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ENGINEERING MANAGEMENT TREATISES

Jin Wang

The Construction of Tetrahedral Model of Engineering Ethical Evaluation

Abstract To achieve great projects, great attention should be attached to ethical issues of engineering. But endless immoralities in the field of engineering expose the lack of attention and the ineffectiveness of implementation of engineering ethical evaluation. The “Mirror” and the “Lamp” — these two metaphors used by M. H. Abrams vividly expose the differences in people’s way of understanding which inspires author’s study of the model of engineering ethical evaluation. With four elements of the project —artifact, engineer, user and environment, a tetrahedral model of integrity, strong restoring force and high stability is built. While their roles and responsibilities differ, each has to demonstrate a commitment to professional and ethical standards. In this model, four “Lamps” — i. e, four elements of engineering — in four corners provide light while four “Mirrors” — the result of reflection of four elements — reflect whether the tetrahedral model can truthfully evaluate the level of engineering ethics. The combination of the “Lamps” and “Mirrors” illuminates engineering ethical evaluation and leads to a plurality of evaluation standards, while simultaneously fostering both the avoidance of simple de-instrumentalization and the sustainability of ethical evaluation. Plurality of evaluation standards means the consideration of value differences in a multi-value state. The avoidance of de-instrumentalization means to prevent the engineer’s expertise from fossilization. The sustainability of ethical evaluation accelerates the fulfillment of our dream, for the ultimate benefit of humankind. Ethical evaluation of the project not only helps more engineers to use expertise in pursuit of the public good, but also make more projects to meet people’s short-term expectations and long-term cares.

Keywords: tetrahedral model, ethical evaluation, engineering, Lamps and Mirrors

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Jin Wang (✉)
School of Civil Engineering, Central South University, Changsha 410004, China
Email: csruwangjin2@126.com

1 Introduction

In the trend of high-technicalization, large-scale integration and the profound socialization of engineering (Xing, Liu, & Wang, 2008, p.40), the sound development of engineering must be guaranteed by engineering ethics. But the endless immoralities in Chinese engineering construction like disregarding rules, overlooking the standards, ignoring public opinions, shirking responsibilities, taking bribes, cutting corners, are greatly threatening public welfare. In China, engineering decisions are frequently replaced by management decisions. A key index of evaluating engineering activities is the level of implementation of local administration’s will. This stems from a deficiency of engineers’ individual ethics, and the imperfect engineering ethical evaluation system. Ethical evaluation is not only a yes-or-no judgment, but also an exploration of moral reasoning (Richard & George, 2009).

At present, five major problems exist in the field of engineering ethical evaluation. Firstly, too much attention has been attached to the fulfillment of the projects’ pre-set goals and the implementation of technical and economic indicators. Secondly, consistent ethical evaluation conclusions can hardly be drawn by universal sci-tech ethics. Thirdly, people are ambivalent about human alienation as a result of engineering products. Fourthly, traditional ethics become aphasic in face of those mega-projects which are highly systematic and deeply involved with complicated technology. Last, ethical evaluation lacks autonomy and independence. That is to say, it hardly “forms [its] own judgments on what to think or do; that [it] is disposed critically to reflect on [its] own first-order judgments; and what [it] is disposed to integrate [its] actual belief and conduct round these first-order and reflective judgments”(Dearden, 1984, p.9). Engineering ethics is prospective and comprehensive. It is prospective because it embraces a feature of predictability and a sense of crisis. It is comprehensive because it requires the engineer to put the public safety, health and welfare in the first place. Thus the ethical dimension becomes an indispensable part of engineering evaluation which can meet the requirement of sustainable development and guarantee the common interests of both contemporary and future generation. The idea of constructing a tetrahedral model of engineering ethical evaluation is from famous literary critic M. H. Abrams' *The Mirror and the Lamp* (Abrams, 1971). But unlike M. H. Abrams' *The Mirror and the Lamp*, this tetrahedral model is spangled with four "lamps", namely artifact, engineer, user and environment. By analyzing the ethical relationship between any two elements, the ethical issues embodied in each "mirror" are explored. The combination of four "lamps" and four "mirrors" illuminates engineering ethical evaluation and leads it to diversification, de-instrumentalization and sustainability. The tetrahedral model exposes the external structure of engineering ethical evaluation and the internal mechanism of engineering to the benefit of mankind. The model not only broadens the horizon of engineering ethics, highlights its research focus, but also stimulates its academic development.

