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Engineering and Philosophy of Engineering

Abstract Philosophy of engineering lays the philosophical foundation of recognition, understanding and management of engineering. Being the kernel of philosophy of engineering, engineering ontology becomes the master key to understanding of engineering. The paper proposes and interprets the principal theses of engineering ontology, which differs from understanding of engineering in separate elements. Engineering ontology believes that engineering is the direct, realistic productivity that runs dynamically and feasibly and creates values. Engineering involves the relationship between human beings and the nature as well as the relationship between human beings and the society, and it has been a basic motive force and a basic way of promoting the social development, so that engineering gains the ontological status and fundamental value in social existence and social development. From the historical point of view, the engineering appears before the emergence of technology and science. Engineering has its own basis for existence, its own structure and its own laws for movement and evolution. Engineering should not be simply regarded as the ramification and derivative from science or technology. Engineering ontology is the theoretical basis of the triism of “science, technology, and engineering”. To understand and handle the mutual relationship among engineering, technology and science, by the evaluation criteria of engineering as the direct productivity, the process and effect of engineering-centered selection, integration and construction must be emphasized and the characteristic and mechanism of selection, integration and construction must be paid high attention. Under no circumstance may the engineering be deemed as an unchanged matter, which is constantly evolving and developing, so the studies on engineering ontology are closely and internally related with the theory of engineering evolution.

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1 Introduction

While philosophy of science and philosophy of technology have been established for a long time, philosophy of engineering is slow in coming. At the end of the twentieth century, almost no one showed any interest in research of philosophy of engineering (Durbin, 1991). However, at the beginning of the 21st century, philosophy of engineering rises in the East and the West (Li, 2008). Within five years, from 2002 to 2007, four books entitled philosophy of engineering, *An Introduction to Philosophy of Engineering* (Li, 2002), *Engineering Philosophy* (Bucciarelli, 2003), *Philosophy of Engineering* (Yin, Wang, & Li, 2007) and *Philosophy in Engineering* (Christensen, Delahousse, & Meganck, 2007), were published. Interestingly, three Academies of Engineering, Chinese Academy of Engineering, National Academy of Engineering of America and the Royal Academy of Engineering, have paid attention to philosophy of engineering without previous arrangement since the beginning of the 21st century, which stands out as one of the landmarks in the history of philosophy of engineering. The Division of Engineering Management of the Chinese Academy of Engineering has finished three research projects on philosophy of engineering since 2004 and published three books, *Philosophy of Engineering* (first and second edition) (Yin et al., 2007, 2013) and *Theory of Engineering Evolution* (Yin, Li, & Wang, 2011). In 2004, the Committee on Engineering Education of the National Academy of Engineering of America established Steering Committee for the Philosophy of Engineering in order to study philosophy of engineering. The Royal Academy of Engineering embarked on a series of seminars on the philosophy of engineering in March 2006 and published *Philosophy of Engineering* (Volume 1) in 2010 (The Royal Academy of Engineering, 2010). Now, in many countries, the scenario of philosophy of engineering is just unfolding.

Chinese engineers and philosophers consider engineering

ontology the core issue of philosophy of engineering (Yin & Li, 2013). In this essay engineering ontology will be interpreted briefly.

The engineering refers to all kinds of creation activities by the human beings to improve their own conditions for survival, reproduction and growth according to the local understanding on the nature at that time. It is a materialized labor process.

The engineering is a direct productivity that runs dynamically and feasibly, creates values and serves as a material basis for the existence and development of the human beings and the society.

The engineering reflects the relationship not only between the human beings and the nature, but also between the human beings and the society. Therefore, it should be surveyed and studied from the triilistic relationship among “the nature-human beings-the society” (see *Figure 1*). Under no circumstance may such engineering activities be simply deemed as the “purely technical activities” or “purely economic activities”. And the engineering, in addition, may not be simply summarized as the “application of science” as well.

