Managing building projects in ancient China

A comparison with modern-day project management principles and practices

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Abstract

Purpose – The Chinese civilization is an important part of the history of mankind. The purpose of this paper is to show that there are project management lessons to be learned from Chinese history, including that relating to the management of the building process in ancient China.

Design/methodology/approach – Through a review of the literature, this paper discusses the key management and economic practices in the building process of ancient China and highlights these practices from an important document, the *Yingzao Fashi* or ("Treatise on Architectural Methods"), that was compared with the modern-day project management framework.

Findings – This paper explains the official systems instituted for public projects; the management of labour, design and planning of construction works; quantity surveying practices; the use, control and recycling of building materials; and inspection of building elements in ancient China.

Practical implications – The study suggests that lessons in the principles of construction project management in ancient China bear many similarities with the nine areas of modern-day project management body of knowledge relating to integration, scope, time, cost, quality, human resource, communications, risk, and procurement management. An area for future research would be to compare the *Yingzao Fashi* with modern-day codes of practice for building works to determine which of its "ancient" provisions relating to quality management are still relevant today.

Originality/value – It was found that much emphasis was placed by the ancient Chinese on the quality aspects of prominent building projects. This is one facet from which modern-day project managers and clients can draw lessons.

Keywords Project management, Building services, China, History

Paper type General review

Introduction

There are compelling reasons to study China and to understand the Chinese way of thinking. The first reason is the demographic mass in China. The Chinese people have probably made up the largest single mass of human beings in the world to live in one country at any given period of time in the history of mankind. It has long been established that China has had a long and illustrious history of civilization lasting some 5,000 years. Recent archaeological digs have even suggested that Chinese history should be pushed back to 10,000 years ago, making it the oldest civilization in the world. Its long history, therefore, suggests a wealth of wisdom waiting to be unearthed. Hence, the other reason for this study is to harness this wealth of time-tested wisdom embedded within the fascinating civilization of ancient China.

Historically, the Chinese people were able to unify their country because of the existence of a common written language and a uniform political philosophy. Ancient China was well known for her technological feats even though these may not have been

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made use of to her best advantage (Low, 2001c, 2004). China already entered into the Iron Age during the Zhou Dynasty (1027-221 BC). In spite of the political turbulence and confusion, the Zhou Dynasty (1027-221 BC) was significant in producing a significant number of breakthroughs by the Chinese people both in terms of hardware (science and technology) and software (philosophy and strategic treatises) (Yu, 1992).

Iron became a substitute for bronze in ancient China around 500 BC, partly because charcoal was increasingly used for smelting ore. A wide range of iron tools and weapons were made. These included ox-drawn iron-tipped plows, hoes, scythes, axes, wheels, chisels, drills, knives, and swords up to three feet in length. There were also breakthroughs in the field of astronomy. A lunar eclipse and a solar eclipse, which occurred in 1311 BC and 1137 BC, respectively, were recorded in annals. The movement of two planets, Jupiter and Saturn, were already known in details by 350 BC Halley's comet was similarly described in 240 BC (Meyer, 1994; Roberts, 1996).

By the fourth century BC, lacquer was developed as a finish for wooden objects. In the third century BC, the Pythagorean theorem was mentioned and the mathematical concept of π advanced. The first treatise on trigonometry was derived. Efficient irrigation and flood control measures were developed and put in place by ancient Chinese engineers. The northern sections of the Great Wall, the only man-make object that can be seen purportedly from the moon with the naked eye, were built. Attempts were made to standardize weights and measures. The solar year was calculated at 365.25 days by 444 BC, even though the ancient Chinese continued to use the lunar year for ritualistic purposes (Nevius, 1995; Low, 2001a, b).

By virtue of its long history, valuable lessons from the point of view of technology, management and economics may be found within Chinese civilization. Some of these lessons may be historical in nature. Nevertheless, their fundamental principles and truths can still be relevant today. This includes the Chinese way of managing the building process which this paper documents.

Apart from documenting the ancient management practices of the Chinese relating to building projects, the other objective of this paper is to compare these ancient Chinese practices with modern-day project management principles to identify their similarities, if any. This comparison would be highlighted in the conclusion section after a review of the ancient Chinese management practices relating to building projects. For the purpose of comparison, the nine knowledge areas in the project management body of knowledge (PMBOK) published by the Project Management Institute in the USA will be adopted (PMI, 2004). These nine knowledge areas relate to integration, scope, time, cost, quality, human resource, communications, risk, and procurement management.

Records of building practices

Although records of Chinese history span more than two millennia, the historiography of China's architecture is less than a century old. Because of the abundance of timber supply in the region and the ease of crafting with timber, timber was the main and most important building material in the ancient days. Unfortunately, buildings were not regarded as fine arts such as calligraphy and painting. Consequently, not much records of building practices were passed down from the olden days. Only two such records of building practice survived history. The earlier one is known as *Yingzao Fashi* (referred to as the "Treatise on Architectural Methods") or *Building Standards*,

published by the Office of Building in the Ministry of Public Works of the Song Dynasty (960-1279 AD). This was printed in 1103. The second manual is the *Gongbu Gongcheng Zuofa Zeli* or "Engineering Manual for the Board of Works" published by the Ministry of Public Works in the Qing Dynasty (1644-1911 AD) and printed in 1734. The aim of both publications was to facilitate the accounts of public buildings for which the ministries were responsible. It was not to teach imperial officials how to become architects for obviously the craftsmen already knew their trades very well by then (Liang, 1983).

