Opportunities and threats for the electric two-wheelers in China

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Abstract
Being the country with the largest number of electric two-wheelers (E2Ws), China has received more and more attention over the last few years. However, this large-scale adoption was not led by the strong political will in developing Alternative Fuel Vehicles. This study applies two different methods to identify the driving and resisting factors of the E2W development. An integrated method of force field analysis and SWOT (Strengths, Weaknesses, Opportunities, Threats) aims to uncover the reasons behind the rapid E2W technology penetration in the Chinese society. The technological innovation system is applied as the analytical framework to investigate the weaknesses of the E2W system. The result shows that the E2W adoption has been mainly driven by low cost of the product and the biking habit embedded in the society. Notably, the legitimation of E2W is somehow recognized as the main system weakness at the current stage.

KEYWORDS:
Electric two-wheelers, technological innovation system, force field analysis

Introduction

As the second largest economy in the world, China has been influential on the global market for its quick development in many fields; however, this arbitrary growth has also led to some severe challenges for the country. Together with economic growth, the rapid urbanization drives millions of people into the cities seeking for better quality of life. This results in progressive private transport demands and triggers the need for a radical change in the transportation system. Therefore, both the acknowledgement of the sever impacts brought by the intense fossil fuel consumption and the foreseeable congestion and pollutions in many cities, brought forward strong intentions to promote Alternative Fuel Vehicles. Among all the

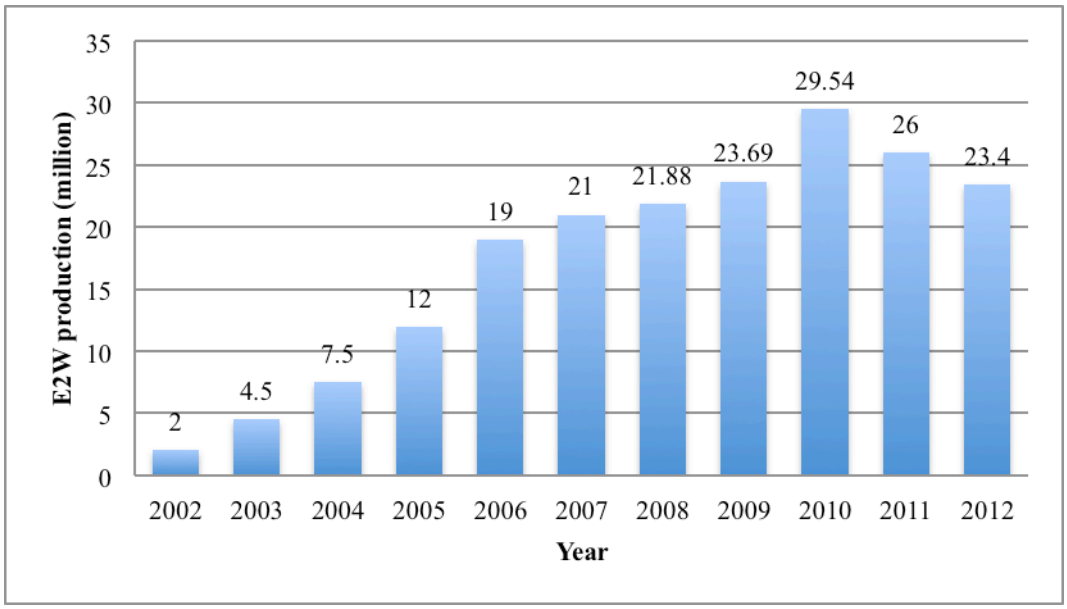
vehicle models, the E2Ws successfully entered the market and kept gaining widespread acceptance in China (Weinert et al., 2007). Comparing with electric cars, which still have very low penetration rate even in the western society, E2Ws have unexpectedly overcome the barriers without extra effort.

E2Ws are defined as the two-wheeled vehicles with electric propulsion, including electric bikes (E-bikes), electric mopeds (E-mopeds), and electric motorcycles. In accordance to the 1999 National Standard (GB17761-1999), the E2W is assigned into two categories based on the way of riding: bike style electric bikes (BSEB) or scooter style electric bikes (SSEB). These vehicles have identical function but are categorized according to their power, style, material and electrical mechanism. Yet, the distinction between electric mopeds and bikes is somehow elusive. According to the definition in the 2009 National Standard (GB/T 24158-2009) for the electric motorcycle and E-moped, the electric motorcycle should be designed with a speed limit over 50km/h and less than 400kg in weight and with two or three wheels. On the other hand, a two-wheeled E-moped is designed with a speed limit under 50km/h (over 20km/h) and less than 40kg in weight. As for the E-bike, it should be designed with pedals and limited to a top speed of 20km/h and also less than 40kg in weight (GB17761-1999).

