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ENGINEERING MANAGEMENT THEORIES AND METHODOLOGIES

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On the Core Essence of Engineering Management Theory

Abstract At present, China's economy is in rapid growth. The scale of engineering construction is significantly increasing and a number of major projects have been completed and put into use, bringing the engineering management practice new issues and challenges with each passing day. In the meantime, Chinese scholars are constantly summarizing what they have learnt in these activities and making great effort to gradually establish their own theoretical system of engineering management, of which the core essence of theoretical system of engineering management becomes a critically important topic. By studying our engineering management theory and practice, this paper preliminarily sums up the core essence of the engineering management theory in China as: "establishing a perfect harmony between human and nature through a people-oriented approach and dual innovation", with a hope to help and enrich the research on the theoretical system of engineering management in China.

Keywords: engineering management, theoretical system, people-oriented concept, perfect harmony between human and nature

1 Introduction

When delivering a speech at the opening ceremony of the 2000 International Conference of Engineering and Technological Sciences, Mr. Jiang Zemin said. "Engineering science and technology has played a role of engine in promoting the progress of human civilization" (Jiang, 2000). In recent years, China's economy has been showing rapid growth. Judged from the overall economic development, China's industrial production, construction and retail sales are doing very well and the scale of construction is the highest in the world. During this period of rapid economic development, engineering management practice is being increasingly enriched and relevant study of engineering management theory is gradually deepening. Engineering management is the management of entire engineering process from conceptual design to full formal operation and the quality of engineering management is a decisive factor in determining if an engineering project would turn out to be a success or failure, which will further affect economic development. Exploring the core essence of engineering management theory system can, therefore, not only improve and enrich the contents of engineering management theory but also have great significance in guiding the engineering management practice.

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2 The theoretical system of engineering management

2.1 Engineering and engineering management

There are strict differences between each two of the terms "science", "technology" and "engineering" (He, Chen, & Hong, 2005; Yin & Li, 2013; Yin, Wang, & Li, 2007). "Science" refers to the knowledge system comprised of different disciplines which reflects the objective laws of the nature, society and thinking, etc., and the activity of scientists is to discover these objective laws. "Technology" refers to the experience, knowledge and skills obtained in work activities, and more broadly, it also includes the skills in operation and production, and the activity of technology experts is to achieve technological innovations. From one-dimensional perspective of science, foreign scholars consider technology as a kind of application of science, a creative activity to turn scientific principles into new products. Starting from the ontology of engineering, we could define "engineering" as a collective human activity for his survival and development to achieve specific purposes, to create or change things by applying science and technology and collectively utilizing resources. Scientists try to understand the world while engineers try to adapt to the world. Engineering is the engine propelling the human being's development and also the means for him to adapt to the world. Large scale civil and hydraulic engineering projects in ancient China, such as the Great Wall

and the Dujiangyan Irrigation System, and those since 1949 and especially after the economic reform and opening up, such as the satellite manufacturing and aerospace exploration, the Three Gorges Dam, the Qinghai-Tibet railway, the construction projects in various industrial sectors as well as the infrastructure construction projects across the country, all embody the organized adapting to the nature by the Chinese people to make it more suitable for human survival and development.

On the understanding of engineering management, Chinese and American scholars have different point of views. The American Society for Engineering Management (ASEM) defines engineering management as "an art and science of planning, organizing, allocating resources, and directing and controlling activities that have a technological component" (American Society for Engineering Management, 2012), while in its consultation report, Chinese Academy of Engineering (CAE) defined it as follows: Engineering management refers to decision-making, planning, organizing, directing, coordinating and controlling of engineering projects in order to achieve the desired goals with efficient utilization of resources (He, Chen, & Hong, 2005).

Engineering management, in a broad sense, comprises the management of engineering construction (including the planning, pre-feasibility and feasibility studies, survey and design, construction and operation), the management of the process of developing, manufacturing, producing complex and important new products, equipment and facilities, and what is more, the management of the technology innovation and transformation, transfer in line with international standards as well as the development layout, strategic development study and management of industries, engineering and technology. Engineering management, in a narrow sense, refers to construction engineering management.

By studying its process, engineering management could be considered as the management of the whole life of an engineering project so as to achieve its success, which includes the management of decision making, design and planning, construction, operation and maintenance. Engineering management involves in the management of all aspects of an engineering project, including technology, quality, safety, environment, cost, schedule, resources and procurement, site, organizing, legal affairs and contracts, information, etc., which constitute the main contents of engineering management.

Engineering management is a kind of integrated work as the requirements for an engineering project are comprehensive and it is a management issue of multi-target constraint: It involves in coordinating various engineering disciplines and managing the interfaces among these different disciplines involved because an engineering project will be completed by the personnel from different companies and institutes. In the process of planning and controlling, engineering management must have a comprehensive consideration of the issues of technology, economy, schedule, contract, quality, safety, environment, resources, etc. All of these mean that engineering management is a management work of a high degree of complexity (Yin, Wang, & Li, 2007).

