Transportation in Shanghai: A Decision Support System to Move towards Sustainability

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Abstract: An excellent transportation system is integral for Shanghai as it aims for sustainable development. Decision-making has a far-reaching impact on transportation, which should be improved and supplied with assistance. This thesis aims to design a tool based on a Decision Support System (DSS) named the Transportation Sustainability Decision Support System (TSDSS). The Framework for Strategic Sustainable Development (FSSD) is a key element that was integrated in the TSDSS which will guide the users to backcast from sustainability principles to be strategic in moving transportation in Shanghai towards sustainability. The TSDSS has 3 modules based on the ABCD method and 4 base systems including a Database System, a Model Base System, a Method Base System and a Knowledge Base System, which are designed to help Shanghai’s transportation system move in the right direction towards sustainability.

Keywords: Sustainability, Transportation, Decision Support System
Statement of Contribution

This thesis shared the discovery solution to today’s emerging transportation issues through the research of thesis team. We paid more attention to the transportation in Shanghai combining with sustainability ideas and information management. Each of members played a very significant role in the study of the whole research process.

We focused on the Shanghai transportation, using our information management and information system and economics background, adding the sustainability tools and concepts to design a tool to solve the Shanghai transportation problem from the decision-making process.

All the members participated in the discussion, plan, writing report and presentations of the whole thesis period. So this thesis not only reflects our knowledge and learning, it represents the good design experience as a team and our collective contribution to move Shanghai transportation towards sustainability.

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Executive Summary

Introduction

Nowadays, humans face the sustainability challenge all over the world, and no single area and country can expect to be immune from the problems that this challenge causes. Likewise, China as one of the fast developing countries faces the sustainability challenge. And the issues in Shanghai, the economic centre of China, are particularly acute. Especially, the problems of transportation are in the sharp focus, it has a large impact on many aspects like energy consumption and environmental protection. Besides, the transportation in Shanghai contributes to the sustainability challenge in many other ways.

The Framework for Strategic Sustainable Development (FSSD) is an essential and effective framework to guide the study on moving transportation towards sustainability. It consists of five levels including System, Success, Strategic Guidelines, Action and Tools, and it is used for planning and decision-making for success in any system. (Robèrt 2000, 243-254). At the system level, transportation is in Shanghai within the society within the ecosphere. In the success level, the success of the transportation in Shanghai is achieving sustainability. The sustainable society would respect four sustainability principles. In the strategic guidelines level, backcasting, is used as a way of imagining the envisioned future before planning actions for guiding people to find the gap between desired future and current conditions and creating measures and moving step by step towards the future. At the action level, concrete actions will be taken in the guiding of strategic guidelines to reach sustainability in the system. At the tool level, computer-based tool could support decision-making in which faults and mistakes may cause many problems to hamper sustainable development. So it is crucial to optimize the decision-making process and design a feasible and dependable computer-based tool for decision-making in transportation. And ABCD method is a tool to apply backcasting from basic principles for
sustainability efficiently. It includes four steps: A (Awareness), B (Baseline Assessment), C (Creative solutions) and D (Prioritization).

The purpose of the paper is to design a new computer-based tool which is combined with the concepts and methods of sustainability to provide decision makers with the strategic guideline of backcasting from sustainability principles and support in the whole process of decision-making.

The research questions of this paper are:

Primary Research Question: What would a computer-based tool for supporting decision-making to move transportation system in Shanghai towards sustainability look like?

Secondary Research Question: What architecture, components and functions would this computer-based tool have?

**Methods**

In order to create a reasonable and effective tool, two necessary stages were taken into account: information collection and tool design. Literature is main method of information collection to gain adequate and useful information including the demand of decision-making in transportation, the knowledge about information technologies, and the application of sustainability concepts. Tool design was the core stage of the study. Due to the interactive relationship between computer-based system, decision-making process, and methods of sustainability, tool design was a systematic work in which authors considered each aspect. The computer-based system design should follow several criteria which the authors created: It should provide the support for transportation decision-making in Shanghai. It should apply the concepts, methods or tools of sustainability and it should be easy to use and flexible.
Results

The Architecture of the TSDSS. The Transportation Sustainability Decision Support System (TSDSS) is a system which is based on a decision support system template and applying sustainability methods for decision-making in transportation in Shanghai.

The TSDSS is made up of 9 parts: three sustainability modules, database system, model base system, method base system, knowledge base system, man-machine interaction system and multi-base coordinator.

The four base systems realize the storage, management, maintenance, retrieval and access of data, model, method and knowledge. They could realize a lot of functions such as analysis, prediction, evaluation and simulation for decision makers to analyze the current condition compared to the sustainability principles and assess the decisions which are proposed.

The three sustainability modules are designed according to the B, C and D steps in the ABCD method. Module B is used for analyzing the current condition of transportation in Shanghai from sustainability principles. Module C provides suggestions for helping decision makers make compelling decisions. Module D is used to display the conditions when decisions are implemented and evaluate and analyze them for helping decision maker prioritize decisions.

The multi-base coordinator in the TSDSS would connect each base system to establish information links between different bases. At the same time, the information retrieval would be shown as well as the composition among different bases, and the output will be transferred into different modules.

The man-machine interaction system is a dialogue system between users and the TSDSS, it has three functions: it allows users to operate the system, it provides a variety of input and output and it provides different styles of dialogues.

Process and Flows of the TSDSS. When decision makers want to improve
the condition of transportation and move it towards sustainability, they should attain the knowledge of sustainability and set their goal before decision-making. After that decision makers will access the Model B for knowing the present condition of transportation and analyzing the current situation of transportation compared the 4SPs with the support from base systems. When decision makers got the results which list some aspects which increase the contribution to the violation of the 4SPs, they will access the Module C which could point out the aspects from the Module B which should are possible to be changed and provide suggestions for decision makers, which can help them make creative decisions and measures to deal with sustainability challenge. After decision makers created decisions, they will access Module D to choose and assess decisions through analysis, prediction, evaluation and simulation.

**Discussion**

*Strengths.* The TSDSS could increase the accuracy and efficiency of information processing and the effectiveness of decisions. It could make a contribution to moving the transportation in Shanghai towards sustainability. It has an opportunity to be a generic tool used in many other systems. And it is easy to operate for decision makers.

*Limitations.* The TSDSS just focuses on the decision-makings to affect extended work in transportation such as construction, management and maintenance to make a contribution to moving Shanghai transportation system towards sustainability through making strategic decision and it couldn’t affect extended work directly. The TSDSS needs a lot of people to update, modify and maintain every base, module and system. And the TSDSS couldn’t solve such sustainability problems which have never appeared in the past.

*Research Finding.* It is possible to put the concepts, methods or tools of sustainability into a computer system. This study has an attempt to integrate the Framework for Strategic Sustainable Development into a computer system. And the authors have proposed the idea that applies sustainability
in the TSDSS. Firstly, it is possible that the analysis of current condition compared to sustainability principles is a work which not only could be accomplished by manpower, but also it could be finalized splendidly by computer. Secondly, the ABCD method could be applied in the computer system, which could promote the analysis, evaluation and prioritization are done in scientific and quantitative way and move towards sustainability.

**Conclusion**

The authors studied the approach in the application of sustainability method in the TSDSS in this paper, proposed the architecture, components and functions of the TSDSS and decision-making process combining ABCD method. On the account of its advantages in the functions of calculation, analysis, evaluation, prediction and simulation, it could be a more helpful support tool for transportation decision makers, and help them make excellent decisions for strategic sustainable development in transportation in Shanghai in comparison with applying of ABCD tool or implementation of DSS separately.

*Further Research.* A first suggestion for further research that could be built from this work could be the improvement of artificial intelligence of the TSDSS. A second suggestion would be integrating more methods and tools of sustainability into the TSDSS. Establishing a platform in the TSDSS for collecting and analyzing opinions and feedback of the masses would be a third suggestion. This would be a good way to reflect the current condition of transport from residents and passengers, and evaluate the decision through people’s feedback. A fifth further research could focus on the establishment of an assessment system which could assess whether the implementation is on the right track to the goals of decisions.
Glossary

**ABCD Method**: ABCD methodology is a tool to apply backcasting from basic principles for sustainability efficiently. It includes four steps: A (Awareness), B (Baseline Assessment), C (Creative solutions) and D (Prioritization).

**Backcasting**: A way of imagining the envisioned future before planning actions. Beginning with the desired future in mind is the first step, and then moving backwards from the vision to the current condition for determining what should be done today in order to reach the desired future is the second step. Finally, creating measures and moving step by step towards the future.

**Database**: A base which contains data and information extracted from the government databases, external databases, decision makers’ personal databases. It also includes summarized data and information most needed by decision makers.

**Database Management System (DBMS)**: A set of computer programs that controls the creation, management and access of database, as well as controls the storage, organization, retrieval, maintenance and presentation of the data elements.

**Database System**: A system which stores data, provides data for users, and transfers data to another part in the system.

**Data Dictionary**: A centralized repository of information about data such as meaning, relationships to other data, origin, usage, and format. Based on the basic unit of data in the database, according to a certain order, and gives a detailed description of their data sets.

**Decision Support System (DSS)**: An integrated set of computer tools that allows a decision maker to interact directly with to make unanticipated, semi-structured, and unstructured decisions.

**Ecosphere**: It is a part of Earth which directly or indirectly maintains its
structure and flow using the exergy (ordered energy, available work) flow from the Sun.

**Framework for Strategic Sustainable Development (FSSD):** A planning framework for sustainability that uses a combination of backcasting method and a clear, scientifically-sound definition of sustainability.

**Four Basic Principles for Sustainability (4SPs):** In a sustainable society, nature is not subject to systematically increasing:

I…concentrations of substances extracted from the Earth’s crust,

II…concentrations of substances produced by society,

III…degradation by physical means,

and, in that society…

IV…people are not subject to conditions that systematically undermine their capacity to meet their needs.

**Knowledge Base:** A special kind of database for knowledge management, providing the means for the computerized collection, organization, and retrieval of knowledge. Also a collection of data representing related experiences.

**Knowledge Base Management System:** A system which stores and manages artificial intelligence tools. These tools can obtain knowledge from past data, decisions and cases, and contribute to supporting decision making.

**Knowledge Base System:** A system that helps decision makers by providing artificial intelligence assistance and knowledge information based on the experience of experts in related fields in decision-making processes and problem-solving processes. It includes three parts: a knowledge base, a knowledge base management system and a knowledge dictionary.
**Knowledge Dictionary:** A dictionary which stores the information of knowledge which stored in knowledge base. It is useful for users search, study and calls the desired knowledge conveniently.

**Lithosphere:** A lithosphere (from the Greek for “rocky” sphere) is the solid outermost shell of a rocky planet. On the Earth, the lithosphere includes the crust and the uppermost layer of mantle (the upper mantle or lower lithosphere) which is joined to the crust.