2 Mechanism analysis of tetrahedral model of engineering ethical evaluation derived from Abrams' *The Mirror and the Lamp*

2.1 Literary interpretation and origins of Abrams' *The Mirror and the Lamp*

Ever since its publication in 1953, M. H. Abrams' *The Mirror and the Lamp: Romantic Theory and the Critical Tradition* has been one of the most influential studies in the field of literary criticism and theory. The title of the book identifies two common and antithetic metaphors of mind, the "Mirror" comparing the mind to a reflector of external objects, the "Lamp" to a radiant projector which makes a contribution to the objects it perceives. Also in this book, a well-known scheme (see *Figure 1*) is proposed by Abrams which distinguishes four elements, namely work, artist, universe and audience that make up 'the total situation of a work of art.' In this triangle, the work of art is put in the center. The work of art is explained principally by relating it to another thing: the universe, the audience, or the artist. Literary theories, Abrams argues, can be divided into four main groups: mimetic theories (interested in the relationship between the work and the universe), pragmatic theories

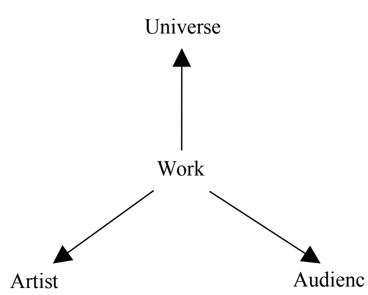

Figure 1. Abrams' scheme.

(interested in the relationship between the work and the audience), expressive theories (interested in the relationship between the work and the artist), and objective theories (interested in close reading of the work).

The metaphor of "Mirror" makes its first recorded appearance in Plato's *The Republic* which suggests that "…turning a mirror round and round — you would soon enough make the sun and the heavens, and the earth and yourself, and other animals and plants, and all the, other things of which we were just now speaking, in the mirror"(Plato, 2007, p.387).

The analogy of a mirror in order to illuminate the nature of one or another art continues to be a favorite with aesthetic theorists long after Plato. The analogue is especially popular for comedy. For example, Cicero once mentioned that comedy is "a copy of life, a mirror of custom, and a reflection of truth." As to M. H. Abrams, the metaphor of "Mirror" exposes the fact that until the Romantics, literature was usually understood as a "Mirror", the imitation of life or holding the mirror up to nature; but for the Romantics, writing was more like a "Lamp".

Abrams' idea of "Lamp" is inspired by William Wordsworth, the great Romantic poet. The manifesto of Romanticism—"poetry is the spontaneous overflow of powerful feelings." — declares the independence of the poet. Wordsworth also declared that the emotion was recollected in tranquility and that the spontaneity of its overflow was merely the reward of a prior process of deliberate thought. The shift from "Mirror" to "Lamp", is not only a change of metaphor, but also a shift from an Aristotelian to a hermeneutic view which entailed a shift from 'truth' to 'meaning'. Since then, the work of art is no longer considered as a mere reflector, a "Mirror", but a radiant projector, a "Lamp" from which the light of the writer's inner soul spilled out to illuminate the world.

2.2 Theoretical development of Abrams' *The Mirror and the Lamp*

The light of Abrams' *The Mirror and the Lamp* has not faded as time passes by. It has greatly influenced many followers. Based on Abrams' idea, many scholars put forward their own schemes among which James Liu's and Donald Keesey's schemes are fairly representative.

James Y. Liu inherits and reforms Abrams' scheme (see *Figure 2)*. In fact, one of Liu's life-long ambitions was to come up with a theoretical framework that would be comprehensive and sound enough to make due allowances for differences in beliefs, assumptions, prejudices, and ways of thinking. This stimulates Liu to replace Abrams' triangle scheme with a circular one which exposes his aspiration to be trans-historical and trans-cultural. The major weak point of Abrams' scheme is that: "Otherwise we should no longer speak of 'literature' but only of discrete 'literatures,' nor of 'criticism' but only of 'criticisms'." Moreover, in this scheme, Abrams' unidirectional arrows are all replaced by bi-directional ones which make dynamic a salient characteristic of Liu's scheme

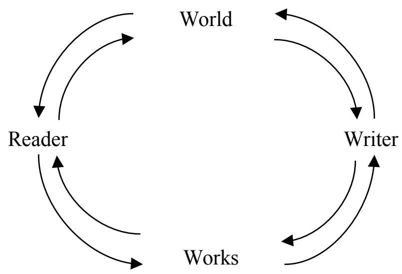

Figure 2. James Liu's scheme.

(James, 1976).

Donald Keesey also proposes a scheme (*Figure 3*). Unlike Abrams' triangle and Liu's circular schemes, Keesey's scheme is a bilateral symmetry with work in its center. The scheme consists of two axes. The vertical axis represents the communication between the author and the reader, taking the work of art as its medium. The horizontal axis represents the relationship between reality and literature. A conspicuous feature of this scheme is the use of bidirectional arrows. Keesey expounds his opinion in the preface of *Contexts for Criticism*. "We hear of old historians, new historians, and anti-historians, of Freudians, Jungians and Lacanians, of Marxists and feminists, affectivists and geneticists, structuralists and poststructuralists, old New Critics and New Critics…these terms are not all built on the same principle…we need a conceptual scheme that will include the many types of literary criticism and at the same time separate the competing voices in a way that will help make useful comparisons"(Keesey, 1994).

