Self-Service Electric Vehicle

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Electric vehicle sharing is necessary for achieving carbon neutrality. The self-service electric vehicle mode offers unique advantages in terms of freedom of movement and privacy protection. Meanwhile, this mode requires a high-quality service guarantee because of the separation of management and use.

Keywords: self-service electric vehicle ; service life cycle

1. Introduction

Environmental protection is increasingly urgent, as 12% of greenhouse gases and 25% of urban ambient PM2.5 are produced by transportation links [1], so promoting green transportation has become an important means of sustainable development [2]. Shared travel comes in many forms, and it is characterized by low carbon, economic, and great environmental protection value [3][4]. Car sharing has unique advantages in medium and long-distance shared travel, which first appeared in Switzerland in 1948, and its rapid development began around the beginning of the 21st century [5]. Car sharing can replace a certain number of private vehicles and meet people's travel needs. Research has shown that one shared car can replace 15 private ones [6]. However, car sharing cannot absolutely achieve the purpose of protecting the environment because shared cars tend to be operated for long periods daily, and the development of the car sharing industry may promote the production scale of internal combustion engine (ICE) vehicles, which exert great environmental impacts [7]. The result is a paradox, since the use of ICE vehicles adversely affects human health and living quality, while current climate problems require the reduction of greenhouse gas emissions [8]. As the carbon emissions from electric vehicles (EVs) are lower than that of ICE ones over the lifespan in all scenarios [9], the dilemma can be addressed by EV sharing. Promoting EV sharing can reduce the ownership of vehicles and the pollution from ICE vehicles simultaneously, while exerting the effect of environmental protection [10][11]. In conclusion, EV sharing can meet people's travel requirements, reduce vehicle congestion, and benefit the control of global warming, which is important to sustainable development [12][13].

Many EV sharing modes are available to consumers. In terms of vehicle operators, they can be divided into ridesharing EVs and self-service EVs (SSEVs). Meanwhile, SSEVs are even more popular with consumers [14]. This is related to the reality that when sharing limited space with strangers during travel, passengers may feel uncomfortable with the awkward atmosphere and proximity [15][16]; moreover, a negative correlation exists between consumers' loss of autonomy, lack of privacy, and ride-sharing [17]. In contrast, in self-service mode, consumers do not have such psychological barriers, and they could have more freedom while driving by themselves. Therefore, SSEV has an irreplaceable value in shared travel because of its privacy protection and flexibility characteristics.

However, since the management and use of SSEVs are naturally separated, the security issues of using SSEVs are closely related to the quality of their services. First, SSEVs are in a state of continuous use, and their operating intensities are greater than ordinary EVs. EV technologies are not as mature as ICE ones [18][19]; with the absence of drivers' continuous tracking, some faults and safety risks may not be found in time, thereby leading to losses of consumer interest. Second, SSEVs are like public goods, so consumers may not properly use them or may dirty them. Improper usage may damage the functions of EVs, and sanitation problems can lead to the spread of diseases. Third, consumers who have different driving experiences may drive EVs independently with absolute autonomy, while they may lack the sufficient experience or not possess a complete picture of the EV's conditions, which exposes them to a variety of risks and causes a higher accident rate [20]. Fourth, the legal and property relations of the usage of SSEVs are complicated, so consumers are in a relatively weak status. This asymmetry is easily prone to inaccuracies and injustices in terms of liability determination, violation handling, dispute settlement, and other matters. In summary, the reliabilities of SSEVs are affected by multiple sources, including frequent use, lack of continuous tracking, uncertainties in sharing, complex relations, and so on. The safety performance of SSEVs requires car sharing companies (CSCs) to provide reliable services to counter uncertainties in sharing to guarantee the interests of consumers. Typically, the service reliability of

CSCs directly affects the travel convenience, property safety, and even physical safety of consumers, etc. However, due to cost control measures or managerial negligence, CSCs may provide unqualified services, so the interests of consumers will not be guaranteed.