2.2 The theoretical system of engineering management

With the development of engineering management practice and the deepening research and study of engineering management theory, a relatively complete theoretical system of engineering management is being established gradually in China (Wang, Ding, & Yang, 2011). The purpose of studying of theoretical system is trying to establish a scientific theoretical system, and the study contents are mainly the logical relationships among different theoretical points of view with an aim to organically combine the various parts and categories which constitute the theoretical system and thus form the "network of category" and the "network of theory" of different levels. By doing so, we could not only clearly define different concepts and the relationships among these concepts but also reveal their essential characteristics, and thus enrich and improve the contents of engineering management theory. Engineering management is different from both technical work and pure management work because it is a technical work which requires rigorous working style and thinking, and it is also a kind of management work of a high degree of systematicity, comprehensivity and complexity which requires the arts of communication and collaboration, and also the knowledge, experience, social skills and comprehension. In terms of discipline, it is an interdisciplinary field of "engineering" and "management" (He & Wang, 2008).

The theoretical system of engineering management is comprised of the theory modules based on engineering philosophy, the engineering management activities and the application theory modules. Engineering philosophy is to understand the essence of engineering from the perspective of philosophy and guide people to explore the philosophy, thinking, view for the world and methodology, etc. and thus establish the concepts of development, dialectics, system, value, harmony and innovation to guide the practical activities of engineering management (He & Wang, 2008). Engineering management practice is the logical starting point of the theoretical system of engineering management, without which there is no engineering management theory and not to mention the theoretical system. Engineering management activities in a broader sense include the management of planning and decision-making, design, production and construction, operation and maintenance, new product development, technology innovation and strategy. The basic values of these works are embodied as theory innovation of engineering management, optimization of engineering and industrial resources and improvement of economic efficiency. Engineering management activities will generate new ideas and methods in the cross field between the specific engineering theory and the general basic theory and thus establish the application theories of engineering management such as quality management, cost management and risk management,

etc., which are obtained from engineering management activities and are the summary and improvement of engineering management practice, and they can be further applied as guidance to new engineering practice (Editorial Committee of Current Situation and Prospects of Engineering Management in China, 2007). In short, engineering management could be considered as the application and development of general engineering theories and methods such as engineering philosophy, management, economics and engineering in both engineering practice and theory.

3 The core essence of the theoretical system of engineering management

All engineering activities are to serve the people and rely on the people as well. Both engineering and engineering management must, therefore, take a people-oriented approach. Human beings are living in groups and in natural environments so that a harmony must be maintained among the man, society and nature, that is, the so called "establishing a perfect harmony between human and nature". Engineering is mainly the integrated application of mature technologies to ensure a smooth and safe completion of an engineering project, in which management innovation is, therefore, important for achieving a higher efficiency of technology integration. In engineering activities, especially for large-scale ones, we, however, often face complex new situations and need to overcome technical barriers, thus in each phase in engineering activities, innovation as a driving force is required in both management and technology. Engineering activity itself is bound to break the original balance (harmony) with the ultimate aim to build a new balance, that is, the harmony among man, society and nature. The core essence of engineering management could be, therefore, summed up as "establishing a perfect harmony between human and nature through a people-oriented approach and dual innovation".

From the perspective of philosophy, engineering management could be defined as the following: It is a science about the status and role of the man in engineering activities and the relationships between man and man, between man and society and between man and nature and also the interaction among them. For an engineering project, in terms of management function, engineering management refers to decision-making, planning, organizing, directing, coordinating and controlling; in terms of engineering process, it refers to the management of the pre-feasibility and feasibility studies, decision-making, design, implementation and operation; in terms of key elements of engineering management, it refers to the comprehensive integrated management of the resources, contract, risk, technology, information and culture, etc., in order to achieve the required objectives concerning the quality, cost, schedule, occupational health and safety, and environmental protection. The definitions summed up in the perspective of philosophy coupled with the three dimensions of function, process and key elements, constitute a comprehensive definition of engineering management.

A people-oriented approach and a perfect harmony between human and nature which are complementary each other and inseparable constitute the core thought of engineering philosophy. In the following, we will discuss the people-oriented concept and the perfect harmony between human and nature separately due to different focuses but will not to separate them mechanically. For example, one important issue of engineering ethics is the professional ethics of engineers so we will discuss the engineering ethics in the subject of the people-oriented concept whereas the content about environment in engineering ethics belongs to the category of perfect harmony between human and nature. Another example is that the people-oriented concept also runs through the engineering economy, engineering quality and engineering environment.