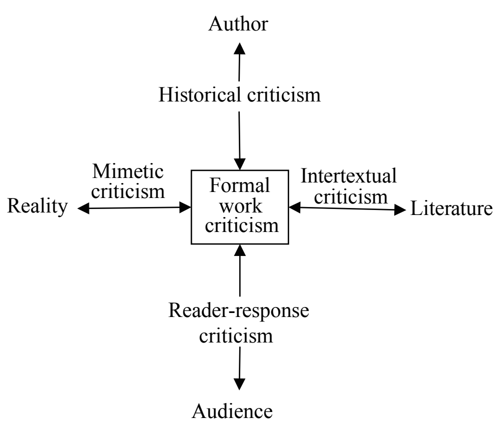

Figure 3. Donald Keesey's scheme.

Although different in shapes, both Liu's and Keesey's schemes try to be dynamic by use of bidirectional arrows.

2.3 Mechanism analysis of tetrahedral model of engineering ethical evaluation beyond Abrams' *The Mirror and the Lamp*

Similar to literature, engineering also consists of four indispensable elements: the artifact, the engineer, the user and the environment. It is convenient and practical to make an analogy between literature and engineering. In the field of engineering, the work of art is analogous to artifact, the engineer to artist, the environment to universe and the user to audience.

Unlike literature, engineering has its own characteristics which make it difficult to apply Abrams', Liu's or Keesey's schemes mechanically in engineering. The reasons are as follows.

First, although four elements of engineering—artifact, engineer, user and environment—are closely related, each of them has its own specific characteristics. Liu's circular scheme means to avoid centrism with a loss of emphasis on the individuality of each element. Second, the link between any two elements is established not only by mere reflection but also by direct interaction. Successfully avoiding the static and isolated feature of Abram's scheme, Liu's circular scheme, however, does not expose the direct interaction between universe and work, artist and audience. Third, the comprehensive discussion of the active interaction among any three of four elements of engineering is beyond Abrams', Liu's or Keesey's bi-dimensional surface. The dynamic circulation and impact among any three of them form a plane surface which eventually makes the construction of a tetrahedron feasible. Last, engineering is a dynamic process involving constant change and latest innovations, especially in a great new era of information. The mechanical application of Abrams', Liu's or Keesey's scheme in engineering will make thinking fossilized and greatly hinder the theoretical development of engineering ethics as all of them are closed.

For these reasons, the author adapts Abrams' theory and constructs a tetrahedral model to explain the profound ethical value embedded in engineering activities. In this model, each element rather than the work of art alone acts as a lamp, a radiant projector, lighting itself and illuminating mirrors simultaneously. The emphasis shifts from the "mirror" to the "lamp" which indicates the prominent place of each element and the transformation from a lateral, static bi-dimensional plane to a bilateral, dynamic tri-dimensional object. (see *Figure 4*) The construction process of this tetrahedral model follows the following steps. (1) To discriminate the profound meaning of engineering ethics based upon the detailed description of engineering's four elements and their relationship. (2) To construct a tetrahedral model to help all parties involved to identify the hidden engineering ethical problems and find a comprehensive solution to them. An overall solution from the macro-, meso-and micro-perspective is strongly recommended. (3) To steer engineering ethics toward macro-direction in the network of complicated relationship formed by the interaction among the point, line and plane of the model. (4) To realize that the tetrahedral model is a self-contained organism whose stability represents the impact and contribution the engineering ethics plays to engineering management.