**Man-Machine Interaction System:** A dialogue system between users and the TSDSS, it helps decision makers make correct decisions while unlocking their wisdom and creativity through the input of different kinds of relevant information like data, model, method, experience and judgment and the output of results.

**Method Base:** A base which is used for methods storage and it consists of algorithms, possesses favorable commonality and flexibility, which are the components of all manner of mathematical models.

**Method Base Management System:** A system which provides manipulation of methods for adding, deleting, modifying and servicing for the method operation.

**Method Base System:** A set of programs that includes statistical analysis of data, economic-mathematical methods and other utility programs. It consists of three parts: method base, method base management system and method dictionary.

**Method Dictionary:** A dictionary which stores the relevant information to method itself for finalizing method programme logon, provides required information on programme study and connection with other bases establishment.

**Module Base:** A set of various kinds of models stored in computer; it consists of a lot of program modules.

**Module Base Management System:** A set of computer programs embedded within a DSS generator that allows users to create, edit, update,
and/or delete a model.

**Module Base System**: A system which includes a library of mathematical models and analytical techniques stored as programs, subroutines, spreadsheets, and command files, and which provides a model program and interface for users to build application programs. Decision makers use it for prediction, choosing, analysis and evaluation.

**Module Dictionary**: A dictionary which stores the introduction and information about models and the model base. Users could search the relevant content of them. These introduction and information introduce and describe the connection and relationship among different models and other systems.

**Multi-base Coordinator**: Used to connect database system, method base system, model base system, and knowledge base system with each other, to establish information links between different bases. It could realize the information retrieval and composition among different bases, and output into different modules.

**Semi-Structured Decision**: Decisions in which some aspect of the problem are structured and others are unstructured. They are partially programmable, but still require human judgment.

**Structured Decision**: Decisions are made under the established situations which are fully understood and could be described by defined language and model. In other words, they are programmable, preplanned and made for routine tasks. Users could choose the best decisions through appropriate algorithm.

**Sustainability**: It is defined by four sustainability principles and it is a condition achieved by not violating the four sustainability principles.

**Sustainable Society**: A society that does not systematically degrade the ecosystem’s ability to provide life support services, and where all people have the opportunity to meet their basic needs.

**Transportation Sustainability Decision Support System (TSDSS)**: A
system which is based on decision support system and applying sustainability method for decision-making in transportation in Shanghai. The authors designed it.

**Unstructured Decision**: Decisions are made under the emergent situations which are uncertain, unclear, and complex and no standard or best solutions exist for resolving the situation. Some or all of the structural elements of the decision situation are undefined, ill-defined or unknown.
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1 Introduction

1.1 Sustainability & Sustainability Challenges

Sustainability is a term which is often mentioned in development activities. A widely cited definition of sustainable development is: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland Commission Report 1987) This is an excellent idea and concept which not only considers present needs but also future development. Furthermore, sustainability can be defined by four sustainability principles and strategic sustainable development is considered as the process of moving towards sustainability in a strategic way. The sustainable society would respect four sustainability principles:

In a sustainable society, nature is not subject to systematically increasing:

I …concentrations of substances extracted from the Earth’s crust,

II…concentrations of substances produced by society,

III…degradation by physical means,

and, in that society…

IV…people are not subject to conditions that systematically undermine their capacity to meet their needs. (Ny et al. 2006)

At present, the sustainability challenge is made up of a series of interconnected global problems, and could severely affect human society at the global level. These sustainability challenges can no longer shunted aside in the process of development. “Non-sustainable development could be visualized as entering deeper into a funnel, in which the space to succeed becomes narrower and narrower.” (Robèrt 2000, 246-247), which is shown
in Figure 1.1. For instance, resource reserves are systematically decreasing, while the global demand and environmental pollution are systematically increasing. It is obvious that both aspects cause harmful effects in sustainable development from two directions, which include economic problems, environmental problems, resources problems, and social problems. This is one example to justify that these challenges are interrelated and systemic, and they would cause combination effects to influence both the ecosphere\(^1\) and society. Thus, in order to solve these problems, avoid meeting new issues, decrease risks and strengthen further development, it is necessary and urgent for people to take measures to improve the current condition and pull out of the funnel in order to move the whole society towards sustainability.

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\(^1\) Ecosphere: It is a part of Earth “which directly or indirectly maintains its structure and flow using the exergy (ordered energy, available work) flow from the “sun/space battery””. (Holmberg and Robert. 2000, 308)
sustainability and make decisions and plans for sustainability. Similarly, China also faces the sustainability challenge, Shanghai as an economic centre in China faces many problems, like transportation problems, environmental problems, and housing problems. Especially, transportation problems have a large impact on economic development, transportation efficiency, energy consumption, environmental protection, whereas, an excellent transportation system could promote harmonious development of society and nature. Thus, as one of the most important parts in a municipality, transportation in Shanghai is a field which could make a great contribution to the sustainability of Shanghai.

In order to deal with the sustainability challenge and promote the process of transportation sustainability in Shanghai, the authors needed the guide of a structured comprehension or a conceptual framework (Robèrt 2000, 248-250) to move the whole study and the development of transportation in the right direction. The Framework for Strategic Sustainable Development (FSSD) is such an essential and effective framework which could guide the study on moving transportation towards sustainability.

1.2 Framework for Strategic Sustainable Development

The Framework for Strategic Sustainable Development (FSSD) is applied to the system “Society in the Ecosphere”. It consists of five levels: System, Success, Strategic, Action and Tools. At the system level, the basic elements of society such as individuals, organizations, communities and nations and the dynamic interrelationship between society and ecosphere which society is within should be understood. At the success level, it is very important to define success as compliance with the basic principles for sustainability. At the strategic guideline level, it needs the logical and generic guidelines for the process based on baskcasting to inform a step by step approach within an overall strategy. At the action level consists of a variety of actions to facilitate strategic planning. At the tool level, it has various tools and concepts. (Robèrt. 2000, 248-250)
The five different levels are not approached step by step but affect each other through the whole process, and it allows a system to ensure that it has all the indispensable elements to move the system towards the goal of sustainability. (Robèrt. 2000, 243-254)

1.2.1 System Level: Transportation in Shanghai within the Ecosphere

*Society within the ecosphere* All affairs to be performed for sustainability could not be considered without considering nature. Humans live in society, and own a very tight connection with nature. So inevitably any sustainability issues are associated with nature as a whole. The following figure shows the connection between human and nature, and some of the flows between the two:

![Figure 1.2. Society within the ecosphere](Robèrt et al. 2007, xxiv)

As can be seen in the figure 1.2, there are three main parts representing
three systems. These three systems are lithosphere\(^2\) (bottom of figure), society (inner circle) and ecosphere (outer circle). Society exists within the ecosphere. Both society and ecosphere interact with the lithosphere (earth’s crust). (Robèrt et al. 2007, xxiv)

Humans live in society and can directly extract the energy and matter from the lithosphere by mining and drilling. Meanwhile, humans can gain resources from the ecosphere through physical means such as harvesting. Humans can also directly manipulate the ecosphere, for example by changing land usage. Human beings discharge man-made waste into the ecosphere and influence the lithosphere. On one side, matter and energy flow from lithosphere to ecosphere by weathering and volcanoes. On another side, matter and energy flow from ecosphere to lithosphere by fossilization and sedimentation. So the three systems have very close relationships. This is the simple description of the flows and activities among the three systems. It is not difficult to understand that the development of society is a process of the coordinated development of mankind and nature, and people should build up harmonious relationships between society and the ecosphere in order to enhance the capability of sustainable development steadily, increase the efficiency of resource use eminently, improve ecological environment gradually and push the whole society on to a path towards sustainability.

*Shanghai and the Transportation in Shanghai* The system which the authors will focus on in this study is the transportation in Shanghai, which is within the ecosphere; it faces a flood of problems, the same as the whole system (the ecosphere). The transportation in Shanghai is a complex system and all materials, energy, activities and relevant information used in the transportation of Shanghai are included in the system boundary.

Shanghai is the biggest international port in China. It is situated on the west Pacific Coast, in eastern China and it is well-located and is easy to access. (Bureau of Shanghai World Expo Coordination 2009, 18) Meanwhile, it is the most populous city in China. It has 19 districts and its area is 6,340

\(^2\) Lithosphere: (from the Greek for “rocky” sphere) is the solid outermost shell of a rocky planet. On the Earth, the lithosphere includes the crust and the uppermost layer of mantle (the upper mantle or lower lithosphere) which is joined to the crust. (Robèrt et al. 2007, 341)
square kilometers. In 2008, Shanghai had a population of 18.9 million (United Nations Environmental Programme 2009, 7) In addition, Shanghai is the biggest financial and commercial centre in China. (United Nations Environmental Programme 2009, 7) Shanghai has become one of the cities that enjoy the highest economic growth speed in the world. In 2008, the GDP of Shanghai was three times as large as in 2000 and the per capita GDP was 72,000 Yuan. (United Nations Environmental Programme 2009, 7) Relatively, it also has small area, scarce resources and limited environmental capacity. (Bureau of Shanghai World Expo Coordination 2009, 8) Shanghai has a very large transportation network which has a rapid growth year after year. Civil vehicles and public transport will be examined in order to introduce the immensity of the transportation in Shanghai.

In 2009, the annual number of passengers carried by public transportation in Shanghai was 5.13 billion, up 4.6 % over the last year. The average daily number of passengers carried by public transportation is 14.047 million. (Shanghai Municipal Transportation and Port Authority 2009) There are a huge number of civil vehicles in Shanghai. Particularly, the number of motor vehicles and motorcycles accounted for a large proportion in the number of total civil vehicles. And the number of motor vehicles was 1321 thousand and that of motorcycles was 1273 thousand in 2008. (Shanghai Statistical Bureau, 2009) Shanghai has an advanced and comprehensive rail transportation network. In 2009, there were ten metro lines and a maglev train in Shanghai and most of the metro lines were extended in recent years. The total length of the rail transportation lines is about 363km and it has 232 stations. (Shmetro Group CO., LTD and United Nations Environmental Programme 2009) Shanghai is covered by a vast bus transportation system including 16,400 buses and 991 routes in 2008. Shanghai had 86.2 kilometres of bus lanes in 2008 which will be extended to 300 kilometres in 2010. (United Nations Environmental Programme 2009, 32) All of the numbers mentioned above means that Shanghai has a large transportation system and it plays an important part in the development of Shanghai. Thus, an excellent transportation system is an essential component of a sustainable city.
Municipal Plans for Development in Shanghai In order to move Shanghai which has a huge transportation network onto the path to sustainability, Shanghai municipality gives high recognition to the issue, makes development plans and provides financial support for sustainability.

According to Over All City Plans in Shanghai (1999-2020), the development purpose of Shanghai is to be an international economic, financial, commercial and shipping centre. (Bureau of Shanghai World Expo Coordination 2009, 2) The construction and development of Shanghai should persistently follow the sustainable development strategy and take the path of sustainable development continuously. So it is urgent to change the traditional development model to sustainable development model for the purpose of becoming a resource-conserving and environmental-friendly city. (Bureau of Shanghai World Expo Coordination 2009, 1-2) In order to achieve this purpose, Shanghai took various measures in recent years and will go on working on the sustainable development in the future. In particular, Three-year Environmental Action Plan and Shanghai Urban Transportation 11th Five-year Plan are the main plans which exercise influence over the process of transportation towards sustainability.

