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Reflection on Development Strategy of Engineering Management Discipline in China

Abstract A large number of engineering management professionals are required to promote engineering management efficiency, but the existing engineering management training system has some gaps with economical and social development in China. Development of engineering management discipline has very important strategic significance in China. This paper explores the disciplinary characteristics of engineering management, and analyzes the developmental issues about education of engineering management discipline. Meanwhile, the paper also proposes that the construction for development strategy of China's engineering management discipline should be accelerated in the following aspects: Theoretical system of engineering management must be built and methodology of engineering management needs to be explored and perfected; advantages of various universities should be fully expressed, to show their own characteristics with accurate and reasonable positioning; knowledge system of engineering management discipline must be organized and integrated; practical ability of engineering management professionals needs to be promoted; education level of engineering management discipline should be perfected and training objectives at various levels must be clarified; teaching methods and means have to be reformed.

Keywords: engineering management, disciplinary characteristics, development strategy

1 Introduction

China's economy has maintained rapid and continuous growth since the 1980s. The fixed-asset investment in 2012 was 37.4676 trillion yuan, increasing by 20.3% compared with that of last year. By deducting price factor, the actual growth is 19.0%. A large amount of investment has generated a large batch of engineering projects. A series of engineer-

ing management achievements have been brought about by large-scale hydraulic projects represented by Three Gorges Project and high speed railway projects with self-dependent innovation results. China's engineering in rapid development has generated huge demand for engineering management professionals. Meanwhile, it has also provided rare opportunities for development of the discipline of engineering management in China. It has great strategic significance for continuous improvement of China's engineering and economy to establish China's engineering management discipline and strengthen education for engineering management.

2 Current situation of the engineering management discipline in China

At present, over 120 universities have established undergraduate program of engineering management in China, and formed a certain education scale. The teaching institutions fall into two types. One covers the schools of management or economy; for instance, the construction task for engineering management program is assumed by School of Management of Xi'an Jiaotong University. The other covers the schools of construction or civil engineering; for example, engineering management program of Tsinghua University is undertaken by its School of Civil Engineering. In addition, independent schools or faculties are founded for engineering management, such as the Faculty of Construction Management and Real Estate of Chongqing University, and the School of Investment Economics of Central University of Finance and Economics. Higher education institutions with this program mainly cover comprehensive universities, technological universities, universities of finance and economics, agriculture and forestry universities, and normal universities. Among them, technological universities, comprehensive universities, and universities of finance and economics are the major force: The comprehensive universities and technological universities that establish engineering management program often possess strong industry background and their primary depending industry is the construction industry. Similar universities cover Tongji University, Tianjin University, Tsing-

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hua University, Chongqing University, and Xi'an University of Architecture and Technology. And besides the construction industry, their depending industries include the highway industry, such as Chang'an University and Changsha University of Science & Technology. The railway industry involves Beijing Jiaotong University and Southwest Jiaotong University; the oil exploitation industry supports China University of Petroleum; the chemical industry stands behind East China University of Science and Technology.

To bring up engineering management professionals, educators have established relatively perfect education systems, covering undergraduate and postgraduate programs and in-service training programs. In 2012, under the drive of the Engineering Management Section of the Chinese Academy of Engineering, Tsinghua University, Xi'an Jiaotong University, and Central South University, and after argumentation for several years, a group of CAE members and professors proposed suggestions to Office of Academic Degrees Committee of the State Council and gained approval to establish a new master degree, Master of Engineering Management (MEM). This new program emphasizes the combination of the engineering discipline and the management discipline. And for the first time, 76 higher education institutions were authorized to award MEM. The establishment of this new program plays a positive and promotional role in cultivating high-quality engineering management professionals for China.