The compilation of *Yingzao Fashi* started in the Yuanfeng reign. However, it was found to be impractical when completed during the Yuanyou reign of Emperor Zhezong. Therefore, Li Jie, then deputy head of the Directorate of Buildings and Construction, was made responsible for the revision of the book. Commissioned in the fourth year of the Shaosheng reign period (1097 AD) and completed in the third year of the Yuanfu reign period (1100 AD), this manual covers both the design and specifications of structural members. There are altogether 34 chapters in the *Yingzao Fashi,* preceded by an introduction by the editor, Li Jie, on preliminary works and calculations. The first two chapters list 49 terms for construction members, with quotations from literary sources dated from the Zhou Dynasty (1027-221 BC). The rest of the work can be divided into four parts: rules, labour, material, and drawings. Chapters 3-16 deal with construction methods for different structural members. Chapters 17-25 explain the work units used, i.e. the amount of work for each different category of trade which a skilled artisan is expected to carry out in a day. Chapters 26-28 list the amount of materials needed for each type of work and the ratio of ingredients for mortar, plaster, pigments, and glaze. Chapters 29-34 consist of drawings which illustrate the details of construction as well as plans and cross sections of buildings. The chapters are further classified into 12 sections: moats and fortifications, stone work, carpentry, joinery, wood carving, turning and drilling, sawing, bamboo work, plastering, painting and decoration, brick work, and the manufacture of tiles.

In the *Yingzao Fashi,* the calculation of wages for the labour involved is clearly described and detailed in the manual. The unit for calculation is the workday and the variations in the length of workday during the different seasons are taken into consideration. There are three categories for workdays. The days of the two spring and two autumn months are regarded as the standard; the days of the four summer months are longer than the standard, and the days of the four winter months are shorter. A standard workday is the unit of calculation, with a long day figured to be 10 percent longer than the standard day and the short day 10 percent shorter. The artisan had to work from sunrise to sundown, and their wages were calculated accordingly. The general rule for computing how much the artisans were paid equates the wages of three soldiers to the wages of two artisans. During the time of intense building activities, which is coupled with a shortage of skilled artisans, soldiers were summoned to assist in the construction projects, but they were only paid two-third of what the artisans received.

The concept of the modular system for design is not an entirely new innovation created only recently. As early as the Tang Dynasty (618-907 AD), a modular system with cross-sectional measurements for each timber, calculated for desired width and depth of the "jian" (a unit in a modular system of design indicating the space marked by adjacent frame supports) or space already exists. But it was only until the

Song Dynasty (960-1279 AD) that instructions become more precise and were recorded in the *Yingzao Fashi*. The timber members are classified into different grades ("cai"). Each grade has a basic modular unit called the "fen" which is approximately one-fifteenth of the height of the cross-section of that grade. There are eight different grades for the timber units. The nature of the building – i.e. palaces, government offices and their scale, such as the number of "jian" would determine the necessary grade. The dimensions of the building, the width, depth, and height would give the artisans an idea of the number of "fen" required for the cross-section of each structural member with some allowance. Thus, the absolute dimensions of various members may vary, but the proportionality among them will always remain the same. The grading of the timber members, therefore, enables the practice of modular coordination and by grading the timber prefabrication is made possible in the olden days. This greatly reduced the time needed for construction during the period when the *Yingzao Fashi* was being practised.

There are also altogether eight gradings ("Cai") of timber, each of a particular cross-sectional area and size as well as the recommended usage. For instance, in the case of a grade one timber, the depth is 9 in. and the breadth is 6 in. It is also noted that 0.6 in. make one section ("fen"). The recommended usage is for halls that are nine to eleven spans long. As for grade two, the depth is 8.25 in. and the breadth is 5.5 in. In this case, 0.55 in. makes one section. This grade is used for halls that are five to seven spans long.

In relation to modern-day quantity surveying practice, one can, therefore, draw some similarities between the Song's version of the *Yingzao Fashi* and the *Standard Method of Measurement* (SMM) originally published by the Royal Institution of Chartered Surveyors based in London. Both the publications deal with the measurement of quantities of building materials and both the publications also provide uniform measuring units for different building components. The final result is that both are used for the estimation of cost and time required for a project. The only difference is that the *Yingzao Fashi* tends to be more detailed in that it covers many aspects which the *SMM* does not. For instance, the *Yingzao Fashi* includes construction techniques for different carpentry works and the cross sections of timber members are stated which allow the artisans to proceed immediately with construction if the span is already known. There are also instructions in the various chapters of the *Yingzao Fashi* on what colours to be painted/decorated for different official ranks and size of buildings.

As for the Qing Dynasty's (1644-1911 AD) version of the *Gongbu Gongcheng Zuofa Zeli,* the principles are quite similar to the Song Dynasty's (960-1279 AD) version of the *Yingzao Fashi*. The former consists of 74 chapters. The first 37 chapters describe construction methods for building frames of 27 different sizes. The next 14 chapters describe the construction method for bracket sets. The next six chapters then deal with construction methods for part building with stone and tiles. The next 13 chapters deal with the quotas of materials and the last 14 chapters deal with labour.

The Qing Dynasty's (1644-1911 AD) manual states carefully the size of each structural members and this is different from the Song Dynasty's (960-1279 AD) version which gives general rules and ratios for designs and computations. However, the Qing Dynasty's (1644-1911 AD) version has a drawback in that, there is no explanation of the technical terms used and no drawings were used to illustrate the text. In addition, the positioning and joining of structural members are also poorly indicated. In comparison, the Song Dynasty's (960-1279 AD) version is far more organized

and illustrated. This could be due to the fact that its editor, Li Jie, who was later Vice-Director of the Ministry of Public Works' Office of Building, was earlier in charge of erecting palaces and government buildings in the Northern Song capital of Bianliang (Kaifeng) before he was ordered by the Emperor to edit a manual for public buildings (Chinese Academy of Architecture, 1982; Qinghua University, 1985; Institute of the History of Natural Sciences, 1986).