3.1 The people-oriented concept

The people-oriented concept which was first proposed as a ruling ideology by the famous prime minister of the State of Qi, Mr. Guan Zhong, during the Spring and Autumn Period of ancient China (Fang & Shu, 2005), then followed by the development of a long history, infiltrating politics, various aspects of religions and people's daily life with the contents being enriched constantly, has become an important part of Chinese culture. The Chinese people-oriented thought is as shining and illuminating as the Western humanism. The people-oriented concept in engineering management not only advocates the idea that the human being is the fundamental purpose of all engineering activities, but also answers the questions why and for whom the engineering activities are conducted. Moreover, considering that human being is the fundamental driving force of engineering activities answers the questions how and by whom the engineering activities are conducted. "For whom" and "by whom" are inseparable. "All for the people" and "all dependent on the people" and the unity of these two constitute the complete contents of the people-oriented concept.

The engineering construction projects across China have reflected the people-oriented concept with numerous such examples. The primary purpose of the Three Gorges Project is the flood control. After its completion with a huge flood control capacity, it has played an important role in ensuring the safety of life and property in the middle and lower Yangtze River. At 0:00 am on April 1st, 1997, China started its first Railway Speed-Up Campaign, opening the prologue to the railway speed-up engineering projects, and increased the average speed of national railway passenger train from 48.1 km per hour in 1993 to 54.9 km per hour with a maximum speed of 140 km per hour, and run the fast speed trains and the evening-morning trains for the first time, which made much more convenient for people to travel. Some of the high-speed passenger train stations have been built not only as the stations for railway passengers but also comprehensive transportation hubs connecting the bus, subway, taxis, other

local transportation systems, long distance coaches and even the airports. All of these are typical examples of people-oriented engineering projects.

The people-oriented concept embodied in engineering management is the status and role of the people. Many other concepts in engineering management such as engineers, engineering ethics, engineering organizations, engineering innovation, engineering safety and engineering culture are all permeated with the people-oriented concept as the base line.

3.1.1 Engineer—the very soul of engineering activities

Engineers are important creators of new productivity, but also the pioneers of emerging industries. When addressing at the opening ceremony of the 2000 International Conference of Engineering and Technological Sciences, Mr. Jiang Zemin also said, "All the achievements made in the process of modernization in China are inseparable from great support of engineering science and technology. The Chinese government and people spoke highly of the contribution made by Chinese engineers, we are very proud of having a large number of internationally renowned engineers, represented by Zhan Tianyou, Mao Yisheng, Li Siguang, Qian Sanqiang and Qian Xuesen"(Jiang, 2000). Moreover, since economic reform and opening up, more and more distinguished engineers have emerged from the major engineering projects such as the Three Gorges Project, the Qinghai-Tibet railway, the Daqing oilfield and aerospace projects, etc. and numerous infrastructural projects across the country and made outstanding contributions for the modernization of China. Engineer is the very soul of engineering activities because all the new thought and inspiration come from the engineers. Engineer is also the main carrier of engineering ethics, bearing the responsibility of the effects of engineering activities on the society, economy and environment. Engineers should have, therefore, good professional ethics, innovative ideas, firm grasp of modern design, construction technology and engineering management capabilities. Engineer's primary obligation is loyal to the clients or employers and responsible for the public health, welfare and safety.

3.1.2 Engineering ethics—the constitution of engineering activities

Although people's definition of engineering ethics is not entirely consistent, at least two aspects are included from the perspective of the research fields of engineering ethics. On one hand, the engineering activity is a social practice so engineering ethics is studying the moral values involved in engineering practice. On the other hand, as a sacred profession, engineers should have its own unique professional ethics. Whether as practice ethics or professional ethics, engineering ethics has its normative dimension and descriptive dimension.

The first essential meaning of engineering ethics is that "engineering project is for the benefit of mankind" (Xiao, 2009), that is, the people-oriented concept. Engineering ethics emphasizes the loyalty, honesty, responsibility and team spirit of engineers. The broad responsibilities should include the responsibilities of engineering projects on the society and nature, namely the environmental protection and green engineering. Engineering in a broad sense also includes the biological engineering, information engineering and aerospace engineering. In these projects, engineering ethics has to be extended to the issues such as moral principles of human cloning, network ethics, space ethics. In all these aspects of engineering ethics as discussed above, the core essence could be summarized as establishing a perfect harmony between Human and nature through a people-oriented approach.

3.1.3 Engineering organization—the main body of engineering activities

Qinshan Phase II nuclear power plant has established and improved the organization, management process and security system covering the nuclear safety supervision, quality assurance, environmental protection, radiation protection, industrial safety, occupational health and fire safety and emergency, and strictly enforced the supervision and management before, during and after events. Qinshan Phase II nuclear power plant owner's organization is implementing a two-level management, that is, the company level and the department level. These specific level managements are responsible for the management functions of design, purchase and construction and the functions of planning and contract control, of which a number of deputy managers and deputy chief engineers or the general manager are in charge. In the meantime, it also has set up the quality assurance department and the treasury department which are independent of the engineering management and control departments and directly under the control of general manager (Huang & Yang, 2012). All these have made the whole project organization well organized and managed. Such an organization mode is beneficial for having the initiatives of independent design and localization of equipment production, more flexibility in equipment purchase, and is conducive to technology transfer, coordination and command unity, which can result in the reduction of the total cost.

