Sustainable Design Guidelines for the Chinese Expressway Service Areas

By
Zijie Huang

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ABSTRACT

During the construction of Chinese Expressway, more and more attention is paid to the expressway service area because of its relationship with the environment and economy. However, due to a lack of sustainable design concepts, in China, currently little attention is given to satisfy the requirements of users and many questions on the construction of the expressway service area -- do not focus on the waste and efficiency of building resources. With the development of the understanding on LEED, the green design is the feature of the Chinese expressway service area in the future.

The aim of this thesis is the planning and designing of Chinese expressway service area under the guidance of sustainable design principles. Firstly, the paper summarizes the LEED’s application of sustainable design theory in China and the United States. The sustainable design of Chinese expressway service area integrates local natural conditions, economic conditions, and ecological conditions with taking use of the LEED system. Secondly, this thesis mainly explains the differences of expressway service area between in China and in the United States, such as the status of current expressway service areas, road width, median strip, and interval distance. The paper conducts a research on the current situation of Chinese expressway service area. In order to illustrate the topic, the research methodology uses the examples in Hubei Province and Shaanxi Province. Thirdly, this thesis gives corresponding design principles of LEED application on Chinese expressway service area. Lastly, this
thesis discusses the aspects of the future design of Chinese expressway service area. These include (i). nature integration, (ii). material saving, (iii). land saving, (iv). nature resource saving, and (v). social communication design. The five proposed design factors are illustrated through practical cases.

**Key words**: sustainable design, expressway service area, humanization design, LEED.
CONTENTS

ABSTRACT.........................................................................................................................2

CHAPTER

1. INTRODUCTION........................................................................................................6

2. LITERATURE REVIEW ON CURRENT CONDITION OF EXPRESSWAY SERVICE AREA...............................................................7

   2.1 Introduction of LEED and LEED’s Application.................................................7

   2.2 Current Condition of Chinese Expressway Service Areas.............................11

   2.3 Summary of the Research on expressway service area Between China and the United States.................................................................12

3. METHODOLOGY OF RESEARCH ...........................................................................15

   3.1 Research Design Overview.............................................................................15

   3.2 Study Design....................................................................................................17

   3.3 Data Collection................................................................................................18

4. CASE STUDY..............................................................................................................20

   4.1 The Introduction of Jingzhu Expressway Xianning Service Area and Fuyin Expressway Yongshou Service Area.........................................................20

   4.2 Problems of Xianing and Yongshou Service Area.........................................24

      4.2.1 Problems of Xianing Service Area..............................................................24

      4.2.2 Problems of Yongshou Service Area..........................................................28

   4.3 Case Study: The Service Plazas in Florida Turnpike .................................33

   4.4 Comparison Chart between Chinese and American Case Studies ..............41

5. DISCUSSION..............................................................................................................44

   5.1 The Sustainable Design Principles in Application of Chinese Expressway
1. INTRODUCTION

Though China is experiencing a high-speed period of expressway construction, the construction of Chinese expressway service areas is not appreciated by designers and the public. Therefore, this study focusses on understanding how Chinese expressway service areas could be developed with green design principles. In order to illustrate the questions, this thesis summarizes scholars’ reviews on green design and adaptive reuse about expressway service areas. In the Western world, the architects usually incorporate the LEED system to build the expressway service area. That’s why the LEED system can be a standard to make a comparison between China and the Western world. Besides these theory reviews, this thesis collects the data from China by quantitative methods, such as questionnaires for travelers, governments and architects. At the same time, Chinese journal papers (e.g. Journal of China and Foreign Highway) could offer some analysis on the current service area construction. Based on the analysis of characteristics on expressway service area from traffic conditions, construction standards and functions, this thesis plans to make use of green design theory to help viewers and scholars to make a future plan for Chinese expressway service areas.

To introduce the topic of this thesis, the paper will solve a list of questions. Firstly, the research question is how to develop service areas with a sustainable design. In addition, we should know about the current conditions of Chinese expressway service area. Then we gather information from literature review that the sustainable
design is applied on expressway service areas in the United States (US) so that we could reveal the advantages and disadvantages of the style. Furthermore, how we use the LEED system to develop Chinese expressway service areas will be discussed.

Meanwhile, the thesis could develop other questions about the sustainable design. Compared with usual designs, what are the advantages and disadvantages of the sustainable design? Are there any differences of sustainable design in interstate transportation infrastructure between China and the US? These questions could help scholars and viewers to understand the reason of the present research and the possibility of further plan on sustainable design in expressway service areas.

2. LITERATURE REVIEW ON CURRENT CONDITION OF EXPRESSWAY SERVICE AREA

2.1 Introduction of LEED and LEED’s Application

As the LEED fellow Dr. Bahar Armaghani asserted, green building complies with a minimum requirement for certification under one of the green building rating systems. (Bahar Armaghani) The definition of sustainable building is that the building environment has the sustainability on economics, social and ecology. According to Armaghani’s introduction, benefits of green buildings are understood by the architects. There are three perspectives on the benefits. One is for the planet. The water and air quality can be improved. One is for profits. The operating costs are
reduced, such as energy and materials. In contrast, the productivity is improved. Relatively, the test scores of the built environment are increased. For people, they could get profits from economy and ecology. Leadership in Energy and Environmental Design (LEED) is an ecological-oriented building certification program that runs under the supervision of the US green Building Council (USGBC). El-Rayes et al. investigated the requirements and possibilities for the rest areas to achieve LEED certification under the LEED rating system for the existing buildings. (Khaled El-Rayes, Liang Liu, & Moatassem Abdallah, 2011)

In addition, Dr. Armaghani strengthened the importance of LEEDv4. There are eight factors related with the organization of LEED -- Innovation & Design, Location & Linkages, Sustainable Sites, Water Efficiency, Energy Saving, Materials & Resources, Indoor environment quality and Awareness & Edutainment (edutainment is a concept that combines education with entertainment). (Armaghani) In this paper, speaking of the expressway service area, we could find the related factors from the eight factors to make a research on Chinese expressway service area. LEED is a system that evaluates the results of green designs. That’s why LEED certification levels are popularized among architects.