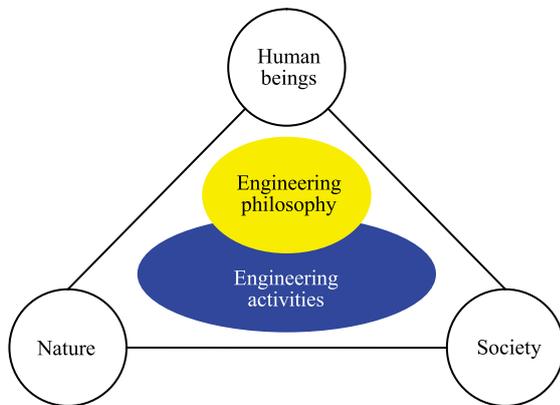


Figure 1. Position taken by engineering activities in the triadic system of “the Nature, Human Beings and the Society”. Data adapted from *Philosophy of Engineering (2nd Ed.)*, by Yin, R., Wang, Y., & Li, B., 2013, Beijing: Higher Education Press.

The engineering embodies the comprehensive integration for the configuration of elements between the nature and the human beings, and the related processes on conception, decision, planning, design, construction, running, management etc. It is full of philosophical implications.

The philosophy is a process to pursue the “Tao” and to ask repeatedly and probe into fundamental questions about the essence and laws of existence, as well as the meaning of human life. And the human beings, in return, shall guide and standardize all kinds of practical activities by following their understanding and comprehension on the “Tao”. During the development history of the human beings, the engineering serves as a fundamental form of practice all the time. The

engineering activities, besides, have a long history of development. The engineering appears before the emergence of technology and science and thus shall be the topic on which the philosophy focuses. Since the beginning of the 21st century, the engineering philosophy has become a very important field of the practical philosophy.

2 Observations of engineering from different views

All kinds of human activities of creation have both natural attributes corresponding to natural laws and social attributes with purposes.

From the point of view of modern knowledge, a corresponding knowledge chain exists between the nature and the society. The above-mentioned knowledge chain is one used to understand the logical relationship, rather than one used to understand the inheritable relationship of historical time sequence. It is a complicated knowledge chain and a multi-layers knowledge network where diversified and complicated relationships exist among different links and layers. *Figure 2* represents an abstract graph for summarization.

Before the emergence of the philosophy of engineering, people used to observe the engineering from different views and they seldom observed or studied engineering as engineering itself or on the engineering-centered principle. “Different projections” on engineering will be gained in case of engineering observations from different views and different understandings will be thus obtained on engineering itself.

(1) From the economic point of view, it may be concluded that the investment is a fundamental element for engineering activities and material engineering activities, including material construction activities, material production & manufacturing activities, material transmission activities etc., are a specific carrier for the economic operation, as well as the main content and the primary form for substantial economy.

(2) From the industrial point of view, it may be concluded that the engineering is a primary unit of industry and relevant engineering entities (factories, enterprises, etc.) of the same type are the “cells” of the industry. Engineering usually has the industry features. Different types of engineering may form different industries, including the agriculture, animal husbandry, forestry, mining, process manufacturing, equipment-product manufacturing, transportation, information transmission, medical care, etc.

(3) From the technological point of view, it may be concluded that the engineering is a collection of technologies and the technological knowledge, methods and equipment are the indispensable premise and basis for engineering activities. Relevant technical groups with different natures and functions may be integrated together through the engineering system and be transformed into the valuable practical productivity with specific functions, after the combination of such elements as the capital, resources, labor, etc. Neither may a single technology form the engineering, nor may the

