# The Genesis of Electric Vehicle Standardization in the View of Electric Vehicle Development

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## 1 Abstract

In urban traffic, due to their beneficial effect on environment, electric vehicles are an important factor for improvement of traffic and more particularly for a healthier living environment. The development of electric vehicle technology has been accompanied from the earliest days on with activities in the field of standardisation concerning the electric vehicles, their components and their infrastructures.
The gives an overview of the origins of electric vehicle standardisation, highlighting the areas where standardisation activities have developed and more in particular on the genesis of these standards and on the motivation behind the standardisation work.
Standardisation or regulation activities can in fact be driven by several factors, and in each case separate actors can be identified who are likely to see these activities pursued. Standards may for example be drafted in order to enforce safety, or to facilitate interchangeability of components and infrastructures. Such standards are in favour of some form of common benefit; standardisation however may also be driven by hidden agendas and commercial benefits of a some concerned parties. Furthermore, for historical, cultural and technological reasons, some key actors involved may or may not perceive the need for standardisation work to be pursued in a certain domain.
This knowledge will improve the understanding of the standardisation process and its influence on the technical and economical development of electric vehicles. The identification of relevant standardisation trends will allow to explain ongoing and future developments in the field, and to highlight problem and potential areas. “Standardization” on itself may in fact seem to be a rather dreary subject, particularly to the general reader who is not actively involved in it, but its study allows to get a distinct vision on the underlying technologies and on the actors behind them.
The paper reflects ongoing research performed by the author in the domain of standardisation. 

## 2 Keywords

Standardization, EV

## 3 Standardization

The main issue of this paper concerning “standardization”, it seems desirable, at the outset, to define this concept. What is a “standard”, and how does it come to being?

If applied to technical or industrial standardization, the definition is more specified, while keeping the same signification, as is shown from the official definition of a standard by the international standardization bodies:

> “a standard is a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context” [1]

The origin of standards goes back, historically, to the earliest beginnings of human culture, the first formal standards being established being weights and measurements.
With the advent of the industrial revolution, the introduction of rational production methods involving division of labor, and the increased mobility through the availability of railroad transportation, the need for industrial standardization emerged, and by the end of the nineteenth century specialist organizations devoted to standardization came into existence. It was soon appreciated in fact that effective standards could only be developed by competent technical bodies, as attempts for standardization drafted by legislature often yielded unusable, inadequate or foolish specifications.
The road was shaped by the electrical industry, which was new and did not have a body of precedents or earlier practices to follow, and was the first to take hold of international standardization properly, as will be seen in the next chapter.

What makes standardization, as taken into account here, unique is the way the documents are implemented: standardization in fact is the fruit of voluntary collaboration between actors in the field, backed by a recognized body such as a national or international standards organization.
The fundamental base principles of successful standardization, which were already present in early standardization work [2], and which are reflected up to this day in the activities of the various standardization bodies, can be summarized in a few main points as follows.

- The standardization work should represent the interests of all stakeholders concerned, as well producers as consumers; it should not be purely academical, but in close touch with practical requirements.
- Standards should not be promulgated “ex cathedra” like articles of faith but should be the fruit of a democratic process based on consensus by all concerned.
- Standardization bodies should undertake their work only when there is a specific demand for it.
- Standardization work should be at all times subject to revision, in order to incorporate improvements and to reflect the evolution of technology.

The two last point put the attention to the imminent danger of “overstandardization”. Standards should serve recognized needs, there is no need for “standardization for the sake of standardization”. Furthermore, standards should not be allowed to “crystallize”, ultimately retarding further developments, so that the various trades would become hide-bound, or their methods stereotyped. This point can be well summarized in the following statement:

> “Standardization is an useful servant, but a bad master.”[3]

The useful societal impacts of standards are manifold. They have a value for education, presenting guidance and information to both user and manufacturer who wants to make or use a new product. They have a value of simplification and rationalization, reducing time and material expenditures and thus allowing a conservation of energy and material resources. They finally have a value of certification, serving as hallmarks of quality.