From 2000, Shanghai municipal government initiated the Three-year Environmental Action Plan to promote the work of the environmental protection. It carried out hundreds of projects to improve the environment of the city in the first three rounds of the action plan. In the fourth round of the plan (2009-2011), 260 projects will be implemented, a total investment of 82 billion Yuan. (United Nations Environmental Programme 2009, 8)

According to the Shanghai Urban Transportation 11th Five-year Plan, the optimization and improvement of urban transportation in Shanghai should seize three main components: the optimization of structure, the improvement of market mechanisms and the improvement of management styles. (Shanghai Municipal Transportation and Port Authority 2007, 14) It should focus on the idea of “people-oriented, convenient transportation,” which is “environment-friendly, information-oriented”. (Shanghai Municipal Transportation and Port Authority 2007, 14) At the same time, it also needs to combine predictability and operation, guidance and pertinence,
short-term goals and long-term plans. The main goals of the plan are developing the reasonable transportation system which effectively reduces the energy consumption, eases urban traffic congestion and improves the ecological environment of the city. (Shanghai Municipal Transportation and Port Authority 2007, 14-16)

**Sustainability Challenges of Transportation in Shanghai** As introduced above, Shanghai has a huge and complex transportation system, and the transportation in Shanghai has a fast development and vehicle use is growing rapidly. Sustainable development in Shanghai has strong support from the municipal government and the government worked out long-term plans and took a lot of measures to promote the development of transportation, including traffic management, infrastructure construction, priority of public transportation. Shanghai still has vast arrays of pronounced sustainability challenges of transportation. These essential challenges primarily are summarized in four aspects: the target of meeting human needs, the usage of resources, effects of transportation on urban environment and degradation of nature.

The target of meeting human needs: The essence of transportation is transporting people and goods. Nowadays the people-oriented concept has been widely received and advocated by society, and human needs attract more and more attention. However, under these circumstances, the lacking capacity and the inadequate infrastructure of transportation couldn’t fulfill the need and satisfaction of most residents, (United Nations Environmental Programme 2009, 29) for much wider vehicle lane and narrower pavement could be seen in Shanghai. What is more, some main roads have 8 vehicle lanes, while the pavements are only about 2 meters wide. These kinds of designs are more suited to meeting motorists’ needs rather than meeting the needs of pedestrians and cyclists. The phenomenon is not consistent with the social consensus about fairness and justice and the idea of human-orientation. There are a lot of similar cases existing in Shanghai, for instance, at bus stops, passengers know the bus lines, but they don’t know the exact time of each frequency, it is inconvenient for passengers to plan their trip time, and the relevant transportation information is inadequate and unclear for residents. Furthermore, there are few facilities for passengers to
have a rest in many stops and the seating in most of public buses is very cramped and uncomfortable. It is very difficult for disabled people to get on the bus, take advantages of public transport facilities and meet their special needs. Another serious point is that the bus and metro are always full of passengers, especially at rush hour. The unreasonable plan for setting stops means that there is not enough space to hold many buses and it causes buses to scrape other buses. (Qin, Zhang and Li 2008) From the perspective of sustainability, the fact that the current system cannot meet residents’ needs shows the weakness and challenges of the transportation system in Shanghai. So there are a lot of improvements that should be done in order to achieve the goal of moving the transportation system in Shanghai towards sustainability.

The usage of resources: resources are the basis for the survival of the human race and development of society. The current condition is that resource availability is systematically decreasing along with systematically increasing of global demand, (Zhao, Zhang and Yu 2009, 747-748) and non-renewable energy occupies the largest part of the energy consumption structure in transportation at present. Energy issues, a significant sustainability challenge to transportation, are becoming more serious with the reduction of the total energy resources. As estimated, the energy consumption of transportation will account for 16.3% to 17.1% of total energy consumption in 2020 in China. (Gu 2008, 7) Shanghai is no different and is facing a lot of problems. However, the challenges did not arouse enough attention from the public and municipality. What is more, many of the issues make the condition of sustainable development worse and worse. For example, redundant project building and rebuilding are caused due to unreasonable and unscientific decisions and planning, and there has been demolition of some transportation infrastructures which were nearing completion or newly completed, caused by the conflict between different projects. This not only led to delays in the pace of the project, but also resulted in redundant consumption of tremendous manpower, time, economic cost and resources. Meanwhile, these activities have a destructive or damaging influence on the environment, cause inconvenience for inhabitants’ trips and affect the inhabitants’ health. Based on that, it is not difficult to draw a conclusion that putting unreasonable decisions into
practice further aggravates the trend of unsustainable development in Shanghai.

Effects of transportation on the urban environment: The transportation system meets the needs of transporting people and goods, but inevitably it brought about a series of problems on the urban environment. (United Nations Environmental Programme 2009, 20-21) Shanghai has a vast and complex transportation system and a great number of vehicles, however, since fossil fuels are the main energy source for most vehicles in Shanghai, it means that these vehicles emit a large volume of poisonous gases such as carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbon (HC), aldehyde (RHO) and leaded particulate matter, which has a negative effect on human health and the urban environment. (Zhang and Wang 2009) Another point which shouldn’t be overlooked is that the vibration caused by vehicles can do damage to the roadbed and foundation. Moreover, the terrible traffic conditions increases the time cost and economic cost of inhabitants’ trips. In the meantime, it impacts the efficiency of transportation, inhabitants’ daily life and urban sustainability. In Shanghai, there are lots of large-scale traffic construction projects implemented and planned every year because of the rapid development of the city. Against this background, the discharge amount of industrial dust is quite shocking in the course of construction, which exacerbates air pollution. In addition, many construction projects also bring about noise pollution, water pollution and other problems.

The degradation of nature: Human beings live in society, which exists within the ecosphere. Matter and energy flow between the ecosphere and society, and people get necessary resources from the ecosphere and discharge waste to the ecosphere. Nature not only provides humans with resources but also helps humans in dealing with waste, which depends on its self-purification capacity and restorative capacity, and which is the basis for the productivity in the ecosphere and biodiversity in the ecosphere (Holmberg and Robèrt 2000). Nature is therefore very significant and meaningful to human beings and sustainable development. But at present, nature is being degraded by physical means in Shanghai. The demands of the road network grow quickly with the increasing problem of traffic jams.
In order to solve this problem the municipality has expanded the traffic network continuously. This condition has resulted in most of the land resource in downtown occupied by buildings and transportation infrastructure. This trend further spread to the suburbs immediately: the natural environment was damaged, many grasslands and croplands were occupied, and many rivers were filled in. This trend has led to the degradation of the productivity and biodiversity in the ecosphere, and then resulted in the decrease of self-purification capacity and restorative capacity of nature. Thus, the equilibrium of the ecosystem is disturbed, and it is hard to imagine what will happen if the condition continues to get worse and worse.

As mentioned above, the transportation system in Shanghai faces many challenges and problems causing a lot of influence on society and nature, and a sustainable transportation system is essential and beneficial at present. In order to improve the condition of transport and environment and make contribution to the sustainable development, it is urgent and necessary to apply four sustainability principles.

1.2.2 Success level: Basic Principles for a Sustainable Society in the Ecosphere

The success of the transportation in Shanghai is achieving sustainability. The sustainable society would respect four sustainability principles which the authors introduced above.

The first three principles deal with the problems and damages which are caused by human activities to the ecosphere in direct and indirect way. The fourth principle focuses on barriers for people’s capacity to meet their basic human needs, which are significant elements for maintaining social stability and realizing social sustainability.

The sustainability principles mentioned above are vital features of a sustainable society. Similarly, these are also the basic principles for sustainability by which should be abided by in the sustainable development of transportation. And they also should be observed in the whole process towards sustainability.
In plain language, the transportation in sustainable society within the ecosphere should be efficient, clean and safe. There should be favourable and excellent coordination of the relationship between transport decisions, urban planning and land utilization. It should make contributions to urban economic sustainable development, urban environmental protection and urban social sustainable development. It has reasonable and optimized combination of the kinds of vehicles for realizing the transporting passengers and goods; it could decrease the environmental pollution and damage and save resources efficiently. It could satisfy the trip needs of inhabitants and save trip time significantly. It decreases the vehicle emissions and noise pollution for residents’ health and elevates the living standards gradually. It also has a powerful monitor and management department, comprehensive polices, laws and rules to ensure traffic operation and transportation development on the right track.

1.2.3 Strategic Guidelines Level: Backcasting to Guide the Process and Design in Moving towards Sustainability

Backcasting is a way of imagining the envisioned future before planning actions. Beginning with the desired future in mind is the first step, and then moving backwards from the vision to the current condition for determining what should be done today in order to reach the desired future is the second step. Finally, creating measures and moving step by step towards the future (Holmberg and Robèrt 2000, 294-295). Furthermore, backcasting from basic principles for sustainability is to create a future goal based on sustainability principles and then plan actions with keeping the desired future in mind, and lastly prioritize the most practical ones for implementation to achieve the goal.

1.2.4 Actions Level: Taking Concrete Steps to move Transportation in Shanghai towards Sustainability

At the actions level, through backcasting from basic principles for sustainability, a whole set of actions are planned to strategically step by step achieve the goal of sustainability.
1.2.5 Tools Level: Effective Tool for moving transportation in Shanghai towards sustainability

Due to the complexity and diversity of the transportation system in Shanghai as mentioned in the system level and the interactive relationship of each of the four sustainability principles, an applicable and practical tool should be applied in the system to help improve the situation, decrease the contribution to the violation of the four sustainability principles and achieve a successful and desired sustainable society as described in four sustainability principles.

Decision-making Related to Transport As mentioned above, transportation in Shanghai faces sustainability challenges. For instance, there were few facilities for passengers to have a rest in bus stops, some construction projects were rebuilt because of unreasonable design and plan, some new transportation infrastructures were pulled down resulting from the conflict between different projects, the implementation of too many large-scale traffic construction projects led to an overload of the environment and degradation of the nature. In fact, based on the analysis of challenges mentioned above, it is not difficult to find that the sustainability challenge of transportation in Shanghai is related to decision-making which means the whole process from analysis of current condition, planning of project to completion of decision. These series of problems are visible phenomena, traced to the source; the mistaken decisions are one of the reasons causing these sustainability challenges.