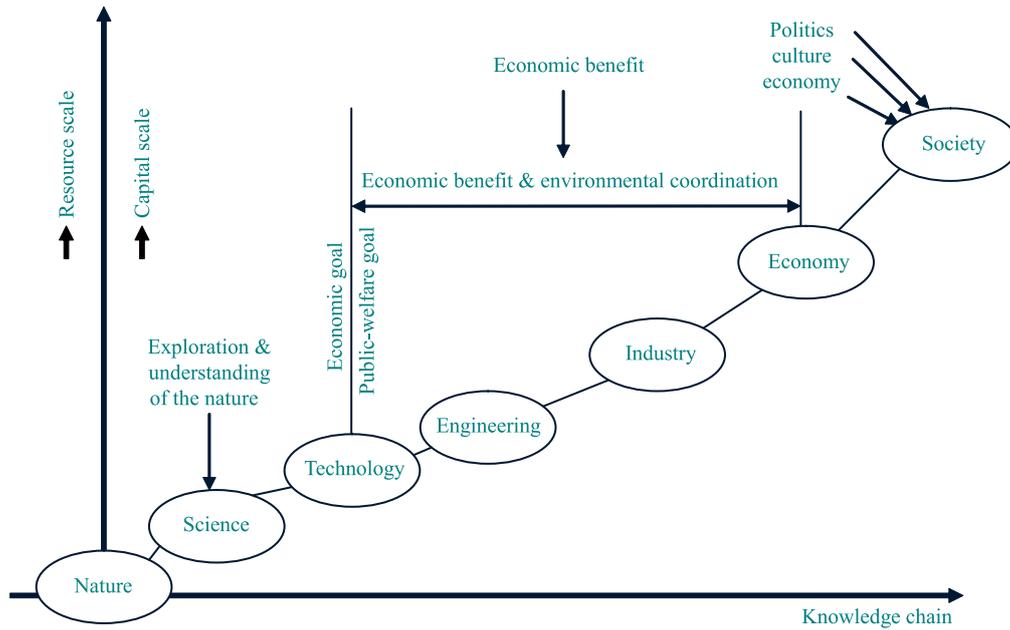


Figure 2. Relationship between a knowledge chain and an expansion process of resource & capital scales. Data adapted from *Philosophy of Engineering (2nd Ed.)*, by Yin, R., Wang, Y., & Li, B., 2013, Beijing: Higher Education Press.

engineering simply apply a single technology. As an integral element of the engineering, only may the technologies perform their respective functions and efficiencies after they are embedded, in a dynamic and ordered way, into the engineering system (including the engineering design, construction, production & manufacturing, transportation, information transfer, maintenance, fault diagnosis and disposal etc.). On the one hand, the technology is the basis for the engineering; on the other hand, the selection, integration and construction of different technical routes and equipment will be inevitably conducted for the engineering design and engineering activities on the basis of the “engineering needs”. To sum up, the technical selection, integration and construction are required for the engineering. During the selection of technical elements for the engineering, the advancement of technical elements themselves may not be simply used as the unique standard. The “engineering purpose” and the “overall engineering requirements”, instead, shall be adopted as the basic standard for selection.

(4) From the scientific point of view, differences between the science and the engineering will be firstly found. The science is truth-oriented, while the engineering (including the technology) is otherwise efficiency-oriented or value-oriented. The science aims to explore and find the composition and nature of things, as well as their rules of movement. The scientific activities are not intended for making new inventions, but they aim to find out the running rules of objective things that actually exist. Scientific discoveries may be converted into productivity through the technology and the engineering. Many scientific activities, however, are not always to realize the convert into practical productivity. From the

historical view, engineering activities have existed since the primitive society, while the modern scientific activities only have been developed for hundreds of years. Within a long period in history, the implementation of engineering activities does not rely on the findings of scientific principles. Even the first industrial revolution was not “driven” by scientific theories. After the first industrial revolution, the engineering and the science become more closely related and the relevance between the engineering activities and the modern science is enhanced increasingly; at the same time, many new problems and directions with respect to the science have been put forward by the engineering.

(5) From the resources point of view, it may be concluded that specific resources are the essential premise and basis for engineering activities. Among the engineering activities, those “materials” “without any value difference” in physics become valuable “resources” with difference uses. The resources in the world, in addition, are distributed in an unequal and unbalanced way. The constraint and development of resources are important contents under the engineering activities. The resource-based view of engineering activities is greatly different from the material-based view of natural science in their meanings and contents.

3 Significance of observations & studies of engineering from the view of engineering ontology

As for engineering, we not only need to understand all el-

ements as well as different performances and sides of the engineering from different views, but also need to probe into its nature from diversified phenomena. In this way, a more comprehensive and overall understanding on the engineering may be gained from different “single sides”. Misunderstanding or one-sided understanding will inevitably occur if we can’t study engineering from the generation, development and evolution of the engineering itself, and understand the root of the engineering activities.

We have also experienced a gradually deepening process for understanding what the engineering ontology is.