Official systems for public projects

The effective organization of construction activities can result in reduced material wastages and shorter construction time. Since, ancient time, the division of labour and specialization had already been practised in China. Officials were put in charge of various types of construction works to facilitate control and effective management. It was believed that during the rule of Yao and Shun, there was a position of *Zong Gong* that was conferred to the officials put in charge of construction engineering works. There were historical records of a person by the name of Chui, who made the compass, the square, the plumb bob, and the line-maker during this time. There is an inference that by this time, there had already emerged a group of people who, by their knowledge of geometry and skills in surveying, organized and directed construction works.

From the materials that could be collected, the organization chart for construction activities during the Zhou Dynasty (1027-221 BC) is as shown in Figure 1. Although this is a very brief organization chart, one can, however, see that a special official was put in charge of the project and was given the title of *Si Kong*. This is quite similar to modern-day architects who are in charge of designing and managing construction works. In the Zhou Dynasty (1027-221 BC), this *Si Kong* was to take charge of the buildings of city walls, roads, canals and palaces. He is conferred by the Emperor with the power to survey the country far and wide in search of suitable sites and materials and to muster a labour force for constructional purposes. The labour force was usually

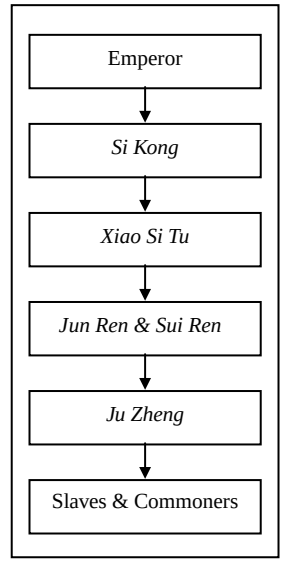

Figure 1.
Organization structure in the zhou dynasty

made up of the commoners who were unskilled and who will be in charge of the physical works. Some skilled carpenters and artisans were also forced to join in the construction works. These labourers had to bring their own tools, their own food, drive their own carts and see to their own draught animals. During the reign of Emperor Xuan of the Zhou Dynasty (1027-221 BC), Duke Zhao used forced labour to build a city for Count Shen.

In the "Book of Rites of the Zhou" it was mentioned that woodworkers were categorized into seven categories, specializing in wheel, sedan, bow, dwellings, craftsmanship, cart making, and carpentry. The Master Craftsman was highlighted because of his importance in constructional activities. The role of the Master Craftsman was quite similar to modern-day engineers and architects. Their duties were to survey, level, orientate, as well as plan and design for the works. They are vested with the power to command and direct the slaves in their works. As a matter of fact, in ancient China, surveying and site selection were all done by the carpenters which is quite different from the distribution of work today.

In the Qin Dynasty (221-207 BC), the official post of *Jiangzuo Shoufu* was created to control all construction works. The title of *Si Kong* of the Zhou Dynasty (1027-221 BC) was replaced with the title of *Yushi Dafu* and his duty was to supervise and impeach. In the Western Han Dynasty (206 BC-9 AD), the Emperor adopted the same system as the Qin Dynasty (221-207 BC), but the title of *Shoufu* was changed to *Dajiang* in recognition of his contributions. The title of *Jiangzuo Dajiang* remained in use until the Ming Dynasty (1368-1644 AD).

In the Eastern Han (25-220 AD), Wei (220-265 AD) and Jin (1115-1234 AD) Dynasties, various posts like *Mincao Shangshu, Mincao, Zuomin Shangshu* and *Qibu Shangshu* were created. These were all related to construction engineering. During these dynasties, the post of *Jiangzuo Dajiang* was made concurrent and was no longer permanent. An appointment was made only when there was work to do.

During the Sui Dynasty (581-617 AD), the Ministry of Works was set up. The Ministry of Works took charge of the building and management of construction projects for farming, reclamation, forestry and water conservancy in the country. At the same time, there was another department, the Jiangzuo Si (Directorate of Buildings and Construction) which was later changed to *Jiangzuo Jian*. This department was responsible for the construction of palaces and office buildings of the central government in the capital. This practice was continued in the Tang Dynasty (618-907 AD) with the organization chart shown in Figure 2.

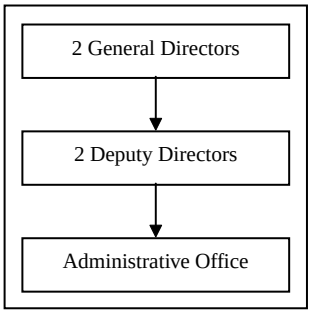

Figure 2.
Structure of the directorate of buildings and construction

The General Administrative Office was in charge of the workmen engaged in civil engineering projects. Under this General Administrative Office, there are the left, right, and middle departments which were concerned with woodwork, surface rendering, and logistics support, respectively. Another department was put in charge of stone carving and earthenware-making. There are also a number of superintendents known as the *Bai Gong, Jiu Gu, Ku Gu, Xie Gu, Tai Yin*, and *Yi Yang* who were concerned with tree-felling and lumbering. In addition, all these departments were classified into internal and external works. Internal works dealt with construction works in connection with the palaces and the external works referred to the city gates, government offices and suburban temples.