When it comes to shifting from an internal combustion engine (ICE) vehicle to an electric car, users are more sensitive to the driving range concerning charging possibility and price premium. However, these barriers are minor when it comes to E2Ws. Owing to the open-modular (O-M) industry structure and the rather low technology proficiency requirement for E2W production, E-mopeds or electric motorcycles are less expensive than the ICE vehicles in China. Because E2W users expect a lower driving range than EVs, there is lower range anxiety and demand on charging, the adoption of E2Ws in the cities is fairly smooth.. Although the production has been in a rising trend for approximately a decade, the expansion of E2Ws seems to stagnate over the last few years (Figure 1). This could imply that some resisting forces have begun to hamper the market. Weinert et al. (2008) has investigated the evolution of E2Ws in China and quantified the forces influencing this technology.

Although the E2W technology revolution started since the 90s, regulations are currently of low profile when comparing with the ones for cars or motorcycles. Safety problems emerged due to frequently happening violations, such as speeding and running over red-lights on the roads. In China, only electric motorcycles are classified with clear standards; while E-mopeds and E-bikes, the majority on the E2W market, are only required to fulfil the basic criteria on the size and the pedal function. With increasing traffic accidents, several cities have banned the motorcycles; some even included the overall use of E2Ws.

Possible solutions to revive the E2W market are to foster safety awareness through education and to reformulate the national standards for vehicle design in a more stringent manner. A systematic change for the electric vehicle, on both the user and the producer side, is expected to resolve the dilemma of E2Ws. Together with the trend of transport electrification, the analysis of driving forces and the system weaknesses for the rapid E2W uptake could act as a reference to overcome the obstacles encountered with the electric vehicle deployment.



Source: China Market Report Center, 2010; Ministry of Industry and Information Technology of China, 2013

Figure 1 - The E2W production number in China

Methodology

Two methods were used and compared in this study regarding to the suitability of different aims. For identifying the driving forces boosting the rapid E2W adoption, an integrated method of SWOT and force field analysis (FFA) were applied. The technological innovation system (TIS) analysis was used to obtain the landscape of the E2W system and to feature the system weaknesses hindering the process.

SWOT-FFA analytical framework

SWOT analysis is able to provide a holistic view of the strengths (S), weaknesses (W), opportunities (O), and threats (T) for a certain innovation. Traditionally, SWOT analysis is perceived as a process to generate information in line with the organisation's goals, programmes, and capacities to the social environment in which it operates (Jackson et al., 2003). Created by Kurt Lewin (1952), FFA is a tool for systematically analysing the factors found in a complex problem. It frames the problems in terms of factors that support the current situation or pressures that trigger a change in a desire direction.

These two management tools are complimentary in classifying the driving forces and resisting factors of the E2W deployment in China. To quantify the driving forces identified, the results of SWOT analysis and FFA are justified in accordance with the literature.

TIS analytical framework

TIS analysis is a salient method to evaluate the maturity of an innovation under a systematic landscape. According to the theory of Hellsmark and Jacobsson (2009), *Technology*, *Actors*, *Institutions*, and *Networks* are the four structure components that shape the fundament of TIS. With the mission to gather knowledge, the *Technology* is considered both a structural entity and also an output that is to be analysed with the functions (Bergek et al., 2008). *Actors* refer to individuals and organisations dedicating resources to develop the system. *Networks* come in to associate and connect different actors for better communication and resource exchange; furthermore, *Networks* are able to motivate the system to trigger changes to institutions. *Institutions* define the policy for the society in terms of legislation, norms, and vision. Identification of the structural components provides the basis of the analysis and leads to the discussion of the functional terms within the system.

