Chapter 21
Engineering Action in Micro-, Meso-, and Macro-contexts

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Abstract Context initially referred to linguistic context of language texts and discourse in the fields of linguistics and communication. But philosophers of engineering should research the context in which engineering practitioners both speak and act. Engineering action means not only an individual's action, but also a collective action participated in by many kinds of engineering practitioners. Modern engineering action is usually undertaken by an enterprise as a special kind of community. The context of engineering action can be divided into three levels: micro-, meso-, and macro-levels. For a particular engineering decision-maker and a particular engineering action, the boundary between action and context is to some extent may be changeable, but it does not mean that there is no boundary between action and context. The problem of context is not only a theoretical one, but also a practical one.

Keywords Engineering action • Engineering community • Context • Micro • Meso • Macro

The publication of *Engineering in Context* (Christensen et al. 2009) marked an important advance in the study of engineering. In its preface, the editors referenced the book *Science in Context: Readings in the Sociology of Science* (Barnes and Edge 1982) as a classic in the sociology of science. Their own volume sought to bring engineering under the same contextualist perspective. As a further contribution to this approach, the present chapter in a new collection on engineering in context reviews the emergence of context as a general principle of understanding and then explores its application to engineering at three levels.

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The Emergence of the Theory of Context

The theory of context was brought forth in the later years of the nineteenth century. Studies on various issues of context in such academic fields as linguistics, philosophy, anthropology, and communication, have now become common.

In the history of science, Gottlob Frege (1848–1925) is the earliest scholar who placed context at the core of theory. He used the concept of "context" for the first time in *Die Grundlagen der Arithmetik* (The Foundations of Arithmetic) (Frege 1980[1884]), and brought forth the famous "context principle", which urges people never to ask for the meaning of a word in isolation but only in the context of a sentence. For various reasons, Frege was virtually unknown when alive and did not become famous in the fields of linguistics, philosophy, logic, and analytic philosophy until the second half of the twentieth century, when he was recognized as the founder of modern logic and a major figure in analytic philosophy. Because his primary status was as mathematician and logician, his views on context exerted an influence mostly on logicians, philosophers of mathematics, and analytic philosophers, and were unfamiliar to scholars in other fields. For a long time and even now, scholars especially in the fields of social science failed to appreciate Frege and his work.

Many scholars regard Bronislaw Malinowski (1884–1942) as the founder of the theory of context. Malinowski proposed the concept "context of situation" in 1923 and used it in translating and understanding utterances. In 1935 he put forward the new concept "context of culture" and applied this idea in anthropological studies. While Frege focused only on context of words, Malinowski focused not only on words but also on larger units of language, sentences, passages, and so on. He paid close attention to both written and verbal language, and to linguistic and non-linguistic contexts. As a result, Malinowski has been influential well beyond anthropology.

In the second half of the twentieth century, the theory of context evolved rapidly. Many linguists, such as J.R. Firth, M.A.K. Halliday, D. Hymes, J. Lyons, Wang Zhanfu, and Wang Jianhua, developed their own linguistic theories of context (Zhou Shuping 2011, pp. 13–49). As a result, linguistics became an important field in which the study of context bore rich fruits. At the same time, scholars expanded its scope. As the study of context entered new fields, contextualism emerged as a general approach. Differing from those who interpreted text as language text, and context as linguistic context, the French philosopher Paul Ricoeur (1913–2005) expanded the understanding of text and context. Ricoeur proposed that not only book text and verbal language can be regarded as a text, but action can be seen as another kind of text. Ricoeur pointed out that not only the context of a language text, but also the context of an action, can and must be studied as such (Ricoeur 1981, pp. 197–221).

While in the fields of linguistics, communication, and linguistic philosophy scholars focused attention mainly on the context of written language, verbal language, discourse, and book text, philosophers of science focused attention on both the contexts of written scientific papers, on the one hand, and of scientific experiments as a special kind of practice, on the other.

Studies of context have been further advanced in the philosophy of technology. For example, Anthonie W.M. Meijers has argued that the properties of technical artifacts can be divided into three types, one of which is context-dependent properties (Meijers 2001, p. 83). In addition, there is more attention to and conscientious historical study of context in the history of technology. The publication of the book *In Context: History and History of Technology* (Cutcliffe and Post 1989) demonstrated how historians of technology appreciate the importance of the study of context.