During the Song Dynasty (960-1279 AD), the Directorate of Buildings and Construction was subordinated to the Ministry of Works. This was different from the Tang Dynasty's (618-907 AD) practice. In the beginning, this Directorate only existed in name. It had no formal responsibilities and duties. Construction works were undertaken by another department known as *Sansi*. It was only during the Yuanfeng reign of Emperor Shenzong when following the restructuring of the government, the directorate was put in charge of the construction and maintenance of palatial buildings, city walls, bridges, boats, and carriages. As noted earlier, Li Jie, the deputy head of the directorate at that time, was responsible for the revision of the most important documentary work on ancient Chinese architecture which culminated into the *Yingzao Fashi*.

During the Jin Dynasty (1115-1234 AD), there was no Directorate of Buildings and Construction which was responsible for public projects during the Tang (618-907 AD) and Song (960-1279 AD) Dynasties. Taking its place was the Ministry of Works. Such a practice was also adopted in the Yuan Dynasty (1279-1368 AD). In the Yuan Dynasty (1279-1368 AD), the emperor, the queen and the princes all had their own men and organizations for works of engineering construction. This is quite similar to the modern day concept of having nominated/term contractors for some developers and major employers. Experienced craftsmen were given due respect and they were appointed as officials in charge of construction works in the Yuan Dynasty (1279-1368 AD). For example, Sun Wei was appointed General Supervisor of Workers for his experience in making armour and helmets.

During the Ming Dynasty (1368-1644 AD), the Ministry of Works of the Yuan Dynasty (1279-1368 AD) still existed in name. However, the actual work was handled by the Building and Repairing Department in the Ministry (formerly known as *Jiangzuo Si*).

The system in use in the Qing Dynasty (1644-1911 AD) was slightly different. While the Ministry of Works still took charge of the construction of temples and government offices in the capital, the Ministry of Internal Affairs took charge of the construction of gardens and palaces.

The above provides a general overview of the official system related to construction works in the various dynasties. The system was only valid for public projects. For private projects, the Master Craftsman was usually the person-in-charge. As he is a person of extreme importance, his role needs to be elaborated further here. Master craftsmen are artisans with high levels of skills. They were called *Du Liao Jiang* or *Si Wu* in the Song (960-1279 AD) times. They may both be working freelance and

take charge of construction engineering projects, or they may enter into employment with government offices (Yu, 1984; Ju, 1998; Wang, 1998).

Labour force

No work can be done without involving the labourers. This statement is very much appropriate in ancient China. An extensive labour force was required for earth ramming, weight lifting, and transportation. In ancient China, the labourers are mostly the peasants who were forced to do the work without wages. The labourers need to prepare their own food and take care of their own draught animals. Other than the peasants, there are also the soldiers and the convicts. For example, the Great Wall of China was built mainly by convicts. In the Han Dynasty (206 BC-220 AD), convicts were made to build city walls and mausoleums. During the Song (960-1279 AD) and Tang (618-907 AD) Dynasties, there was an increasing trend of soldiers being recruited for construction works. As noted earlier in the *Yingzao Fashi*, there were writings of how the wages of the soldiers and the civilian workers are calculated using a certain ratio for conversion. In the Ming Dynasty (1368-1644 AD), the soldiers accounted for approximately 30 percent of the labour force.

Design and planning

The construction process involves four elements; namely planning, organizing, leading and controlling, with individual processes being carried out concurrently. How are planning carried out in ancient times for a construction project in China? Before the designs can be put into practice to achieve the goals, a lot of preparatory work has to be undertaken. Without a well thought out plan, it would be impossible to ensure that construction works involving thousands of workers can proceed smoothly.

This aspect was mentioned by a famous scholar in the Song Dynasty (960-1279 AD), Su Dongpo, in his article, "Some Thoughts on Good Governing". Su Dongpo explained that:

> When a rich man wants to build a house, he must first estimate the resources at his disposal and then determine the size of the house to build and ask in what amount materials and labour are needed, how long it will take, and where to get the materials such as earth, stone, bamboo and reeds. The architect will tell him where to get all the materials required and how much is the cost and labour involved. By following his advice, the man is able to complete the construction of the house on schedule. It is due to the fact that everything has been carefully planned ahead that the new house is found all in order.

This extract from Su Dongpo provides a brief idea of how planning for construction was carried out in ancient China.

The Master Craftsman (known as *Si Wu, Du Liao Jiang* or *Gong Si* and *Shi Shi*, as mentioned in the "Manual on Architecture" by Lu Ban) made out the draft plans and drawings, and then gave an estimation of the materials, costs, labour and time needed, after taking into account the client's requirements and environmental constraints. His role was quite similar to the modern day architect and consultant engineers, except that he undertook all the works himself.

As for government projects, an extract from the "Commentary on the Spring and Autumn Annals" suggests that:

> . . . the governor considered the matter and turn it over to the official in charge. The latter then calculated the amount of work to be done, the number of workdays required and the expenses involved, got ready materials and equipment, considered the distance, selected the site, stored up grain and put men in charge of various jobs. The project was completed in 30 days without mishap.

The project referred to in this extract concerned the building of the city of Yi by the prefect of Chu in the 11th year of the reign of Duke Xuan.

Another extract from the commentary concerning the construction of the city of Chengzhou by Ni Mou of the Jin Dynasty (1115-1234 AD) in the 32nd year of the reign of Duke Zhao, explains that:

> The distance was measured, the terrain surveyed, the time, the work force, materials and various kinds of supply estimated, then the services of the dukes were enlisted and Han Jianzi appointed as the chief supervisor.

A brief idea of the planning process and preparatory work before actual construction works begin can be gleaned from the above extracts.