An engineering organization is an organic entity optimally comprised of engineering staff under the prerequisite of respecting people for an orderly implementation of project. In the engineering organization, not only the whole efficiency of the organization can be fully exploited but also the personal initiative fully played. Engineering organization is undoubtedly the main theme of engineering activities, and its core essence is the people-oriented concept with the target "for the people" rather than for the engineering goal. If there is no the concept and thought "for the people", no optimized goal could be developed and even if having such a goal, it is difficult to achieve it. Of course, this is not only applied in the service for the customers, but also for the engineering

staff, such as providing standards-compliant operation environment and good safety management and arranging reasonable labor and health insurance. Engineering organization is also "managing the people," that is, managing the relevant engineering staff by applying various management functions including planning, organizing, directing and incentives, etc. Finally, an engineering organization is also "dependent on the people", relying on those who are outstanding in organizing capability, engineering practice ability, professional knowledge and ethics.

3.1.4 Engineering innovation—full play of personal initiative in engineering activities

The construction of Qinghai-Tibet railway began in the 1950s. The former Ministry of Railway was in a dominant position in the process of technology innovation with fully aware of the "three major issues"—permafrost, high altitude and fragile ecological environment, and solved them one by one through technology innovation. The legal person responsibility system was introduced for the first time in the innovation practice of engineering management for public welfare railway construction projects. Five control targets specially required for the project were proposed, i.e., quality, environmental protection, health and safety, construction schedule and scale of investment, and they had been all achieved through the layers of responsibility, the implementation of the targets in very details and the control of process step by step with all personnel fully involved. Quality management with the responsibility system as its core was proposed, specific supervision personnel system was implemented for environmental management and critically controlling schedule and investment management were focused. On the basis of having developed the overall technology innovation plan, pre-station engineering was divided into 33 tender sections and post-station engineering into 17 tender sections in order to select the best internal and external contractors and suppliers to participate in the construction and technology innovation. The former Ministry of Railway arranged 88 major scientific research projects and more than 120 sub-projects, carried out the on-site experiments with pinpointed issues and conducted more than 80 research projects of permafrost (Wei, Yang, & Liu, 2003). Technology innovation played the role of scientific research and ensured the successful completion of this project, resulting in a large number of independent scientific and technological innovations and setting more than 100 world records in engineering.

Engineering innovation embodies the full exploitation of personal initiative. Engineering innovation is also the major field of innovation activities and national innovation system construction. Engineering innovation process is a process of constantly breaking barriers and avoiding pitfalls, whose driving force comes from the people-oriented concept and the harmony between Human and nature. The former requires engineering to be more humanism for a better service for the people, whereas the latter requires a better, faster and more economical completion of project. All these require constant engineering innovation. The combination of technology innovation and management innovation, i.e., the dual innovation will determine if an engineering project would turn out to be a success or failure, in which the management innovation refers to the process of the formation of creative concepts of thought and their transformation into useful products, services or operating methods. The combination of technology innovation and management innovation forms the unified booster in which technology is the productive force whereas management is the production relation, the two complement each other to keep a dialectical unity in the development of engineering. Both technological innovation and management innovation should be, therefore, conducted at the same time under the premise of the people-oriented concept with an organic combination of these two.

3.1.5 Engineering safety—the most basic requirement of engineering activities

During the Qinghai-Tibet railway construction phase, a great attention to the employee's life safety and health concerns was paid due to the life threatening issues such as high altitude, hypoxia, cold, dry and windy weather, strong radiation and natural sources of plague, and the following countermeasures were taken accordingly: establishing the health protection system and the altitude sickness prevention and treatment system, and the joint prevention of occurrence of plague; strengthening the management of high-pressure, explosive and flammable materials and equipment, comprehensive prevention and management of traffic accidents (Wei, Yang, & Liu, 2003). For the issue of hypoxia, 17 oxygen producing stations and 25 hyperbaric oxygen chambers were set up, and a mandatory oxygen inhaling of a daily average of no less than two hours was implemented for 40,000 workers.

