Chapter 1

Overview of Transportation System Engineering

1.1 System Engineering

1.1.1 Conception of System

Which era do our human beings live in? How can we name this era?

Someone said that this is a post-industrial era. They proved that, industrialized process began with the usage and the improvement of the steam engine, which is the symbol of the industrial revolution. Then, thanks to the electric revolution and nuclear revolution, we reached the end of the industrialization. In the late twenties, people set foot in a post-industrial era.

Someone said that we are in an era of knowledge-based economy. The knowledge-based economy was proposed by OECD (Organization for Economic Co-operation and Development), United Nations, in the report "*The knowledge-based Economy*" in 1996. One of the symbols of the knowledge-based economy is to recognize the importance of knowledge's diffusion as well as its production, and this economy appeared after the Nomadic Economy, Agricultural Economy and Industrial Economy. Knowledge-based economy is a kind of new economy relying on the class of intellectual. It is sourced by the knowledge and information, supported by high-tech industry and tertiary industry, driven by human resources and technological innovation, and characterized by the sustainable development.

Someone said that we are in an era of cyber economy. In the 1980s, Internet came to our life. Nowadays, information network based on advanced computer technology and communication technology has been widespread and played an increasingly important role in every part of our lives. E-commerce, electronic government affairs, network institution, distance education, remote medical treatment, electronic medical records, online shopping, online booking, online retrieval, email, MIS (Management Information System), HIS (Hospital Information System) and 'golden' projects (tax, custom, security, sanity, etc.) have entered our work and life imperceptibly. We have to admit that the network is indispensable to our humans.

Someone said that this is an era of new economy. They are probably not satisfied with what have

been mentioned above, so they introduced the term ‘new economy era’. Actually, it’s an expedience. ‘New’ and ‘old’ are opposite. The ‘new’ represents a situation where the new things emerge in an endless stream and keep pace with the times. Our current economy is the ‘new economy’ comparing with the industrial economy. But, I’m afraid that, another one hundred or several hundreds of years later, the current ‘new economy’ would become also an ‘old economy’. Nevertheless, it is reasonable for a temporary use of this definition to emphasize the ‘new’ factors of our current economy.

Someone said that this is an era of computer. Since the appearance of the first computer ENIAC in 1946, computers have upgraded continuously and the renewal period is getting shorter. Looking at the development of computer, tube computer was the dominant in the 1950s. Transistor computer developed in the late 50s to mid-60s. At the end of the 60s to late 70s, the dominant was the integrated circuit electronic computer. Since the late 70s, large scale integrated circuit and very large scale integrated circuit electronic computer played an important role. The rapid development of computer makes it possible for other application fields to develop in a short time, such as text format, data processing, communication, design drawing, education training, and various management jobs. The computer becomes one of the indispensable parts of our lives. Electronic computers are called ‘electronic brain’, indicating that we cannot live without them.

Some other people argued that we are in an era of information. In the 1940s, the man finally found out that the world consists of three elements: substance, energy and information. It is not composed by only substance, or two of those three elements. At the moment, no one can deny the existence and function of information. Furthermore, everyone accepts and uses information. We can find the unprecedented functions and means of information processing in a wide range of ways. Information networks, information superhighway, e-commerce, e-government, etc. are changing human’s working habits, life habits, even, the way of thinking. Distance is no longer a barrier for us and the earth is getting smaller thanks to a wide variety of information communication.

There are also some people arguing that we are in an era of nanometer. Nanometers (nm) is a unit of measure. 1 nm equals to one over one billion of 1 m, equivalent to the length of the 10 hydrogen atoms getting a line up. Nano-structure refers to the scale of structure between 1 and 100 nm. Within this extent, thanks to the recombination of the atoms, the newly-combined material will possess the characteristics different from a single atom or a single molecule. In this way, their basic physical and chemical characteristics, such as melting point, capacitance, conductivity, light, magnetism may probably change. This way of creating new material through recombination is the so-called nanotechnology. It makes it possible for our human to have an access to many new materials that can be applied to scientific research, productions and all the other parts of life.

There are certainly other definitions for the present era. The definitions from different angles are all reasonable. However, we can also deem it from the view of system engineering. To put it in another way, we are in an era of system engineering.

How do you think about it?

As scholars of system engineering, we should promote this point of view in order to let more people understand it and accept it.

So, here come the questions: what is a system? What is system engineering? How can it be applied to transportation?

These are what we would like to talk about in this book.

This chapter will focus on a basic introduction to system engineering and Transportation System Engineering, as well as their prospects.