To many people however, the notion of “standardization” is most forbidding. They see it as the antithesis of individuality, as a process that will reduce everything to a drab monotony [4.] With standardization in the true sense of the word however, this should not be the case, as said above standardization should be a faithful servant, who makes life easier, and not an evil master imposing his will. The democratic process in which standards are drafted and revised, and the voluntary aspect that is at the base of industrial standardization are factors guaranteeing this. In the case when standards are absorbed by legislation and are enforced by the government, care must be taken that the implementation and the follow-up of these legal documents are performed with the same principles and exerting the same care than for proper standard documents..
Generally speaking, the benefits of standardization and its influence on our world are so considerable that one can in fact say that:

> “Standardization, in a sense, is the bed-rock of civilization” [5].

# 4 The Genesis of Electric Vehicle Standardization from within the Electric Vehicle Community: the Activities at the Electric Vehicle Association of America

One of the main 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) that is promoting the electrically driven vehicle to-day.

## 4.1 The Call for the Need of Standardization

The first convention of the EVAA was called to order on October 18, 1910 [6]. This meeting united nearly 300 delegates and representatives, from the central station, vehicle, battery and allied interests.
The address of President William H. Blood, Jr., highlighting the aims and policies of the new association, was considered a document of great importance.
The statements expressed in this key address already deal with several key standardization issues, such as:

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

Standardization was considered “one of the most important things that our association has to do with” [7].

## 4.2 Standardization of Charging Plugs

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 here, 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” [8]. It was clear however that this knowledge was not often present with the average driver or garage man, and

> “it at once becomes apparent that if electric vehicles are to be the great success we all confidently expect, not only must we have plenty of charging stations, but these stations must be equipped with suitable charging plugs” [9].

The standardization of two sizes of charging plugs and receptacles, a heavy form for commercial wagons and trucks and a lighter form for “pleasure” cars, was considered as “one of the greatest conveniences for the users of electric vehicles”
The introduction of such equipment was supported by all large manufacturers of electric vehicles at the time [10]
The plug was presented on the Second Annual Convention of the EVAA [11] by its chairman Alexander Churchward, the electric vehicle expert of General Electric Company, and the Chairman of the EVAA Standardization Committee.

This standard concentric plug found its way abroad. It was included in the standards of the British Engineering Standards Association (the forerunner of the British Standards Institution known up to this day) as British Standard 74 (1917): “Charging plugs and sockets for electric battery vehicles”.

## 4.3 Standardization of Voltage

A second standardization issue which 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 [12].

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 standardization of the voltage was adopted by electric vehicle manufacturers; on the second annual convention of the EVAA in 1911, it was stated that nearly all companies now made vehicles within reasonable limits of the two proposed standards, the difference not varying greater than 28 to 32, and 40 to 44 lead cells respectively. This evolution was considered satisfactory by the Standardization Committee, as the charging apparatus could easily take care of these variations around the two standards[13], with rated charging voltages of 78 V on the smaller vehicles and 110 V on the larger vehicles being used [14].

## 4.4 Standardization of Speed

A third attempt at standardization taken on by the Electric Vehicle Association of America concerned the 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" [15].

This phenomenon raised safety concerns among the Standardization Committee. Electric "pleasure" vehicles were in fact advertised to be simple and easy and operate, and where 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." [16]

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").

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 of 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." [17]

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 [18].
The attractiveness of the high-speed vehicle would however prove to be greater, and the definition of a standard maximum speed was not materialized.

# 5 Automotive Standardization Development

Through the efforts of the Standardization Committee of the Electric Vehicle Association of America, a cordial relationship had been established with the Society of Automobile Engineers, which had appointed an Electric Vehicle Committee, to give careful consideration to electric vehicle conditions in the automobile world [19].
On the June 1914 meeting of the EVAA, Mr. E.R. Whitney, Chairman of the Standardization Committee, offered a resolution requesting the establishment of a collaboration in standardization matters between the EVAA and the SAE [20]. This action was reported as being favorably received by the SAE [21].
The further standardization actions concerning electric vehicles were gradually transferred to SAE.
The Electric Vehicle Division continued the work of the EVAA Standardization Committee and also took on new subjects.

## 5.1 Standardization of Charging Plugs

The concentric plug standardized by the EVAA 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. Some dimensions were enlarged, lenghtening 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. [22]

## 5.2 Standardization of Voltage

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..[23]

## 5.3 Speed and Mileage Ratings

For this, we come to 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." [24]

It was soon realized that defining a standard for electric vehicle performance ratings was not a straightforward thing.