Context with Regard to Engineering

Insofar as context can now be applied to the study of engineering, there are three points to be noted and underscored. The first is related to the object of study in context. Different from scholars in the fields of rhetoric, linguistics, and linguistic philosophy who take the context of language text as the object of the research, philosophers of engineering should lay emphasis not only on the context of written and verbal language of engineering papers but also on the context of engineering action as a particular kind of text. In other words, the crux of the matter lies in the context in which an individual or an enterprise acts rather than in the context in which an individual speaks.

The second point is that following economists, ethicists, and sociologists who put forward the hierarchical distinction between micro-, meso-, and macro-levels of both action and analysis, philosophers of engineering should analyze and investigate the context of engineering action based on this same three-level framework (Li Bocong 2012, pp. 31–35).

A third point concerns the Chinese translation of these terms. When studying context in the field of philosophy of engineering, Chinese scholars must translate the English word “context” into Chinese. However, there is a problem here. In linguistics, rhetoric, and philosophy of science, “context” is generally translated into the Chinese word 语境 (*yŭ jìng*) that refers to linguistic context or the environment of discourse or utterance clearly and strictly in Chinese. Yet when studying the context of engineering action, the context obviously refers not only to the environment of discourse or utterance, but more importantly, to the social, economic, and natural environments of engineering action. But such a meaning cannot be included in the Chinese 语境. Engineering action is not just a linguistic action, but a kind of action creating artifacts. In order to express these meanings, “context” must be translated by another Chinese word, 场境 (*chăng jìng*) which has a wider meaning than 语境. Therefore, while the same English word can be used to express both the environment of a text such as novel, poem, or scientific paper, and the environment of an action, two different Chinese words 语境 and 场境, which should not be confused, must be used respectively to express the meaning of the context of language and the context of action, that is, the environment of language and of action.

Practitioners' Engineering Action in the Micro-context

The divisions of micro and macro in physics, economics, and sociology have been supplemented by economists's addition of the concept of meso, thus establishing a micro-meso-macro framework. The three levels of the framework are obviously inter-related and connected, although the micro level is in some sense fundamental.

While the scientific community consists of scientists as homogeneous members, the engineering community consists of heterogeneous members, including workers, engineers, managers, investors, and other stakeholders (Li Bocong et al. 2010, pp. 27–29). Consequently, engineering action inherently involves multiple actors including workers, engineers, managers, investors, and so on.

When analyzing the activities of engineering practitioners who are the micro subjects of engineering action, one discovers an interesting phenomenon: different members of engineering communities have reciprocal relationships with each other between action and context. For instance, engineers, managers, investors, and some other stakeholders become the context of activities of workers. At the same time, workers become an important factor of the context for managers, engineers, investors, and other stakeholders. What follows touches on some issues related to the context of activities of workers and engineers.

As we know, many scholars focused their studies on workers's activities. Social scientists and management experts proposed various theories to interpret workers's activities. A good example is the Hawthorne experiments of Elton Mayo (1933 [1960]).

The Hawthorne experiments, which were carried out at the Western Electric Company's Hawthorne plant in Cicero, Illinois, in the 1920s and 1930s, have had a far-reaching influence. The initial purpose of the experiments was to determine the relationship between the situation of the physical workplace and productivity. At the beginning of the experiments, researchers did not obtain results they expected. However, as a result of subsequent involvement Elton Mayo and Fritz Roethlisberger, the experiments underwent dramatic changes. In particular, a significant breakthrough was made in the theoretical explanation of the experimental results.

Admittedly, different researchers have given different interpretations to the same results by approaching them from different perspectives. Some scholars interpreted the Hawthorne experiments from a humanistic perspective. From this perspective, workers should not be regarded merely as "economic men" but also as "social men". It was argued that after the Hawthorne experiments, management theory entered the "era of social men". To a certain extent, this can be thought of as a human nature oriented theory.

But there is another, context-oriented theory that differs from the human nature oriented theory. Although the interpretation that focuses on the social nature of human beings is to a great extent justifiable, it would be a mistake to believe that the Hawthorne experiments demonstrate only the importance of human nature in engineering action and that the context of the workplace is of little importance.