The study of system engineering(SE) focuses on the system.

System is the core and basic concept of system engineering. We are familiar with the system. In Chinese, it is usually used as a noun. It can be also used as an adjective or an adverb. System, as a term of system engineering, has other specific definitions as well.

There is a wide variety of systems in the nature and human society. Let's enumerate several different groups of systems before the start of research:

Each single car, plane, train, computer, campus network is a system;

As well as a country, a government, an army, a business, a school, a hospital, a band, a team, a family;

What's more, a project (The Three Gorges project, the western development, the revitalization of the northeast, the Shenzhou five, the fight against SARS, the Olympic Games), a textbook, an article, a song, a Chinese medicine prescription, are systems respectively;

The forms and properties of these systems differ from each other. A system can contain and be contained, can cross and fuse in themselves mutually. A system exists commonly and objectively. Everyone lives in the system, and everyone lives in various and crossed systems.

However, not all the objects can be called as a system. In terms of a car, a number of gears and screws disassembled does not make up of a system. For a team, separate team members do not constitute a system. When it comes to a football match, normal fouls (there may be many times) do not constitute a system. Moreover, the crowd on the beach constitutes no system, and the same claim goes to a set of chess neatly placed in the box.

In conclusion, from many real and unreal systems, the definition of '*system*' can be extracted as following:

The system is an ensemble made up of many interconnected, interacted elements combining with each other, which in turn possesses specific functions.

This ensemble is also known as the overall or general. Elements are known as parts or components, to a certain extent, so they are also known as a subsystem. The ensemble of system and the parts in a system are viewed differently. Certain parts of the whole system can be seen as their subsystems, and the whole system can be considered as a part of a larger system, which is also a subsystem. For example, the engine of a car or a plane, a production line of an enterprise, a department of a certain college, etc., can be considered respectively as a subsystem. In contrast, a car for a car fleet, a plane for an airline company, an enterprise for the national economy, a university for the regional or the national higher education system, is respectively one of the components or a subsystem.

A system is an ensemble consisted of two or more organically connected and interacted elements that possess a specific function, structure and environment. This definition has four key points:

(1) System and its elements. System as a whole is composed of at least two elements, they can be single objects (elements), or a group of objects combined as a subsystem etc. System and its components is a pair of relative concepts that depends on specific objects and the range concerned.

(2) System and the environment. A system is also a component of another larger system (the environment or a super system). They interact with each other, keeping a close relationship of their input and output. System and its environment, as well as the super system form an overall system together. System and environment are also two relative concepts.

(3) The structure of the system. There must be many organic connections among the elements in a system. Thanks to this, the system's internal structure and order are formed. In a word, the structure is the way of interconnections of elements in a system.

(4) The function of the system. The existence of a system should have its own role, value and specific purposes of operation, which means a system actually having its specific function. The realization of the function of a system is affected by its environment and structure.

Transportation system is an organization and management system focusing on the whole transportation activities, using the principle and method of system engineering, providing the optimal programs and plans, and coordinating and controlling in an effective way, in order to get the best economic benefits and social benefits.

When it comes to the system engineering, the range and scale of the system depend on the problem concerned in our research. System has a specific structure, characterized by a certain function and behavior. What's more, the function and the behavior of a whole system are determined by the elements included in the system and system structure. However, we can't talk about these functions and behaviors with only a single part of this system.

A particular system is usually a subject of natural science and social science. For instance, solar system is the subject that we talk about in astronomy. Plant community is one of the subjects in botany research. We treat animal community as one of the research directions in zoology. Obviously, the human body and diseases are studied in the domain of medicine. The social system is discussed in history and sociology, etc. The system engineering and the system science (System Engineering is the Engineering Technology of the department of System Science) are never limited in staying a certain system, neither duplicate the research in other disciplines. On the contrary, they focus on the universal attributes and common laws of all kinds of systems, as well as their effective organization and management.

Domestic and foreign scholars have defined the system from different perspectives. American Webster dictionary, for example, called the system as "*organized or associated as a whole, which is formed by the overall concepts and principles of comprehensive, the rules of interaction, a collection of the essential elements in the form of interdependence*".

The founder of General System Theory, Austrian biologist Ludwig. Von Bertalanffy, (1901-1972), called the system as "*a complex with interacted elements*". If an assemblage of substances comprises more than two different elements, and all elements associate with each other in their specific way, then we consider this assemblage as a system. The element mentioned above

refers to different components of a system, which can no longer be subdivided as they are already parts au minimum.