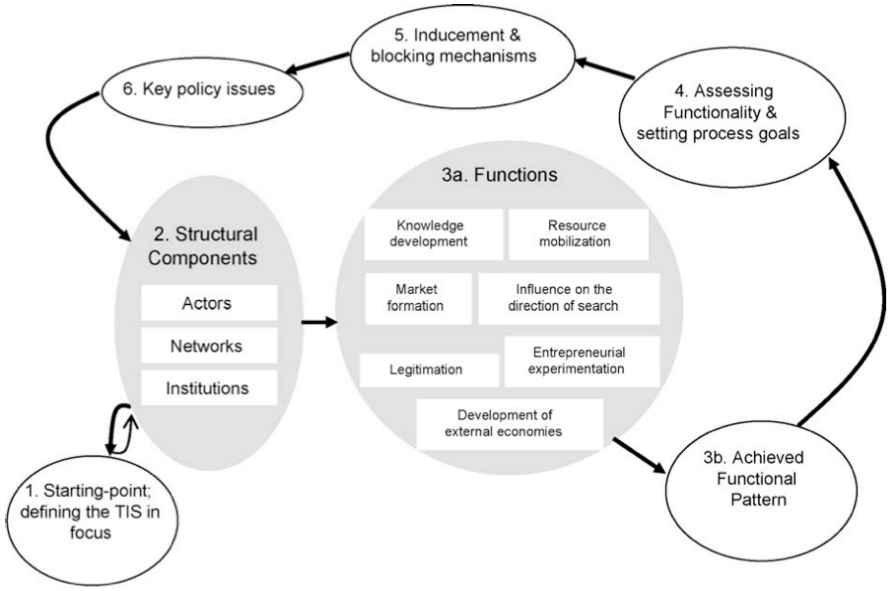


Figure 2 - The analysis scheme for TIS (Bergek et al., 2008)

The actors operate the system with the seven functions presented above (Figure 2, 3a) as the key innovation process. *Knowledge development and diffusion*, *Influence on the direction of search*, and *Entrepreneurial experimentation* are the three functions especially crucial for the innovation at the formative phase (Bergek et al. 2008). *Market formation*, *Resource mobilisation*, *Legitimation*, and the *Development of positive externalities* are essential for supporting the innovation to reach the maturity (Bergek et al., 2008). The seven functions are linked to the structure components and are interacting with each other (Figure 2). Policy

makers can evaluate system dynamics of the innovation according to the strength expressed by the functional terms. Conducting a weakness analysis for the system based on the state of functions and their interaction with the structure components could pinpoint the ideal spot for policy intervention (Jacobsson & Karltorp, 2013).

The driving forces for the change towards E2Ws: SWOT-FFA

The driving forces and resisting factors can be quantified under FFA analytical framework on basis of the outcome from the SWOT analysis. Several factors for the E2W market were identified through the SWOT analysis based on literature reviews (Figure 3).

Strengths	Weaknesses
- Lower cost - Less technology required - O-M industry structure - Clean fuel consumption - Less range concerns	- Low tech proficiency - R&D of vehicle - Low recycling rate (battery and vehicle) - Lack of standards - Safety issues (vehicle & traffic)
Opportunities	**Threats**
- Easy to adopt - Compatible with urban life style - Motorcycle bans - Lack of standards (policy) - Contagious viral disease (SARS) - Advances of battery technology - Value and brand on the market	- New public policy (standards) - Development of BEV - Disordered market - User quality (training) - User perception & perspectives - Poor roads & traffic conditions - More expensive raw materials

Figure 3 - Result of SWOT analysis of the E2W development

Concluding the results from FFA-SWOT and the literature, the key driving forces for the E2Ws are concluded as the following:

a. Relatively low cost and comparable performance.
b. Easy adoption and utilization.
c. Policy and standards (motorcycle ban, air pollution and emission concerns).
d. External factors.

Relatively low cost and comparable performance

Three components were classified as the driving force of the "low cost and comparable performance": technology development, industry structure and product structure (Weinert et al., 2008). The technologies for E2Ws regarding the battery, vehicle size, power and speed have been improved over the years. The O-M industry structure, which allows more competition among suppliers, has lowered the production cost within the supply chain and

thus results in lower vehicle price on the E2W market. Instead of manufacturing the vehicle from scratch, the E2W assemblers buy the components from the suppliers and sell the assembled E2Ws to the retailers or directly to the customers.

The cheap vehicles have been mostly welcomed in the suburban areas, where the household income is low and long trips are required (Weinert et al., 2008). An ICE motorcycle cost around 5,000 CNY to 8,000 CNY (one CNY is approximately equal to 0.12€ or 0.16 USD). According the investigation in Shanghai, the average E2W cost is around 2,400 CNY and can range from 1,400 to 4,000 CNY (Liu et al., 2008), which is affordable to the majority comparing with the ICE motorcycles. The performance of E2Ws is also widely accepted due to practical expectations from the users. E2Ws are usually used to fulfil rather short-distance mobility and light freight transport needs earlier managed with conventional cargo bikes or mopeds.