The theory of the green building in China is still at the initial stage. The first evaluation regulation was issued in September, 2001. The regulation was decided by the Bureau of the Architecture. The LEED evaluation program includes six parts, developed location and linkages, water efficiency, energy and atmosphere, materials
and resources, indoor environmental quality, and innovation and design. According to the ASHRAE’s standard, energy use reaches the standards of green building, and reduces by 30%. Moreover, the water efficiency improves by 20%, and the air quality reaches the standards, significantly reducing solid waste discharge. In the international market, all the states and governments take use of the LEED TM system to evaluate buildings. With the details of the LEED TM system, the official organization scores the architecture through five aspects, including location, energy and atmosphere, materials and resources, water efficiency, and indoor environment quality. The total scores are 110. If a building receives 40 grades or above, the building gets the certificate of the LEED system. In order to clarify the different programs, the LEED system uses different standards. For the service plaza, LEED-NC and LEED-CS are usually used to evaluate public buildings. In order to illustrate the differences between LEED-CS and LEED-NC, here lists a chart as follows:

<table>
<thead>
<tr>
<th>Factors</th>
<th>LEED-NC (2.1 version)</th>
<th>LEED-CS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Scores</td>
<td>Percent</td>
</tr>
<tr>
<td>Location</td>
<td>14</td>
<td>20%</td>
</tr>
<tr>
<td>Water Efficiency</td>
<td>5</td>
<td>7%</td>
</tr>
<tr>
<td>Energy and Atmosphere</td>
<td>17</td>
<td>25%</td>
</tr>
<tr>
<td>Materials and Resources</td>
<td>13</td>
<td>19%</td>
</tr>
<tr>
<td>Indoor Environment</td>
<td>16</td>
<td>22%</td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>----</td>
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</tr>
<tr>
<td>Innovation and Design</td>
<td>5</td>
<td>7%</td>
</tr>
<tr>
<td>Total</td>
<td>69</td>
<td>100%</td>
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<td>Sum</td>
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<tr>
<td>Pass</td>
<td>26-32</td>
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<tr>
<td>Silver</td>
<td>33-38</td>
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<tr>
<td>Gold</td>
<td>39-51</td>
<td>36-47</td>
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<tr>
<td>Platinum</td>
<td>52-69</td>
<td>48-61</td>
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<td>Notice</td>
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<tr>
<td>Tracking period is one</td>
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<td>year</td>
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<td>program for one year</td>
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</tbody>
</table>

According to LEED, the set of performance standards is seen as a guide for...
architects to design green buildings. The contributing aspects include sustainable sites, water efficiency, energy and atmosphere, and materials and resources. In the perspective of the efficiency of water use, the designer ought to take consideration in efficient water landscaping, water use reduction, and wastewater technologies. In the service plaza, toilet flushing and restaurant water are the main uses of water resource. More and more service plazas in the US use sanitary to wash down and trap water to exchange each other to reduce the water use and recycle wastewater.

2.2 Current Condition of Chinese Expressway Service Areas

The design of Chinese expressway service area has two kinds of problems. One is the lack of humanization and edutainment. The other one is the ignorance of geographic factors. Gao Xing, a Master from Hunan University, concluded that the humanization and edutainment problems present in two aspects – the disordered streamline of service facility and the ignorance of costumers’ communication. (Gao Xing, 2009) In addition, the problem on the ignorance of geographic factor is gathered during the modernization of Chinese expressway service area. The designer ignored the local geographic conditions, and took use of the general design in the expressway, instead of making full use of natural resources. Furthermore, Shi Shan, Wan Liuqiang, and Jin Shanzeng, from China Train Project Research Institute, summarized their construction experience and pointed out the geographic problems. They stated that the development of expressway service area in China pays too much attention on the design of building but not the greening and energy saving; and the
designs of expressway service area focused on the plan, but ignored the three-dimensional design, all of which lead to the waste of land. (Shi, Wan & Jin, 2011)

In the current Chinese service areas, the situation is being changed by the influence of the LEED’s concept. According to the report by Shi and Zhou (2013), The new service areas extend the functions from rest function to entertainment function. The old expressway service areas have only restaurant, convenience shop, gasoline stations, and toilets, while the new expressway service areas could contain hotels, entertainment centers, and so on.

Secondly, the service area is used general designs. All the function areas are not considered according to their locations and local customers’ demands. But now, the tendency of the expressway service area changes from the traffic rest zone to the social service zone, enabling the passengers to understand many different kinds of cultures in the service areas. The designers should take consideration of local cultures and geographic conditions to develop the service plazas.

Thirdly, the service plaza is changing to business operation. The service area is used as a shopping center and transportation center. More and more vehicles could transport the goods to and from the service plazas.

2.3 Summary of the Research on expressway service areas Between China and the United States
According to the officers from the US Florida turnpike program, the plaza on the turnpike has three goals – transitional, rural, and commuter. (Turnpike) Compared with Chinese expressway service areas, the expressway service area in the US has two additional goals – rural and commuter. Among all the service areas in Turnpike, there are 12 plazas that have received LEED silver certification. In the research of a Turnpike organization, they divided their plazas into three kinds – new exploring, renovated, and current plaza. For the new exploring service areas, the designers take consideration into the spacing distance and LEED standard. For the renovated service area, the designers take consideration into the humanization and sustainable problem. However, these factors are usually ignored by Chinese architects. Even these plazas have their own themes that are related with their geographic features. Some plazas are next to the sea. Thus, their themes are related with water. (Paul Naranjo, 2012)

The objective of this study is to develop sustainable design guidelines for the development of Chinese expressway service areas. This includes investigating the current situation of sustainable design in Chinese expressway service areas and determining the advantages and disadvantages of sustainable design of expressway service area, and developing an adaptive sustainable design in Chinese expressway service area.

According to Shi and Zhou (2013), the standards of expressway service area in China are simple. Under the circumstance of realism in Chinese architectures, Chinese architects pay more attention on the functions and the land resources.
However, American architects mainly focus on the convenience and commodity, which helps designers to reduce the land use and protect environment.

Firstly, the difference between China and the US is the distance of two service areas. In the US, in the areas with a high traffic flow, the distance between two service areas is 16-24 kilometers in average. And in the areas with the low traffic flow, the distance is 32-48 kilometers in average. However, in China, this distance is decided by the distance of two towns, but not traffic flow.

Secondly, the difference is from the arrangement of the functions. In the US, there are gasoline and gas stations, parking lots, vehicles maintenance shop, and toilets in service areas. In some service plaza, the walking ways are offered for the pets. The special culture of American gasoline stations is a brand culture. All the service areas attract customers by different gasoline brands. In China, the land square of service areas is relatively small. The designers try to set more vehicles in a limited land. In order to save lands, all the buildings are built together. The functions are just satisfied by customers’ basic demands, whereas the green plant is ignored by the circumstance of the limited lands.

Thirdly, the exits and entrances of service areas are decorated with different objects in the US and China. In China, the objects are fences, walls or trenches. These objects separate the natural environment from the service areas. In the US, the objects are lawns without any fences or walls, allowing the natural environment to contact with the service plazas. (Shi and Zhou, 2013)
3. METHODOLOGY OF RESEARCH

In order to compare Chinese and American expressway service areas, this thesis employs quantitative methods. The comparison starts from case studies in China and the US. This thesis takes two different geographic condition of expressway service areas In China as examples; additionally, this paper introduces a research on the Florida turnpike’s service areas in the US. From these comparison of these two different countries, the advantages of sustainable design will be illustrated.