In the decision-making process, decision makers should undertake each step of the decision-making process seriously and carefully, but sometimes they fail to attain an intended result and desired goal due to faults in one or more links. These mistaken or deficient decisions not only make a contribution to the violation of sustainability principles, but also hinder the future development of transportation. A short-term decision of road construction which does not consider the growth of population and private cars and the injurious influence on the environment and society, would not only damage the land and environment, but also cause serious traffic
congestion. On the contrary, a superior decision could avoid many problems and harmful effects, take a precaution to minimize unknown risks reasonably, increase the efficiency of transportation system, improve the traffic environment. The faults in decision-making would cause a series of issues in further work, because it is an earlier and fundamental work in the whole process from decision to construction, management, maintenance. And far-seeing decisions point out the right direction and desired goal for further jobs. What’s more, it is much easier to make changes in the beginning of the whole process than the improvement of extended work after decision-making. Accordingly, the earlier work, decision-making, should be performed in a rigorous way. To put it another way, each link in the process should be accomplished neatly and rigorously and an excellent decision should be precise and meticulous. But as a matter of fact, it is easy to be poised on the brink of failures and mistakes most of the time in a comprehensive decision-making process.

In the practical process of decision-making, decision makers should calculate to get the precise results, make concrete analysis of current data and information, catch the future development trends of economic growth, population growth and transportation development, predict possible conditions in certain range. Because the decision-making process is exceptionally arduous and complex, it not only needs a large amount of data and information, but also needs a great deal of analysis, statistics and calculation. In a word, it needs a lot of work which should be taken into consideration. If all work is accomplished by manpower, it would cost much time to finalize the process and face the risks of mistaken calculation, incorrect prediction and other problems. Thus, an effective and practical tool is necessary to supply decision makers with support in the process.

**Computer-based Systems** With the development of transportation and increasing amounts of data and information, decision-making becomes more and more difficult. Nowadays, computer-based systems have been applied in many fields and have many advantages. The data and information could be stored permanently and programs could be called conveniently, it has a powerful capacity and functions like a fast calculation and operation speed and high veracity, it could realize the resource share
and communication. Generally speaking, a computer-based system is an efficient tool which could increase the efficiency and correctness of analysis, calculation and analysis. Because of these advantages, a computer-based system is obviously a helpful tool which could be introduced into decision-making process. After the implementation of a computer-based system, a lot of work would be turned over to the system, it would lighten decision maker’s burden, enhance the integrity of information collection, increase the speed and veracity of information processing, support operations of statistics and calculation and supply with the function of prediction, evaluation and analysis. All of this would help in optimizing the decision of transportation to make contribution to raising the effectiveness and quality of other follow-up job in order to accelerate the process of sustainability.

Hence, choosing or designing a feasible and dependable tool for decision-making in transportation is a significant work in the tools level for supporting decision makers to apply the backcasting from sustainability principles and work out actions at the strategic guideline level and action level.

The following figure demonstrates the primary application of FSSD on this study design:
### 1.3 Purpose, Scope and Limitations

The purpose of the paper is to design a computer-based tool which is combined with the concepts and methods of sustainability to provide decision makers with the strategic guideline of backcasting from sustainability principles and support in the whole process of decision-making. Therefore, decision makers could make strategies and create, choose and prioritize actions in a strategic way, which could make a contribution to advancing the transportation in Shanghai within the ecosphere towards sustainability.

To sum up, the computer-based tool created in this paper has three important goals:

- Firstly, improve decision-making process by applying backcasting from sustainability principles;

<table>
<thead>
<tr>
<th>System</th>
<th>• Transportation in Shanghai within the ecosphere</th>
</tr>
</thead>
</table>
| Success | • Four basic principles for sustainability  
• Effective and high-quality decision-making process |
| Strategic Guidelines | • Backcasting to guide the process and in Moving towards Sustainability |
| Actions | • Create and take concrete actions which are guided by strategic guidelines |
| Tools | • Various tools and concepts for sustainable development  
• Computer-based tool for decision makers |

*Figure 1.3. The application of FSSD  
(Robèrt 2000, 248-250)*
Secondly, help decision makers make effective and high-quality decisions which could decrease their contributions to the violation of the sustainability principles;

Finally, move the transportation in Shanghai within the ecosphere towards sustainability.

The tool in this paper covers three areas:

- **Information system**: This tool is a computer-based tool and it is used for decision-making, so the architecture, components and functions of this tool are possible to be based on information system.
- **Sustainability**: This tool applies the relevant knowledge and methods of sustainability, and the goal of using this tool is to make contributions to moving the transportation in Shanghai towards sustainability.
- **Transportation in Shanghai**: This tool is used for decision-making improvement in transportation in Shanghai. In the decision-making process, this tool should provide decision makers with assistance that is based on the current condition of transportation.

So the scope of this paper is as shown in the following figure:

![Figure 1.4. The scope of the thesis](image.png)
The study of this thesis has two main limitations. The first one is that the information and results about decision-making in transportation in Shanghai are founded on the authors’ study and analysis in relevant literature and without collaboration with transportation departments or organizations in the transportation area. Another one is that this thesis only focuses on the system analysis and system design, not on system testing, system implementation and system maintenance. The architecture, components and functions of this computer-based tool are designed on theoretical feasibility.

1.4 Research Questions

The research questions of this paper are:

Primary Research Question: What would a computer-based tool for supporting decision-making to move transportation system in Shanghai towards sustainability look like?

Secondary Research Question: What architecture, components and functions would this computer-based tool have?
2 Methods

2.1 Information Collection

Information collection was a significant work at the beginning of the thesis process, which was the basic stage and preparation for information processing. Literature was the main method to gain adequate and useful information for supporting the next design processes.

In order to design a computer-based tool which was concerned with decision-making improvement for sustainable development of transportation, much information was reviewed through literature. The most important information was known in the tool design process including the demand of decision-making in transportation, the knowledge about information technologies, the applying of sustainability concepts, method. The details about this information are listed below:

- Decision makers’ demands for the tool in decision-making process, the functions of this tool that they need, the help from the tool for decision makers, problems and faults which are easy to appear in decision-making process and possibility of further improvement.
- Which tool is a suitable and possible one that could be introduced into the decision-making and what functional parts should this tool have in order to improve the process of decision-making and make a contribution to transportation development.
- Which methods, tools and concepts of sustainability could be applied into this tool to help transportation in Shanghai realize the goal of sustainability.

2.2 Tool Design

Tool design was the core stage of the study in this paper. Due to the interactive relationship between computer-based system, decision-making
process and methods of sustainability, tool design was a systematic work in which authors considered each aspect. Thus, the architecture, functions and constituent parts of this computer-based system were designed methodically and logically based on the process, goal and function from a systematic view. So that the computer-based system could produce active and positive effects in the decision-making process.

A computer-based system is a fundamental platform which has relevant subsystems and realizes many functions. In order to design the tool which the authors expected, authors created several criteria which should be followed:

**The computer-based system should provide the support for transportation decision-making in Shanghai.** Because decision-making in transportation is a comprehensive task, a computer-based system is an important tool to be harnessed to support that decision-making, including overcome difficulties and increasing effectiveness. That is the main function and also the most important purpose of the computer-based system. And the demands and characters of decision-making in transportation decide the kind of effective and high-quality computer-based tool which is to be used in the decision-making process.

**The computer-based system should apply the concepts, methods or tools of sustainability.** In order to promote sustainable transportation in a strategic way, the concepts, methods and tools of sustainability are extremely necessary to be considered for guiding decision makers to make far-seeing decisions and advance the sustainability process, especially backcasting from sustainability principles. It’s also beneficial to train the responsibility consciousness of sustainability. And the tools and methods should be easy to use for decision makers. Besides, the application of the methods or tools of sustainability could be accomplished in the computer-based system. Moreover, it could be programmed in this computer-based system.

**The computer-based system should be easy to use and flexible.** The architecture, interface and components concern the convenience and performance of the system. So user-friendliness is a very important feature
of this computer-based system.

Subsystems are the functional components in the computer-based system, each subsystem provides different supports for decision-making and each function of each subsystem is part of the functions of the whole system. Due to the role of this tool which is for decision-making, modification, and the realization of the sustainability in the transportation in Shanghai, both purposes determine the choosing of subsystems in this computer-based tool. Meanwhile, they play an important role in the formation of the whole functional components. The design of functional components should be designed with the following criteria:

**The subsystems should be flexible and achievable for the computer-based system.** Flexibility is a significant characteristic of tool subsystems, and it is also the fundamental prerequisite for the realization of its function.

**The subsystems in this system should be closely relevant to the transportation decision-making in Shanghai.** It is an important point which could make an impact on the realization of the purpose which is moving transportation in Shanghai towards sustainability. So the subsystems should be in accordance to the current condition and practice.

**The subsystems in this system should be coordinated with the method of sustainability which is applied in the computer-based system.** Both the subsystems and the method of sustainability play significant roles in the decision-making process, so the subsystems should be beneficial to promote decision makers to use the method of sustainability and provides help for the application of the methods of sustainability in the computer-based system.

**2.3 Expected Results**

The computer-based system has modules which apply backcasting from sustainability principles and accomplish the jobs in specific methods of sustainability. The system could encourage decision makers to be think
about backcasting from sustainability principles and follow the useful methods in the decision-making process. It has subsystems which supply relevant support to decision makers for completing analysis, evaluation and simulation. In a word, it could make a contribution to decision-making improvement and moving the transportation in Shanghai towards sustainability.
3 Results

3.1 Decision Support System

There are a number of computer-based systems which are used for different purposes. Comparing the functions and advantages of the many popular computer-based tools, not all systems could supply suitable support to decision makers in the decision-making process. For example, Office Automation Systems (OASs) combine various technologies to reduce the manual labor required in operation (Li 2006, 140). These technologies include e-mail, desktop publishing, word processing and other services. All office functions like typing, coping, fax, records management could be integrated into this system. It could accelerate word processing and information share, increase the efficiency of documents and administrative management and reduce a lot of manual labor (Li 2006, 140). For decision-making in transportation, it could increase the effective of daily work in the department, but it could not deal with decision-making issues. Other systems are like OASs: they may have strong points in some aspects, but they couldn’t play a significant part in the process of decision-making and affect decision evaluation and choosing.

But one computer-based system called Decision Support System (DSS) is an excellent system which could bring big changes in the decision-making process. DSS is an interactive, computer-based information system which allows a decision maker to interact directly with computers to create information useful in making semi-structured and non-structured decisions, and it provides an integrated set of flexible computer tools for analysis and helps decision makers focus on the future (Li 2006, 135). It can be described as an interactive human-computer information system based on computer technology (Zhang 2005). It is a class of information systems that emphasize the process of decision-making and changing users through their interaction with the system (Kendall and Kendall 2002). Its main object is providing valuable information for decision makers to help them deal with semi-structured and non-structured decision issues.
The decision support system has four main features: The first is supporting decision makers rather than replacing them; the second is applying data and models, the third is solving problems with multiple kinds of structure including non-structured (Bonczek et al. 1981), structured (Keen and Scott-Morton 1978), semi-structured and unstructured\(^1\) (Sprague and Carlson 1982); and the fourth is focusing on effectiveness rather than efficiency in decision-making processes.