Roethlisberger, who participated in the Hawthorne experiments as an assistant of Mayo, generalized their findings in *The Elusive Phenomenon* as follows:

> 1. Work conditions have more effect on production than the number of workdays in the work. …
> 3. The supervisor's method is the single most important outside influence. Home condition may affect the worker and his work. However, a supervisor who can listen and not talk can in many instances almost completely compensate for such depressing influences.
> 5. The most surprising result came toward the end of the experiments, … when the researchers returned to the original forty-eight-hour week without rest pauses. Once again, productivity rose! Yet again, it seemed that the workers were responding to the positive concern of the experiments rather than to the physical work conditions (quoted from Gabor 2000, pp. 113–114).

Obviously, the Hawthorne experiments never denied the importance of context. But they definitely reject any view that regards context as only the physical work conditions or the material environment. And the experiments fully revealed that workers work in contexts with various factors.

When mentioning the content and research method of context, Andrew Jamision (2009) indicated that the context of engineering includes economic, social, and cultural contexts, and Sylvain Lavelle (2009) pointed out that context may be studied from analytic, phenomenological, and pragmatic perspectives. The Hawthorne experiments do not mean that only humanity or morale is important while context is unimportant for practitioner's activities. From the contextualist point of view, the Hawthorne experiments have two important theoretical implications:

1. Context includes various aspects, such as the physical, social, and cultural environment. So the colorful and plentiful contents of context should not be simplified.
2. The Hawthorne experiments demonstrated that worker morale is affected by the cultural context. It is the special cultural context created in the experiments by Mayo that inspired the worker morale. Without the special cultural context created in the experiments, the results would not have been obtained.

Mayo's theory has been widely regarded as the foundation of human relations management. Strangely and even paradoxically, the two theories – the theory of human relations and the theory of human nature – amount to two different theoretical orientations. The latter focuses more on the properties of the subjects – especially the properties that are not easily affected by an external environment. The former focuses more on the correlation and interaction of different subjects, and on the properties and features of different subjects that are likely to be affected by an external environment and external relationships. Judging from this, human relations theory is imbued with a strong sense of contextualism.

While Mayo focused on workers' actions, some other scholars focused on engineers' actions. The work of engineers is important and complicated in engineering action; the tasks of engineers complex and mixed. "The position of engineers, partially as labor and partially as managers, prompted Herbert Shepart to call engineers marginal men; part scientist and part businessman, sharing value and ideologies with both camps" (Beder 1998, p. 25).

Shepart's opinion is initially surprising. However, on reflection, many people, even engineers themselves, may accept Shepart's thesis. It is certain that the role of an engineer is different from that of a scientist. Engineers more often than scientists undertake difficult and contradictory tasks. Sometimes, if the demands of labor or scientific factors put great pressures on engineers, engineers will tend to be partial to one over the other. If the pressures of capital and business become stronger, engineers will lean toward satisfying the needs of capital – although this does not always happen. These shifts in behavior do not imply that engineers have a kind of ethical disorder. They simply reveal the fact that engineers, whose positions and functions are quite different from those of workers and investors, are on the horns of a dilemma, which should be analyzed from a contextualist perspective.

Enterprise Engineering Action in the Meso-context

Generally speaking, engineering action involves collective action. In other words, it is carried out by a team, a group, or an organization rather than an isolated individual. In the contemporary world, an isolated individual, for example, an isolated manager, an isolated engineer, or an isolated investor, could by no means engage in actual engineering action. Especially, those who have the same profession or occupation, such as workers or engineers, cannot by themselves initiate engineering action. Engineering teams or groups must be composed of different kinds of members: engineers, workers, investors, managers, and other stakeholders.

Many scholars regard engineering activity as what engineers do. There is no doubt that this is to some extent true. But it is only part of the truth. The complete truth is that engineering activity consists of what engineering teams do, including what engineers do, what workers do, what investors do, what managers do, and especially, what the team as a whole does. If there are only engineers, without the participation of investors, workers and managers, such engineers could not take engineering action at all. In fact, engineers only engage in some part of engineering action. A complete and actual engineering action must be completed by an engineering team composed of engineers, workers, investors, and managers. Adopting the concept of social reality put forward by J. R. Searle (1995), we have every reason to believe that an enterprise is a particular type of social reality (Li Bocong 2009).