3.1 Research Design Overview

From the perspective of the research design, the influenced factors of the sustainable design of Chinese expressway service areas will be discussed in this research. The paper chooses Xianning service area on Jingzhu expressway located in Xianning city, Hubei Province, and the other one is Yongshou service area on Fuyin expressway located in Xianyang city, Shaanxi province. In the analysis of the two expressway service areas, the geographic factors, economic factors, and humanization factors are considered as independent variables. The geographic factors contain plants, natural resources, and landscape. These factors possess great influences on the design of expressway service areas. Based on the indicators and valuables, these data were collected from the questionnaires. The data collection of the paper was performed using quantitative methods. To do it, this paper received opinions from the customers and architects from Chinese expressway service areas. The questions on the questionnaire will cover the economic and ecological aspects. In the design of the
questionnaires, traffic conditions, construction standards and functions of expressway service areas were made up of the main body of the questionnaires. These questions were about the satisfaction of the participants. These answers were set into a series of the levels of satisfaction from level one to level ten. Based on these data, the paper could summarize the causal relations between the participants’ satisfaction and these objective factors. Besides the questionnaires, the paper also found the related materials about the expressway service areas in China. The natural resources, economical costs, and geographic conditions were abstracted from the official departments, which is helpful for this study to propose a future plan.

This Jingzhu expressway service area lies in the Jianghan Plain. The obstacle factors of the landscape are less than those of the other expressway service areas in mountains. The natural resource factor influences the choice of architecture materials, water resource, and energy use. These factors are the general geographic conditions of the Jingzhu expressway service areas, and are relatively stable. Furthermore, the economic factors were also taken into consideration. The economic factors include building costs, customer service fees and facility maintenance expense. These factors decide the human functions of the expressway service area. The dependent variable is mainly the evaluation of customers. The evaluation is different with the other samples. In the research process, the extraneous and intervening variables were following the LEED concepts. The customers in China who receive the education of LEED system are fewer than those in other states. Taking these variables into consideration, this research obtained reliable data.
3.2 Study Design

From the perspective of the study design, the study introduces relevant knowledge about the LEED system. Meanwhile, the paper also illustrates the problem in the expressway service areas by analyzing the complaints from customers. The design took use of the before-and-after style to compare the current situation with the future design. The before-and-after style could be used in the single comparison of the economic and ecologic factors. Furthermore, the paper uses the cross-sectional way to explore the study design. By analyzing the examples of Jingzhu expressway Xianning service area and Fuyin expressway Yongshou service area, the cross-sectional picture of the building will be presented in details, which is convenient for the designers to figure out the problems. Hence, the reference period is an intensely social problem. The reference period of the study plan is associated with the trend of the sustainable design in the Chinese expressway service area. According to the ways of data collection, the reference period is only one month. In addition, the investigation is based on the official data from the Chinese official websites and materials. For the study design, the paper prefers to the quasi-experimental style. The questionnaire data are mainly quoted from some scholars’ articles from Chinese journals. Considering the sustainable design, the paper needs to conduct a prospective study. The prospective study also uses the cross-sectional way to describe the changed details. Thus, the study takes the non-experimental way to analyze the examples of Chinese expressway service area. Due to the disadvantages of the questionnaires, the current study avoids collecting data from questionnaires. The samples of the questionnaires
could not provide the same results and have large deviations. Therefore, in the study
design, this study collects the primary data and secondary data about the geographic,
economic, and ecologic factors from the official websites.

3.3 Data Collection

In the processing of data view, the sustainable design of Chinese expressway service areas should be presented with the description of the example service areas. To describe the basic concepts of sustainable design and the problems of the current design in the Chinese expressway service area, the present study collects a series of data from the official websites and news. For example, the geographic data were collected from the local geological survey; among them, the weather data was extracted from the bureau of meteorology, and site plans was copied from urban planning bureau. For the case study, the building data was gathered from the local architecture or urban plan bureau. In addition, the details of cross-sectional and the longitudinal picture of the buildings cannot be found on the official websites, but could be found on the pages of other people’s blogs or I had them shot myself. Thereby, the secondary data is as important as the primary data. Some previous studies and information from newspapers may demonstrate the details of the Jingzhu expressway service area. These data were quoted by the present study to make analysis on the current situation. Besides, this thesis also introduces concepts of the LEED system into the Chinese expressway service areas. According to the basic data of the LEED system, this thesis tries to collect these related data from the official
websites and the secondary resources to make a comparison between the LEED standards and the Chinese cases. In addition to the official and secondary data, related architects that joined the design of Jingzhu expressway Xianning service area were interviewed. The similar expressway service areas in the Hubei Province also offered valuable data for our analysis. The similar geographic and ecologic conditions provide some data of independent variables. During the process of data collection, all data were gathered during the last year. With the development of the economy in Hubei province, the data on the economic condition has no relation with these of the last five years. As for the Florida Turnpike service plazas, it’s easy to find much information mentioned above on Google. This process can effectively decrease the work load of data collection and ensure the accuracy of data collection.
4. CASE STUDIES

4.1 Introduction of Jingzhu Expressway Xianning Service Area and Fuyin Expressway Yongshou Service Area

Xianning service area in Hubei Province of Jingzhu Expressway

Yongshou service area in Shanxi Province of Fuyin Expressway

Xianning service area, which is located on the Jingzhu Expressway, is the largest expressway service station in Hubei Province. Jingzhu Expressway starts from Beijing and ends in Zhuhai with the total length of about 2310 kilometers. Xianning service area covers an area of 150,000 square meters. To contain a large number of
vehicles, Xianning service area just finished expansion. Nowadays, Xianning service area can contain 460 vehicles and serve 600 customers. The size of the building is about 20,000 square meters, next to the Futou lake. In the region that the Xianning service area locates, the climate is wet and the landscape is hill land. The geographic factor is complicated for the Xianning service area to expand to be the largest service area in Hubei Province. However, the designers took use of the lake wetland and woods to expand the building area.
The Yongshou expressway service area is located on the Fuyin expressway (Fuyin expressway has the total length of 2485 kilometers, from Fuzhou to Yinchuan),
in the territory of Shaanxi Province, Xianyang City. It covers an area of 138.266 square meters, with 9044.19 square meters building area. The Yongshou expressway service area sets up catering, accommodation, refueling, commodity sales, and automobile offer services to customers. The Yongshou service building area is divided into two parts. One is a restaurant business area of 660 square meters that can accommodate 400 people to have dinner at the same time; the supermarket is 450 square meters, having more than 450 kinds commodities. The other part is bright and spacious lounge. The lounge covers an area of 310 square meters, which can contain 40 people to rest at the same time. It is equipped with broadband network, entertainment equipment, and 16 rooms on the second floor. To further embody the humanized construction, the main service facilities in the Yongshou service area have been equipped with blind and disabled channels for disabled people.