3 Discipline positioning of engineering management

There are two international perspectives in cultivation of engineering management professionals, and the difference of discipline positioning has resulted in obvious discrepancy in training systems and research directions (Babcock, 1974; Kocaoglu, 1990; William, 2001). The first one is construction management directed to a specific industry, that is, construction industry. American Council for Construction Education (ACCE) has guidance and evaluation functions for institutions offering this program. Cultivation positioning for students of this program is: to gain professional knowledge in construction field; to acquire comprehensive and balanced education, and to obtain the chance of lifelong learning; to gain professional consciousness and leading ability, and to serve construction industry and the society. Louisiana State University, Clemson University, Southern Polytechnic State University, Georgia Institute of Technology and University of Florida conduct education with such cultivation tenets. The other type is engineering management not aimed at a specific industry, but for more general engineering management. Cultivation positioning for students of this program is inter-disciplinary talent with organization and management ability for engineering projects. American Society for Engineering Management (ASEM) defines engineering management as the art and science of planning,

organizing, resources allocating, directing and controlling activities with engineering technology components (ASEM, *n.d.*). ASEM provides guidance for cultivation of such professional talents, and meanwhile, it strives to improve engineering management theory and method by holding annual meetings on engineering management and publishing engineering administration manuals. Institutions with such education tenets include Stevens Institute of Technology, United States Military Academy, University of Missouri-Rolla, University of Vermont, University of Virginia, and St. Cloud State University.

Engineering management education in China can trace back to the beginning of the 1960s when the engineering economics experts studying in the Soviet Union in the 1950s and the engineering economics experts studying in Britain and America before the 1950s set up technological economy discipline. At this stage, the study mainly included economic analysis of projects and technical activities such as project evaluation and feasibility analysis. In 1979, 11 Chinese higher education institutions, including Xi'an Jiaotong University, established the engineering management program. In 1980, Huazhong University of Science and Technology began to recruit undergraduates of materials management engineering. In 1981, Harbin University of Civil Engineering & Architecture admitted construction management engineering majors; later, the programs of real estate operation management and international engineering management were established in succession. Undergraduate programs of China's colleges and universities were revised for four times in 1963, 1989, 1993 and 1998. The previous relevant programs, covering construction management engineering, basic implementation management engineering, management engineering (sub-area of construction management engineering), real estate operation management, foreign construction engineering creation and management, and international engineering management, were integrated into the engineering management program, which, in 1998, formally became a sub-discipline under the general discipline of management science and engineering. According to the requirements of the Teaching Steering Committee of Ministry of Education, the engineering management program is to cultivate senior inter-disciplinary management personnel who are equipped with the basic knowledge of management, economics and engineering technology, who have mastered theories, methodologies and instruments of modern management science, and who can be occupied in project decision making and whole process management in engineering construction fields at home and abroad. Further, in terms of knowledge and ability, graduates from this program should: grasp basic theories and methodologies of engineering (and real estate) management; obtain basic theories and knowledge bases about investment economics; be familiar with knowledge about engineering technology; be acquainted with policy, laws and regulations of engineering project construction; have good knowledge of developmental trend of engineering management at home and abroad; acquire ability of solving

problems with computer; develop ability of working on project decision and whole process management; master basic approach of document retrieval and data query and possess ability of preliminary scientific research and practical work; grasp business knowledge required by international engineering project management and gain good foreign language ability (Ren, Zhu, & Gu, 2001). In documental dimensions, according to the above illustration, undergraduate education positioning of China's engineering management is almost consistent with that in America.

Orientation of the MEM program in China accords with the ASEM definition of engineering management. The knowledge system of the MEM program has integrated core knowledge domains of various engineering fields and core curriculums of management education. By offering core curriculums about marketing, finance, intellectual property, and business law, the institutions can help graduates and practitioners with a bachelor degree of engineering to improve knowledge reserve and experience accumulation, so that they can creatively solve management problems in the increasingly complex engineering activities under the emerging technological environment. Different engineering backgrounds and engineering activities need different parts of knowledge, and different engineering fields have unique businesses and new technical problems. Therefore, innovative solutions should be made for the complex business problems. This requires practitioners to be equipped with advanced knowledge of various engineering fields, business knowledge and experience accumulation. As far as basic starting point is concerned, the MEM and Master of Business Administration (MBA) programs were established for different aims, the former emphasizes combination of engineering background and management knowledge while the latter stresses training for business knowledge and experience. In terms of the knowledge system, compared with the MBA curriculum, the MEM curriculum lays more emphasis on providing pointed knowledge training for managers of organizations based on engineering technology, and overall ability developing for solving management problems in engineering activities by combining engineering with management. For practitioners in engineering management, the knowledge and ability objectives include project management competence, interpersonal communication competence, experience in field of technology, experience of financial and practical work, and research and development competences. According to actual knowledge demands of engineering management practitioners, the MEM program has satisfied the need of underlining relevant experiences in field of technology, while the MBA program has met the need of stressing financial experience (Bergey, 2014; Kocaoglu, 1994).