First edition of the *Philosophy of Engineering* was published by us in 2007 (Yin et al., 2007). In the book, though the scope of engineering ontology has not been clarified, it has been pointed out that the engineering is a practical and direct productivity, and it may be comprehended, in essence, as the combination of the integration & construction process, method and mode with respect to a new artificial existence, with the utilization of all resources, knowledge and related basic economic elements. Later, we have further studied the engineering activity from the view of philosophy ontology and deepened and sublimated the above-mentioned points of view as our understanding on the ontology. After our basic understanding above-mentioned on the engineering is related with the scope of the engineering ontology, it is more profoundly concluded that the engineering activity is the basis for the existence and development of the society and the engineering shall thus take an ontological rather than attached place. In a word, to understand the engineering from the view of philosophy, it shall be acknowledged that the engineering has its profound and fundamental nature and meaning as the ontology. As a consequence, in the second edition of *The Philosophy of Engineering* (Yin et al., 2013), the point of view representing the ontology is outlined. In order to understand what engineering is, we must analyze and study the scope, concept, features, connotations, definitions, boundaries and thinking logics of the engineering from the ontological view. The “engineering ontology” is a basic point of foothold and starting point. With the “engineering ontology” as a fundamental root and viewpoint, a more comprehensive and objective understanding of engineering will be obtained, which fits in with engineering reality more closely.

4 Engineering ontology and “derived theory of engineering”

The view of engineering ontology is greatly different from that of the derived/attached theory of engineering. The former believes that since the engineering takes an ontological or root position, we must adhere to understanding the engineering from the engineering itself. The latter, however, believes that the engineering only takes an “attached” or “derived” position.

After the Second World War, the view of derived theory of engineering is very popular both in the western and eastern

worlds. Many people “usually” regard the engineering as the “application of the science”, and mix up or “conclude” engineering achievements as scientific achievements. For example, the achievements by the U.S.A., Russia and China in the aerospace engineering are concluded as the achievements made in the aerospace science.

Though the above point of view has an obvious historical flaw and needs to be theoretically discussed, it has become a very “popular” standpoint in the whole world. This historical flaw was shown by the fact that in the history of mankind, the modern science only has been developed for few hundreds of years, while the engineering activities of the human beings have been developed for more than thousands and thousands of years. For this reason, the engineering which had been formed even before the emergence of the modern science can not be regarded as the application of science.

Undoubtedly, after the formation of the modern science, the relationship between the science and the engineering becomes closer and more complicated. After the first industrial revolution, there seem to be many phenomena indicating that the engineering activities must rely on the science knowledge, and the engineering knowledge is derived from the science knowledge. The further analysis and studies prove that it is not the case. If the purpose and social significance and other related issues are taken into account, the standpoint that the engineering is simply deemed as the “application of science” is not supported.

The opinion that “the technology is nothing but the application of science and the engineering is nothing more than the application of technology” was even analyzed and criticized by the Professor Chen Changshu in one of his essays in 2002. The standpoint that the engineering is the “application of science”, however, seems not to be actually shaken ever.

Theoretically speaking, the crucial, central point of the thesis that the engineering is merely the “application of science” lies in denying the root position of engineering. Just as above mentioned, engineering has ontological status, which means that engineering is neither a derivative of science, a derivative of technology, nor a derivative of investment.

The engineering ontology believes that the engineering activities are not derived but the root. Engineering activities are the practical and direct productivity that are generated, developed and constantly evolved for the survival, reproduction and development of the human beings. The engineering emerged before the emergence of sciences and engineering activities are the material basis for the existence and development of the society. The human beings would not survive without engineering activities.

From the point of view of engineering ontology, it must be concluded that: though the close relationship between the engineering and the science & the technology may not be denied, it shall not be thus believed that the engineering is attached under the science and the investment activities as well. Of course, it must be emphasized that as to the engineering, the technology is its essential connotation and the science is its important element for knowledge support. The

engineering, however, has its undeniable “ontological” position. And under no circumstance shall the engineering be deemed as the derivative, outgrowth or outcome from the science and the technology.

Due to the root position taken by the engineering, the engineering can not be separated from its integral elements, and shall select and integrate all elements thereto according to certain value objectives and criterions. The mechanisms of the selection, integration and construction of the engineering are the bridge to connect together the root theory and the elements theory of the engineering.