Figure 6, Yongshou service area location, source: (http://map.baidu.com/?newmap=1&ie=utf-8&s=s%26wd%3D%E7%A6%8F%E9%93%B6%E9%AB%98%E9%80%9F)
4.2 Problems of Xianing and Yongshou Service Area

4.2.1 Problems of Xianing Service Area

The Xianning service area has five problems, which are shortage of service facilities, long distances between services, uneconomical scale, insufficient use of facility functions, and the lack of outdoor green shelter.

The entry rate is an important factor for a highway service facility, which means the number of vehicles entering service facilities. The proportion of cars that makes up the main traffic of the highway is one of the most important elements of the scale of service facilities.

The number of section traffic is recorded by using the visual method. The
Xianning service area has 11323 vehicles passing by every day. The number of entering vehicles is also recorded by using the visual method. The Xianning service area has 2139 vehicles entering every day. Therefore, the rate of entering vehicles is 18.89%.

Through the visual measurement, the feature of the Xianning service area is trans-provincial transit traffic. The larger proportion of large vans and trucks requires a higher demand for services.

In the Xianning service area, the single-sided parking lot has 420 berths, including 80 berths for small cars, 40 berths for buses, and 300 berths for big vans. The total number of vehicles parking in the expressway service area per day is 2139. The average turnover rate for parking garages is 2.55 times per day, and the average parking time is 8 minutes for a car and 25 minutes for a van. The average saturation rate of the parking lot is 0.26, and the peak rate is 0.65. In conclusion, the average degree of saturation in the parking lot is not high, most parking spaces are vacant, and it can be reduced to less than before.

The single-side filling fuel station in the Xianning service area has a refueling machine and a two-way co-fuel position. About 46.24% vehicles entering the service area will use the gas station. The proportions of the vehicles that refuel in the fuel station are 33% for buses, 3% for minivans, 12% for medium truck, and 13% for large work. Among the kinds of the refueling vehicles, the trailers and the passenger cars are the main kinds, and the medium and large trucks are the lowest.
At the same time, in order to save space to make more parking positions for the planned site, the functional layout of the building in the Xianning service area was not reasonable. For example, for the convenience of construction and management, restroom and supermarket, restaurant and accommodation were built together without concerning the hygiene, causing bad feelings in the small range of environment. No outdoor green shelter for customers to relax and interchange and even enjoy the natural landscape.
Figure 9. Xianning service area main building, source:
(http://image.baidu.com/search/index?tn=baiduimage&p=1&ct=201326592&lm=-1&cl=2&nc=1&ie=utf-8&word=%E5%92%B8%E5%AE%81%E6%9C%8D%E5%8A%A1%E5%8C%BA)

The good news is that some of the parking space has being reduced, and electric cars charging piles were built recently. Unlike the traditional cars using fuel, and stopping or waiting at a gas station will cause congestion, when electric cars stop and recharge, they will not cause such problem in the service area.

The congestion problem at the gasoline and gas stations is crucial for the Chinese expressway service areas, including the Xianning and Yongshou service area.
4.2.2 Problems of Yongshou Service Area

The Yongshou service area has five problems in the design without sustainable design theory.

Firstly, the design of parking area. The Yongshou service area adopts a layout form of separation mode. The main building is located in the center of the field, and the parking lot is mainly divided at the right side, the front side and the back side of the main building. This mode covers too large area, causing a huge waste of the land and being conducive to manage.
Secondly, the arrangement of parking lots. In the Yongshou service area, the car parking areas are arranged at the outer part of the parking lots. However, the cart is usually parked at the outer part of the parking lots. On the other hand, the car parking lots are much more than the cart parking lots. In reality, the carts are the main part that customers will use in the expressway service area.

Thirdly, the location of the main building. The current main building is SBW 51 degrees. Its main surface is seriously influenced by the sunshine. In summer, this design largely increases the usage of air conditioning, reducing the building energy efficiency. In winter, the back part of the building lacks construction and trees, therefore the temperature is low due to the windy day. The distance between the building and the main building is about 107 meters, the buildings are so dense that makes customers uncomfortable.
Fourthly, the usage of water resource. The Yongshou service area takes use of self-taken water and water facilities. The problem is inadequate water reuse. The service area sets up the sink to recycle the sewage back into the ground. However, this style causes strong pollution to the underground water in Yongshou District. Plus, Shaanxi province is short of water resource, but the Yongshou service area is all derived from water.

Fifthly, the lack of humanization design. The arrangement of the rest area lacks humanization design. The outdoor seats are far away from the main building. There are no green plants to keep the sunshine off, and there is no communication and edutainment space near the outdoor seats.
In the case study, there are several positive factors of the service area mainly gathered in the green design. Firstly, Chinese and American service areas focus on the humanitarian. Both of them set up the main building in the middle part of the service areas. The main buildings contain restaurants and convenient shops. Secondly, the location of the service area is connected with local geographic conditions. For example, Xianning service area lies in front of Futou Lake so that it has sufficient water resource. The weather conditions are also adapted by the service area to supply comfort conditions. Meanwhile, the plain is helpful for the designers to increase the size of the service area. Thirdly, Chinese expressway service areas pay attention to the scenery view. For instance, Xianning service area is next to Futou Lake. In the service area, the designers built a hotel in the middle part of the service area. The customers in the hotel could enjoy the outside lake scene. It seems like the Pompano service that is next to Pompano Beach is strongly related with the beach view of Pompano Beach.

However, some negative factors in Xianning expressway service area are also presented. The typical problems are listed as follows. Firstly, the parking lots are too large so it is a waste of land use. The parking lots are not adapted to the ecological standard. There are not green plants to decorate the parking lots. The same problem also occurs in the US. The Pompano service area lacks green plants, too. Secondly, there are not enough gas stations in all the China’s service areas. In general, the gasoline stations and charge modules have become the main refueling ways. The lack of gas stations will cause traffic jam and exhaust emission.
Thirdly, all the service areas have problems in their layout. For example, restrooms are next to restaurants, which will bring unpleasant smells to the restaurant. This kind of design leaves customers negative impression and bad experience. Fourthly, the new technology of the facilities in the service area is still ignored by the China’s designers. The designers did not consider the functions of natural resources. The energy of the sun in the Xianning expressway service area pushes forward the application of Solar power. Fifthly, the China’s expressway service area has ignored the green design principle, for example, the American designers would set a walking space between the parking lots and the main building.