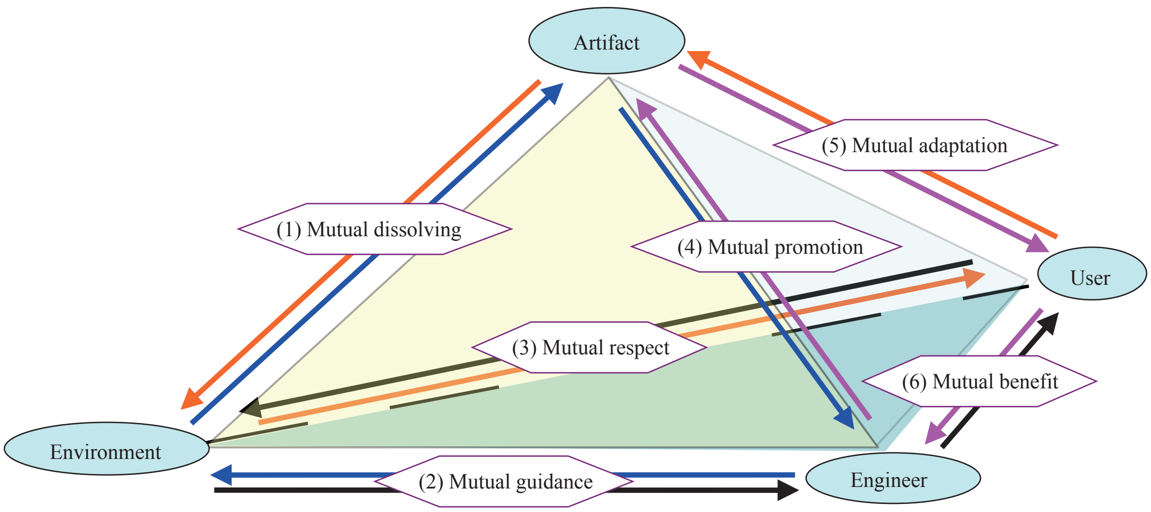

Figure 4. Tetrahedral model.

Table 1 *The Explanation of Figure 4*

1	Mutual Dissolving	(1-1) Incarnation (Artifact→Environment)
		(1-2) Dissolution (Environment→Artifact)
2	Mutual Guidance	(2-1) Integration (Engineer→Environment)
		(2-2) Guide(Environment→Engineer)
3	Mutual Respect	(3-1) Respect(User→Environment)
		(3-2) Support(Environment→User)
4	Mutual Promotion	(4-1) Experience(Artifact→Engineer)
		(4-2) Inoculation(Engineer→Artifact)
5	Mutual Adaptation	(5-1) Satisfaction(Artifact→User)
		(5-2) Application(User→Artifact)
6	Mutual Benefit	(6-1) Accountability(Engineer→User)
		(6-2) Boosting(User→Engineer)

3 Four bright lamps firmly fixed in four corners of tetrahedral model of engineering ethical evaluation

A tetrahedral model, four elements of engineering—the artifact, the engineer, the user and the environment—highlights profound ethical connotations because of their inherent values. Each element is set in one corner of the tetrahedron, lighting itself and illuminating mirrors simultaneously. First, the brightness of the lamp indicates the goodness of each element's ethical performance. For instance, if the engineer has ethical consciousness and can adopt a zero-tolerance approach to bribery, fraud, deception and corruption in any form, the lamp in this corner will be bright. Otherwise, this corner will be plunged into complete darkness. Moritz Schlick mentioned: "But much more important than the question of when a man is said to be responsible is that of when he himself feels responsible."(McGuinness, 1985, p. 154) One of an engineer's basic obligations is to guarantee human safety and respect their rights to consent. Huang Wanli, the famous hydraulician boldly pointed out Soviet experts' unreasonable set of sand-flash orifices of the Sanmenxia Dam. He said: "I know something wrong. So I must speak it out. I am a researcher of the Yellow River. I am responsible for our country. It is just like seeing a child drowning, I cannot keep silence. I will yell out so that people would come and save him." This is one brilliant example of ethical consciousness.

Second, the dim light of a lamp not only plunges the corner which it occupies into terrible darkness, but also makes the mirror opposite to it lose its reflection function. It is the loss of autonomy as well as heteronomy. For example, the conscience acts as a special setter and decision maker in an engineer's moral life which will urge the engineer to achieve personality perfection (Georg, 1991, p. 163). The absence of conscience makes the beforehand prejudication, the mid-event superintendence and the afterward appraisal right all become empty talk.

Third, the extinguishment of a lamp makes the light zone between this lamp and other light sources fade. And the appearance of a complete dark zone becomes inevitable. For example, the corruption and the destruction of historical site in the process of engineering are those dark zones which lamps can hardly shine in. Another example is the different attitudes toward wilderness. The anthropocentrism argues that the wilderness cannot provide useful resources to humans. It is only through exploration that the wilderness can have economic values. The exploration of the wilderness is also a symbol of civilization and progress. Wasteland reclamation rate should be considered as a key indicator of the ecological environment. The eco-centrism, however, takes the wilderness as a natural objective entity. The wilderness has its own intrinsic and systematic values. For this reason, the reclamation must be carefully handled in order to achieve a balance between the gain and loss. By comparison, it can be easily seen that if each one of us is anthropocentric, a harmonious relationship between man and environment would only be a daydream.