It was noted that there were a few considerations to be taken into account in the process of planning. These relate to the location and orientation, the scale of the project, the availability of the water sources and the availability of the building materials in the region. The availability of water and building materials was very important in the planning and construction of a city. Water was needed for irrigation, for survival and of strategic purposes as well. The availability of building materials in the nearby region can save cost on transportation and the time required to acquire these materials. For example, in a region where there is an abundance of bamboo, the main building materials would be bamboo. This theory was followed throughout the ancient dynasties and there is a Chinese saying to this effect which says *jiu di qu cai*. For example, the Sui (581-617 AD) rulers gave up the old site of Chang'an of the Han Dynasty (BC 206-220 AD) and built a new capital elsewhere. Other considerations in building a city included sewage disposal, fire prevention, the provision of wells, the availability of roads, and suitability of the environment. Superstitious influences were another determinant in the planning for construction works. These influences became stronger during and after the Song Dynasty (960-1279 AD). Till today, superstitious influences, such as *Fengshui* or geomancy, still play an important role in construction works in Chinese communities worldwide.

As for the design of the building, there was a system or rule-of-thumb to follow. In ancient China, a system was developed in which the human body, utensils, vehicles, and articles of furniture, etc. (whose dimensions were based on the size of the human body) were taken as the basic units in designing. It was stated in the "Survey of Constructional Work" that "the room was measured in term of *Ji*, the hall of *Yan*, the palace of *Xun*, the field of *Bu* and the road of *Gui*." *Ji* refers to a table three χ long (approximately 90 cm). *Yan* refers to a mat, about nine χ^2, used to cover the floor on which people used to sit in ancient times. *Xun* represents a length of eight χ, which is approximately the length of outstretched arms. *Bu* equals six χ and *Gui* equals eight χ which is approximately the width between two wheels of a cart.

The "Survey of Constructional Work" also mentioned the requirement of having nine roads running from north to south in the capital and nine roads running from east to west. These nine roads shall be nine *Gui* wide, which is about 72 χ or (21 m).

It was a practice in ancient China to make a city gate wide enough for three roads to pass through it, with each road allowing three carts to run abreast on it. Hence, it can be observed that gates and roads were based on the size of carts.

During the Ming (1368-1644 AD) and Qing (1644-1911 AD) Dynasties, the furniture was standardized in size and number. A fixed number of tables and chairs made a set of furniture. With this fixed, the minimum size of the hall can then be determined. A modular system was also developed to maintain relational harmony among the structural members. This system was clearly recorded in the *Yingzao Fashi* (Wong and Chung, 1982; Steinhardt, 1984).

Quantity surveying practice

Another duty of the designer (Master Craftsman) was to estimate the materials and labour required. This is the job of the quantity surveyor today. However, in ancient China, the designers would do the estimation. To accurately estimate, there has to be a reliable method for the computation of labour and materials. This area will be elaborated further below because of its importance.

There were numerous writings on how to calculate volumes and areas in ancient China. For example, in the book on "Nine Chapters on Mathematical Art" there is a list of ways for calculating different solid volumes such as parallelepiped with two square faces, the frustum of a pyramid with rectangular base of unequal sides. In Chapter 16 of the *Yingzao Fashi*, specific gravity is documented which can be used to calculate volumes using formulas.

As early as the Song Dynasty (960-1279 AD), fixed quotas based on large amounts of statistical figures obtained from architectural practices were introduced for various kinds of work. This was recorded in the *Yingzao Fashi*. With these fixed quotas, estimates can be made easier and are less time consuming. However, for simple repetitive labour, the direct measuring method was used to calculate the work done. As recorded by Shi Wenying in the book "Idle Talk in Jade Pot Study":

> Shovelfuls were added to make a χ, then a *zhang* (ten χ), and so on. Then the shovelfuls which a worker dug up from morning to dusk and the amount of earth excavated were calculated. By this method, the number of workmen needed was found from the grand total. At the end of the job, there were only nine men too many.

This extract was about the digging of the Huimin Canal. It suggested that based on the depth of earth reached by the shovel and the thickness of earth dug up, which was a constant constituting the basic unit for reckoning, the earthwork done by an individual (in a workday) could be worked out, and from the total quantity of earthwork done, the number of workmen needed was derived.

The calculations of the man-hours consumed can be a very subjective one. It was stipulated in the *Yingzao Fashi* how a workday may be determined as there may be variations in the workday due to the different seasons and the type of work. Although the workday is supposed to start from sunrise and end with sunset, under oppression and exploitation, the actual work time was often exceeded and workers were made to work everyday. During the Northern Song Dynasty (960-1127 AD), Superintendent Liu Chenggui forced the workers to work all night long by using candlelight.

According to the *Yingzao Fashi*, the following points should be taken into consideration:

- The work of the manufacture of the structural members.
- The installation and the auxiliary works involved in various projects.
- Classification of work into three types according to how difficult a job was, which constituted the dividing line between skilled and unskilled workers.

The classification of work into long, medium, and short-day types was on the basis of the seasons. (Long-day work covering April, May, June, and July; medium-day work covering February, March, August, and September; and short-day work covering October, November, December, and January.) This classification was also seen in the "Six Decrees of the Tang Dynasty (618-907 AD)". The work days mentioned in the *Yingzao Fashi* were based on medium work, thus one point had to be added for long-day work, and subtracted for short-day work.

The *Yingzao Fashi* provides that if old materials or ready-made members are available for use in a project, the corresponding amount should be deducted from the general estimate. It also lays down the rule that for special structural members which are different from what is provided for in the book, necessary adjustments should be made in work days and in the amount of materials needed by comparing them with similar cases in the book. This practice is akin to the modern day concept of variation orders.