In conclusion, positioning of the discipline of engineering management should be a discipline that studies management issues concerning the planning, organizing, resource allocating, commanding and controlling of activities of engineering. It has characteristics different from those of other management disciplines.

3.1 The object of the discipline is the management rules based on engineering technology

The research object of engineering management discipline is management issues in engineering activities. Two problems should be solved: One is the engineering rule that should be followed by engineering activities, and the second one is the management rule involved in engineering activities. Engineering involves various industries, and engineering technology has all-embracing contents. Therefore, for researchers of the engineering management discipline, industrial characteristics of the research object should be considered (Roberts, 2004).

3.2 The methodology of the discipline is the integration of engineering technologies and management theories

Due to characteristics of the research object, the research methodology of the discipline is also very special, and it is the integration of engineering technologies and management theories (Hazen, Yun, & Sankar, 2012; Wang, 2005). Different from general commodity production, engineering construction has strong planning, legal and procedural nature. It has a great influence on economy, society and environment, and the influence possesses hysteretic nature. The engineering construction rule is different from the common production rule, so comprehensive consideration should be given to engineering technologies and relevant management theories of the industry for the research object during the process of research. This is also reflected in the knowledge system of the engineering management programs of the world. Education of engineering management emphasizes the study of technical courses, and in some Chinese engineering colleges and universities that have established the engineering management program, technical courses make about 1/2 of all platform courses. Besides, the colleges and universities also require students to participate in practice concerning the technical courses of the curriculum, such as engineering measuring, building construction design, and construction engineering budgeting, so as to better understand the engineering object and the knowledge attained in the classroom. In the field of management, apart from basic platform courses, inter-disciplinary courses with strong professional contents closely related to engineering management are set up, such as engineering project management, construction enterprise management, construction technology economics, construction technology accounting, construction cost estimation, and cost planning.

With the change of the external environment and the advancement of learning of the various disciplines of technology and science, development is required for the engineering management discipline, to solve the new problems with new theories and methodologies. Advancing with the times has become an inevitable requirement for the engineering management discipline. As engineering technology advances, the territory of engineering management is changing con-

stantly for the different application backgrounds. It is a trend of engineering management development to combine common knowledge of engineering management with technical characteristics of the industry. Solving of the management problems in actual engineering activities is the mission of the engineering management discipline, and therefore, its object of study should be adjusted timely according to the environmental change.

3.3 The coverage of the discipline is the combination of theoretical research and engineering application

The engineering management discipline was born to solve such practical management problems in engineering activities, as concerning time, cost and quality in engineering construction (mainly construction project but not limited to construction project). Its theories and methodologies can directly provide theoretical support and strategic guidance for optimizing the schedule, reducing the cost, and improving the quality of construction, and its important components include feasibility study required by engineering project, engineering quotation, bidding documentation, and construction organization design. Therefore, the discipline emphasizes applicability and pertinence. However, at the same time, the discipline also stresses theoretical and methodological studies of management concerning such aspects of engineering activities as intelligent decision support system, information system based on CIS, and project development. It is an important task for China's researchers in engineering and management to study the problems emerging in and the experiences accumulated in construction and operation of multiple engineering projects, and to study the theories and methods of engineering management in the cultural and technological context of China.

4 Development of the engineering management discipline

The basic task of construction of the engineering management discipline is to produce achievements and talents, concentrate our efforts on structural improvement and quality enhancement, pay equal attention to teaching and research, and make them promote each other. One thing must be taken into consideration for the development of the discipline: When trying to keep with advanced international researches, we must fully consider the actual demands of China in engineering management. We need to tail after international advancement in the field of engineering management for a long time, so as to grasp the latest progress and absorb the most pertinent achievements. Meanwhile, it is necessary to realize the obvious applicability and pertinence of the discipline. Research workers of the discipline should pay high attention to management problems with Chinese characteristics, and it is the important mission for researchers of the discipline to solve practical management problems in the engineering activities of China. Knowledge fusion and cross-disciplinary

content must be intensified. Birth and development of the discipline is closely related to theories and methods of other knowledge fields and disciplines. Theories and methods of new mathematical analysis, new information processing, new technology, and new psychology have provided important knowledge sources for research of the engineering management discipline. It's quite necessary to conduct scientific research and application of the discipline with the most recent knowledge achievements.