Fourth, a bright zone can also be formed with a loss of one lamp if the other three lamps are bright enough. This is especially evident in the implementation of modern projects. Take PX projects for an example. PX projects have been trapped in a difficult situation in China. The residents in Dalian, Xiamen, Ningbo, Pengzhou, and Kunming have protested successively against the local PX project plans. They resolutely say "No." to the PX project. This perfectly shows the users' increasing consciousness of the right to safe-guarding and environmental protection. Apparently the project investor is too strong to be shaken. The final result proves that if a lamp is bright enough, it can also dispel the dark cloud over the tetrahedron. At present, the ethical consciousness of most Chinese engineers is still at an elementary stage. The focus of attention is on "doing the project well" rather than "doing a good project". Mitcham argued that the ethical concern about engineering is not only a responsibility of experts, but also of everyone. Through a transition from expert centrism to public participation and the co-responsibility of both scientific and technical personnel and common people, an engineering evaluation system with a much more extensive mass base and expert support can be established (Mitcham, 2003). This system welcomes both public discussion and technical assessment.

Fifth, although each element is regarded as a separate lamp, each element itself can form a network. Take the engineer for an example. An engineer is actually a superset which contains many subsets, such as the engineer's power, certification and ethical consciousness. The subsets are just like light bulbs in an electrical circuit which can be connected in series or parallel. Although varied in wattage and color, these subsets function as a whole and finally influence the light of superset. This means the lamp of the engineer in this tetrahedral model is not a single lamp but a collection of various light bulbs. From the perspective of broad ethics, "engineering community" would be a more appropriate name to address the lamp of the engineer. Things can be good or bad. So are engineers. The engineers with a strong sense of responsibility are white bulbs, while those perverted engineers are black ones. In reality, most engineers are gray bulbs, swinging between the light and dark zones. It is absurd to let the engineer to initiatively undertake a universal responsibility. But it also seems unreasonable to let the engineer undertake the minimum or bottom-line responsibility. The validity of the superset "Lamp" deeply relies on how to guide the engineer to undertake reasonable moral responsibility.

4 Four mirrors to ensure the effect of tetrahedral model of engineering ethical evaluation

The most important purpose of evaluation is not to prove, but to improve. The purpose of engineering ethical evaluation is consistent with that of engineering in nature. In addition to its purpose of value judgment, engineering ethical evaluation also involves value selection and value guidance (Stufflebeam, Madaus, & Kellaghan, 2000). These three purposes can only be achieved with the aid of four mirrors formed by those four elements of engineering. Otherwise, the ethical evaluation will be lagged behind.

4.1 The relationship between any two of four elements of tetrahedron

Six pairs of bi-directional relationship act as the structure bars of the tetrahedral model of engineering ethic evaluation.

First, the mutual promotion relationship between the engineer and the artifact. The artifact is an artificial entity. The project is actually the external expression of the engineer's fantastic ideas. Meanwhile, the engineer can optimize his professional skills by getting fairly new experience in designing and implementing the artifact.

Second, the mutual adaptation relationship between the user and the artifact. The artifact is the final existence of the project. The extent to which its functions can meet the user's requirement determines the degree of the user's satisfaction. Meanwhile, if the user wants the artifact to function well, he has to master proper methods and operation keys of the artifact. Furthermore, timely feedbacks of the user's requirement are strongly recommended at the earlier stage of a project.

Third, the mutual dissolving relationship between the artifact and the environment. The life cycle of the artifact is constrained by the environment. The engineer always needs to consider how to dissolve the artifact in the environment. As objects in nature are mutually related and at the same time mutually restricted, the birth of an artifact declares itself an essential part of the environment. Shortly after the establishment of an artifact, the construction of the following artifacts around it should take this artifact as a considerate dimension of the environment as a whole.

Fourth, the mutual benefit relationship between the engineer and the user. Through a long period of training and study, the engineer has acquired specialized skills and knowledge, and continues to maintain and update them through professional life. As a result of this specialized expertise, the engineer has significant power to affect individual users and wider society. Therefore, the engineer has a responsibility to introduce to the user some relevant technology and potential danger of the project. The user's requirements reflect his expectation toward the artifact and urge the engineer to improve his ability and professionalism.

Fifth, the mutual guidance relationship between the engineer and the environment. On one hand, nature provides resources essential to the practice of engineering. It also possesses autonomous dynamical features of relevance to the performance of engineer's devices. On the other hand, the engineer's work affects the environment and the lives of millions of people, for better or worse. Just as Wang Guowei wrote "there is the personal state and there is the impersonal state." "In the personal state the poet views objects in terms of himself and so everything takes on his own coloring. In the impersonal state the poet views objects in terms of objects and so one cannot tell that is the poet himself and what is the object." As to the field of engineering, in the "personal state", an engineer's mind and activities are influenced by the change of human needs, while in the "impersonal state", an engineer's mind and activities are determined by nature's characteristics and disciplines. Environment is home of human beings which also plays a role of guide in an engineer's life. Only when the engineer is fully immersed in the environment can he ensure rational use of natural resources and actively promote sustainable development of human beings.