DSS has several functions as below:

- Organize information for decision situations
- Interact with decision makers
- Expand the decision maker's horizons
- Present information for decision maker understanding
- Add structure to decisions
- Use multiple-criteria decision-making models
  
  (Kendall and Kendall 2002)

3.1.1 Development of Decision Support System

Before the appearance of DSS, traditional management systems couldn’t bring numerous economic benefits to the enterprise; it is obvious that people should play a critical and positive role in information processing. As time passed, people enhance understanding and promote learning the rules of information processing, and they need high-level systems for decision support in the constantly changing environment and demands. The rapid development of computer application technology provides the basis for the appearance of DSS.

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\(^1\) Structured Decisions: Decisions are made under the established situations which are fully understood and could be described by defined language and model. In other word, they are programmable, preplanned and made for routine tasks. Users could choose the best decisions through appropriate algorithm.

Unstructured Decisions: Decisions are made under the emergent situations which are uncertain, unclear, and complex and no standard or best solutions exist for resolving the situation. Some or all of the structural elements of the decision situation are undefined, ill-defined or unknown.

Semi-structured Decisions: Decisions in which some aspect of the problem are structured and others are unstructured. They are partially programmable, but still require human judgment. (Sprague and Carlson 1982) (Kendall K. and Kendall J. 2002)
The concept of DSS was proposed by Keen and Scort Morton in the early 1970s. At that time, it was called a management decision-making system (Scott Morton 1971), and it was a part of management information system (Gorry and Scott Morton 1971). At present, DSS has undergone extensive development in theory and practice. Generally speaking, DSS becomes more powerful than management information systems (MIS). According to the basic principle of general system methodology (Zhou 1987), the function of a system depends on the architecture of system; the architecture is an internal condition of function (Xiao and Wang 1993).

### 3.1.2 Multiple-base Structure

Sprague first proposed the view about the structure of DSS (Xiao and Fei 1992). In his view, DSS has three units, which were consist of Dialogue Unit, Data Unit and Method Unit (Sprague and Fick 1980), so he gave the opinion that DSS structure has two bases called Database and Model Base. With the development of DSS in the non-structure area, it would inevitably introduce the method and technology of artificial intelligence (AI) (Xiao and Fei 1992). So it is necessary to add the knowledge base to form the structure of three bases. In order to manage models effectively, it is necessary to separate specific methods from model base, so the method base was formed, that was the formation process of the structure having four bases (Xiao and Fei 1992).

In this kind of multiple-base structure, every base has its management system and dictionary help users to manage the base and solve problems in using and operation process. We put these three parts together as a whole subsystem. With the increasing of subsystems, the system needs one module to coordinate every base, so users introduced the multi-base coordinator into the system. So far we obtained the general form of DSS, and its core base is the model base.

### 3.1.3 The Function of Decision Support System

The architecture of a DSS combines the ability of information processing from computer and the capacity for logical and analytic thought from decision makers to improve the ability to deal with complicated decisions
problems and increase the quality and effectiveness of decisions (Zhang 2005). DSS as an information technology can provide strategy information and solutions for decision makers, lighten the decision makers’ and managers’ burden of low-level information processing and analysis and make them focus on their high-level work (Liu 2002) which needs professional judgment and experience. As a result, DSS could enhance the quality and effectiveness of strategies and decisions.

Take a real life example of a DSS to introduce the function and implementation of DSS: Airline DSS. The American Analytical Information Management System (AAIMS) is a DSS used in the airline industry. It was developed by American Airlines but is used by other airlines, aircraft manufactures, airline financial analysts, consultants, and associations. AAIMS supports a variety of airline decisions by analyzing data collected on airline aircraft utilization, seating capacity and utilization and traffic statistics. For example, it produces forecasts of airline management in order to make decisions on aircraft assignments, route requests, ticket classifications, pricing. Of course, AAIMS makes the work easier. (Li 2006, 137)

3.2 The Application of ABCD Method

In order to provide backcasting from basic principles of sustainability for decision makers, help them make strategic decisions which could reduce the violation of sustainability principles and attain the sustainable development of transportation, the tool called ABCD method which is fitting and operative to guide decision makers in making strategies and actions in the right direction to approach the goal of moving the transportation in Shanghai towards sustainability could be integrated into DSS.

3.2.1 ABCD Method

ABCD method is a tool to apply backcasting from basic principles for sustainability (Holmberg and Robèrt 2000) efficiently. It includes four steps: A (Awareness), B (Baseline Assessment), C (Creative solutions) and D
(Prioritization), It starts with A step for understanding the system and success, and analyze the current reality in B step, and then create solutions in C step, finally, prioritizes the solutions which created in C step to achieve success. (Ny et al. 2006)

**Figure 3.1. The ABCD method of backcasting from sustainability principles**  
(Ny et al. 2006)

**A-Awareness**

In step A, the decision makers would know how to apply backcasting from basic principles for sustainability, assuring the way of using backcasting from sustainability principles and decide the usage of ABCD method. It is the basic work for decision makers to know the knowledge, information and usage about backcasting from sustainability principles.

**B-Baseline Assessment**
In step B, it is necessary and significant to analyze the aspects in the contribution of transportation system to respecting or contributing to violations of the 4 principles of sustainability. It is also an important step in the decision-making process and an efficient method to know the current situation of transport system in Shanghai. Decision makers could analyze the current condition of transportation system from the sustainability principles, and find problems and gaps between the current reality and desired future.

C-Creative solutions

In step C, decision makers would create creative and compelling initiatives and actions through brainstorming. Decision makers could apply backcasting from sustainability principles to create creative decisions having an envisioned future in mind and based on the analysis of current condition in transport system compared to the sustainability principles. The brainstorming solutions which decision makers propose could abide by the sustainability principles or decrease the contributions to violations of sustainability principles, which is a significant feature of sustainability society.

D- Prioritization

In step D, decision makers could prioritize actions which were created in step C to create a strategy to achieve success of transportation sustainable development step by step.

There are three guidelines for prioritizing actions which are (1) right direction, (2) flexible platform, and (3) return of investment. The details about these three guidelines are below:

I. Does this measure proceed in the right direction with respect to the principles of sustainability?

II. Does this measure provide a flexible platform for further improvements?

III. Is this measure likely to produce a sufficient return on investment? (Holmberg and Robèrt 2000, 296-297)
Based on the analysis of the present condition of transportation system in Step B, ABCD methodology provides 3 questions and decision makers also could list other criteria for choosing and prioritizing the decisions and measures which are listed in brainstorming solutions in the step C, each prioritization should comply with successful objectives and sustainability principles. On the other hand, the prioritizations should be feasible in economy and technology.

According to the introduction and analysis above, ABCD methodology is an efficient method and tool to help decision makers avoid making non-strategic decisions which would bring harmful influences on the process of moving the transportation in Shanghai towards sustainability. In order to ensure the decisions could be beneficial to move towards sustainability, ABCD method could be applied in the DSS, and decision makers could do the decision in the following of ABCD method.

In the processes followed by ABCD steps, decision makers need to discover sustainability problems carefully and present conditions fully and effectively from a systems view. However, sometimes it is difficult for decision makers to collect full data and information about the current reality of transportation on sustainability, to analyze the challenges and problems comprehensively, to propose and prioritize measures and decisions creatively and reasonably without functional support from DSS. It’s also beyond decision makers to predict the accurate results of decisions and get useful information without models and methods. Here is another point that not all decision makers have enough knowledge of sustainability and have the experience on sustainability in transportation and its relevant areas. Most of time, decision makers not only need a good process to follow, but also need a great deal of support.

In order to take an accurate and reliable analysis of current reality in transportation system compared to the sustainability principles, decision makers need a variety of data and information about the transportation in Shanghai. In addition, the analysis of current conditions is critical and fundamental work in the decision-making process. While the information collection, storage and processing is not only the base for accomplishing
the analysis of current condition, it is also one of the essential elements for finalizing others for decisions such as prediction evaluation and analysis. Therefore, it is vital to introduce a subsystem to deal with the data issues and provide the support which is relevant to data and information for decisions. Database system is such a subsystem which should exist in the DSS for finalizing this work.

For making compelling measures and prioritizing the proposed decisions in a rational sequence, DSS is expected to provide support for accomplishing complicated work such as calculation, evaluation, and simulation. These tasks need a number of methods and models. Through the methods and models, decision makers could gain scientific results in the different kinds of work. So methods and models are the important roles in decision-making process, and DSS should have two components which could realize the functions of these two parts. That is the reason for introducing the model base system and method base system.

It is necessary to supply knowledge which the decision makers are not familiar with and the problems in which decision makers have less experience. So DSS should have one component to assist decision makers when they acquire relevant knowledge regarding transportation, computer-based systems and sustainability. It is also necessary to supply decision makers with experience, solutions from experts and case studies to help them solve unfamiliar problems lacking of experience. So it is necessary for the computer-based system to have the knowledge base system to help decision makers.

The computer-based system based on the DSS applies backcasting from sustainability principles and ABCD method, which has the three sustainability modules and four base systems for guiding decision makers to apply ABCD method and providing data, methods, models, experience and knowledge. Due to the fact that purpose of this tool is moving transportation towards sustainability; the authors named it the Transportation Sustainability Decision Support System (TSDSS).
3.3 The Transportation Sustainability Decision Support System (TSDSS)

The Transportation Sustainability Decision Support System (TSDSS) is a system combining sustainability methods and transportation based on a Decision Support System. The purpose of this system is for affecting the decision-making processes in order to move transportation system in Shanghai towards sustainability. The TSDSS is made up of 9 parts including three sustainability modules, database system, model base system, method base system, knowledge base system, man-machine interaction system, and multi-base coordinator. The architecture of the TSDSS is as below:

![Architecture of TSDSS](image)

*Figure 3.2. The architecture of the Transportation Sustainability Decision Support System (TSDSS)*

3.3.1 Database System

A database system is such a system which could store data in it, provide
data for users and transfer data to another part in the system. The database system consists of three parts, which are database, database management system and data dictionary. As shown in the following figure:

**Figure 3.3. The architecture of the Database System of the TSDSS**

A database contains data and information extracted from the database of the government, external databases, decision makers’ personal databases, and it also includes summarized data and information most needed by decision makers (Li 2006). The data involves many types of content such as documents, numbers and images.

In the TSDSS, the database has three classes of information: the urban information of Shanghai, the transportation information of Shanghai, and the information that has a connection with sustainability.

- The urban data of Shanghai mainly includes geographic data, climate data, population data, economic data, financial data, administrative data and legal data.
The transportation data of Shanghai is primarily made up of historical transportation data in Shanghai, airline data, highway data, water transportation data, railway data, bus data, car data, and taxi data.

Sustainability-related data in the TSDSS is composed of energy information, material information, environmental impacts information and social impacts information.

- Energy information: energy consumption, energy efficiency, energy price, energy structure.
- Material information: material consumption, material stock, material price.
- Environmental impacts information: impacts on air, water, green land, soil, vegetation, animals, noise, vibration, temperature.
- Social impacts information has main four aspects: the influence on city, economics, transportation and people.