A survey has shown that consumers are greatly concerned about the reliability of shared EVs, and they will assign low scores due to risks, failures, and other problems; hence, the attention on reliability should not be ignored [21]. In the service process of using shared EVs, if consumers have negative experiences or safety concerns, their enthusiasm will drop, which will sacrifice the opportunity to reduce carbon emissions [22][23]. Other serious consequences will occur with the widespread of negative words and media reports. Specific CSCs, and even the whole EV sharing industry, may be greatly impacted, meaning such a scenario needs to be avoided. Therefore, it is necessary to systematically assess SSEV services to indicate the risk types and risk levels of service failures. Potential risks may exist in the entire service life cycle (SLC) of SSEVs from the registration stage to theuse stage to the final account cancellation stage. Thus, the current entry carries out risk assessment from the entire SLC to figure out the important services and their corresponding failures, so as to improve the reliability of the services as a whole.

In pursuit of the reasonable allocation of resources, effective improvements of safety performance, and consumer satisfaction, a novel framework for service risk assessment and safety improvement, which is based on fuzzy failure mode and effect analysis (FMEA) and the Kano model, is proposed. Thus, service improvement strategies can be formulated based on consumer requirements and risk assessment results. CSCs can identify the importance of service security, improve the quality of services, and develop characteristic service strategies through this entry; market regulators can supervise CSCs referring to the results; and consumers can choose relatively reliable SSEV service providers accordingly. All of these contribute to the promotion of the development of the SSEV industry and, then, the goal of carbon neutrality.

2. SLC Analysis of SSEVs

2.1. Construction of Expert Team

Referencing to previous relative studies [24][25], according to the professional level and professional experience of experts, four expert candidates who have more than five years' relevant working or research experience were invited. The mutual evaluation information is given and shown in **Table 1**. They all meet the assessment requirement.

Table 1. Mutual evaluation information of candidate experts.

Expert Mutual Evaluation		**Evaluated**			
		E^1	**E^2**	**E^3**	**E^4**
Evaluator	**E^1**	**F**	**SH**	**VH**	**H**
	E^2	**H**	**F**	**H**	**H**
	E^3	**H**	**SH**	**F**	**SH**
	E^4	**F**	**SH**	**SH**	**F**

2.2. Service Life Cycle Analysis

Safety problems cannot be ignored because injuries caused or magnified by service failures will bring serious burdens to customers, the CSCs, and society. Hence, to control the risks, the necessary services and their corresponding service failure modes should be clearly identified first. Such task is organized herein by analyzing the SLC (**Figure 1**). As shown in **Figure 1**, the SLC of the SSEVs is divided into three stages: registration stage, use stage, and account cancellation stage. The use stage is divided into three parts according to the using process: starting part, driving part, and stopping part. Different consumers may experience different SLCs. For example, some consumers will cancel after registration or use, while some will not cancel after registration and use, and so forth. However, generally speaking, most consumers will go through the stages of registration, use and cancellation in the SLC. Thus, this entry identifies services and their FMs according to the general process.