Last, the mutual respect relationship between the user and the environment. Nature is the material carrier of human survival, proving us with abundant products. The environment's sustainable development is based upon the user's modern consumption ideas and good character. The user's attention should focus on real rather than fake or false information. The user must clearly know that it is the environment that makes all his social activities feasible and then show great respect toward the environment.

The relationship between any two of four elements of the tetrahedron greatly enhances the centripetal force as a whole. The linear relationship forms the frame of engineering ethical system. The four planes can show the complex and systematic relations among four elements of the engineering community.

4.2 The ethical level of engineering truthfully reflected by four mirrors of the tetrahedron

First, the mirror of sustainability consisting of the engineer, the user and the environment. On this mirror surface, the engineer should satisfy the user's requirement and take due account of the limited availability of natural and human resources at the same time. The environment provides material support for the fulfillment of the engineer's designs and the user's requirements with its intrinsic characteristics. The user constantly proposes innovation requirement to the engineer with the aid of the environment.

Second, the mirror of satisfaction consisting of the artifact, the engineer and the user. On this mirror surface, the artifact is the integration of scientific discovery and technological invention. It is the final product of the engineer's wisdom. With the help of various techniques, the engineer is responsible for the design, construction and operation of the artifact. The timely feedback of the user's new demands is a source of the engineer's inspiration and enthusiasm. Meanwhile, the engineer should ensure to use advanced design concepts and build high-quality project to fulfill his duties. The extent to which its functions can meet the user's requirement determines the degree of the user's satisfaction.

Third, the mirror of dissolving consisting of the artifact, the engineer and the environment. On this mirror surface, the artifact is the external expression of the engineer's creative design and also an essential part of the environment. As a system with its own operation discipline, the existence of the artifact will more or less break the balance between the social and the natural environment. In order to guarantee the stable operation and sustainable development, the artifact should be dissolved in the environment just as sugar dissolved in water. The perfectly dissolved artifact will play a leading role in guiding the following projects.

Fourth, the mirror of harmony consisting of the artifact, the user and the environment. On this mirror surface, only with continuing exchange of material, energy and information with the environment, the artifact can maximize its function. The more operation knowledge of the artifact the user grasps, the better the artifact can dissolve in the environment. Cherished by the user, the environment will suffer less damage and keep its balance. It also shows the user's respect toward the environment. Consequently, the environment provides various resources for the user to enable him to live a convenient and comfortable life. If a virtuous cycle of the user, the artifact and the environment can be formed, we can expect "Full of merit, yet poetically, man dwells on this earth."

5 The lamps and mirrors illuminating the tetrahedral model of engineering ethical evaluation

"The primal instinct for innovative artifacts and the skills required in their making, had emerged during the earliest stirrings of the human imagination." (Harms, Baetz, & Volti, 2004, p 3) Engineering is not a value-free process of problem solving, but a value-loaded process of decision making. An effective way to solve the ethical problems in current engineering field is to evaluate it in an ethical dimension. Engineering intends to build a spiritual home for human being which contains three dimensions, namely reasonable truth, valuable kindness and sensible beauty. Truth is the base for kindness and beauty, while kindness is the value direction of truth. Beauty is the supreme will of truth and kindness. Engineering is a unity of truth, kindness and beauty. Ethical evaluation helps to perfect engineering science and to keep it in an ethical field.

First, when four elements of engineering are of same weight, an equilateral tetrahedron can be formed. Because of its stable geometrical shape, this tetrahedron is firmly fixed and can perfectly explain with what reason the engineering can achieve success and in what way engineering becomes a unity of truth, kindness and beauty. The tetrahedron consists of six loops between any two of four elements. If one element or one lamp fails, the other three elements or lamps will be affected. So it is synergy among four elements that determines the stability and sustainability of the tetrahedron.

The artifact is at the top of the tetrahedron because it forms a fourth kingdom of human society (Dessauer, 1956, p.159). It is a comprehensive and external unit of the other three elements. On one hand, the engineer needs to undertake a responsibility of environmental ethics to nature because the engineering must obey the natural law and return to nature. On the other hand, engineering is the social scale test of man. It is mainly represented in two aspects. That is, engineering is carried out under partially ignorant conditions and its ultimate outcome is uncertain. As to engineering, risk is inevitable. And the specialty of engineering test object asks the engineer to ensure the peaceful life of community residents affected by the project.