1) The influence on the city: Urban structure, regional planning, land use, population distribution.

2) The influence on the economy: Economic development, financial support, real estate values.

3) The influence on transportation: Traffic network, traffic structure, traffic operations, traffic management, traffic lines, traffic flow, traffic safety and traffic congestion.

4) The influence on people: Personal trips, quality of life, living habits, passenger satisfaction, resident satisfaction, passenger safety, resident safety.

Database Management System (DBMS) is a set of computer programs that controls the creation, management and accessibility of the database (Eom 2001), as well as controls the storage, organization, retrieval, manipulation, maintenance and presentation of the data elements. The DBMS accepts requests for data from the application modules and instructs the operating
system to transfer the data. Users could change and modify the database system much more easily with a DBMS, and also could add new kinds of data into the database without rebuilding and reconstructing the existing system.

The data dictionary is a database of information about the database. It is a "centralized repository of information about data such as meaning, relationships to other data, origin, usage, and format." (IBM 1993) The data dictionary gives a detailed description of their data sets in according to a certain order, which is based on the basic unit of data in the database.

The database system is one of the basic systems in the TSDSS. The database system in the TSDSS has a large number of data and information, besides this, it has many links to data and information from external systems. Correspondingly, the data which could be retrieved and used by decision makers in the database system is from two sources: one part is from the internal database itself in the TSDSS. The other part of the data is from external database in other systems of relevant departments and organizations.

The database’s structure can avoid data and information redundancy and prevent the database in the TSDSS system becoming too large. On this account, the database only stores the necessary data which does not exist in the external database. This makes it easier to maintain and update the database, leads to decreasing the human-resource cost, financial cost, materials cost and time cost. It realizes data transmission and information sharing among different departments and organizations and is beneficial for avoiding lack of information and decision uncertainty. In the decision-making process, the users could create, add, modify and update data when the decision makers need new kind of data and the obsolete data could not reflect the latest condition and development so that the new data could help users make far-seeing decisions.

Data is an important base for making correct decisions. The complete and correct data about transportation and urban information provides the right description and reflects the social condition and environmental situation for decision makers. Otherwise, incomplete data or incorrect data and
information could influence the timeliness and correctness of decision. Certainly, coincidence with the actual situation is prerequisite of implementation. The TSDSS supplies with a variety of information on transportation and sustainability. Thus, based on the information stored in the database and the analysis of this information, the decisions of transportation will be coincident with the actual facts such as the population growth, economic growth, transportation development, environmental condition, and passenger needs. In other words, the database makes decisions more beneficial for moving transportation towards sustainability.

3.3.2 Model Base System

The model base system includes a library of mathematical models and analytical techniques stored as programs, subroutines, spreadsheets, and command files (Li 2006, 136). The base also provides model programs and an interface for users to build application programs. Decision makers can also use the model base for prediction, choosing, analysis and evaluation (Lin et al. 2000). The model base system is the most important and indispensable part (Xiao and Fei 1992) of DSS and it consists of model base, model base management system and model base dictionary. As shown in the following figure:
Figure 3.4. The architecture of the Model Base System of the TSDSS

The building of models is based on the demand of problem-solving. For different projects and aspects in transportation, decision makers have different demands and help, so they need a variety of models to support their decisions. Users could use the different kinds of models in the system, and could build, modify, and run models through modeling language.

The model base is a set of various kinds of models stored in computer; it consists of a lot of program modules. There are a great many models stored in model base, primarily, it covers prediction model, construction model, competition model, analysis model, evaluation model and simulation model.

The prediction model involves prediction model of population, traffic distribution, transportation demand, trip generation, energy demand and material demand.
The construction model is made up of urban construction model and transportation construction model. The latter model includes road construction model, railway construction model, transportation junction construction model, port construction model and airport construction model.

The competition model has external competition and internal competition, and it could reflect the internal and external interactive competition relationship of different kinds of vehicles. Internal competition could reflect the interactive influence of changing among lines, frequencies, stops and others. This interaction is in a variety of traffic conveyances in the same transportation mode, like the influence of bus development on the number and efficiency of bicycle. And external competition could reflect interaction in a variety of traffic modes, like the influence of the development of railway transportation on road transportation.

The analysis model and evaluation model are used to analyze and evaluate the effects and feasibility of decisions. The evaluation of effects resulting from decisions includes environmental impacts evaluation and social impacts evaluation. The feasibility analysis model is used for analyzing feasibility which is an essential feature of a decision and it is the prerequisite for practice; it means feasibility analysis is an important process and work before implementation of a decision. It has four sub analysis models: economic feasibility, technical feasibility, operational feasibility and social feasibility. The environmental impact evaluation model is a sub model which is used for the analysis and evaluation of the environmental impacts relating to transportation decision and transportation development on air, water air, water, soil, vegetation, animals, noise, vibration and temperature. Social impacts evaluation model is a sub model which is applied to analyze and evaluate the social impacts resulting from transportation development. These social influences caused by transportation development consist of varying effects on city, transportation and residents. First, city impacts include urban structure, regional planning, land use, population distribution, economic development, land and real estate values. Transportation impacts include traffic networks, traffic structure, traffic operations, traffic management, traffic lines, traffic flow,
traffic safety and traffic congestion. Finally, impacts of residents comprise the impacts on personal trips, quality of life, passenger satisfaction, resident satisfaction, passenger safety and resident safety.

It is difficult to get accurate results through analytical study. So it is necessary to make analysis and experiment through simulation model. The simulation model plays an important part in the decision-making process and it could avoid a number of problems which can easily be omitted before applying it. It has a macroscopic simulation model and a microscopic simulation model.

The macroscopic simulation model is composed of urban simulation model, transportation simulation model, meteorological damage and geological hazard simulation model. The macroscopic simulation model is mainly used to simulate the situation from a big structure and range. It not only can simulate the present condition which the decision makers should know before they make decisions, but also it can simulate the condition after the decisions were taken into practice. The macroscopic simulation model could help decision makers check the accuracy and feasibility of their decisions, find the challenges and problems which should be paid attention to, and discover the disadvantages and faults which should be modified immediately. So this model could reduce the financial cost, and at the same time, it avoids increasing the contribution to the violation of sustainability principles such as decreasing the damage to environment.

The microscopic simulation model could simulate each individual and unit in the transportation activities. It is composed of a simulation model of passenger behavior, disabled passenger behavior, as well as vehicle and pedestrian behavior. The microscopic simulation model could allow decision makers to simulate the experience of passengers, drivers and pedestrians, so they could clearly understand the needs and satisfaction of those groups. Hence, it is conducive for decision makers to make compelling decisions which should satisfy the needs of different groups. These advantages include decreasing passenger inconvenience, shortening trip times, increasing traffic safety, and decreasing traffic accidents.

The model base management system is a set of computer programs
embedded within a DSS generator that allows users to create, edit, update, and/or delete a model (Eom 2001). It is a centralized control system for model establishment, operation and maintenance. This system usually includes: Model establishment and maintenance, providing model language and executing module access, composition and operation, establishing a dynamic link with database to realize the models input, output and interim result access, establishing dynamic link with method base to realize retrieval of target, sensitivity analysis, simulation and so on. It accomplishes the static and dynamic management of models and provides interface operations among base management systems. (Wang, Huai and Xia 1998).

The model dictionary stored the introduction and information of model and model base. Users could search the relevant content of them. This dictionary could introduce and describe the connection and relationship among different models and other systems.

3.3.3 Method Base System

A method base system is a set of programs that includes statistical analysis of data, economic-mathematical methods and other utility programs. The method base system consists of three parts: method base, method base management system and method dictionary. As below:

![Method Base System Diagram](image)

*Figure 3.5. The architecture of the Method Base System of the TSDSS*
The method base is used for methods storage and consists of algorithms, possesses favorable commonality and flexibility, which are the components of all manner of mathematical models. The method base stores many kinds of numerical methods and non-numerical methods and these methods include prediction methods, statistical methods, optimization methods and mathematical methods. Each of the methods is used for different aspects and objects, but most of them are use in comprehensive decisions.

The method base includes 6 main methods: basic mathematical method, statistical method, optimum method, prediction method planning method and financial method, which is illustrated in Table 3.1 as shown below.

- Basic mathematical method is made up of elementary function algorithm, interpolation algorithm, fitting method, smoothing method and extrapolation.
- Statistical method comprises the regression analysis, variance analysis, binary correlation analysis, factor analysis, discriminatory analysis.
- Optimum method includes linear programming solution.
- Prediction method has time series methods.
- Planning method contains program evaluation and review technique and matrix algorithm.
- Financial method includes financial ratio and statement method.

<table>
<thead>
<tr>
<th>Method Base</th>
<th>Basic Mathematical Method:</th>
<th>Statistical Method:</th>
<th>Planning Method:</th>
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<td></td>
<td>Elementary function algorithm</td>
<td>Regression analysis</td>
<td>Program evaluation</td>
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<td></td>
<td>Interpolation algorithm</td>
<td>Variance analysis</td>
<td>Review technique</td>
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<td></td>
<td>Fitting method</td>
<td>Binary correlation analysis</td>
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<td>Smoothing method</td>
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<td>Optimum Method:</td>
<td>Linear programming solution</td>
<td>Prediction Method:</td>
<td>Financial Method:</td>
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<td></td>
<td>Time series methods</td>
<td>Ratio and statement method</td>
</tr>
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</table>

*Table 3.1. Six main methods of the Method Base System*
The method base management system provides manipulation of methods adding, deleting, modification and retrieval and service for method operation (Wang, Huai and Xia 1998). It is a centralized control system to manage method modules and the main functions are method storage, method classification, method description, safety projection and Computer-Assisted Learning.

The method dictionary stores the relevant information to method itself, for instance, categories, function, and call method, parametric form of method and so on, for finalizing method programme logon, provide required information on programme study and connection with other bases establishment.

3.3.4 Knowledge Base System

The knowledge base system is a system that helps decision makers by providing artificial intelligence assistance (Akerkar and Sajja 2010) and knowledge information based on the experience of experts in related fields in decision-making processes and problem-solving processes. Most of decisions need much knowledge and data. In accordance with this condition, a large amount of data often requires their introduction and interpretation for helping decision makers understand their definition and application. The knowledge base system includes three parts: a knowledge base, knowledge base management system and knowledge dictionary. As shown in the following figure:
Knowledge base is a special kind of database for knowledge management, providing the means for the computerized collection, organization, and retrieval of knowledge. Also a collection of data representing related experiences. (Rahwan and Simari 2009)

There is a variety of knowledge and experience organized in many forms such as data, record, article and words, which is stored in knowledge base. The knowledge and experience is classified in two ways. The first classification is according to knowledge field like the relevant knowledge on sustainability or specialized knowledge on transportation. The second classification is according to the steps where decision makers will need relevant knowledge.