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. The mileage definition was thus simplified:

The result of this correspondence was given in the Third Report:

"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 a continuous run at the SAE rated speed with one-half load over hard, smooth and level roads or pavements." [25]

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 on the vehicles. This problem exists up to this day [26].

## 5.4 Standardization of Battery Jars

During the year 1916, considerable work was been done on this subjectA proposal was agreed upon for all dimensions except the length (which is a variable based on the number and thickness of plates and thus the battery capacity). A table of proposed lengths was prepared by the Division and submitted to battery makers for discussion, with the aim of reducing the number from about fifty to about twenty-five or thirty. [27]

A standard was eventually proposed in 1917. It recommended two types of battery jars, with respectively "high" and "low" ribs on the jar bottom. [28].

Furthermore, the establishment of standards for the arrangement of battery cells in trays was announced.

The standard was revised in March 1921 [29], abandoning the "low-rib" jars, rationalizing jar sizes and adding a number of long jars for heavy-duty vehicles. The new standard also added specifications for the "hard-rubber" (ebonite) material of which the jars were made.

## 5.5 Motor Ratings

The recommended practice on motors (featuring the motor voltage and motor name-plate recommendations described above) was completed in 1923 with a paragraph about motor rating:

"The rating of electric automobile propulsion motors shall be based on a temperature rise not to exceed 65 deg. cent. (117 deg. fahr.) by thermometer, or 75 deg. cent. (135 deg. fahr.) by resistance after 4 hr. of continuous operation at normal rated load.

The tests shall be made on a stand with the motor covers arranged as in service." [30]

The temperature rise of 65 resp. 75 ˚C corresponds to the standard admissible temperature rise of 50 ˚C, augmented with the values stated in the standardization rules of the American Institute of Electrical Engineers. The proposed duration of the test, four hours, is an addition of the SAE however.

The idea that automobile motors may be operated at higher temperatures than stationary motors had been justified with space and weight considerations; one other argument which can be added here is that the working life (in hours) of a vehicle motor is usually much less than of a stationary industrial motor. This working life is strongly dependent on operating temperature.

The need to specify a nominal rating for automobile motors is not recognized; this also marks the difference with other electric traction motors like those for railway use.

This clause was only included in the SAE Handbook in 1923; the SAE was however following up the AIEE activities in the field as early as 1916.[31]

### 5.6 Efficiency Test of Solid Tires

This matter was given careful consideration by the SAE Electric Vehicle Division, based on a number of tests which have been made from practical experience by members, and recommendations were given covering the rebound method of testing solid tires for efficiency. These recommendations were not adopted however, principally because of lack of familiarity with the method recommended [32].
It may seem strange why this subject, which as of equal significance for gasoline vehicles, was referred to the Electric Vehicle Division, were it not that the extra consumption involved would seriously affect the range of the electric vehicle, and thus be "a matter of life and death with the electric truck to have efficient tires" [33], whereas it is only a question of the amount of fuel with the gasoline truck.

### 5.7 Evolution of Electric Vehicle Standardization in SAE

The work of the SAE Electric Vehicle Division had been intensive, but its activities were limited in time. Since its inception in 1915, it had produced five six-monthly activity reports, the outcome of which has been discussed in the paragraphs above.
After 1917 however, with the United States entering the First World War, the electric vehicle became relegated to the background, and fewer activities of the Division could be discerned, apart from adaptations to existing standards as published in the SAE Handbook.

## 6 Overview of Early Standardization

The paragraphs of this chapter have 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.

### 6.1 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.
The JEVA in Japan is a notable exception to this case however.
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 AIEE were established in a spirit of co-operation; there was no sign yet of the "competitition" between different organizations which would come into play later.

## 6.2 Impact of Standardization

### 6.2.1 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 consumer.
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.

### 6.2.2 The Question of Ratings

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 the end of the century, as will be seen below.

### 6.2.3 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 “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.
Standardization of tires also proved difficult, and the committees did not come out of it or manage to come to an agreement.

### 6.2.4 Further Evolutions

After 1920, the electric road vehicle receded into niche applications, such as industrial vehicles. The effect of this phenomenon on the standardization of electric vehicles and their components will be the subject of further research.

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