The characteristics of the engineering activity should be comprehended and analyzed from the view of engineering ontology. The engineering activity aims at making artifacts or installations through selection, integration and construction and at optimization of elements, structure, functions and efficiency under certain boundary conditions. These processes and results of the engineering activity are both in-

tended for the realization of the engineering in the form of a practical and direct productivity.

Under the engineering integration, the unity of opposites featured by “one” root yet “several” elements is embodied. The integration is by no means equal to the piece together or random combination of several elements. The engineering is a kind of material social activities of the human beings. It involves not only those elements with respect to ideology, value and knowledge, but also resources, capital, land, equipment, labor, market, environment and other elements. Only when an operable and valuable engineering entity, with a certain structure and functions, is formed after the selection, combination, interaction and integration of such knowledge, tools, means and elements, may the engineering be realized in the form of direct productivity. The connotation and elements of the engineering may be abstracted into the model below (see *Figure 3*).

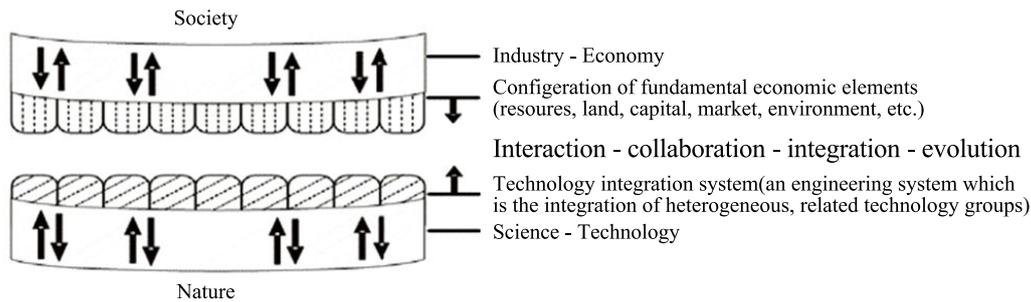


Figure 3. Connotation of engineering and its elements and integration. Data adapted from *Theory of Engineering Evolution*, by Yin, R., Li, B., & Wang, Y., 2011, Beijing: Higher Education Press.

To sum up, the engineering may be interpreted as follows: the engineering is a purposeful, planned and organized “man-making” material practice in order to construct and run artificial realities. In the process of engineering human beings utilize their diversified knowledge utilized in an intended, planned and organized way (including technical knowledge, science knowledge, engineering knowledge, industry knowledge, social-humanity knowledge etc.) and all kinds of resources effectively configured (including natural resources, economic resources, social resources, knowledge resources etc.), through the optimized selection and the dynamic & effective integration of elements, using a variety of equipment and means of production.

5 Summarization of the engineering ontology

Engineering ontology is an important issue in the study of philosophy of the engineering. The above analysis about engineering ontology can be attributed to the following points of view.

(1) Engineering ontology is a philosophical discussion of the origin, matrix and root of the engineering. The so-called engineering ontology is to view engineering from the view of human survival and development, in particular, to clarify the fundamental position and role of the engineering activity from human existence and social development as well as the construction and re-establishment of the relationship between man and nature, man and society, etc., and other philosophical visions.

(2) From the point of view of the engineering ontology, the engineering activity is one of the most basic and historic human activities. Engineering realistically shapes the appearance of nature and the relationship between people and nature, shapes the world of human life and the human beings themselves, shapes the material aspect of society and embodies the social connections between people. Engineering activity is the foundation of human survival and development; as a real productivity, it is the basic way and strength to promote social development. Engineering ontology emphasizes the ontological status of the engineering as a real productivity, as well as the broad values and fundamental

values of the engineering activity.

(3) Engineering ontology is the theoretical basis for the triism of “science, technology, and engineering”. Engineering ontology believes that engineering has its own basis of existence, its own structure, motion and law of development, and its own goals and pursuit of value. We cannot start from the view of scientific ontology, to simply treat engineering as a derivative and growth of the science or the technology.

(4) Engineering ontology confirms the root and ontological position of the engineering, starting from the evaluation criteria of direct productivity in the understanding and treatment of the relationship between engineering, science

and technology, emphasis on the selection, integration and construction process and results which define engineering as the body, and attach great importance to the features and mechanisms of selection-integration-construction.