In the conclusion, all of these positive and negative factors could provide a lot of inspirations and important information for our own designs in the future.
4.3 Case Study: The Service Plazas in Florida Turnpike

In the Florida Turnpike, there are eight service plazas. The Turnpike project takes 26 months to reconstruct. At the same time, the Turnpike project accepts $40,000 per month (Florida’s Turnpike Service Plaza Program Design Build Institute of America, June 27, 2012). The 312-mile project receives 12-LEED silver certification. Among the project, Okahumpka and Pompano Beach rebuilt their restaurants and convenient stores. The site of Pompano Beach belongs to the Broward County. The milepost is only 65 miles away. The service area is relatively closer to other service areas. Because the Pompano Beach nears the sea, the service plaza lies in the plain. In the area of the service plaza, the wet land makes some obstacles to the service area, which means increased building costs. In contrast, the site could offer the ecosystem...
through the wet land. Meanwhile, the choice of the site takes traffic flow into consideration. The Pompano Beach is a scenery spot and attracts many customers. The site can meet the customers’ demand.

In the Turnpike project, the designers use different themes to express the natural concepts to the customers. The themes are decided by the features of the locations. In the Pompano service plaza, the theme of the service area is water. Firstly, all the interior facilities use blue color to represent the sea. Moreover, the interior design takes use of ocean factors, such as blue color, the ocean view - wave sculpture and fish tanks, and the ocean sight. Furthermore, through making use of the ocean theme and taking environmental protection into consideration, some interior materials such as rocks and lumber, and plants such as palm trees, eustoma grandiflorum and
Dombeya wallichii are directly from the Pompano Beach. These materials and plants not only reduce the building cost, but also are economical and environment-friendly. Also, along with green plants and green space outside the main building that offer people a great place to communicate and relax, there is also a great place for people to learn about knowledge on landscape, protection of wet land and green resources, and even plants. That is what I called edutainment.
Figure 17. United States Florida turnpike Pompano Beach service plaza water theme, source: (https://www.google.com/search?q=pompano+beach+service+plaza&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj17J6OuPuPvUAbUB5oMKHT0A38Q_AUBygC&biw=1920&bih=947&dpr=1)

The convenient store has 40% energy savings. Besides the materials from the ocean, the main building in the Pompano Beach takes use of different designs and makes use of natural energy. The main building is lit by the windows that are made of glass. The circle in on glass window guides the sun light, making the building bright. In the daytime, the design could help the plaza to reduce the usage of electricity. In the convenient shop, the designers gave up the surrounded brick walls, but chose the glass walls to increase the accessibility of sunlight.
Figure 18. United States Florida turnpike Pompano Beach Annual Sunshine time and UV Index, source: http://beach-weather.com/Northern-America/United-States/Florida/Broward-County/averages/Pompano-Beach/.

Figure 19. United States Florida turnpike Pompano Beach Annual Rainfall and Rain days, source: http://beach-weather.com/Northern-America/United-States/Florida/Broward-County/averages/Pompano-Beach/.
The longest days in Pompano Beach are in June, with an average of 13.8 hours of daylight; December has the shortest days with an average of 10.5 hours of daylight; and, the annual average daylight is about 13 hours. Also, the ultraviolet index is very high. It reaches the highest of 12.4 in July, and the lowest of 5.1 in December. The annual average ultraviolet index is about 11.1. Without any doubts, there’s a lot of solar energy here.

As for the precipitation, Pompano Beach locates near the Atlantic Ocean, from the table, it is easy to tell that the wettest month in Pompano Beach is September with 75.16” of rain in the most days of rain and with some rain in 20.7 days. It is a very wet time to visit the beach. Therefore, rainwater resources are abundant and should be collected and utilized well.
Therefore, at the top of the main building, there are many water containers for saving water. The water containers not only are for rainwater collection, but also can deal with the waste water to flush toilets and water green plants. The water in the containers is the used water from restaurants and wash vehicles. However, the water containers are not enough to support the major water demand in the service plaza.

The new restaurant and convenient stores are built with the principles of the green design. The restaurant building lies in the middle of the plaza. The proposed parking lots are surrounded by the restaurants. In order to offer convenience for the customers, the surrounded parking lots are offered for customers’ cars. The trucks parking lots and the bus parking lots are arranged together at the back of the car parking lots. The kind of arrangement provides more rooms for trucks and cars. Meanwhile, the arrangement offers convenience for the drivers due to the location of the diesel fueling. Two diesel fueling stations lie at the entrance of the plaza, and the fueling stations lie at the front of bus and trucks parking lots. In addition, the design of the Pompano Beach service plaza concerns about the humanization. The pet walk connects with the restaurants. The customers could take their pets with themselves on the journey.
Different from Chinese expressway service areas, the service plaza in the United States Florida turnpike Pompano Beach service plaza plan and landscape.
US focuses on the amount of parking lots and the number of refueling machines. The fuel station has plenty of fuel pumps with wide spaces between them, therefore, it won’t waste travelers’ time and cause traffic jams inside the service plaza. Also, the station is close to the main building and parking area, bringing convenience to costumers.

Figure 23, United States Florida turnpike Pompano Beach service plaza gas station, source: (Florida’s Turnpike Service Plaza Program Design Build Institute of America, June 27, 2012)

4.4 Comparison Chart between Chinese and American Case Studies

<table>
<thead>
<tr>
<th></th>
<th>China</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant using</td>
<td>Low green rating,</td>
<td>High green rating,</td>
</tr>
<tr>
<td></td>
<td>Green rating is less than 20 %,</td>
<td>offer shelter for the vehicles and customers.</td>
</tr>
<tr>
<td></td>
<td>low survival for the transplanted trees.</td>
<td>Green rating is more than 50%.</td>
</tr>
<tr>
<td>Material Saving</td>
<td>High waste materials, high</td>
<td>Recycled materials, low V</td>
</tr>
<tr>
<td></td>
<td>VOC emission materials.</td>
<td>OC emission materials.</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td><strong>Land Saving</strong></td>
<td>Frequently taking use of farm land and waste land.</td>
<td>Prohibit taking use of any farm land and wet land, only use old expressway service area or waste land.</td>
</tr>
<tr>
<td><strong>Natural Resource Saving</strong></td>
<td>Ignores water efficiency, and transports electricity from the town, and is often faced up with electricity shortage.</td>
<td>Pay attention on water efficiency, and uses the solar power to produce electricity.</td>
</tr>
<tr>
<td><strong>Humanization Design</strong></td>
<td>The parking lots are arranged in the front of main building, and the gasoline stations are in the middle part of the service area. No outdoor green shelter.</td>
<td>The gasoline and gas stations are located at the entrance and exit of service area, and the parking lots are divided into the cars and trucks. Have outdoor green area</td>
</tr>
</tbody>
</table>