The 20th Bureau, China Railway, developed the oxygen-producing equipment of 24 m^3/h for the Fenghuoshan Tunnel, the world's highest altitude one of an altitude of 4,905 m above the sea level, in which full tunnel supply of oxygen was applied to increase the oxygen level inside equivalent to that at an altitude of 1,200 m. Many tent hospitals were set up on the construction sites, providing the service and treatment for a total of 530,000 patients during a period of five years, of which there were 470 cases of high-altitude cerebral edema and 931 cases of high-altitude pulmonary edema and they were all effectively treated without one case of fatality. In the prevention of plague, the policy of "three no's" and "three reports" was implemented, that is, no hunting of the animals in the areas of natural sources of plague, no eating the animals from those areas and no privately taking the animals and products out of those areas, and reporting the dead rats, reporting the suspected plague patients and reporting the patients of unknown fever and sudden death. In the same time, the plague isolation wards, monitoring and medical systems were established, and the professional rat-anti personnel trained. As a result, no case of plague happened during the

construction of the Qinghai-Tibet railway. These measures were sufficient to ensure the worker's safety and health.

Engineering health and safety is the basic ethics in engineering activities and also the important manifestation of the people-oriented concept in engineering activities, including the people safety and the property safety of which the most important is the former. Engineering safety should be positive, not only to protect the project staff from being hurt, but also keep them in good physical and mental health. Safety education and warning labels and contents should be humanized, actively creating a civilized, safe and healthy working environment, and establishing a clear visual image of attention. The safety in the areas outside the engineering project should be also valued and strengthened because the health and safety management is not only applied in the project area but also in the areas outside it.

3.1.6 Engineering culture—humanization of engineering activities

In June 2013, Shenzhou Ten spacecraft was launched at Jiuquan into the space and then made successful rendezvous and docking with the target aircraft, Temple One, flying in orbit for 15 days in the whole flying process, of which 12 days was the flight of the combined formation of Shenzhou Ten with Temple One. The successful launch of Shenzhou ten marks that China has entered the new stage of manned space engineering. China's manned aerospace engineering always adheres to the spirit of "constant innovation, unified cooperation, scientifically seeking truth from facts, people-oriented approach and patriotic dedication", and it becomes one of the fields that are most innovative and require innovation which is the driving force for its further development. Aerospace industry is characteristic of high investment, high risk, technology-intensive and complicated system so that scientifically seeking truth from facts is its eternal theme to guarantee an aerospace mission a success. Manned space flight must be people-oriented as astronaut is placed in the first system of eight systems in China's manned space engineering. The people-oriented concept runs throughout the whole process of design, research, development and manufacturing of spacecraft, rockets and other air-crafts in order to produce safer, more comfortable and more user-friendly products for the astronauts. From the moment of the start of China's aerospace industry, it is carrying the national mission and dignity and the fervent hope of millions of people. China's aerospace spirit gives a vivid interpretation of the national spirit with patriotism as its core and the spirit of the time with reform and innovation as its core, which embodies the socialist core value system in aerospace industry (Ma, 2012). It is this culture that leads and ensures that China's aerospace people keep making progress and achieving innovation.

Engineering culture is the humanization of engineering activities and the embodiment of the people-oriented concept in engineering activities. Each engineering project has its own specific environmental conditions and historical traditions that it forms its own philosophy, ideology, value and behavior, whereby each project has its own unique engineering culture. Engineering culture is abranch of culture formed during the engineering management practice under specific cultural background and a kind of application-oriented culture closely associated with the engineering management practice. Culture is the foundation, whereas the engineering project is the platform. The role of culture is powerful because it can penetrate into all aspects of engineering management. For example, promoting a culture of innovation within the engineering team could make the project be more and deeper innovative, and the health and safety culture could make people more consciously strengthen the security and safety measures at every space and any time, and so on. Thus, strengthening the construction of engineering culture plays an important role in unifying the team, improving engineering management quality and ensuring a successful completion of the project, which can not only help to reduce accident, but also to raise the working passion of the team and improve the work quality so as to enhance the overall efficiency of the project. It is generally considered that an engineering culture is the formed behavioral orientation of the main body of the project in order to achieve the engineering objectives, but an engineering culture not conducive to a smooth implementation of the project could be formed if this behavioral orientation deviates from the inherent law requirements of engineering activities.

In addition, there is another connotation of engineering culture, namely, the art and culture embodied by the achievements of the engineering project itself. It is because any engineering project is serving the people that the engineering achievements should reflect the people's joy when people are using its service. Both Beijing's Great Hall and History Museum embody the Chinese traditions of solemnity, simplicity and dignity, facing such great buildings will inspire people's sense of national pride and patriotism, whereas any one of mosques reflects the Islamic culture which could be also loved by non-Muslim people.