Engineering action is impossible without the activity of individuals, including workers, engineers, investors, and more. At the same time, engineering action is a collective action. The two points mentioned above are not contradictory because any human activity must, in the final analysis, be carried out by individuals. If it is not the case, there will be no engineering action to speak of. However, without a team or a collective organization, for example in an enterprise, there would be no engineering action either. What is the bridge that connects one point with the other?

The answer lies in division of labor and cooperation, work in cooperation with an appropriate division of labor.

We must pay attention to the fact that when individuals do something in an engineering team or an enterprise, usually, they cannot do it just on their own initiative or for their own sake but only for the sake of others. For instance, designers design for investors and users instead of for themselves and engineers and workers also do their duties for the sake of others. In an enterprise, workers and engineers cooperate with their partners. What they do must be suitable to what their partners do. For instance, the general manager of an enterprise signs an agreement on behalf of the enterprise, which means that people must differentiate an individual acting in some role within a team from that the same individual acting on his or her own. More importantly, people should not confuse an enterprise with some isolated individual or even with all its members. There is a distinction between an individual's action and an enterprise's action, which leads to a conclusion that when studying context of engineering action, we should study not only the contexts of individuals but also the contexts of enterprises.

When engineering action is taking place, the context in which an enterprise acts is different from the one in which an individual as a member of an enterprise acts. So there are two kinds of context which correspond with two kinds of action, an individual's action and an enterprise's action. How should we distinguish these two kinds of context? Are there still other kinds of context?

As some economists argue, an economy can be divided into three levels: the micro-economy, the meso-economy, and the macro-economy. Similarly, the contexts of engineering action can be divided into three kinds of context: the micro-context, the meso-context, and the macro-context. Generally speaking, the meso-level is at the place which is situated between micro- and the macro-levels. Usually, an individual acts in micro-context and an enterprise acts in meso-context.

Obviously, the meso-context is more complicated than a micro-context. When studying the meso-context in which an enterprise acts, scholars must pay attention to why and how technological, economic, institutional, cultural, and social environments influence the structure and function of an enterprise, and why and how meso-contexts play important roles in an enterprise's decision-making and its engineering actions. Because an enterprise can keenly understand and experience meso-contextual influences which may profoundly affect its development, the enterprise must carefully and prudently take into account meso-contexts such as the regional economic situation, cultural traditions, institutional environments, and business prospects.

Silicon Valley in the United States is an attractive region for many enterprises, especially for those in the field of information and electrical engineering. Many entrepreneurs hope they can build their enterprises there. What makes Silicon Valley more attractive than some other regions is that it is blessed with special technological, economic, cultural, and political contexts which are superior to other regions in their receptivity to and promotion of innovative activity. The gist of AnnaLee Saxenian's *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (1994), for instance, is to analyze and emphasize the importance of context for business and engineering development, especially the importance of cultural context.

Nobody can deny the huge impact of some advantageous contexts on enterprises and engineering action. A good context can significantly facilitate business and engineering development. By contrast, a context with all kinds of disadvantages will surely impede engineering development. Considering such situations, many countries and governments set up "industrial parks" with a view to create an enabling context in which enterprises can act and develop smoothly.

Engineering Action in the Macro-context

Macroeconomics focuses on the structure, function, and trends in an economy as a whole. In the global era, macro refers to not only a national but necessarily as well to international contexts. A similar interpretation applied to macro in the fields of philosophy and sociology of engineering.

In different countries, different enterprises and different kinds of engineering act in different macro contexts. Now, consider railway engineering as an example. Many countries have constructed railway systems during the modernization process. However, even three leading modernized countries – the UK, the US, and France – are quite different from each other in the railway development process, which cannot be attributed only to technical factors. The railway network in the UK developed initially at a fast pace but ran up against problems such as redundancy of transportation capacity and low construction quality on some lines with resultant replacement construction. In the US, the construction of a railway network was faster and on a larger scale. But during the great development of railway engineering in the US, some companies overestimated the rate of return of engineering investment and went bankrupt. In addition, some railway lines in America were defective in design and construction. The characteristics of the construction of French railway network were that the government took the leading role in the railway network. The French railway system was constructed much slower, which helped prevent unnecessary needs for replacement construction, and established a railway system that in the end had reasonable design and high quality. Frank Dobbin's *Forging Industrial Policy: The United States, Britain, and France in the Railway Age* (1994) carefully and thoroughly analyzed the marked and serious differences in the railway construction in these three countries. He pointed out that the root cause lay in the vast differences of the three countries in industrial policy, economic policy, political condition, and cultural environment. To put it simply, it is the different macro context of the three countries that led to the different processes of railway construction and resulted in different railway networks in the three countries.