In the US, the refueling machines are usually satisfied with the demand of 40 vehicles. However, in China, the refueling machines are usually satisfied with the demand of less than 10 vehicles. The American designers takes the humanitarian into
consideration. The trucks and buses are arranged at the outer part of the refueling machines. In order to avoid making obstacles in the refueling stations and minimize safety issue, the American designers set up the refueling machines for trucks and buses far away from cars. On the other hand, the service plaza in the Turnpike, the main building only offers customers with dinners. All the main buildings only have three food brands. The customers have very few choices. The convenient shops and the restaurants share the same entrance and exit, thus, All customers have to gather in the main building. However, the Chinese expressway service area has clear boundary between different function areas, such as restaurants, hotels, and convenient shops. This kind of design disperses the flow of customers and reduces customers’ waiting time. In contrast, the dispersed gates make customers have less choices than in the US. In addition, the lack of hotels makes the American customers busy with catching up with their journey, which leads to a higher traffic accident rate. The customers do not have places to take rest. In general, the mileposts of the service areas in the US are further than those in China. The reason is that China sets the service areas based on the locations of the cities. All the service areas are related with the cities on the expressway. The distance between cities in China is shorter than that in the US. In the US, the service areas are decided by the different kinds of the landscapes. The other contributing factor in the US is the traffic flow. In the US, the traffic flow is higher, which requires more service areas in order to satisfy such large customers’ demand.
5. DISCUSSION

5.1 Sustainable Design Principles in Application of Chinese Expressway Service Areas

5.1.1 Plant Using

In most Chinese customers’ impression, expressway service areas in China are open areas without delicate designs and advanced infrastructures. In summer, there is no shelter for customers to avoid the direct sunlight. The dusty cement floor makes the air in the expressway service area worse than in other public places. In addition, the afforestation is faced up with two thorny problems. The trees transplanting and lawns interplanting are difficult issues for designers to combine them together in the design scheme. Additionally, due to the weather and water shortage, most trees and lawns transplanting failed at the initial stage of the construction of the expressway service area. Generally, the green rate of the service area is lower than 20%.

In the green design, all the Chinese programs require designers to increase the green rate up to 50%. In the main building, the trees and lawns are surrounded by the parking lots and buildings. At the entrance and exit of the service area, the lawns are required to guide the drivers into the expressway service area. In the truck, bus, and car parking lots, the trees are transplanted in the area to offer shelter for these vehicles. The trees are also used to reduce the air pollution from the trucks, and
obstruct noise and dust from the expressway.

5.1.2 Material Saving

In the view of materials and resources, the expressway service areas in China waste a lot of materials and do not use recycled materials. After building the programs, all the rubbish was left on the floor. The programs would arrange trucks to transport these rubbish to the trash bins, but not make any integrated garbage treatment. The designers of the green building would like to insist on the “save, reuse, recycle” concept and leaves 25%-30% building’s structure. This measure helps the program to save materials and resources. In addition, the program takes use of the materials form the current buildings to rebuild or recycle materials. The measure is helpful for protecting the environment and reducing the usage of natural resources. For choosing the kinds of materials, the designers are accustomed to select high-performance and durable materials. Moreover, these materials are chosen from industrial products and cannot be produced at the construction site.

5.1.3 Land Saving

From the perspective of locations, Chinese programs usually choose the farm land and wet land to build public programs. Since the architecture regulation was implemented in 2001, the principles of selecting locations focus on minimizing environmental damage, instead of shortening distance between the service areas. Before that, Chinese programs used to focus on reducing the cost of programs by
taking the shortest line. However, the shortest line is often used for farming and keeping natural environment. Nowadays, Chinese programs would like to take the environment into consideration, and do not occupy farm lands and wet lands. The lands of programs are now usually the wasteland. The regulations are listed as follows:

(i) The shape and square of constructed programs avoid leaving any serious disadvantages on the ecological system. (ii) The constructed program takes advantage of current landscape to finish design. If some buildings have their specialties on their landscapes, the regulation could help designers to reduce the work load, especially on the mining quality. (iii) The large and historic trees on the excavate area must be kept, making these plants as part of the scenery. (iv) After building the main building, the designers should have measures to recover the natural environment on the excavated area.

Influenced by the new regulation, all the expressway programs choose wasteland, and old expressway line will be rebuild. The expressway service areas consider to reuse the materials and lands of the old service plazas. In addition, Chinese programs implement the regulation as an important part of the evaluation of the programs. The regulation reduces the cost on removal reparations for farms. Furthermore, the expressway service takes use of wastelands and reduces environmental destructions.

5.1.4 Natural Resource Saving

From the perspective of the efficiency of water use, the old expressway
service areas in China did not consider it. That’s why some expressway service areas have water shortage, causing that toilets are tatty for customers and that the sanitary conditions of restaurants are unacceptable. These phenomena make the service areas the most annoying places. After the concept of the LEED system came out, Chinese programs are designed with concerning the efficiency of water use. Firstly, the function of water saving landscape design reduces by 50% of daily water. Secondly, furniture using water could reduce the amount of drinking water and irrigation. Thirdly, the regulation requires designers to innovate the technology of wastewater treatment and recycling.

5.1.5 Humanization Design

The perspective of indoor environmental quality is divided into two steps in the building progress. In the first step, designers should control the pollutants during the construction progress. In the second step, designers should consider the air quality and temperature condition. In the past, Chinese designers usually ignored the air quality in the construction progress so that there were a lot of dust in the air. When the customers use principles to build the new expressway service areas, noxious smells from new furniture’s materials come into the air. In addition, a lot of passengers usually smoke in the public places.

With the request of the bureau of architecture, the expressway service area must be satisfied with the standards of the indoor environmental quality. The standards include air monitoring and indoor environmental control plan during the
construction progress, and take use of recycled materials and coatings with low VOC (Volatile Organic Compound) emissions.
6. Design Concepts

This design concept is based on the original location of the Xianning service area, Jingzhu expressway, Hubei province, China. The concept is being developed considering various innovation sustainable design solutions.

6.1 The Sustainable Conceptual Design of Xianning Service area

The designs of public building energy conversation involve severe cold zone, cold zone, hot-summer and cold-winter zone, and hot-summer and warm-winter zone. In the case studies, the Xianning service area is located in the middle latitude that belongs to subtropical climate affected by the monsoon, including long-lasting summer and winter, distinct seasons, and abundant rain fall.