Easy adoption and utilization

The familiarity of the technology and the existing infrastructure for biking opens the opportunities for large-scale deployment of the E2Ws (Cherry, 2007; Yan, 2012). Based on the Chinese biking custom, the behaviour change required to embrace the E2W is minor. E2Ws provide users with more flexible mobility than cars do in the city. The required on-road space is much smaller than that of a car, which allows E2W to go through congestion areas quickly and also gives more possibilities for parking (Weinert et al., 2008). Since the purpose of having an E2W is to fulfil frequent and shorter-distance trips (e.g. grocery shopping), users have less expectation about driving range and less demand for charge points comparing with passenger cars. Users usually charge their E2Ws at home with a normal socket and are able to cope with the driving range over a single charge.

For the vehicle industry, the E2W creates an opportunity for the development of local automotive industry. On one hand, the technology of E2Ws is independent of foreign resource. On the other hand, in the near future, millions of workers would drive into the city with ICE vehicles and lead to serious congestions and air pollution. As a result, electrified transport could conceptually prevent this situation and set the future market for the industry.

Policy and standards (motorcycle ban, air pollution and emission concerns)

The absence of legislative control for the production and use of E2Ws can be considered as a stimulus factor at the early stage of E2W evolution. Currently, the 1999 National Standard and the Law of Road Traffic Safety are the only legally enforced national regulations for E-bike. However, owing to the lack of enforcement of the National Standard at the local level, cities have adjusted the standard's approach to encourage the use of E2Ws and reassure the E2W industry (Wienert et al., 2008). Besides the imperfect legislation system, some policies

are able to trigger the innovation adoption through the reduction of competitiveness of other similar alternatives, e.g. the motorcycle ban. The prohibition for gasoline-powered motorcycles indirectly stimulated the development and adoption of E2Ws. More and more people start to consider E2W as their primary transport mode choice.

External factors

Together with the strong will of the industry, the E2W market has expanded due to the user's familiarity, low cost and some external opportunities contributed by some occasional incidents. The outbreak of SARS (Sever Acute Respiratory Syndrome) in 2003 indirectly increased the sale of E2Ws because people were keen to avoid crowded and enclosed areas, including subway and buses. Consequently, E2Ws suddenly become popular in the Chinese cities, especially in the cities where gasoline motorcycles are banned (KaW, 2011; Yan, 2012).

The resisting forces (system weakness) of the E2W development: TIS analysis

Actors, network, institutions

Several actors are deemed important in the TIS system of the E2W. The identification of actors was based on a selection according to the political hierarchy, the authority and interest level of the organisations or institutions. The actors were identified within the TIS boundary and the industry boundary. The actors within the TIS boundary are directly related to the development of the new technology and affect the system effectively. Nevertheless, actors like associations, research institutes, utility companies, business sectors, and users are also motivating the system with a variety of feedback. The E2W users and the media are the main feedback sources for this business. Many association groups at different levels are connected with the E2W, including the China Association of Automobile Manufacturer, China Association of the Electric Vehicle, and several local bicycle associations at provincial level.

In China, the main policy guidance is set by the central government. With the highest authority in the political system, the central government has direct and solid influence on the development of the E2W via the National Economic Plans (The Five-year Plan) and through the subsidies for the New Energy Vehicles (official name for the Alternative Fuel Vehicle in China) . Improving regulations for E2W usage and the technical specifications for E2W production are the key factors needed to strengthen its development. At the early stage, the E2W market was largely ruled by the SMEs. More than 2700 SMEs existed on the market around 2004, when the amount of E2W companies topped the record (China Market Report Center, 2012). Due to the adjustment and concentration of the E2W industry, there are around 1000 enterprises with larger business scale nowadays. The research and technical development of E2W has been initiated and carried on by the industry group. Currently, a large part of the technology has been associated with development of the battery.