(5) Engineering cannot be deemed as a fixed matter; it is actually evolving all the time. In the graduate or capricious processes and mechanisms, there are interactions and joint effects among driving force, pulling force, braking force, screening force, etc (see *Figure 4*). There is also a close relationship between the research of the engineering ontology and engineering evolution.

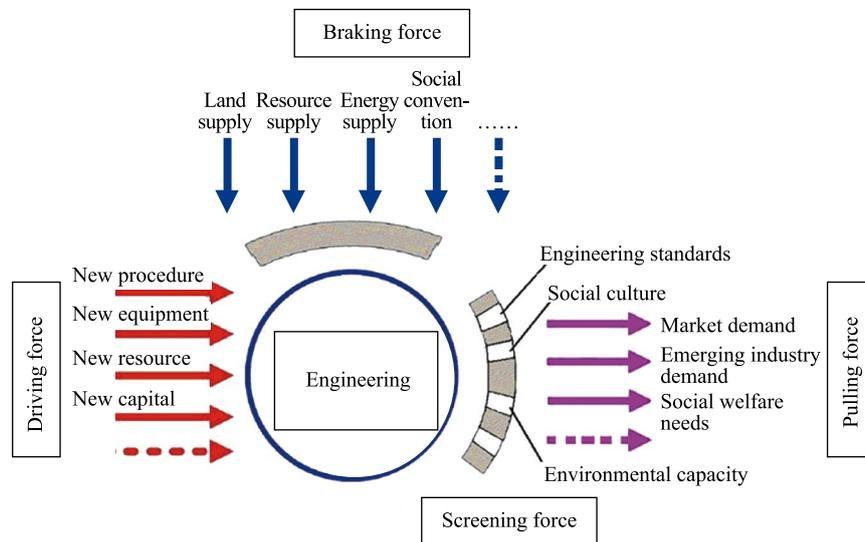


Figure 4. The Model of Dynamic System of Engineering Evolution (Yin, et al., 2011, p. 70).

6 Engineering transcendence and philosophy transcendence: the emergence of philosophy of engineering as the times require

Any engineering is permeated with the pursuit of human values; it is the value-permeated engineering that constructs the life world of human. Engineering activities of human beings are a process of creating and enhancing human values. The so-called engineering value, a special value created through engineering activities, reflects the extent to which engineering activities and their results meet human needs.

According to the different connotations of the subject requirements, engineering value can be divided into several types, such as economic value, ecological value, military value, social value, cultural value and so on. The diversified, multi-dimensional, multi-targeted features of such values are determined by the cross-cutting features of the engineering activities and the reality of beneficial diversification.

Engineering has not only a utilitarian value, but an ul-

tra-utilitarian value. The utilitarian value reflects the practicability of the engineering; the ultra-utilitarian value engineering embodies the taste-humanistic values, i.e. basic interest and pursuit of beauty.

Human life has a dual nature, that is, has not only its own biological life, but also the transcendence that makes people different from animals. Engineering happens to be an effective way to achieve human transcendence. It is through engineering practice that people’s metaphysical ideality may be effectively converted into tangible reality. It is also through this type of conversion that engineering shapes “materialness” and “humanity”, and shapes the way of people living. Engineering shall pursue the unity of regularity and purpose, that is, pursuing not only utilitarian value but also human transcendence, and embodying humanistic values, to bring people freedom and full development.

Obviously, in the process of understanding engineering, people can read nature, read life, read society, and read dialectical relationship of “integration of knowledge and action”, “harmonious development” and “harmonious survival”.

Philosophy has been established in the process of understanding the nature, society and people, accompanying with inquisitive, repeated questioning, and pursuit of ideal. Ideal is a question about reality, and yearning for or pursuit of future goals. In the background of a new century, engineering shall be a new frontier, or a new layer of state to think about philosophy. It shall be one of the important objects of philosophical reflection. For engineering, it is an urgent need to use philosophical thinking for equipment and upgrades. Because an important goal of philosophy is to think or display a new realm of future “life”; whereas the fundamental purpose of the engineering is to try to build and achieve the new realm of future “life”. In this sense, there are many intersections and unions in the process of philosophy and engineering transcendence, therefore, engineering needs philosophy, and philosophy must face engineering; the interaction between them hasten the delivery of the engineering philosophy.

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