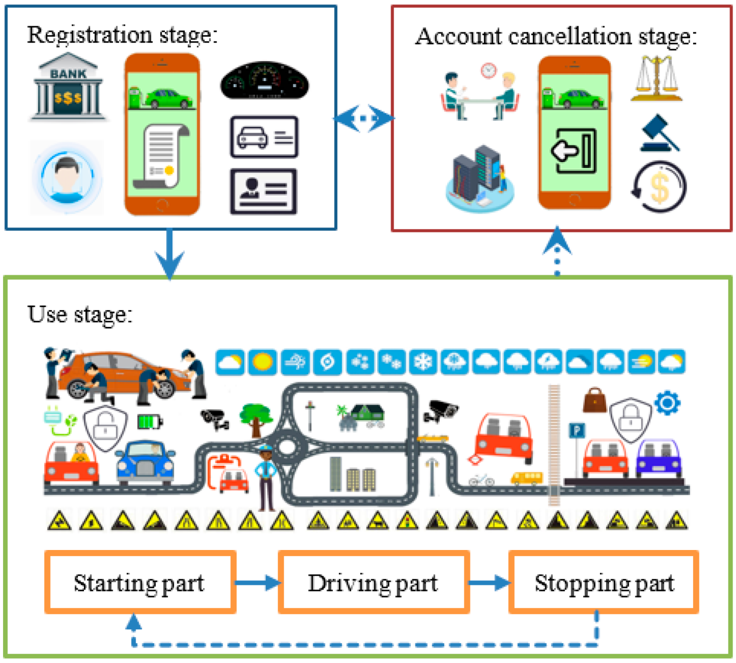

Figure 1. SLC of SSEVs.

To identify critical services in the SLC and their FMs, a great deal of time was spent reading online reviews on China's largest Tieba [26] and auto forum website [27]. These data were written by users based on their own experiences, which span about five years and are relatively comprehensive and truthful. As these online reviews were complex and limited in numbers, using machine learning or artificial intelligence was inefficient and lacked materials. Hence, directly manual reading was adopted. Imitating what grounded theory does in terms of extracting elements [28] and what service QFD does in terms of selecting important services [29], a large number of services and their corresponding FMs were screened out through reading and comprehensive analysis. Experts need to further analyze and summarize them according to the SLC and their professional knowledge, to guarantee the data are being interpreted professionally and comprehensively. Following the principles of importance, independence and integrity, 16 necessary services and their corresponding FMs of the SSEV mode in the SLC were screened out (**Table 2**). A brief analysis including service differentiation, service features, service FM identification, service demand scenario, and risk consequence analysis is presented later.

Table 2. Necessary services and their corresponding FMs of SSEV mode in the SLC.

Stages		Essential and Reliable Services	Service Failure Modes	Codes
Registration stage		Effective information protection	Information abuse	FM1
		Fair agreement service	Agreement trap	FM2
Use stage	Starting part	Provide reliable quality EVs	Provide defective EVs	FM3
		Professional maintenance services	Careless maintenance	FM4
		Safe and convenient charging service	Unreliable charging service	FM5
		Clear identification of responsibility	Unclear identification of liability	FM6
	Driving part	Professional security identification	Lack of security identification	FM7
		Reasonable and transparent charges	Unreasonable charges	FM8
		Sufficient safety equipment	Inadequate safety equipment	FM9
		Complete and adequate insurance	Inadequate vehicle insurance	FM10
	Stopping part	Convenient and safe parking service	Troubled parking	FM11
		Timely and comprehensive safety alerts	Imperfect security alerts	FM12
		Convenient handling of violations	Complexity in handling violation	FM13

Stages	Essential and Reliable Services	Service Failure Modes	Codes
Account cancellation stage	**Quick and convenient deposit refund**	**Troubled in refunding deposit**	**FM14**
	Impartial dispute resolution service	**Unfair treatment in dispute**	**FM15**
	Real-time quality customer service	**Poor customer service**	**FM16**

2.2.1. Registration Stage

In the registration stage, consumers need to submit personal information. Comprehensive information such as driving license, ID card, and even facial information will be collected, which involves privacy and may be abused by CSCs. Although the CSCs may not abuse the information deliberately, it may be stolen by employees or accessed by criminals via a software virus. Consumers may be harassed or even defrauded because of it. The scope of infringement may be considerably wide, and it is difficult to precisely determine whether these infringements are from shared services.

To guarantee that consumers will not damage the EVs or shirking responsibilities, they usually need to pay a certain amount of security deposit. However, if CSCs do not operate well, or if they deliberately do not refund the deposit, consumers will face losses in the account cancellation stage. At the same time, consumers also need to sign a user protocol, which may have some hidden traps, and it is hard for consumers to be aware of these unfair terms. Under normal circumstance, consumers will face financial or indirect losses from dealing with unfair treatments. However, if CSCs are allowed to stop an EV for maintenance excuses while it is in use, or things such as that, customers will be at risk of faulty operations, travel delays, or accidents.