Great achievements have been made in education of engineering management professionals in China. Yet, still, there is much improvement to be desired for the current engineering management education. Talent cultivation must face the engineering realities and the social needs. This is decided not only by the urgent demand of China's economic development, but also by foreign experiences in engineering management education and industrial development. Graduates trained by the current engineering management education programs (especially undergraduate programs) lack the ability of solving practical problems and it usually takes them a long time to adapt to the need of practical work. Quality of China's engineering management education can be improved in the following ways.

4.1 Constructing the theoretical and the methodological systems of China's engineering management

Engineering management is a complex system of self-organization or autopoiesis, and its distinguishing feature is the all-dimensional openness. Besides, it is also a multi-disciplinary, multi-perspective and multi-methodological area of learning and creation process. In China, application of engineering management is extensive, but learning and absorption of relevant disciplines are insufficient. Engineering management research develops toward an open and complex system; by changing the thinking mode, it transforms from linear thinking to non-linear thinking. Qian Xuesen (1995), a famous scientist of China, proposed the concept of an open complex giant system in 1994, and this system aims to solve the underlying problems of the complex socioeconomic system. Later, Qian (2007) further proposed and established a science of systems. The theory proposed and established by Qian Xuesen laid a foundation for theoretical system of China's engineering management.

At present, China's engineering management is faced with rapid development of society and economy. It has to meet severe challenges, and can avail itself of good development opportunities at the same time. To meet these challenges, it is necessary to improve its quality, and to pay attention to cross-disciplinary advancement, knowledge fusion, mutual accommodation and innovation; to reinforce dynamic integration of natural sciences and social sciences, to strengthen academic exchanges, and to promote academic prosperity; to establish sound and extensive networks as to keep abreast of new progresses of engineering management research at home and abroad and to grasp new opportunities of disciplinary development. At the same time, it is important to intensify

combination of theoretical research and industrial practice, and to take comprehensive consideration of the problems that the industrial and educational circles care about, and to enhance the ability of solving practical problems. At present, we can explore effective methods of solving practical problems by aiming at the major issues of national economy. The systems of theories and methodologies of engineering management of China should be established on the basis of China's environment, legal system, and cultural norms by starting from basic theory, latest development, practical application, and disciplinary infusion.

4.2 Making full use of the advantages of different institutions, and normalizing their characteristics for accurate and reasonable positioning

As mentioned above, there are two different perspectives about cultivation of engineering management professionals in foreign countries. One is construction management which is management directed at construction industry; the other is engineering management which is management based on engineering technology activities. These two perspectives have one thing in common: both of them emphasize the dependence of engineering management on engineering technology. However, their focuses on technological reliance and industrial background are different. The former stresses construction industry. Project investment of all industries involves constructional engineering or civil engineering activities more or less, so it is reasonable to emphasize engineering technology that depends on construction industry. The latter underlines engineering technology of different industries. In other words, we should fully realize that the technologies on which engineering activities in different industries depend are different, for instance, the engineering technology on which the software industry relies and that on which the mineral mining industry relies are obviously different. In view of the history and the practical situation of China's engineering management education, the advantages of different institutions should be made full use of, engineering management programs of different institutions must be accurately and reasonably positioned, and the professional characteristics of different schools should be presented with their advantages, so as to better serve the society and meet social needs. Advantages of different institutions are mainly reflected in the engineering technology they rely on or their educational characteristics. In order to help engineering management professionals meet the actual requirements better, it is necessary to develop their specific engineering abilities concerning one specific industry on the basis of common engineering abilities.