3.2 Harmony between human and nature

A perfect harmony between human and nature is one of the fundamental concepts of classical Chinese philosophy, and also one of the most significant differences between Chinese philosophy and Western ones. A perfect harmony between human and nature is an important point of view of Confucianism. *Doctrine of the Mean*, the Book of Rites, says, "Sincerity is the way of heaven. The attainment of sincerity is the way of men", that is, as long as people have developed the sincerity of virtue, there will be a harmony between heaven and earth. Mr. Dong Zhongshu, a famous Confucian philosopher in the Han dynasty, more explicitly pointed out in his book, *Chun Qiu Fan Lu* (*The Luxuriant Dew of the Spring and Autumn Annals*), that, "Man and nature are inseparable and interdependent to each other". Taoism is also advocating the harmony between Heaven and Earth as Laozi said,

"Human follows land, land follows sky, sky follows Taoism and Taoism follows nature" . Mr. Ji Xianlin explained it as "Nature and human have to understand each other and form friendship between them" (Ji, 1993) and he also considered the concept of a harmony between Heaven and Earth as the greatest contribution of China to the world. A perfect harmony between human and nature means that there should be a peaceful coexistence between human and nature, and human must adapt to nature, neither to conquer, nor to be conquered. In engineering management, it means the harmony and unity between engineering project and society and the harmony and unity between engineering project and nature, and throughout engineering economy, engineering environment, engineering art and engineering decision-making are all permeated the harmony between Human and nature under the premise of the people-oriented concept.

3.2.1 Engineering economy—a bridge and link between engineering activities and society

The South-to-North Water Diversion Project is an ongoing major strategic project in order to ease the severe shortage of water resources in northern China considering the situation of drought in the northern part and flood in the southern part. This project would greatly ease the severe water shortage in the northern part and thus promote the balanced development of the economy, society, population, resources and environment in both the south and the north. This project would meet both the municipal and industrial water consumption requirements and it often would be still cheaper than reallocating irrigation water and easier to operate and thus reduce costs and create greater values. This project would improve the natural environment, especially the water resources in the north and enhance both the carrying capacity and allocation efficiency of water resources, and promote the strategic adjustment of economic structure. It is of important strategic significance in expanding the domestic demand, maintaining a rapid growth of national economy, and achieving a structure upgrading and sustainable development of economy, society and environment in the whole country. By improving water resources conditions, it would be beneficial for the formation of potential productive force to realize real economic growth and by establishing new operation mechanisms; and it would be beneficial for water conservation and pollution control in the watering region to gradually improve the ecological environment in Huang-Huai-Hai Plain. The South-to-North Water Diversion Project would make it possible for the northern part to become a water conservation and pollution prevention society with rational allocation of water resources, secured water supply and good water conditions (Ma & Zheng, 2010), which would effectively sort out the water quality issues in some areas in the north due to the natural causes of groundwater, such as fluoride water, brackish water and the water that contains harmful substances to human body and improve the drinking water quality in countryside. In addition, this project would help to alleviate the constraints on urban development due to water shortage in the north, accelerate the rural urbanization process and improve the urban ecological environment and natural landscape to meet the increasingly higher requirements for better quality of the surrounding environments as people's living standards are improving.

Engineering economy is the bridge and link between engineering project and society, and the implement of engineering project must be accepted by the society in terms of economy. Engineering economy requires obtaining the maximum engineering benefits from the limited resources, and it is the comparison of the social practice effect using technology with the expenses and losses and also is the comparison analysis of the useful results obtained with the paid resources costs and losses, which is kind of economic effect evaluation. It is a dialectical relationship of opposition and unity between engineering technology and economy, of which the economy is the purpose of technological progress and engineering technology is the measure for achieving economic goal and the driving force for promoting the economic development, but at the same time, engineering technology and economy are constraining and conflicting with each other in some aspects. The use of a kind of engineering technology is to enhance engineering benefits so that advanced technology does not necessarily have the economic rationality. A technology that is not economical will not be an appropriate one so we must investigate and select which technologies and combination of technologies are economical and affordable. The focus of engineering economic analysis is, therefore, the engineering prediction, which is a systematical evaluation of engineering economic activity, and of course, meeting the comparable conditions is a prerequisite for technical solution comparison which requires meeting the comparable conditions of the relevant values in use, costs, time, and other evaluation parameters. For the judgment of dialectical relationship of unity between engineering technology and economy, we must deal with the relationships among technology, economy, environment and society and solve the issues in technological practice by applying the knowledge of related disciplines through analyzing and calculating a large amount of data, in particular, prior estimates and judgments, on top of that, we also have to pay attention to the balance of system.

3.2.2 Engineering project quality—the basic ethics of engineering activities

The 2008 Wenchuan Earthquake caused a direct economic loss as high as 845.1 billion CNY, of which schools, hospitals and other non-residential buildings account for 20.4% and residential houses account for 27.4% of the total loss, these two account for nearly half of the total loss (Yun & Chen, 2009). The huge number of casualties in this earthquake was mainly caused by the collapse and damage of a large number

of buildings and houses, which fully exposed the issues of inappropriate architectural structure, layout and form, and low quality of construction, etc. Demanding an investigation and accountability of the low quality of construction in the disaster areas was, therefore, increasingly strong. For the houses and buildings designed and built in accordance with the seismic building codes, the majority of them will not collapse but only crack in the high-intensity areas and low damage in the low intensity areas. The collapse of a large number of buildings and houses in the 2008 Wenchuan Earthquake is truly reflecting the issue of low quality of construction, such as jerry-building, building not in accordance with the seismic building codes and unreasonable operation, and all these have made the damage worse.