- Class B: past evaluation result, the introduction of assessment index, use rules, case studies, and experts’ evaluation, suggestion and experience.
- Class C: excellent case of past measures and projects, the introduction of new technologies and methods, case studies, experts’ experience tips on solutions. This class of knowledge could help decision makers brainstorm and stimulate their thinking for making decisions.
- Class D: criteria and rules for prioritizing.
The knowledge base management system is a system which stores and manages artificial intelligence tools. These tools can obtain knowledge from past data, decisions and cases, and contribute to supporting decision making (Eom 2001).

Knowledge dictionary stores the information of knowledge which is stored in knowledge base. It is useful for users to search, study and assess the desired knowledge conveniently.

3.3.5 Three Sustainability Modules

The TSDSS has three sustainability modules: Module B, Module C and Module D. They are designed according to the ABCD method. Module B is designed based on step B of ABCD for analyzing current condition compared to the sustainability principles. Module C is used to encourage decision makers in making possible decisions in step C of ABCD. Module D is used for supporting decision makers in prioritization of decisions in step D of ABCD.

Module B is used for analyzing the current condition compared to the sustainability principles and displaying the results for decision makers. The data which is stored in the database and reflects the present condition of transportation in Shanghai is the main analysis objective for Module B. In the analysis process, decision makers could choose region scope and objective scope. Then Module B will analyze the selected or whole scope in accordance with the decision makers’ requirement through specific methods. The benefits of Module B are not only in the results of analysis compared to the sustainability principles but also in understanding of status quo for decision makers. The results which are achieved in Module B are the base for creating decisions in Module C.

Module C is used in pointing out the opportunities for decision makers. Not all aspects would be possible to be changed immediately. This module will highlight the significant aspects which are possible to be changed based on the analysis of these aspects which increase contributions to the violation of the sustainability principles in Module B. The work of Module C makes decision makers pay much attention to focal points and optimize what
decision makers could do in current conditions. Decision makers could make certain decisions and measures in compliance with the suggestions from Module C, but they could also choose the serious sides and take improvement in them by decision makers’ own knowledge, experience, understanding and interpretation or through brainstorming. The decisions which are made in Mode C are in the primary choosing scope for the prioritization in Module D.

Module D calls a lot of relevant data, models and methods to support decision makers realize work of prediction, evaluation, analysis and simulation in the compelling decisions which proposed in Module C. It could tell decision makers what will happen in society and nature when these decisions will be taken into practice and it is a beneficial way to inspect the validity and value of each decision. Finally, decision makers could choose and prioritize the excellent decisions through screening.

3.3.6 Multi-base Coordinator

The multi-base coordinator in the TSDSS would connect database system, method base system, model base system, and knowledge base system with each other, to establish information links between different bases. At the same time, the information retrieval would be shown as well as the composition among different bases, and the output will be transferred into different modules. The multi-base coordinator would become a very important link for the TSDSS, and become a bond and bridge between different basic bases and different models.

3.3.7 Man-machine Interaction System

The man-machine interaction system is a dialogue system between users and the TSDSS, it helps decision makers make correct decisions while unlocking their judgment and creativity through the input of different kinds of relevant information like data, model, method, experience and judgment and the output of results. The man-machine interaction system has three functions: firstly, it allows users to create, add, update, modify and delete data, models, methods and knowledge via their individual management systems; secondly, it provides a variety of input and output formats
including tables, forms, color graphics and multiple windows; thirdly, it provides different styles of dialogues (such as menus, graphical user interfaces, many kinds of languages, form interaction and questions and answers).

### 3.4 Process and Flows of the TSDSS

In order to clearly introduce the process of the TSDSS, it is necessary to illustrate with an example, which is based on a hypothetical implementation of the tool in Chuansha, a town that serves as a transportation hub in the Pudong area to the east of Shanghai. If decision makers in Chuansha wanted to relieve road congestion and increase the traffic efficiency, they could make decisions to achieve this goal with the support from the TSDSS. In order to ensure the process of decision-making and the TSDSS manipulation will be operated in proper, correct and skillful way, they should attain elementary knowledge of the TSDSS, sustainability, sustainability principles, backcasting and ABCD methods through the information stored in knowledge base system. They could also be trained in an outside course or workshop.

After man-machine interaction system login, decision makers could operate the TSDSS through this system. In the whole process, decision makers should have their own envisioned future, for example, the interval of bus does not exceed 10 minutes, there will be few traffic jams in rush hour, and the future transportation in Chuansha will decrease the contribution to violation of the sustainability principles significantly. And then decision makers should keep this desired future in mind and backcast from the vision to focus on the present condition in Chuansha. They could know much information about Chuansha through the information which is stored in database. For example, the population, economic information, traffic distribution and the number of bus lines, bus stops, metro lines and metro stops, which is fundamental and important for decision-making. The most important advantage of the TSDSS is that much information could be shown to decision makers, which was hiding behind a mass of figures.
After knowing the necessary information, decision makers will call up Module B for analyzing the current situation of transportation compared to the four sustainability principles, they could choose the area scope and the objective scope like the area scope is in Chuansha and the objective scope does not include aquatic vehicles, so it is no need to analyze the aspects of aquatic transportation. Module B will analyze the current conditions compared to the sustainability principles with the support from database, method base, model base and knowledge base in accordance to decision makers’ requirement. Due to the complete and accurate data stored in database and the specific methods and models provided by the TSDSS, the analysis of current condition would be accomplished in a scientific way with the increasing accuracy and completeness. After the analysis of present situation, several problems which increase the contribution to the violation of 4SPs are shown on the screen.

In this case, such results of the analysis compared to the sustainability principles would be listed as below:

- In SP1, A large amount of fossil fuels are consumed in the activities of transportation, especially, in transportation construction and vehicle fuels.
- In SP2, There is a danger of contamination from man-made waste, like the exhaust gas polluting the air.
- In SP3, A lot of large-scale projects of transportation construction not only affects the planting and growth of crop and plants but also damages terrain.
- In SP4, The roads are always blocked to traffic during the rush hour; buses and pavement are overcrowded, not enough bus lines and transportation facilities in Chuansha.

All these results are based on the analysis of relevant data and information. Decision makers could also know many details about the results, such as the amount of consumption of fossil fuels, the amount of automobile exhaust, and the percentage of greenery coverage. This information could increase the understanding of current conditions in order to improve the veracity of the decision-making. From the results and details, decision
makers could know the aspects which make contributions to the violation of the sustainability principles and the degree of contributions clearly by the right description of each aspect.

Module C will point out the problems and aspects of transportation in Shanghai which are possible to be improved based on the analysis of current reality from the 4SPs for helping decision makers create decisions and measures to deal with sustainability challenges. These directions and aspects are for decision makers’ reference, it narrows the range and shows the vital problems where decisions makers should focus on. In this module, decision makers could gain the relevant knowledge on their measures and obtain experts’ professional solutions and past experience from the information stored in knowledge base, if they need specialized knowledge on transportation and sustainability or experts’ experience and suggestions.

Decision makers could create and propose a lot of decisions to increase the efficiency of transportation through brainstorming in which decision makers could share their opinions and ideas with each others. Meanwhile, the TSDSS can give decision makers advices in according to the analysis of the results of Module B. For instance, the TSDSS could list such advice: An optimization of transportation structure and an expanding underground transportation network could decrease and minimize the disturbance of vegetation and ease the tension in land use. Public transportation priority could reduce traffic jams, and the improvement of the bus stops and passenger trip condition could provide convenience for passengers and pedestrians. Even though the decisions could have a strong connection to the analysis from SPs and the scope or area which the TSDSS recommended, decision makers could give still use their originality and creativity. Decision makes could decide whether optimization of transportation structure, underground transportation development, public transportation priority and the improvement of transportation facilities can improve the condition of traffic congestion and decrease the contribution of the violation of the 4SPs.

In Module D, the models and methods stored in model base and method base could tell decision makers the real condition when the decisions are
carried out. It could realize the assessment of the social and environmental interactions. These social impacts embrace the effects on the transportation structure, economic development, traffic flow, passenger trip condition and so on. The environmental impacts comprise the influence on energy and materials usage, air quality, and urban temperature. It is beneficial to find more problems which were not expected, to avoid the increasing of the waste of finances, material resources, and human resource and so on which are resulting from decision-making error and to improve the transportation decisions before implementing it.

The TSDSS could prioritize the measures created in Module C based on several criteria; the first one is advanced by decision makers before or in the process of decision-making. Decision makers could have their purpose and objectives on transportation development, environment protection, passenger satisfaction and safety or others, the better decisions, which are more helpful to achieve the goal than others, should be given preference as well. The second one is based on the evaluation of results by models and methods. The third one is the three guidelines for prioritizing actions which are (1) right direction, (2) flexible platform, and (3) return on investment. The fourth one is feasibility. Feasibility is an important character of measures which could be taken into practice. This feasibility analysis not only includes economic feasibility, but also technological feasibility, operational feasibility and social feasibility. On the other side, unworkable measures will trigger serious problems such as the aggravation of transportation condition, the decreasing of passengers and residents satisfaction, the increasing of resource waste and so on. Nevertheless, it is difficult and incomplete to make a concrete feasibility analysis of a big transportation project only by experience and knowledge without computer system and prediction. For this reason, the feasibility analysis is an essential function provided by the bases in the TSDSS.

Decision makers could use the methods and modules provided by the TSDSS to choose and prioritize the decisions which are proposed in Model C. Decision makers only need to choose related items such as simulation, feasibility analysis and social evaluation, and relevant methods and modules will work and provide specific functions like analysis, prediction,
simulation and evaluation. In this case in Chuansha, decision makers proposed some decisions which could decrease traffic jams in the previous module, so decision makers could use construction model which could open out the construction appearance, calculate costs, and display the process of contribution projects when decision makers want to optimize the structure of transportation. Underground transportation development would bring big impacts on buses or other vehicles. Competition model could get the quantified results to describe and reflect the relationships. Decision makers could simulate the traffic flow and traffic condition when the public transportation priority will be implemented and simulate themselves as each individual and unit in the transportation like passenger, vehicle and disabled, which is beneficial for decision makers to know the transport operation and human needs. Each decision could go through a feasibility analysis and influence evaluation to obtain results of objective analysis. Through the support from the two bases, decision makers could know the benefits and shortcomings of each decision, which is favorable for choosing. With the functional support from Module D, decision makers could choose and prioritize the decisions which could promote the goal achievement and moving towards sustainability in Chuansha.

Most of time, the methods and models are used together to increase accuracy, get precise results and make accurate judgments and decisions. Decision makers could ask the TSDSS to choose and prioritize decisions for them based on the results of modules and methods. Otherwise, they could decide through their own judgment and criteria.
4 Discussion

4.1 The Expectation of the TSDSS

Designing a computer-based system which is based on the improvement of decision-making process in transportation and combined with methods and tools of sustainability for moving transportation system in Shanghai towards sustainability is the overriding work in this paper. So the authors wanted to create a computer-based system which could be implemented in the decision-making process. In this computer-based system, the authors wanted to design the architecture, components and functions of this system, and apply some methods, concepts and tools of sustainability into the computer system and the tool could help the information exchange and processing more rapidly. Moreover, it could help decision makers make reasonable and systematic decisions, as well as avoid the adverse effects of mistaken decisions. Meanwhile, this tool would use some methods, concepts and tools of sustainability to achieve the aim of helping the transportation in Shanghai system towards sustainability.