Third, the mirror of sustainability which consists of the engineer, the user and the environment is the bottom surface, acting as the foundation of the tetrahedron. This is determined by the nature of engineering ethics which is supposed to promote a responsible engineering practice (Harris & Pritchard, 2008, P.20). Although the artifact greatly changes our daily life, the final influence of the artifact is determined by various combinations of these three elements. These three elements are the base and prerequisite of lifelong engineering. Some projects mean to be real existence but turn out to be fake one because of the user's wild use. Some projects mean to have be good but turn out to be vice because of the engineer's corruption. Some projects mean to be beautiful but degrade into an environment destroyer because they can hardly dissolve in the environment.

Fourth, the solidity of tetrahedron represents the perfection of ethical evaluation model. The more solid the tetrahedron is, the better the evaluation model will be. The solidity of tetrahedron is subject to the fulfillment of the following conditions: (1) Four elements should be equally developed. Otherwise the tetrahedron will lean to a certain structural plane. In extreme cases, it will lead to the collapse of whole system. (2) The bottom surface must be solid and firm enough. Otherwise the tetrahedron will fall instantly. (3) The other three mirrors must be constructed with reliable quality. If any one of them collapses, the other two mirrors will fall down due to a chain reaction. (4) Mirrors in the tetrahedron are mutually related and at the same time mutually restricted. Each mirror must form a mutual support. If any of these conditions is not satisfied, the lamp at the top of the tetrahedron (i.e. the artifact) will fall down and bring disaster to the other three lamps at the bottom plane. This means the disappearance of the tetrahedral model of engineering ethical evaluation. The engineer will be addressed as a "diligent robber".

Fifth, a mega-project is itself a complex system, with a distinct characteristic of self-organization. But when it is put in a broader scope, it is also constrained by the law of social development and cosmic evolution. On one hand, the tetrahedral model can expose the project's performance on the ethical dimension. On the other hand, the tetrahedral model can hardly reflect the ethical evolution of engineering in the process of social changes. Therefore, the openness of tetrahedron model must be taken into account. The tetrahedral model is dynamic which consists of four corners connected by twelve lines. Its volume is finally determined by the length of these twelve lines. Any slight change of any element will result in the reconstruction of tetrahedron. In a society with justice, honesty and steady economic progress, the tetrahedral model of engineering ethical evaluation will be a stable equilateral tetrahedron. It can resist slight disturbance and absorb fluctuations caused by external forces. The better the whole system is, the more stable the tetrahedron becomes. Conversely, the economic recession and moral degeneration will result in the destruction of the equilateral tetrahedron. The lamps will go off. The mirrors will be broken. All these will force the engineering ethical system to change, both from the theoretical and practical aspects. It cannot be stopped until a fairly new balance can be achieved.

The integrity, strong resilience and high stability of tetrahedral model bring a significant change to the ethical evaluation of engineering activities. It is represented from the following aspects.

First is the plurality of evaluation standards. It successfully avoids fossilization of a single standard and shows great concern about mutually restrictive effects among four elements of evaluation system. The solidity of the tetrahedron model is influenced by the extent of cooperation or competition among various participating or affected parties. But pluralism is not diversity alone. Diversity can and has meant the creation of evaluation indexes with little traffic between or among them. Today, evaluation standard diversity is a given, but pluralism is not a given; it is an achievement. Mere diversity without real encounter and relationship will yield increasing tensions in evaluation system and result in the collapse of whole tetrahedron.

Second is the plurality of ethical tension. The complexity of engineering ethical evaluation is determined by different benefits and values of all parties affected by the project. In process of evaluation, all parties' benefits should be taken into account. However, pluralism is not just tolerance, but the active seeking of understanding across different boundaries. Tolerance is a necessary public virtue, but it does not mean the user cannot speak out his ideas, or the engineer can ignore the sustainability of the environment for his own benefit. Tolerance is too thin a foundation for a tetrahedron of various kinds of interactions among four elements. In current society, the ignorance of any one of four elements of engineering will be increasingly costly.

Third is the avoidance of simple de-instrumentalization of ethical evaluation. Andrew Feenberg wrote: “What human beings are and will become is decided in the shape of our tools no less than in the action of statesmen and political movements. The design of technology is thus an ontological decision fraught with political consequences. The exclusion of the vast majority from participation in this decision is profoundly undemocratic.” (Feenberg, 2002, p.5) Thus a preset unidirectional evaluation standard is far from complicated engineering activities and finally degenerates into a complete administrative order. The tetrahedral model helps to overcome the fragility of current engineering ethical standards, to integrate engineering and ethics in an ecological scope and be independent from preset rules. It stimulates people to think priority of ethical acts in engineering and strengthen their faith in pursuit of a better life.

Last but not least is the sustainability of ethical evaluation. The common language of sustainability is that of dialogue and encounter, give and take, criticism and self-criticism. Both the voice of the user’s requirements and the engineer’s creativity should be listened and be satisfied. Measures to promote rational use of natural resources and energy should be taken. The harmony among four elements can be achieved in pursuit of comprehensive benefits—the unity of economic, social and environmental benefits. In this way, the tetrahedral model reveals both common grounds and real differences. The deepest differences among four elements are not in isolation, but in relationship to one another.