Engineering quality is the basic requirement of engineering activities. Engineering quality in a broad sense refers to not only assessing the final quality of an engineering project, but also it should include the overall efficiency of organization, economy, security and safety, and society, etc. in the entire engineering process. The categories of these two concepts, quality and harmony, are not only material but also spiritual and cultural, and they are not only individual but also product-related and society-related. Quality reflects the degree of the development of productive force, the governing ability of government, the degree of industrialization and the degree of modernization and social harmony of the country. Engineering quality concentrates the comprehensive quality of engineering company, including the ideological level of leadership, the quality of team, the level of technology and the merit of corporate culture, and it also reflects the supervision and management quality of government on engineering construction. Engineering quality is associated with all aspects and all walks of life of society into every family and community group, directly affecting every aspect of people's life. Engineering quality is inseparable with social harmony so the quality of an engineering project will directly affect the issues such as the efficiency and quality of economic development, public safety, social operating efficiency, people's happiness index, degree of people's trust on government, etc. The supervision and management of engineering quality is the duty-bound responsibility and obligation of the government, which is not only responsible to the people but also to the public security and safety. The engineering quality supervision workers should, therefore, do their best to achieve a better and more harmonized legal system for engineering quality management, further strengthen and implement the engineering quality responsibility and guarantee the life-cycle quality of engineering project to enhance the overall level of engineering quality and significantly improve the people's satisfaction.

3.2.3 Engineering environment, the harmony between engineering activity and society, and nature

The Tibetan Plateau is a natural ecological fragile place, where the construction of the Qinghai-Tibet railway has, in fact, effectively protected the ecological environment. The Party Central Committee and the State Council clearly stated: The Qinghai-Tibet railway construction must cherish every tree and bush of the plateau. The governing body of the Qinghai-Tibet railway construction signed with the governments of Qinghai Province and Tibetan Autonomous District the first document of environmental protection responsibility in the history of Chinese railway construction, establishing a legal awareness and strengthening legal supervision. As a result, the investment on environmental protection was more than 1.1 billion CNY, nearly 5% of the total investment of the project which became one of the largest environmental protection investments in China's railway construction projects and it also introduced the environmental supervision for the first time in national major construction projects. In the Natural Reserve, the railway lines followed the principle, that is, "to avoid and wind around if we can avoid". The site selection of construction, sidewalk and quarry was subjected to repeated reconnaissance survey and inspection to avoid the damage to vegetation. In order to restore the vegetation on the railway land, the research workers carried out the study of plateau permafrost zone vegetation recovery and revegetation, and applied advanced technology and achieved a plant survival rate of 70%, two times higher than that of natural survival. These initiatives were widely praised by the international communities. In addition, wildlife corridors were established for the first time in the history of Chinese railway construction. The monitoring by Qinghai-Tibet Railway Headquarters showed that the Tibetan antelopes had been adapted to the artificial migration environment and a large number of Tibetan antelopes freely migrated through the wildlife passages (Wei, Yang, & Liu, 2003).

Engineering environment includes both the social environment and the natural environment for an engineering project, and it is a comprehensive reflection of the harmony between Human and nature. The core of the engineering environment is the harmony between engineering and society. Thus, we need to implement a sustainable development strategy and should realize that a sustainable development is based on the protection of nature and society and the harmony between a sustainable consumption of resources and the bearing capacity of ecological environment while we are emphasizing the theme of development and encouraging the economic growth. When we, contemporary people, are pursuing the current development and consumption in our life time, we need to consider not only to meet the demand of our generation and but also do not harm the ability to meet the demand of our future generations. To find a good solution of the harmony between engineering development and environmental protection is the key to achieve a perfect harmony between Human and nature.

As soon as the harmonious development of engineering environment reaches a certain level, engineering arts would be bred because they are originated from the essence that

engineering is serving the people and because engineering is entering people's vision, it needs to have the embodiment of arts. Engineering arts could be also seen as a part of engineering environment. Highest requirements of the embodiment of arts would be the harmony and unity between engineering and society, and between engineering and nature.

3.2.4 Engineering decision-making — a comprehensive reflection of the people-oriented concept and the harmony between Human and nature

Some people think that the biggest waste is no more than that caused by wrong strategic decision-making. According to the World Bank statistics, in the period between the "Seventh Five-Year Plan" to the "Ninth Five-Year Plan", the error rate of China's investment decisions is of about 30% with a waste of money and economic losses in the range from 4,000 to 5,000 billion CNY , which demonstrates that correct and scientific decision-making is so crucially important.