The amount of work fixed is referred to in the *Yingzao Fashi* as *Gong Xian* (job accounting), which gives one an idea of how meticulously the work day was calculated during the Song Dynasty (960-1279 AD) in making an estimate for a building project.

The type of construction work will also affect the number of workday required. In the *Yingzao Fashi*, work is further classified into three categories. These relate to work done in different seasons, the texture of wood and the distance covered in moving earth. All these classifications help to differentiate between simple and complicated labour requirements, the degree of difficulty of jobs, different seasons and whether skilled or unskilled labour were available.

During the Song Dynasty (960-1279 AD), timetables were produced after taking into account the factors to be considered. These include the number of work days required, the commutation of processes, the weather, the transportation and the preparation time, etc. The progress of the construction work was explicitly stated in the timetable, which is similar to the Master Programme used by construction firms today (Li, 1986).

Building materials

Material is another major component in making up the total building cost. Hence, the materials to be used for construction work should be calculated meticulously. In addition to the main structural materials, auxiliary materials such as nails, ropes, glue, etc. should be calculated as well. In the *Yingzao Fashi,* there is a section for these auxiliary materials known as *Liao Li*.

Apart from the calculations and estimation, the selection and inspection of building materials is yet another important area. In ancient China, timber and bamboo were the most commonly used building materials because of their abundance, strength and ease of working. In the Ming Dynasty (1368-1644 AD), there were officials in charge of the supply of timber. Their task is to note down the varieties, sizes, quantities and location of usable trees and report them to the central authority. When the need arises,

the tree may be felled according to the record. There are a number of criteria used to determine which trees are usable. Firstly, the tree must be tall and straight. Secondly, the tree must be of good quality, which means the timber must be able to withstand weathering effects over time. In the section dealing with sawing in the *Yingzao Fashi*, the hardness of the timber is graded. This is because the hardness of the timber is one way to judge the texture of the timber. In Chapter 26 of *Yingzao Fashi,* the squared timber is graded according to its diagonal, length and whether it is made out of the trunk or the branch of the tree.

Because timber and bamboo are the most commonly used construction materials, there is a need to ensure an adequate supply of these building materials. In the Ming Dynasty (1368-1644 AD), the bamboo levying office under the Department of Land Reclamation in the Ministry of Works was in charge of levying a tax on the bamboo and timber used. This was to ensure that bamboo and timber could be hoarded as a reserve for public projects. The practice was to levy a one-tenth tax on the actual goods, and with this measure, part of the bamboo and timber originally for non-governmental use was turned over to the office to be used by the royal court. When bricks and tiles were invented, the same practice was implemented. At times, the office would confiscate the whole lot of timber and bamboo for governmental use.

As for bricks and tiles, it was mostly used for the ruling class. It was the practice to build kilns to make the bricks and tiles required when the construction work starts. In the period from the Southern and Northern Dynasties (420-588 AD) to the Sui (581-617 AD) and Tang (618-907 AD) Dynasties, the "Pottery Office" was in charge of manufacturing bricks and tiles. In the Song Dynasty (960-1279 AD), the department in charge was the "kiln administration."

Because most of the finished products of bricks and tiles were to be used in the construction of government offices and palaces, there must be a strict control over quality. As mentioned in the "Notes of the Winter Official" by Ho Shengrui, "bricks must be hard and well baked" "properly sized" and not "red and rough". While these standards are to be met by all bricks, the fine square floor tiles known as golden tiles used in palaces are to surpass this standard. As for how bricks and tiles were tested for quality in ancient China, it was mentioned in the *Yingzao Fashi* that cylindrical tiles are to pass through a semicircular bamboo mould to ensure that all the tiles are of uniform sizes. During the Ming Dynasty (1368-1644 AD), all bricks were checked against two samples that had been forwarded to the emperor or officials in charge for approval. If the brick is of a different thickness or colour shade, it will be rejected (Liang, 1983).

Material recycling and control

Materials constitute up to approximately 40 percent of the costs of construction. Hence, materials must be used wisely and should be recycled to save on wastages. In ancient China, an importance was always attached to the economic use of materials. In the *Yingzao Fashi,* Chapter 2 under the section "The use of timber" it was clearly stated that a piece of timber that is large enough must be made into big usable structural members. As for those that are not big enough to be made into structural members, these must be turned into members most suitable in width and length. It was also warned that big pieces of timber that can be used as structural members should not be cut into smaller sizes.

In the *Yingzao Fashi,* there is also a section on how to make use of the leftovers; the leftovers may be made into structural members or into boards. During the Song Dynasty (960-1279 AD), a "reject yard" was set up under the Department of Works. The reject yard handles all the materials rejected or thrown away inside or outside the capital. Those of suitable size will be made into suitable structural members and others would be collected and use as firewood.

It had been recorded in "Selections from Authors of Today and Yesterday" that odd pieces of wood had been used as pegs and wedges required in wooden buildings. Other than timber, bricks and tiles were used to pave the ground and to fill up depressions. Selected pieces may be pieced into decorative designs or used to build foundations. In the Ming Dynasty (1368-1644 AD), not only the bricks and tiles were put to inspection. A pigment office was also established to take charge of inspecting pigments and colours.

As for the sequence of work in modern day construction, usually the temporary works such as the hoarding and site offices are built first, followed by the substructure and the superstructure. This practice is no different in ancient China where the city wall was first built and the moat dug simultaneously. In this way, the soil excavated can be used to pile up the wall. This conformed to the economy and rationality in construction. In addition, the moat that may be used for defence purposes, can also be used as a waterway for transportation. Because of the large quantities of bricks required, the most economical way of transportation is by boat; therefore, transportation by the moat is efficient (Liang, 1983).