4.3 Establishing the knowledge system of the engineering management discipline by way of reorganization and integration

The knowledge system of the engineering management abstracts common knowledge of engineering management,

and makes it systematized. At present, there is improvement to be desired of the knowledge system of China's engineering management. It is necessary to optimize and perfect the knowledge system of the engineering management discipline, keeping abreast of engineering development, technological progress and knowledge advancement, responding to social demands and making reasonable use of the educational advantages of the institutions of China and educational experiences of the institution of foreign countries. From the experiences of engineering management education in foreign countries, the knowledge system of undergraduate stage emphasizes combination of engineering technologies and management theories and methods based on engineering activities. However, most candidates reading for postgraduate degrees come from the engineering sectors, so cultivation at this stage mainly stresses theories and methods in management and economy. For example, courses of the graduate programs in engineering management of Brunel University include human resource and organization management, financial management, marketing, project management, production and operation management, quality management, information system, and manufacture strategy. Cultivation of postgraduates of China's engineering management programs also follows this principle. The key point for technological universities to adjust and optimize the knowledge system of the engineering management discipline is to strengthen the engineering technology of special industrial background and content. For instance, foundation courses about engineering of the corresponding industry can be intensified according to characteristics of the institution. At present, technological higher education institutions of engineering management education in China all have one or more than one industries in their background, such as civil construction, transportation, resource exploration and processing, aerospace, and manufacturing industry; and several Chinese universities of agriculture and forestry technology have also established engineering management programs, and agriculture and forestry make an obvious part of their background. As for the above institutions with characteristics, proper fundamental engineering technology courses of the industry can be added on the basis of engineering technology about civil construction. For example, courses concerning mining and material processing can be added for excavation industry. As for financial higher education institutions, due to the lack of the content of engineering technology, it is essential to cultivate the basic knowledge about engineering technology, on the basis of management and economics.

4.4 Promoting practical abilities of engineering management professionals

One of the important means for enhancing the ability of engineering management professional to solve practical problems is to add the educational links to engineering management practice. In order to realize this objective, engineering management education must be broadened and promoted with the cooperation of engineering enterprises or institu-

tions. On one hand, students must go to the enterprises and avail themselves of the opportunities of field training during the learning process; on the other hand, experts working in the field of engineering management for a long time can be invited to the higher education institutions to direct educational activities or give practical courses. Construction of the practice platforms or field work places is the foundation of strengthening practice of engineering management professionals. Selection and construction of off-campus internships and practice training bases for undergraduates in enterprises should be conducted. In enterprises with good conditions, off-campus internships and practice training bases can be established. Based on off-campus practice of undergraduates, combination involving production, teaching and research will be further promoted, and a reciprocal effect can be realized.

Typical cases of China's engineering management should be organized, and experiences and lessons of engineering management must be summarized, to develop as many resources as possible for engineering management education. And typical cases should include the lunar exploration projects, the Olympic Games architecture projects, large-scale hydraulic projects such as the Three Gorges and Xiaolangdi, and traffic construction projects including the Qinghai-Tibet Railway and the high-speed rails. With the case studies of these projects, experiences and lessons in project management, especially large-scale project management can be summarized. Such experiences and lessons may make an importance part of the common knowledge of the engineering management discipline, and may be of strong reference value to other projects. Meanwhile, strengthening knowledge management and knowledge sharing will promote practical ability of engineering management professionals.

What's more, training for engineering management professional teachers must be enhanced. In the 1950s, with the formation and development of modern industrial system of China, numerous engineering technology academies rose, profiting much from a large group of teachers with solid professional and theoretical foundation as well as rich experience in engineering practice. This guaranteed dynamic industry-university-research cooperation, and provided a good practice foundation for talent cultivation. In recent years, on the contrary, with the rapid expansion of higher education and acceleration of teacher replacement, many young teachers were supplemented into higher education institutions. These young teachers have grasped a large amount of modern knowledge, and possess active thought and strong adaptive capacity; but, inevitably, they have weak practical experiences and industrial backgrounds. If teachers lack the ability of solving practical problems, how can they cultivate students' operational ability? Therefore, it's necessary for educational institutions to help their young teachers to enlarge practical work of engineering management by strengthening cooperation with enterprises, so as to promote their practical ability.

4.5 Perfecting education quality of the engineering management discipline, and clarifying training objectives of different levels of education

It is beneficial to promote education quality of this discipline and further clarify training objectives of different levels. Generally speaking, education at the undergraduate level should emphasize close combination with actual activities of engineering, and the educators must develop the students' ability of solving practical management problems in engineering activities. As for doctoral students, scientific research of engineering management can be stressed. Education at the postgraduate level is between these two. Owing to the particularity of the engineering management discipline, the ability of the professionals can be promoted in the following three ways.