According to the existing Xianning service area in Figure 3, the concept design of sustainable transformation is implemented, and the land, water, and sunlight and wind resources are fully considered.
Figure 24. Xianning service area sustainable conceptual design plan.
Figure 25. Xuanming service area sustainable conceptual design plan aerial view
The overall layout of the expressway service area should follow the user-friendly principle, rational distribution, and clear technician streamline. By optimizing its indoor and outdoor plane design, the expressway service area could avoid unnecessary land use and construction expenditure, and deal with the relationship between human and nature. Designers should consider the layout of parking lots, common buildings, gas stations and gasoline stations. For instance, the parking lots should ensure the vehicles to move well and avoid making trouble on common buildings. In addition, the gasoline and gas station should minimize the negative influences on the traffic flow and ensure the vehicles to move smoothly.

The streamline of common buildings is designed for smooth stopping and refueling. To take the streamline design into consideration, the designers should set the common buildings at the center of the expressway service area, and the common buildings are surrounded by the parking lots. The garage is located in the entrance of the expressway service area to ensure the convenience. Relatively, the gasoline and gas station are located at the exit of the expressway service area to facilitate the traffic flow. Based on the green design principle, the parking lots should take use of inclined parking arrangement, which could improve the traffic flow. At the same time, designers should separate trucks and cars. The trucks are arranged at the back of parking lots and are far away from the common buildings to avoid traffic jam by cars. In front of the common buildings, the parking lots are designed for cars. The number of parking lots is calculated by the traffic flow. According to the green design, the plantings are arranged at the parking lots to improve the environment.
Figure 26, Xianning service area conceptual design route analysis plan
Figure 27. Xianning service area sustainable conceptual design route view
From the perspective of the sustainability, the shape of common building is rectangle. The north-south exposure should avoid being overheated by the sun in summer; additionally, the north-south exposure could take use of summer winds to dissipating heat. Furthermore, the energy consumption is influenced by the solar radiation of windows. The glass materials will gather heat and use the air conditioners to dissipate heat. Besides the design of common building, the geographical condition of the expressway service area should also be noticed by the designers. The pavement material complies with the principle of utility and feasibility. Due to the high traffic flow, the pavement material could be cement concrete that has good stiffness. However, cement concrete has the disadvantage of low dissipating heat. In summer, the pavement with cement concrete can absorb heat from the sun, and release it into the air, making customers feel uncomfortable in the hot air. As a green designer, the parking lots in the front of common building should use permeable pavement to improve the heat dispersion and surrounded plantings to absorb the dust and heat.

The Shape Coefficient of Building has a close relation with the facade formation. If the shape coefficient of building is high, the energy-saving is low. In the case studies, in the expressway service areas, the main building has a large surface area especially. On the one hand, the large size is convenient to accept natural light and wind; on the other hand, the large size does not adapt to the standard of an energy conservation building. On the contrary, the coefficient cannot be too low since it cannot finish the plane layout. The main building is limited into the rigid figure. In order to avoid the improper coefficient, the point-style building keeps the shape coefficient lower than 0.4. In the Xianning future design, the external surface area will be 906 square meters, and the volume will be 2930 cubic meters.
Function Zoning Plan

Figure 28. Xianning service area sustainable conceptual design function zoning plan
Figure 29. Xianning service area sustainable conceptual design main building aerial view
Figure 30. Xianning service area sustainable conceptual design energy supply area view
Thus, the shape coefficient of the building is 0.3, lower than the standard of the point-style building. From the perspective of the shape coefficient, the future design is adapted to the green design theory.

As for parking area, since there are too much vacant parking space in the existing service areas, the number of parking positions should be reduced to 110 and the two-way and comprehensive parking space should be increased. If there is too much traffic, cars can be parked in the comprehensive parking space, because comprehensive parking space is larger than the others in the design, thus, buses and RVs and cars can share the space. This kind of design not only can save land use, but also increase the green space in the service areas.

Another important factor of evaluating green design is the ratio of window-wall. For the green building, if the net heating quantity from sun is positive, and the materials of windows is heating device, increasing the window-wall ratio will be helpful for energy saving. As a green designer, the ratio of window-wall could not reach 0.7. In the future Xianning service area’s design, the windows will face north-south to avoid heat and make building air flow better.
Figure 31. Xianning service area sustainable conceptual design parking space.
Figure 32. Xianning service area sustainable conceptual design hot and cold air flow and exchange analysis, red arrow means hot air and blue arrow means cool air.
As for the independence of the Xianning service area, the water system is paid attention by the designers and customers. According to the instruction of the sustainable design, the designers combined the high efficient sewage treatment, water reuse, and storm rain water system to build a water circulation system.

The pollution discharge of the Xianning service area is not stable because of weather, season, and other factors. The sources of wastewater in the expressway service area mainly include domestic sewage, restaurant, public toilets wastewater, gas stations, washing water, and rainwater. Among these sources, the largest sources are the discharge of restaurant wastewater, domestic water, and public toilets wastewater. And there is a high concentration of ammonia nitrogen and COD in the wastewater. Moreover, the pollution from the washing water of the gasoline station contains sediment and gasoline. Tertiary treatment should be used to purify the wastewater before reuse. First, mechanical treatment, such as grille, precipitation, or gas float, can remove rocks, gravel and fat and grease contained in the wastewater. The next step is biological processes. The pollutants in sewage can be degraded and converted to sludge under the action of microorganisms. The final step is the deep treatment of the sewage, including the removal of nutrients and disinfection of the sewage by adding chlorine, UV radiation, or ozone technology.
Figure 33, Xianning service area sustainable conceptual design waste water treatment and recycle analysis map
Rainwater can be collected from roofs and ground. As the average annual precipitation of Xianning city is around 1577.4 mm, in the Xianning service area, the designers may build a reservoir with percolation. The collected rainwater can be used on green plants, vehicle washing, gasoline station, and even as drinking water. The rainwater recycle system is a plumbing process extracting water via several steps. The more extracting steps there are, the higher the quality of water will be. The size of the water storage tank should be large enough to contain the captured water. In the future Xianning service area’s design, the final step of rainwater system is making drinking water. Besides rainwater, the water system starts with dealing with fresh water. At the first stage of the recycled water system, the fresh water enters into the restaurant and public toilet, then the wastewater is recycled by the reclaimed water process via independent pipes. The reclaimed water can be used for irrigation, washing vehicles, and watering plants.
Xianning annual precipitation table, the number in the red box is the annual precipitation in each district of Xianning city.