Finally, the TSDSS realized most parts and functions of the authors’ expectation in the tool design process. The TSDSS could make contributions to solving the problems of Shanghai transportation system and moving the transportation system towards sustainability through improving decision-makings process. After authors created and designed the TSDSS to combine the decision support system with the concepts of sustainability, it is advantageous for decision makers to improve process and achieve goals easier than before due to the favorable aspects of the TSDSS on sustainability. It has three sustainability modules (B, C, and D) and four base systems. Through the support from these components in this systematical tool, decision makers can make excellent, far-seeing and sustainable development decision applying backcasting from sustainability principles to achieve the aim effectively and to move Shanghai transportation system towards sustainability.
Even though the TSDSS could realize a lot of functions and complete many tasks for decision makers, one significant point should be stressed that an important feature of the TSDSS is decision support not decision making. It could support the decision makers to make decisions which can offer the effective ideas and efficient process; however, it could not be used to replace decision makers by making decisions. Undoubtedly, human judgment is still desired or required (Kendall and Kendall 2002). In the TSDSS, decision makers are encouraged to develop their creative and subjective judgment, because creative and comprehensive ideas and vision are very important in the decision-making process. However, the cannot solve these problems, all its functions are based on the regulation and methods what it already has in its system. For example, in many designs and constructions which have the same functions, humans could choose the better one from the aesthetic view, but it is difficult to achieve using a computer-based tool. So in the application process of the TSDSS, the most significant role is still decision makers, while the TSDSS is only an assistant.

But there is still one aspect which is not compatible with the expectation. At first, the authors wanted to design four modules, and each module realizes the function and accomplishes work followed by each step in ABCD. But in the process of study, it was difficult to transform step A into a computer module, because step A is relevant to awareness which is about understanding of sustainability, the basic cycles of nature, the 4SPs, backcasting and the ABCD method. The authors bring the relevant work into the knowledge base system, so decision makers could know the relevant information when they need. Another potentiality is that step A is considered as a study module; it could actively teach decision makers about the methods to apply the ABCD method. This idea has one advantage that decision makers could have enough knowledge about the ABCD method before they perform other work. If users had already attained enough knowledge, it could be performed or skipped depending on decision makers.
4.2 The Strengths and Limitations of the TSDSS

4.2.1 Strengths

The TSDSS could increase the accuracy and efficiency of information processing and the effectiveness of decisions. It could deal with the problems of the storage, retrieval and management of data, models, methods and knowledge. With the support from the TSDSS, decision makers could use the data, model, method and knowledge rapidly, conveniently and effectively. It could store a wealth of data, information, models, methods and knowledge. Because there are a large amount of data stores in external databases, the internal database only stores indispensable data and information which don’t exist in external database and it has many links with other databases in related departments. This kind of database can reduce the redundancy of information, exchange information effectively and make the decision makers devote themselves to make the effective and high-level analysis of data and information. In the model base, it stores many models which could realize and finalize the specialized purpose for decisions. Through a series of models, it is probable to reflect the internal influence and external influence in Shanghai transportation system and make an assessment and forecast on vast arrays of aspects in different ways, which is a critical and irreplaceable tool for decision makers to make plausible decisions, analyze the impacts of these decisions and simulate the conditions when they are carried out. In the method base, it has many methods, which would be used in the operations in the TSDSS. These methods could get the exact results and accurate calculations to promote decision makers make the efficient and correct decisions for Shanghai transportation system. In the knowledge base, a lot of knowledge is stored in it, such as the concepts of sustainability and the knowledge of Shanghai transportation system, which could allow the decision makers to familiarize themselves with the relevant knowledge on sustainability.

The TSDSS could make a contribution to moving the transportation in Shanghai towards sustainability. The TSDSS integrates the ABCD method into the decision-making process. So it could help the decision
makers understand the decision aim and sustainability goal clearly and sufficiently, to guide them on applying backcasting from the sustainability principles, to effectively avoid the pernicious effects of decision fault, especially, the violation of the sustainability principles. Meanwhile, the TSDSS can help decision makers make a reasonable, long-term decision for sustainable development of transportation in Shanghai and move it towards sustainability.

**The TSDSS has an opportunity to be a generic tool used in many other systems.** Even thought the TSDSS is used to encourage decision makers make strategic decisions related to transportation in Shanghai and move it towards sustainability in this paper, the TSDSS has an opportunity to be a generic tool with modification for the decision-making in most of transportation systems and many other systems as well. Many conditions and aspects such as population growth, economic growth, technology development, environment impact, resources scarcity, demand diversification, and serious problems are different in other transportation systems and other systems. In order to enhance the quality and effectiveness of decision and realize the purpose of moving towards sustainability, system designers need to consider about specific aspects in the modification of the TSDSS like the population, landform, vegetation, environment, geographic location, the economic growth, the condition of transportation, the condition of society, culture and the custom. So the data, methods, models and knowledge should have a strong relevance to the systems which decision maker focus on. It is suitable for implementing in other transportation system, and it is also suitable for decision-making in many other systems with creating, adding and adjusting.

**The TSDSS is easy and reliable to operate.** The TSDSS is a user-friendly tool which has its management system, interaction system and coordinators. They could help decision makers operate the TSDSS, add, manage, maintain, modify, transfer data, model, method and knowledge. Decision makers could realize the most of functions without profession knowledge on information system.
4.2.2 Limitations

However, as a computer-based system for moving the transportation system in Shanghai towards sustainability, the TSDSS still has its limitations and shortages in addition to advantages and strength.

Firstly, the TSDSS just focuses on the decision-making process and affect other extended work in transportation such as construction, management and maintenance through strategic decision, which is illustrated in the Figure 4.1. And it couldn’t affect extended work directly. Even though decision-making is a basic and essential part in transportation planning and implementation, that doesn’t mean an excellent decision could attain a desired result which has a tight connection with other work. So there is a need for other factors to be taken into consideration which are not easy to control and predict in the process of decision implementation. So the TSDSS could not realize the same function and goal on other work, which should be improved. For example, the TSDSS just focuses on the improvement of decision and it is beyond its function to work on the implementation including construction, management and maintenance after making the decision.

![Figure 4.1. The focus of the TSDSS and the process from decision to practice](image)
Secondly, the TSDSS needs a lot of people to update, modify and maintain every base, module and system. It can help the decision makers deal with work like storage, retrieval and usage of data, information, models, methods and other materials, to improve decision-making process, to quantize and assess the current condition and decision of transport in Shanghai, but it needs users taking part most of time in the process of the TSDSS. So artificial intelligence would be one of the future researches in the decision support system, in order to use it for decision makers conveniently, effectively and efficiently to make much more strategic decisions for improving transportation system in Shanghai.

Finally, due to the character of computer, the programmed execution couldn’t solve such sustainability problems which have never appeared in the past. Likewise, the TSDSS couldn’t support decision-making relating to new sustainability challenges relies on past data and unsuitable model. In order to use the TSDSS to solve new issues, adding new data and creating relevant method and models are significant.

4.3 Research Finding:

It is possible to put the concepts, methods or tools of sustainability into a computer system. This study is an attempt to integrate the Framework for Strategic Sustainable Development into a computer system. The authors proposed the idea that applies sustainability in the TSDSS. Firstly, it is possible that during the analysis of current conditions compared to the sustainability principles, the process could be accomplished by humans, but also could be finalized by the computer. With the support from the TSDSS, it is not difficult to assume that the analysis by computer could enhance the validity, reliability and correctness of analysis. Secondly, the ABCD method could be applied in the computer system, which could promote the analysis, evaluation and prioritization are done in scientific and quantitative way and move towards sustainability. Even though it has some shortcomings which need to be improved, it is still a good further research direction that the combination of computer and sustainability.
People could use the computer to connect sustainability with their work. In this study, the authors merged success of sustainability fully with the transportation in Shanghai. Decision makers would learn and master foundational and professional knowledge on sustainability gradually in the process of making transportation decisions, they would treat sustainability as the goal of development unfalteringly, they would establish their professional judgment consciousness on the influence and feasibility of decisions which they proposed, and they would accumulate practical experiences of implementing the methods and tools of sustainability in decision-making constantly.
5 Conclusion

5.1 Summary

Sustainable transportation is integral to a sustainable society. Absolutely, it could bring virtuous circle or benign development for economic growth, environmental protection, resource conservation, life quality and so on. This study intended to create a tool for moving transportation in Shanghai towards sustainability. A number of problems became progressively worse in Shanghai and decision-making failures make the current conditions worse. For achieving this goal and solving decision making problems, authors designed the TSDSS, which applies the concepts, methods and tools of sustainability for serving decision makers.

It requires complex system engineering to establish the TSDSS. Authors studied the approach in the application of sustainability method in the TSDSS in this paper, proposed the architecture, components and functions of the TSDSS and decision-making process, as well as combining it with the ABCD method. On the account of its advantages in the functions of calculation, analysis, evaluation, prediction and simulation, it could be a more helpful support tool for transportation decision makers, and help them make excellent decisions for strategic sustainable development in transportation in Shanghai in comparison with applying of ABCD tool or implementation of DSS separately.

5.2 Further Research

A first suggestion for further research that could be built from this work could be the improvement of artificial intelligence of the TSDSS would be improved. It could reduce manpower costs in the collection, update and maintenance of system with the development of artificial intelligence of the TSDSS. Decision makers could exert their subjective judgments and focus on high-level decision processing based on the high-quality and high-grade
artificial intelligence, and to form a system theory and basic framework.

A second suggestion would be integrating more methods and tools related to sustainability into the TSDSS. It is beneficial to put more into the TSDSS. It not only could improve this tool, but also support decision makers with methods and tool of sustainability in decision-making process. How to apply and execute Step A in a computer is a further research in order to raise the consciousness of applying backcasting from sustainability principles.

Establishing a platform in the TSDSS for collecting and analyzing opinions and feedback of citizens would be a third suggestion. This would be a good way to reflect the current condition of transport from residents and passengers, and evaluate decisions through people’s feedback. These two points could help the decision makers of the Shanghai transportation system make excellent people-oriented decisions on transportation.

A fifth further research could focus on establishing an assessment system which could assess whether the implementation is on the right track to the goals of decisions. The staff in the implementation such as construction, management and maintenance could reflect the condition when decisions were taken into practice to decision makers through this assessment system. At the same time, decision makers could know the details and the process of the condition and get feedback from staff. So the assessment system could inspect whether the implementation of the decision is the same as what decision makers predicted in decision-making process. If anything was different from decisions or some aspects had problems, decision maker could reexamine the decisions or encourage staff to improve the implementation in order to ensure the decision and implementations are moving on the right way towards sustainability.
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