(1) The schooling of undergraduates of engineering management should be extended properly from the current 4-year duration to 5- or 6-year duration. Students with a schooling of 5 years can be awarded two bachelor degrees; students with a schooling of 6 years may apply for a bachelor degree and a master degree. During the first 3 years of the undergraduate stage, they can study engineering technology of the industry on which this program depends; and during the last 2 or 3 years, they might concentrate on management theories and methodologies.

(2) The MEM program should be vigorously expanded, and engineering management professionals can be cultivated among graduates from the engineering majors. The cultivation process of the MEM program has resulted in close combination between institutions of higher learning and actual demands of engineering. Especially topic selection of academic dissertation is often associated with design, technology, experiment, and new technology development required by engineering activities, so it can effectively improve the candidates' ability of solving practical problems in engineering.

(3) Continuing education of engineering management professionals should be promoted. Accelerated expansion of knowledge forces enterprises to pay earnest attention to continuing education and in-service training for engineering technicians. Many engineering management professionals come from technicians of engineering construction, so it's especially important to intensify continuing education of engineering management. Institutions of higher learning should play a positive role in promoting continuing education of engineering management, further clarify the education tenet, and conduct accurate positioning. Continuing education of engineering management should be enterprise-oriented, post-oriented, and first-line engineering technician-oriented. It needs to provide flexible, diverse, advanced and pointed educational curriculums that meet the post demands and well improve the vocational ability. At the same time, enterprise training quality must be improved and knowledge updating should be accelerated according to actual requirement of enterprises and latest development of the discipline.

4.6 Reforming the methods and means of instruction in engineering management education

It is necessary to reorganize the curriculum and the contents of the courses of engineering management education, and to reform the instructional methods and means. Modern instructional technology is an important means to reform the instructional methods. The key point of reform is to strengthen students' perceptual cognition about practical management problems in engineering activities, in the following ways.

(1) Increasing on-the-spot instruction of engineering management. Now most undergraduates of the engineering management program enter colleges or universities directly from senior high schools, and they have little perceptual understanding of engineering and don't have conceptual knowledge about management problems of engineering construction. As a result, they may easily indulge in groundless theoretical speculations in the process of study. Thereby, they have learned many modern management methods, but they don't know when and where these methods can be used and how to combine them with practical situation. An ideal way out of groundless labour is to participate in the overall process of engineering construction, and to explore an organic combination of theoretical instruction with practical instruction, so as to enhance the learning effect.

(2) Engaging the students in more case studies. Case studies can provide the students with good opportunities to examine and evaluate problems in engineering construction.

(3) Organizing extra-curricular lectures. Institutions of engineering management education can invite out-of-campus professionals to speak in the seminars of senior students or to give open lectures, as to give the students opportunities to share the practical experiences of engineering management personnel and develop their engineering management ability.

5 Conclusion

At present, there is much improvement to be desired of engineering management in China, and numerous professionals are needed to promote engineering management efficiency. And there is still remarkable gap between the existing engineering management education system and the demands of economical and social development in China. Based on a survey of the institutions of higher education, this paper presented a brief analysis of the current state of the engineering management discipline in China. And, this paper presented a brief discussion of the characteristics of the engineering management discipline, pointing out that discipline positioning of engineering management is a discipline that studies management, focusing on such issues as planning, organizing, resource-allocating, commanding and controlling of engineering activities. It is different from other management disciplines, specifically in that: Its object is the management

rule based on engineering technology; its methodology is the integration of engineering technologies and management theories; and its coverage is the combination of theoretical research and engineering application. Based on this, the paper tried to explore the paths of development of the engineering management discipline of China, suggesting that: The theoretical system of engineering management must be built and the methodological system of engineering management needs to be explored and perfected; the advantages of different colleges and universities should be made full use of, and their characteristics should be normalized for accurate and reasonable positioning; the knowledge system of the engineering management discipline must be reorganized and integrated; practical abilities of engineering management professionals need to be promoted; education quality of the engineering management discipline should be perfected and training objectives at different levels must be clarified; the instructional methods and means of the engineering management discipline have to be reformed.

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