Although many developing countries shared the same view that they must develop their own railway systems, railway construction processes in developing countries too were based in different economic, political, and cultural environments. Among them, China seems to be a very special case. The initial railway development in China might be the most difficult case in the world history of railway. After the first railway line was constructed in the UK in 1825, the US, France, Germany, and Russia rapidly initiated their own national railway construction projects in 1830, 1832, 1835, and 1837, respectively. While there was almost no resistance to construction of railways in many countries, there was violent and stubborn resistance to building railways in the late Qing Dynasty. The resistance was so strong that many events in the history of railway in the late Qing Dynasty are unimaginable to later generations. In 1865, a British businessman built 1-1i-long railway line outside Xuanwu gate, Beijing, without authorization. But the roaring sound of the train triggered a terrible shock to the common people. The railway was rapidly demolished by the government. In 1876, the Woosong Road Company, which was established by British and American businessmen, built a railway line which stretched for ten miles in Shanghai. However, the Chinese government bought it for 285,000 taels of silver and then demolished it.

In 1878, a 3-li-long railway line was exclusively built for the Empress Dowager Cixi along the bank of Beihai Lake in the Forbidden City after a negotiation between Li Hung-Chang and several British businessmen. The railway was designed to provide convenience for the Empress Dowager Cixi to have meals, take rest, and enjoy the scenery of the imperial garden in order to show the advantage of railway to the Empress Dowager Cixi. But because the Empress Dowager Cixi disliked the roaring sound of the locomotive, the exclusive line in the imperial garden was pulled by eunuchs with ropes instead of by a locomotive (Ji and Kang 2011, pp. 8–15).

Objection to railway construction in China came from China's traditional cultural, political, and social conditions in the late Qing Dynasty. For instance, railway construction may lead to misfortune according to *fengshui* (geomancy). It should be underscored that the obstacles were not thrown mainly by some particular individuals but by the Chinese cultural and political tradition as a whole. Chinese officials engaged in fierce debates over railway policy for some 20 years. Only after eliminating many obstructions did the government in the late Qing Dynasty finally and officially began railway construction in China. Such was the macro context in which railway construction began to take place in China.

Time passes on like an arrow. At the end of the twentieth century, the macro context in China was strikingly different from that in China a hundred years earlier. The twenty-first century witnesses the large-scale construction of high speed railways in China. Why does China stand at the forefront of the construction of high-speed railway in the world at the beginning of the twenty-first century? The main cause resides again in the macro context. Although high speed railway technology was mainly invented in developed countries, the construction of a high speed railway system in developed countries has fallen behind that of China. Why did this case take place? The answer lies in the different macro contexts.

Conclusion

Context is an external factor in engineering activity from the perspective of philosophy. When analyzing and studying context, we must pay attention to the different micro-, meso-, and macro-levels. In addition, we should attend to interactions among different aspects and between different levels. Different aspects and levels in context interact in complex ways. Contextualism in the field of philosophy of engineering can be considered an overall perspective that studies various issues of context. Scholars should analyze engineering action, engineering practitioners, and the engineering communities including various sub-communities such as enterprises, engineering teams, and engineering institutions from a contextualist perspective.

We must admit that context is to a certain extent relative. However, such relativity does not necessarily mean that we can take context as an imaginary issue or an issue that can be neglected. There is no doubt that the issue of context cannot be eliminated. It is crucial for any particular individual and any particular research task. More importantly, as for a particular decision-maker or a particular enterprise, the boundary between text and context cannot be drawn arbitrarily. A decision maker or an enterprise must draw contextual boundaries correctly.

To sum up, context of engineering action, including the context of decision-making, of designing, of manufacturing, of maintenance, and of using products is not just an important theoretical issue, but also an important practical issue. To decision makers, to engineering practitioners, and to managers of an enterprise, there are many particular contextual problems they must analyze and treat in a practical manner all the time. To philosophers, to ethicists, to sociologists, to psychologists, and to management experts, there are many theoretically contextual problems in their fields to be analyzed and treated in theoretical ways.

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