Of China's major engineering decisions, the decision-making mistakes of the Sanmenxia Project have brought us a lot of thinking and introspection. The Sanmenxia Project started in 1957, which is the first high dam reservoir built since 1949, and it showed the heroic spirit of the Chinese people who was trying to tame the river and transform the nature. It, however, overlooked the negative effect of the project on ecological protection and made a number of mistakes in engineering design, although it achieved some good results in power generation. At the stage of decision-making, some politicians were excessively pursuing of political significances that ignored the objective facts. In addition, the project was at that time a major construction project supported by Soviet Union so too much reliance had been placed on the foreign experts and technology in decision making and not enough had been done on the actual situation of abundant silt in the Yellow River and on relevant ecological conditions. All these resulted in twice alterations of Sanmenxia dam and three times of operation mode adjustments, and caused the Weihe River flood in 2003 (Yan, Fu, & Ji, 2010). Engineering decision-making mistakes can not only cause economic losses, but also have serious negative impacts on local community and people's life.

The Three Gorges Project had an extraordinary journey spanned for more than 70 years from envisage, surveying, planning, feasibility studies to starting construction. In 1924, Mr. Sun Yat-sen first proposed the idea of the construction of the Three Gorges Dam. From the 1950s, the older generation of revolutionaries and leaders of that time had made several in-depth inspections of the Three Gorges and organized the expert group to have repeated discussions and assessments. On April 3, 1992, a "resolution of the Three Gorges Project" was passed at the Fifth Session of the Seventh National People's Congress, and out of 2,633 delegates, 1,767 voted in favor, 177 voted against, 664 forfeited and 25 members did not vote, nearly a third of the delegates opposed or abstained.

The construction officially started in 1994, the water storage and power generation began in 2003 and the project was completed in 2009. The right decisions of the three gorges project have brought about three major benefits, namely the flood control, power generation and navigation, of which the flood control is considered as the core benefit of the project. The Three Gorges Dam has a normal water level of 175 m with a flood storage capacity of 2.215×10^{10} m^3, and it can provide effective protection for Jingjiang and also have a great flood control effect on the middle and lower Yangzi River region. The Three Gorges hydropower development marks an important milestone in sustainable development in China, especially the development of clean energy. The total installed capacity of the Three Gorges Hydropower Station is of 1.82×10^7 kW with an average annual output of 8.47×10^{10} kW·h, which would have a huge power benefit. The Three Gorges Project is located at the junction of the upper and middle reaches of the Yangtze River and its location is at a very favorable place, upwards canal can reach Chongqing from sandpiper, whereas downwards, the water flow during dry season can be increased in the middle reaches of the Yangtze River below the Gezhouba Dam, which would improve the navigation between Chongqing to Wuhan to meet the needs of navigation industry development prospect in the upper and middle reaches of the Yangtze River.

Engineering decision-making refers to the determination of the overall plan of the engineering project proposed and the comparison, analysis and judgment of different construction plans by the engineering decision-makers. The behavior to select the plan to be implemented is the main theme throughout the planning phase. Engineering decision-making, particularly for the major engineering projects which would significantly affect the national economy and the people's livelihood, is generally dependent on politicians, but it should be done both scientifically and democratically. Decision-making of major engineering project is a complex process, which requires that the politicians must consider carefully the pros and cons to exploit the advantages and avoid the disadvantages, deal with various challenges and problems and resolutely abandon aiming too high and seeking quick success and instant benefits. In this process, they should investigate the necessity and feasibility of project, and fully reflect the people-oriented concept and the harmony between Human and nature, to make decisions scientifically and establish a project assessment system which would tolerate different views to prevent the decision-making from deviating from rational track through democratic means and truly listen to all the parties.

4 Summary

From the discussions above, a comprehensive definition of engineering management could be given as follows.

From the perspective of philosophy, engineering management could be defined as a science about the status and role of the man in engineering activities and the relationships be-

tween man and man, between man and society and between man and nature and also the interactions among them.

In terms of management function, engineering management refers to the decision-making, planning, organizing, directing, coordinating and controlling.

In terms of engineering process, it refers to the management of the pre-feasibility and feasibility studies, decision-making, design, implementation and operation.

In terms of key elements of engineering management, it refers to the comprehensive integrated management of the resources, contracts, risks, technology, information and culture, etc. in order to achieve the required objectives concerning the quality, cost, schedule, occupational health and safety, and environmental protection.

On the basis of studying both the engineering management theory and practice and by philosophical speculation and logical deduction, this paper precisely sums up the core essence of the engineering management theory in China as "establishing a perfect harmony between Human and nature through a people-oriented approach and dual innovation".

This paper is intended to serve as a modest spur to induce someone to come forward with his valuable contributions with a hope to help and enrich the theoretical research of engineering management and its system construction in China.

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