The tetrahedral model of engineering evaluation provides a new perspective of engineering ethics. It means to be synthetic and dynamic. No matter how varied the numerous schools of engineering ethics are, they are mainly one-dimensional, with emphasis on only one of four elements of engineering.

6 Conclusion

“Engineering is the field or discipline, practice, profession and art that relates to the development, acquisition and application of technical, scientific and mathematical knowledge about the understanding, design, development, invention, innovation and use of materials, machines, structures, systems and processes for specific purposes.” (UNESCO, 2010, p.24) Therefore it involves the ethical problem of application of technology in a humane way.

Engineering may now claim to be both a shaper and a reflector of contemporary times. It inevitably becomes the object of ethical evaluation. A major problem that all engineering practitioners have to face is how to transform engineering ethical evaluation from “gray theory” to “evergreen life”, from “ivory tower” to “furnace of reality”. Abrams’ *The Mirror and the Lamp* provides a significant guidance on paradigm of engineering ethical evaluation. The tetrahedral model with a point-line-area structure consists of four elements of engineering, namely the artifact, the engineer, the user and the environment. Four “Lamps” or four elements of engineering provide light for the tetrahedron while the “Mirrors” formed by mutual interactions between any three of these four elements reflect whether the tetrahedral model can truthfully evaluate the level of engineering ethics. “Lamps” and “Mirrors” work together to illuminate the whole tetrahedral model.

The integrity, strong resilience and high stability of the tetrahedral model brings a significant change to the ethical evaluation of engineering activities. They are the plurality of evaluation standards, the avoidance of simple de-instrumentalization of ethical evaluation and the sustainability of ethical evaluation. Plurality of evaluation standards is to consider value differences in a multi-value condition. The avoidance of de-instrumentalization is to prevent the engineer’s disciplines from fossilization. Sustainability of ethical evaluation accelerates the fulfillment of our dream for the ultimate benefit of human beings. The tetrahedral model of ethical evaluation is not closed, but more inclusive and selective. Ethical evaluation must be combined with technical evaluation and introspect those social problems caused by lack and bias of ethical standards. Otherwise the engineering ethical evaluation will become romantic fantasy or mirage-like talk. From a macro-perspective of the engineering community, the tetrahedral model tries to explain engineering in a complex network of relationships. It is prophetic because it conforms to the trend of macro-transformation of engineering ethic research. It provides not only a theoretical reference for the engineer to think about the connotation of engineering ethics, but also an important revelation of current engineering practice.

References

Abrams, M. H. (1971). *The Mirror and the lamp: romantic theory and the critical tradition*. New York: Oxford University Press

Dearden, R. F. (1984). *The Theory and practice in education*. London: Routledge & Kegan Paulchap.S

Dessauer, F. (1956). *Streit um die technik* [The Controversy Concerning Technology]. Frankfurt:Verlag Josef Knecht

Feenberg, A. (2002). *Transforming technology: a critical theory revisited*. New York: Oxford University Press

Georg, W. (1991). *Elements of the philosophy of right* (Nisbet, H.B., Trans.). Cambridge: Cambridge University Press

Harms, A. A., Baetz, B. W., & Volti, R. R. (2004). *Engineering in time: the systematics of engineering history and its contemporary context*. London: Imperial College Press

Harris, E. H., & Pritchard, M. S. (2008). *Engineering ethics: concepts and cases*. Stamford: Wadsworth Publishing

James, Y. L. (1976). *Chinese theories of literature*. Chicago: The University of Chicago Press

Keesey, D. (1994). *Contexts for criticism* (2nd ed.). Mountain View, CA: Mayfield Publishing Company

McGuinness, B. F. (1985). *Moritz Schlick*. New York : Springer

Mitcham, C. (2003). Co-responsibility for research integrity. *Science and Engineering Ethics*. 9, 278-281

Plato. (2007). *The Republic (Penguin Classics)* (Desmond Lee, Trans.). London: Penguin Group

Richard. T., & George, D. (2009). *Business ethics*. New York: Pearson, 27

Stufflebeam, D. L., Madaus, G. f., & Kellaghan. T. (2000). *Evaluation model: viewpoints on educational and human services evaluation* (2nd ed.). Boston: Kluwer Academic Publishers

UNESCO. (2010). *Engineering: issues challenges and opportunities for development*. Paris: UNESCO Publishing

Xing, H., Liu, H., & Wang, Q. (2008). Analysis of the innovative ability of engineering scientists and technicians. *Technoeconomics & Management Research*, 5, 26-28