2.2.2. Use Stage

In the starting part of the use stage, consumers need to carry out a necessary inspection before using an EV, to gain familiarity with its operation. This step is necessary, but it is not all about consumers, so it may be ignored by consumers. CSCs are obligated to provide reliable vehicles, carry out responsible maintenance of vehicles, and guarantee a safe and convenient car charging service. With defective EVs, consumers may face risks related to EV conditions while driving: the breakdown probability will increase, and the safety will not be guaranteed. Consumers will face financial losses and personal injuries with that. EVs have more complex electrical structures and wiring [30], and some potential faults are not easy to identify. With careless maintenance, the sanitary conditions and performances of the EVs cannot be guaranteed. Consumers may have a bad impression when choosing an EV or be infected with diseases because of poor hygiene, and EVs may break down halfway while driving or even have unanticipated accidents due to poor conditions. With an unreliable car charging service, it will take a lot of time and can lead to indirect losses when consumers need to recharge the EVs. Moreover, consumers may face charging accidents including vehicle damages or fires. From the perspective of consumers, if they do not find out existing damages before using an EV, then they will also face a compensation problem, which belongs to the unclear identification of liability.

In the driving part, consumers need to unlock the EVs, drive by themselves, cope with various situations and be billed at the same time. Basically, CSCs should guarantee that the bills are reasonable. If CSCs charge extra fees during the driving process, which is a very dishonest behavior, consumers will stop using the service and spread the word. Meanwhile, CSCs are responsible for preventing dangerous operations from consumers through safety identification. Without security identification service, consumers may have accidents due to rapid acceleration, improper driving, drunk driving, fatigued driving, and other wrong operations. When driving, consumers may face a variety of situations, such as accidents, fires, being trapped in the EV, etc., which may be caused by vehicle failures, passive accidents, or operational errors. Therefore, CSCs need to foresee these situations and equip the EVs with fire extinguishers, tripods, safety hammers, etc. With inadequate safety equipment, consumers may face secondary injury or greater losses. CSCs also need to provide sufficient and complete auto insurance. When taking responsibility in dealing with accidents, if the auto insurance paid by CSCs is incomplete or very low, consumers will face large payouts.

In the stopping part, consumers usually need to park the EV in designated areas or at specific charging stations. In this part, if the positioning fails or lack of parking spaces, consumers probably need to pay extra fees or spend time waiting. They may also choose to park the EV nearby, but this choice may bring troubles to them, such as the loss of dispatch fees. After stopping the EV, if consumers carry some belongings, they also need to take them away and then lock the EV. With imperfect security alerts, consumers may forget their belongings or forget to close the windows, which lead to property losses and liability for compensation. Moreover, without alerts of the battery level, excessive discharge, etc., consumers may not make it to their destination and may be locked in the car because the battery runs out. After parking, if a vehicle is scraped and a new consumer reports the damages in their starting part, the person who is responsible may not be immediately clear. Consumers may face fines in such unclear liability identification cases, while they are actually innocent. After using the SSEV service, consumers may receive violation reminders. CSCs need to assist consumers in dealing with violations, the duration of the process of dealing with the violation typically depends on the arrangement of the CSCs. The complexity of the process may waste too much time, which leads to some unknown indirect losses for consumers.

2.2.3. Account Cancellation Stage

If consumers stop using the EV sharing service of a CSC, they will choose to cancel their account or just ask for a refund of the deposit. When they ask for the deposit, they may encounter losses. For example, some CSCs may not return the deposit for various reasons. After consumers cancel their account, their private information may still remain in the servers of corresponding CSC, which may be sold, stolen, or abused for ignominious purposes and, consequently, leads to consumer losses. Before the cancellation, if some unresolved disputes remain between the consumers and the CSCs, including owing, counterfeiting documents, or borrowing an EV for others, they must deal with these issues first. They may have to pay to settle any troubles, and they may face unfair treatment. Throughout the entire SSEV service process, online or telephone customer service should always be available to answer questions and provide necessary assistance. If customer service is poor, consumers will be helpless and angry, and they will face greater indirect or even direct losses.

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