System weakness: remarks of the evaluation of the seven functions

Based on the historical development of E2Ws, the technology for manufacturing the physical E-bike or E-moped has already surpassed the formative phase since it already has a solid market with low uncertainty technologies (Kemp et al., 1998). Wide acceptance and the strong purchasing intention occurred in many cities in China since the millennium, especially at the countryside. The growth phase, defined as the period that the product can self-sustain its development, is more appropriate to depict the current status of E2Ws. In this phase, much focus is laid on system expansion and large-scale technology diffusion via market formation and linking. Bergek et al. (2008) stated that the increase of *Resource mobilisation*, the continuous maintenance of *Entrepreneurial experimentation*, and the formulation of *Legitimation* are the essential functions to be maintained while the innovation is growing in the society.

The evaluation of the seven functions under the TIS framework of E2Ws allows us to inspect how the system operates and to identify the mechanisms fostering and hampering the development of E2Ws (Figure 4). The inducement mechanisms for E2Ws can be largely associated with sufficient technology development, low-cost, and weak legislation. These factors have motivated the adoption of E2Ws in the Chinese society. The low-cost technology and production reduce the economic barrier for the innovation adoption. The competition within the supply chain delivers low costs to the customers (comparing with the gas-motorcycle) and creates a significant economic incentive.

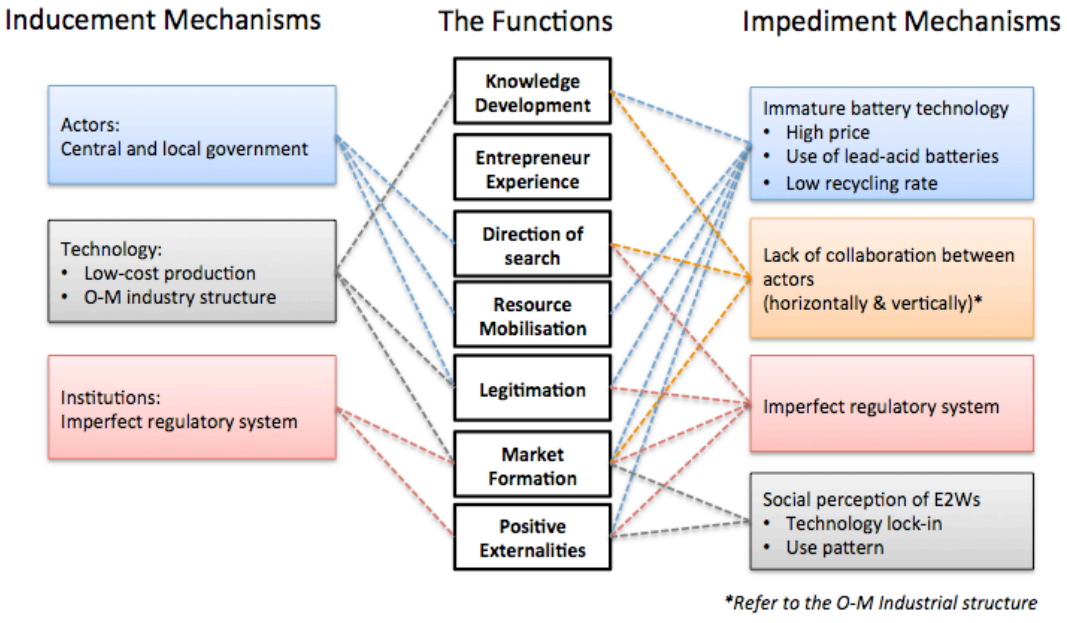


Figure 4 - The inducement and blocking mechanisms of E2Ws concluded from the TIS

The battery technology and legitimation problems of E-bikes are the major blocking

mechanisms for the E2Ws. Similar to the situation of electric vehicles, low-cost batteries with high capacity are still expected from the market. Although the Li-ion battery has already been developed to have longer charge cycle, lighter weight and higher capacity, its popularity is still restrained by a considerable higher price comparing to the lead-acid counterpart. The production of lead-acid batteries and also the low recycling rate contribute to heavy metal pollution. The solution for battery problems requires the cooperation of different actors and an integration of various functions concerning the *Market Formation*, *Knowledge Development*, *Direction of search*, and *Legitimation*.

The imperfect legislation is both an encouraging and a blocking mechanism for the E2Ws. At its early development stage, the "E-bike" is an interesting transport alternative for most people because of the loose standards. Being categorised as the non-motorised vehicle, E2Ws do not require any license to ride thus gain a large population of potential users. However, this feature then raises the risk of traffic accidents on the roads with many untrained E-bikers. Although the 1999 National Standard states that the top-speed of E-bikes should be limited to 20km/h or otherwise should be classified as E-mopeds or E-motorcycles (Road Traffic Safety Law, 2004), no evidence of enforcement has been reported. With the occurrence of many accidents (e.g. fire events caused by batteries, traffic collision), the expectation of new standards from the manufacturers, the retailers and the customers has now deterred the growth of E2Ws in China (Yan, 2012). To ensure the development of the E2W, comprehensive national standards should be prioritised for the central government to regulate and monitor the entire E2W system.