Academician Tsien Hsueshen (1911-2009) has summarized: “we look an extremely complicated object as a ‘system’. Namely, it’s an organic ensemble which is made up of several interacted and interdependent parts, which in turn presents specific functions. Furthermore, this ‘system’ itself is part of a larger system to which it belongs.”, when he talks about the work of “Two bombs and one satellite”.

In Chinese, ‘system’ has more specific explications in other disciplines.

For example, the ‘organization’ used in the management institute and enterprise management is similar to ‘system’, and so often, they are the same.

1.1.2 The Development of System Engineering

Since the 1970s, with the development of science and technology, as well as the social progress, we have more and more production management system in a large-scale, such as modern industry, transportation, biology, ecology and military command and they become also increasingly complex. At the same time, the production process develops rapidly in an integral and automatic way. As a result, the control for the process in engineering and social system is ubiquitously needed. System is characterized by its large scale, complex structure, integrated functions, the amount of factors and its complex control. In consequence, the evaluation, design, control and management for this kind of massive and complex system must be optimized and controlled by making full use of the system science, as well as the theories and methods in system engineering. This in turn brings about a break through from traditional theories, implementations and methods to an optimal control and harmonized management of a big system. In fact, transportation systems are a big system. Even, it’s a complicated big system because of the fact that ‘people’ plays a very important role inside.

Nowadays, system science has been widespread and integrated into several disciplines, such as Control Science, Information Science, Economic Management Science, Biology and Environment Science, Transportation Science etc. In this case, as a result, Transportation System is a combination of Transport and System Science. Under the influence of System Engineering proposed by Academician Tsien Hsueshen, Transportation System Engineering combining Transport with System Engineering was given to birth in the 1980s. From then on, we set foot in a new development era.

System Engineering is an applicable and practical science. It’s a new discipline shaped under the condition of a combination of System Science and Modern Management Science, Information Science, Control Science and Computer Science. Furthermore, it’s definitely a trend to apply System Science theories to a department, a profession or a discipline in the scientific development nowadays. Firstly, it is necessary to have an all-round analysis for the object that you are studying, and then another analysis on the relation between its inside and outside is also requisite. Through

an analysis of decomposition and recombination of a system, we can reach a point where we transform a disorder to an order and then transform the order from a lower to a higher level, which in turn forms gradually the departments, industries and other new disciplines in System Engineering. *The reform and open policy* in China brought in the science and technology, as well as the liberation of people's thoughts. The establishment and the application of System Science promote a rapid academic development, which later becomes the environment for the emergence and development of Transportation System Engineering.

Phases of the development of the system engineering, from preparation, establishment to development, are listed below in Table 1-1, which includes major engineering practices or events, as well as important contributions to theories and methods, etc.

Table 1-1 The emergence and development of system engineering

Phase	Year	Significant projects and practices or events	Significant contributions of theories and methods
Ⅰ	1930	American radio and television system	Formal introduction to the System Approach
	1940	American color TV development plan	Use of the Systems Approach with a great success
		The development of microwave communication system, Bell telephone company, USA	Formal use of the word: System Engineering
Ⅱ	During the World War Ⅱ	Anti-air-strikes and other actions of Britain and the United States	Emergency of Military Operational Research, military system engineering
	1940s	American atomic bomb 'Manhattan plan'	Application of System Engineering which is in full development
	1945	Establishment of research and development (R&D) center of American air force. The predecessor of the RAND company	Introduction to the concept of System Analysis, emphasizing its importance
Ⅲ	Late 1940s-early 1950s	Extensive use of operational research and development, control of emergency and application of control theories and the birth of the computer has laid an important foundation for the system engineering discipline	
Ⅳ	1957	H.Good and R.E.Machol published *System Engineering*, the first book about System Engineering	The mark of establishment of System Engineering discipline
	1958	The development of America Polaris missile yacht	The PERT (Network Optimization Technology),which is the System Engineering technology in an early phase
	1965	*System Engineering Handbook*, R.E.Machol	Pointing out the practicality and standardization of System Engineering
		American automatic control specialist, L.A.Zedeh proposed the concept of "fuzzy sets"	An important mathematics foundation for the modern System Engineering
Ⅳ	1961-1972	Implementation of the "Apollo" moon program, USA	Use of various System Engineering methods achieving a great success, greatly improved the position of System Engineering
Ⅴ	1972	International Institute for Applied Systems Analysis (IIASA) was founded in Vienna	System Engineering Applications focuses moved from engineering fields to social and economic fields, and developed into a new stage