<table>
<thead>
<tr>
<th>行政分区</th>
<th>名称</th>
<th>年降水量 (mm)</th>
<th>水量 (亿 m³)</th>
<th>与上年比 (±%)</th>
<th>与多年比 (±%)</th>
<th>丰枯等级</th>
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<td></td>
<td>23.7</td>
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<td>26.6</td>
<td>10.1</td>
<td>偏丰</td>
</tr>
</tbody>
</table>

Figure 34. Xianning annual precipitation table, source: http://www.docin.com/p-1188577751.html
Rain water collection & Water recycle

Figure 35, Xianning service area sustainable conceptual design rainwater collection analysis map
The garbage compression system is to solve the problem of the garbage in the expressway service area. The designers could set up the garbage compression system on both sides of the expressway service area. In the garbage compression system, the living garbage will be gathered and compressed, and then transported to other places. In general, the garbage compression system should locate at the entrance and exist of the expressway service area to reduce the negative influences on the moving streamline. The garbage compression system could reduce the volume of garbage and decrease the cost of transportation.

The solar panels will be used for producing electricity for the Xianning service area. In China, expressway service areas are usually far away from the cities and towns. Thus, the transmission of electricity costs a lot. As for the average annual sunshine time of Xianning city is about 1754.5 hours (Overview of climate resources in Xianning city, 2009-08-18), using the solar panels to generate electricity to support the service area will have great economic value and ecological value.
Figure 36. Solar energy system, source: (http://saururja.com/solar-power-pack-%E3%81%81)
Figure 37. Xiaoming service area sustainable conceptual design solar energy collection analysis image
6.2 Compare the Conceptual Design with the Current Design

The Xianning expressway service area is composed of three important parts:

One is public service facilities, including restaurants, small supermarkets, annular restrooms and offices, car wash service station, and express motels. In the main building, the restaurant and supermarket are located at the center of the building. On the first floor, a bar is arranged to provide customers with a relax space. On the second floor, there is a small market. There are six exits on the first floor, connecting all directions of the main building, which will greatly contribute to indoor ventilation and natural lighting.
Figure 38. Xuming service area sustainable conceptual design car wash station.
Figure 39: Xianning service area sustainable conceptual design main building interior design level 1
Figure 40. Xiamen service area sustainable conceptual design main building interior design level 2
The other is using local ecological environmental protection materials and plants. For interior design, it will use rocks from Futou Lake and Tong Mountain, and lumbers from local trees such as camphor, beech, cedar, and so on. As for landscape, lily, Torenia fournieri, collard, chrysanthemum, and other flowers will be used to decorate the ground.

Furthermore, at the east entrance, the designers build a passageway. And the west entrance is connected with the express hotels. At the outer of the west side, the designers also build a restaurant area.

All the windows of the main building can be closed and open via electric switches, which is beneficial to keep the fresh air in circulation when the windows are open, and is helpful to keep indoor temperature constant when the windows are closed.
Figure 41. Xianming service area sustainable conceptual design main building and outdoor environment design
Figure 42. Xianning service area sustainable conceptual design main building indoor air flow analysis, red arrow means hot air and blue arrow means cool air.
The surrounding area is the dining area, and the middle areas are the kitchen, bar and rest areas. On the second floor, there is the simple shopping area. The appearance of the main building is like a circular area surrounded by two horns, which seems like Chinese philosophic sign ‘Tai Chi’, and also means an interactive relationship between human and nature that can provide all the customers with a peaceful and happy life in the expressway service area. Considering the customers’ convenience, the south part near the expressway is set as the public restroom. On the other side of this floor – the north part is an office area that can avoid noise by setting the entrance towards west.

Still, there are solar panels beyond the roofs. Taking use of the green roof of the main building area not only can improve the aesthetics of architecture, but also can decrease the flow of rainwater into surrounding buildings, reducing the pressure of rain and flood. The vegetation can get festuca arundinacea from locals, which is good for filtering and storing rainwater. In addition, the green roof is also able to reduce the solar radiation in summer, as well as preserves thermal energy in winter. Furthermore, the green roof can prevent noise effectively and extend roof life.

Moreover, there is an outdoor green leisure space in the Xianning service area in my conceptual design, specially a green leisure park. My purpose is very simple – edutainment, building this area for people to enjoy the beautiful local natural scenery and outdoor relax space, and even learn about plants and landscape knowledge.
Figure 43. Xianning service area sustainable conceptual design for leisure park view 1
Figure 44, Xianning service area sustainable conceptual design the leisure park view 2
Figure 45, Xianning service area sustainable conceptual design green roof structure analysis, source: https://www.researchgate.net/publication/279460969_Application_of_seaweed_as_substrate_additive_in_green_roofs_Enhancement_of_water_retention_and_sorption_capacity
Figure 46/47, Xianning service area sustainable conceptual design green roof benefits, source: (http://www.sappi.it/54WEN/Technical_area/Technical_Reports/Green_roof_-_short_guide.htm) (http://intermountainrooftopscapes.com/benefits)
The second part is for provide energy, including a gas station, a charging station, and a gasoline station. The third part is parking lots, providing space for vehicles, private cars, trucks, and buses. The distance between the fuel and nature gas stations are critical for the traffic flow. In order to avoid traffic jam, this distance is increased to support all kinds of vehicles to refuel at the same time. Meanwhile, the green design increases the distance between oil pumps and gas pumps, which could support dual traffic.
Figure 48. Xuanning service area sustainable conceptual design fuel station
7. CONCLUSION

Due to the introduction of the concept of the LEED system, the Chinese architects have begun to pay more attention on the sustainable design. Though the American architects have advanced experience in this aspect, the Chinese architects could combine local cultures with the innovative green design. Because the sustainable design, customers would have an improved impression on the expressway service area, and get close contacts with nature. Based on the case studies and analysis between the situations in China and the US, the Xianning service area could employ the conceptual design for the sustainable development. The current study found a series of sustainable design principles for Chinese expressway service areas. With the illustration of the future design and the study of the LEED system, the principles are proved to be proper to support the development of the sustainable design of Chinese expressway service areas.

In order to reduce the economic and ecological costs, the designers are accustomed to build the integrated building. Nowadays, the Chinese architects choose to use the ecological and recycled material to decrease the costs. The style of the design in China is changing towards the sustainable development.
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Figure 25, Xian ning service area sustainable conceptual design plan aerial view, designed by Huang Zijie, July 11, 2017

Figure 26, Xianning service area conceptual design route analysis plan, designed by
Figure 27, Xianning service area sustainable conceptual design route view, designed by Huang Zijie, July 11, 2017

Figure 28, Xianning service area sustainable conceptual design function zoning plan, designed by Huang Zijie, July 11, 2017

Figure 29, Xianning service area sustainable conceptual design main building aerial view, designed by Huang Zijie, July 11, 2017

Figure 30, Xianning service area sustainable conceptual design energy supply area view, designed by Huang Zijie, July 11, 2017

Figure 31, Xianning service area sustainable conceptual design parking space, designed by Huang Zijie, July 11, 2017

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Figure 40, Xianning service area sustainable conceptual design main building interior design level 2, designed by Huang Zijie, July 11, 2017

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