Owing to the social perception of E2Ws in China, low cost and low profitability of the 'E-bike' could be one of the factors hindering the technology development of E2Ws. At present, the mass market is still strongly in favour of the low price models and leaves no room for the expensive high-quality ones. Low profit gained per unit offers little interest to the manufacturer to develop luxury products for E2Ws. A change in mind set will be needed to break this social lock-in to create a market for high-quality and durable products.

Discussion: The inducement and impediment mechanisms

Based on both the analysis results from FFA-SWOT and TIS, the lack of governance, low-cost production, sufficient technology proficiency and easy adoption are the major factors encouraging the uptake of E2Ws in China.

The "low cost and comparable performance" identified by FFA-SWOT can be addressed as the inducement mechanism of *Technology* in the TIS (Figure 4). The special features of the E2W technology, such as low cost and being independent of foreign actors, create some advantages for the E2W. The "easy adoption and utilization" can also be partly attributed to

the criteria of *technology* under the social perspective with the legacy of traveling or transporting goods with two-wheelers in China. The familiarity with the riding technique and the travel habit of bikes make people more confortable with the E2Ws. “The lack of policy and standards” can be seen as a result of the *institutional* weakness in the TIS. The imperfect legislative system and the loose legislative enforcement widen the flexibility of product design and the utilization of E2Ws, and hence address incentives of E2W adoption by eliminating restrictions; on the other hand, many problems occur for the same reason, especially the ones related to safety. This institutional weakness from the legislation is also associated with the authority relationship between the central and local governments.

The factors obstructing the E2W development can be identified through analysing the TIS functions and attributed as the system weakness. Most of the crucial function failures are related to the imperfect regulatory system and the development of the battery. The finding of “lack of standards” from the SWOT analysis (Figure 3) is coherent with the failure assessed in *Legitimation*, *Market formation* and generating *positive externalities*. The expectation of new standards and regulations addressed some uncertainty of the market and thus slowed down the production. Some resisting factors are related to the development of the battery; the expensive Li-ion battery with better capacity is not popular with the consumers. More users are inclined to choose the cheaper lead-acid battery with higher technology maturity level. Many accidents happened in Beijing, Suzhou, and Yunnan earlier this year owing to the inappropriate charging and the use of deficient batteries (China Bicycle Association, 2013). The systematic approach allows an overview of the whole production process and of the relationship between the producers and consumers, which is hard to be mapped via FFA-SWOT analysis. The social lock-ins for the E2Ws in China needs to be resolved with some significant breakthrough for vehicle quality and battery technology.

Future transport solutions

The importance of user participation for innovation development has been confirmed with the E2W case. Concerning the best choice of transport modes, the most convenient and cheapest option, which coincidently fits in with the E2W, is still well appreciated by the users (Chang, 2006). This tends to be a straightforward explanation of the E2W situation in China.

The legislation has not yet been clearly defined in the E2W system. Based on the result of the analysis of both FFA-SWOT and TIS, the review and improvement of the legislation for the E2W should be prioritised to stabilise the market and then also the production chain of the industry. This requires some efforts to unify the stakeholders within the legal system. The National Standard for E-bikes needs to be revised considering the contemporary technology and traffic situation at the national level. After the technical specifications are articulated, the local government will need to integrate the new standard with the local social environment.

Besides the E2W standards, the regulations for the charging infrastructure should also be specified at national level. Most of the E2Ws are now charged with normal household sockets or power strips. However, with the improvement of power system and battery capacity, charging without proper safety protection has become more and more dangerous. The policy and technical specifications for the charging infrastructure should be formulated to support the positive development of E2Ws.

To improve the technology proficiency, the integration of the supply chain of the E2W is crucial based on the problems originated with the O-M industry structure. The communication between actors should be strengthened to ensure the knowledge flow and information availability for technology development. The involvement of the central government is necessary to reunite the actors in this field. Besides the great focus on the development and deployment of the New Energy Vehicles, the China government might obtain a lot of progress in terms of electromobility from enhancing and re-building the E2W system.

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