truck); such speeds compared very favorably however with the electric truck's main competitor in these days: the horse-drawn vehicle.

The commercial demand for high speed was also commented: should manufacturers meet the desires of the purchasers for a high-speed car, or should the speed be standardized (i.e. limited) for the benefit on energy consumption and efficiency of operation? The argument cited here is typical for the position of the electric vehicle circles of the time:

”*I think in this, as in a great many other things, it is best to educate the public as to what is best for them, and not always to give them what they want.*” [35]

The adoption of high speeds was in fact strongly frowned upon, for the energy consumption reasons mentioned above, which were one factor in disfavor of the electric vehicle due to limitations in range, but also for the higher strain on the tires. This argument was of course also valid for gasoline vehicles, the adoption of moderate-speed electrics being advocated as a much more economical solution for commercial vehicles. This way, the low speed of the electric was publicized as its advantage [2].

”*As an economic feature in the transport of goods, the electric truck would long ago have secured the dominating position, but for the foolish notion some have derived from the gas car craze that high speed and power are essential to the moving of goods (...)*

With the lower speeds soon going into effect it is apparent that the alleged advantages of the gas car over the electric have ceased to exist." [38]

The attractiveness of a high-speed vehicle would however prove to be greater, and the definition of a standard maximum speed was not materialized.

7 Performance ratings

This paragraph covers another type of standard: the performance standard, which allows the user to objectively assess a product's operational characteristics.
In those days just like today, the performances of electric vehicles were a sensitive issue, and the subject was one of the first to be tackled by the Electric Vehicle Division of the SAE. The approach followed differed from that taken initially on speed standardization by the EVAA, focusing on performance measurement rather than imposing limits.
The first form of recommendation to be proposed on the SAE meeting in January 1915 was as follows:
"*Electric vehicle speed ratings shall be based on continuous operation with one-half load over hard, smooth and level roads or pavements at the actual average battery voltage.*
Electric vehicle mileage ratings shall be based on the rated five-hour discharge capacity of the battery and a continuous run with one-half load over hard, smooth and level roads and pavements." [39]

It was soon realized that defining a standard for electric vehicle performance ratings was not a straightforward thing, and a thoroughly critical discussion was held on the subject [40].
The mileage rating definition based on the five-hour rating of the battery had been selected based on the battery manufacturers' practice of defining this rate as the "normal" discharge rate. This was not always matched to the real discharge rate when fitted in the vehicle, which was in many cases lower than the five-hour rate, it was stated that "*electric vehicles are almost all run six or seven hours with the batteries that are in them*" [39]. The difference with the five-hour rate then provided a "safety factor"; however, the practical object of this defined rating was questioned. It had been proposed by the committee "*to give a basis for comparison*" but not to describe "*a particular test*" [39].
It is clear that mileage ratings of electric vehicles are not an easy thing to standardize, as they are strongly dependent on the type of use of the vehicles. This problem is still an issue up to this day [41].

8 Overview of early standardization

The research described in this paper has drawn a general view of electric vehicle standardization in the early twentieth century.
Some interesting conclusions can be drawn from this study, if considering the standardizing parties on one hand and the actual impact of standardization on the other hand.

8.1 Parties involved

The standardization work concerning electric vehicles was initially taken on by organizations like EVAA whose main aim was to promote the electric vehicle.
It was shifted quite soon to specialist standardization bodies like SAE; this situation has remained up to this day, where electric vehicle promotion organizations, like the new EVAA, or avere, are not drafting standards themselves; although many of their members actively perform standardization work, they do so in the framework of an organization like IEC or ISO which has the international authority for the redaction of standards.
Most of the actual standards of the period concerned were taken up by the SAE, which profiled itself as the main standardization body in the field. Contacts with other bodies such as the

American Insitute of Electrical Engineers (which dealt with electric motor standards) were established in a spirit of co-operation; there was no sign yet of the ”competition” between different organizations which would come into play later, with for example fierce discussions between IEC and ISO on the subject of electric vehicle standardization in the late 20th century [42].

8.2 The impact of successful standards

Some of the standards developed can be designated as successful, in the sense that they saw a large acceptance in the market and did continue to be supported further in time.
A first example are the dimensional standards of charging plugs, which saw continued application in the electric vehicle field. The subject of this standardization continues to generate interest, as work on plugs and connectors is in progress up to this day.
The standardization of traction battery jars and trays found also a wide application. These standards allowed several manufacturers to propose interchangeable products, thus enhancing competitiveness and ultimately lowering the cost for the end user. The heritage of these early standards is now still alive in the dimensional standards for industrial traction batteries [43].
Voltage standards found their application out of practical and cost reasons; it should be said however that standard voltages also became imposed indirectly due to the introduction of standardized battery trays, thus fixing the number of cells in use.

8.3 The problem of ratings and performance standards

The definition of ratings for electric vehicle motors took into account the specific operating conditions of electric vehicles, which are differing from industrial electric motors. The application of electrotechnical ratings on electric road vehicle will continue to be a difficult issue however. Speed and mileage ratings were the subject of considerable discussions, as it is difficult to define a rating of speed or mileage which is coherent to real use of the vehicle, the energy consumption of an electric vehicle being strongly dependent on the type of mission. The definition of such rating and of the test cycles for it will remain a constant discussion point up to now, particularly for hybrid vehicles [44].

8.4 Botched standards

The attempt to standardize speed was botched. This standardization, which in practice would mean the definition of a standard maximum speed, was not feasible facing the rush for high speeds, fueled by the sporting race aspects of the gasoline vehicles. This speed argument continues to counter the electric vehicle up to this day, even if it is, particularly in urban conditions, void of much rationality.

8.5 Further evolution

After 1920, the electric road vehicle receded into niche applications, such as industrial vehicles. Although the effects of the early standardization work on electric road vehicles had a profound influence on the standardization for industrial vehicles, some of which can be discerned up to this day, the standardization work for electric road vehicles virtually vanished until the last quarter of the 20th century when a new interest in these vehicles arose due to their energetical and environmental benefits. Standardization work in the field is now done by international technical committees such as IEC TC69 and ISO TC22 SC21 [45]. Many of the problems and discussion points which were typical for the early standardization work can be recognized again nearly a century later, even taking into account the considerable evolution of the underlying technology, thus highlighting the interest of historical studies of technology.

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