Inspection of building elements

The inspection process is inevitable to ensure that the completed buildings are of good quality. In ancient China, when the technology was still not well developed enough to use scientific apparatus to assess quality, experience was often relied upon for inspection. However, because judging by experience can be subjective, it may not be accurate all the time.

Rammed earth was a technique commonly employed in ancient China. This is quite similar to the modern day raft foundation. Hence, the rammed area must be of good quality so that there will not be uneven settlement or other ground defects. There were a few methods used to assess the quality or hardness of the rammed earth. During the Period of the Warring States (475-221 BC), the widely use method was to test the hardness using an apparatus called *shi*. *Shi* is an apparatus with a pointed metal tip that is less than 5 cm in diameter. Although there were not much records of how the *shi* was used to test hardness, one can, however, deduce that the *shi* may be pressed against the tamped earth and the hardness noted. It appears that the operation is similar to the Schmidt hammer widely used today to check for the hardness of concrete.

The next method is the plummet method. This involves a plummet dropping from a certain height to test the hardness of the tamped soil. This is a better method than using the *shi* because the amount of impact by the free fall of the plummet is constant. Hence, the test result would be expected to be more accurate. The third method is carried out by inspecting the thickness of the loose soil to a piece of block visually. With the loose soil being the control, one can make comparisons and see how well the compaction had been done. This method was widely adopted when earth was mixed

with broken bricks and tiles to strengthen it. Using the *shi* method in this case would give a distorted result.

Another method for checking the quality of the tamped soil is by checking its colour visually. This method is only applicable when mixtures such as lime and earth or lime, earth and sand were used. An example of this was, when Emperor Taizu of the Ming Dynasty (1368-1644 AD) inspected the quality of the tamped soil at random locations to ensure its quality. Lime was mixed with sorghum gruel to reinforce the city wall and if any impurities were found in any of the sections inspected, the builder would rebuild that section.

Most of the buildings in ancient China were constructed of timber. Therefore, inspecting the timber frame was an important operation in the construction process. For example, in the case of the timber column, tiny slots were made at the bottom of its base so that when the column was found to be slanting, a level may be inserted into these slots and the column turned until it is vertically upright again. The holes formed by these slots are then covered over by painting.

When roof tiles were invented in the Shang Dynasty (1700-1027 BC), it was used extensively for the palaces. Consequently, roof tiling must be inspected regularly for water seepage. If the joints between the tiles were not treated properly, water would seep in and cause the wood to rot. To solve this problem, the roof was, therefore, built with a slight curvature to eliminate the excessive gaps between the tiles. Ample mortar was used to ensure that the joints were properly pointed. To further ensure that gaps were properly pointed, a conscious attempt was made to prevent grass from growing on the rooftop. Otherwise, grass roots would loosen the tiles and allow water to seep into the building (Li, 1986).

Conclusion

There is a wealth of management wisdom embedded within the history of China which continues to be relevant today (Kwang, 1999). Although much of this is ancient in context, people are still fascinated by the degree to which some of these management thinking can still be applied today both in everyday life as well as in professional practice. The Taoist philosophy, for example, was found to have influenced Chinese architecture and to be used for shaping living space as part of design evolution today (Mitchell and Wu, 1994). Likewise, an independent panel of experts in the USA concluded that the ancient practice of acupuncture is an effective therapy for certain medical conditions and should be integrated into standard medical practice for these problems (Straits Times, 1997; Kao, 1998). Acupuncture, which originated in China more than 2,500 years ago, involves stimulation of certain points on or under the skin, mostly with ultra-fine needles that are manipulated manually or electrically. Although questions were asked as to why science, capitalism, and individualism did not make any significant inroads into China in the past, there remain lessons to be learned from Chinese history if only one is willing to learn from it. As this paper shows, one would only need to review the current body of knowledge relating to project management today (Dixon, 2000; PMI, 2004) to appreciate that many lessons in construction project management in ancient China bear similarities with modern-day practices where the management of building projects is concerned.

The Project Management Institute in the USA set out nine key knowledge areas in its PMBOK (PMI, 2004). These relate to Integration Management, Scope Management,

Time Management, Cost Management, Quality Management, Human Resource Management, Communications Management, Risk Management, and Procurement Management. A comparison of the ancient Chinese practices with modern-day project management principles as set out by the PMI (2004) in the nine knowledge areas suggests similarities between these two ancient and modern-day management frameworks. Some of their common grounds can be identified as follows:

- Project integration management is made up of the day-to-day processes to ensure that all parts of the project work together (PMI, 2004). In this context, it was noted that the modular system involving dimensional coordination of timber components was already instituted during the Tang Dynasty (618-907 AD). In the construction of the city of Chengzhou, Ni Mou of the Jin Dynasty (1115-1234 AD) provided a glimpse of project integration management in the planning process and preparatory work before actual construction works begin when it was documented that the "distance was measured, the terrain surveyed, the time, the work force, materials and various kinds of supply estimated, then the services of the dukes were enlisted and Han Jianzi appointed as the Chief Supervisor". The sequence of works also reflected project integration management. For example, in ancient China, the city wall was built first and the moat dug simultaneously. This practice ensured that processes were integrated with the soil being excavated used for piling up the wall.
- Project scope management constitutes the processes to ensure that the project includes all of the work required, and only the work required to complete the project successfully (2004). In this context, the Song's (960-1279 AD) version of the *Yingzao Fashi* or "Treatise on Architectural Methods" provided for the measurement of quantities of building materials to predetermine the scope of work involved. The "Commentary on the Spring and Autumn Annals" noted that for government projects in ancient China, the governor would consider the matter and turn it over to his official in charge to determine the project scope by calculating the amount of work to be done, the number of workdays required and the expenses involved. Based on the predetermined project scope, the official would then get the materials and equipment ready, consider the distance, select the site, store up the grain, and put men in charge of various jobs. During the Sui Dynasty (581-617 AD), considerations in building a new capital city would include the project scope for sewage disposal, fire prevention, the provision of wells, the availability of roads and suitability of the surrounding environment.
- Project time management entails adequate planning to predict when a project will end (PMI, 2004). In this context, the Song's (960-1279 AD) version of the *Yingzao Fashi* or "Treatise on Architectural Methods" provided for the measurement of quantities of building materials to estimate the time required for a project. Su Dongpo of the Song Dynasty (960-1279 AD) wrote in his article, "Some Thoughts on Good Governing" that in the design and planning processes, the client who wants to build a house must first estimate how long the project would take after considering the size of the house and resources at his disposal. Timetables, akin to the modern-day Master Programmes, were also produced during the Song Dynasty to monitor the progress of construction work.

- Project cost management involves the process of calculating the costs of the identified resources needed to complete the project, taking into consideration the possible fluctuations, conditions and other causes of variances that could affect the total cost of the estimate (PMI, 2004). In this context, during the time of intense building activities in ancient China when there was a shortage of skilled artisans, soldiers were summoned to assist with construction works. However, the soldiers were only paid two-thirds of what the artisans received because of differing skills competence. The Song's (960-1279 AD) version of the *Yingzao Fashi* or "Treatise on Architectural Methods" provided for the measurement of quantities of building materials to estimate the cost required for a project. In his article, "Some Thoughts on Good Governing" Su Dongpo of the Song Dynasty (960-1279 AD) wrote that in the design and planning processes, the client who wants to build a house must first estimate the resources at his disposal, determine the size of his house, and consider the amount of building materials and labour needed for the project. During the Song Dynasty, a "reject yard" was also established under the Department of Works to handle all the materials rejected or thrown away. To save costs, rejects of suitable sizes will be made into relevant structural members while others would be collected and used as firewood.
- Project quality management is the totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs, and is the sum of the characteristics of a product that allows it to meet the demands or expectations of a project (PMI, 2004). In this context, the "Treatise on Architectural Methods" (dealing with the design and specifications of structural members) published during the Song Dynasty (960-1279 AD) and the "Engineering Manual for the Board of Works" published during the Qing Dynasty (1644-1911 AD) exemplified measures instituted by the ancient Chinese to assure quality standards in building projects. During the Ming Dynasty (1368-1644 AD), several criteria were used to determine which trees are usable by grading their hardness and texture. Likewise, to maintain quality, the *Yingzao Fashi* specified that cylindrical tiles are to pass through a semicircular bamboo mould to ensure that all the tiles are of the same uniform sizes.
- Project human resource management is the ability to lead and direct the project team, customers, project partners, contributors and stakeholders to achieve the desired outcome for the project (PMI, 2004). In this context, it was noted earlier that during the time of intense building activities when there was a shortage of skilled artisans, soldiers were summoned to assist with construction works in ancient China. In addition, the official system for public projects also adopted the practice of division of labour and specialization as part of human resource management in ancient China. More specifically, the "Book of Rites of the Zhou" categorized woodworkers into seven categories to specialize in the construction of the wheel, sedan, bow, dwellings, craftsmanship, cart, and carpentry. As part of human resource management, work days for the labour were also classified into long, medium and short-day types based on seasons.
- Project communications management focuses on determining who needs what information and when, and then producing a plan to provide that information (PMI, 2004). In this context, the establishment of various building related

departments and ministries throughout the history of China provides evidence of the ancient Chinese's attempt to facilitate overall communications management when planning for construction projects. For example, the official post of *Jiangzuo Shoufu* was created during the Qin Dynasty (221-207 BC) to control all construction works. In the Eastern Han (25-220 AD), Wei (220-265 AD), and Jin (1115-1234 AD) Dynasties, various posts relating to engineering construction were created. Likewise, a Ministry of Works was set up during the Sui Dynasty (581-617 AD). There was a Directorate of Buildings and Construction in the Song Dynasty (960-1279 AD). The practice of having a Ministry of Works was also adopted in the Yuan Dynasty (1279-1368 AD) as part of overall communications management to plan for and coordinate public projects throughout the country.

- Project risk management identifies project risks, analyze and rank them and determine what actions are needed to avoid, mitigate or transfer these threats (PMI, 2004). In this context, it was noted that during the Jin Dynasty (1115-1234 AD), risk management in construction projects included the consideration that the ready availability of building materials in nearby regions can save on transportation and the time needed to acquire these materials. Likewise, as early as the Song Dynasty (960-1279 AD), it was noted that fixed quotas based on statistical figures obtained from architectural practices were introduced for various types of work to facilitate the ready establishment of estimates as part of risks management. In the Ming Dynasty (1368-1644 AD), the bamboo levying office in the Ministry of Works was in charge of levying a tax on the bamboo used. As part of risks management, this practice was to ensure that bamboo could be hoarded as a reserve for public projects.
- Project procurement management is the process of purchasing the products and services necessary for meeting the needs of the project (PMI, 2004). In this context, an organization chart adopted during the Zhou Dynasty (1027-221 BC) for building activities identified a group of people who procured, organized and directed construction works by virtue of their knowledge of geometry and skills in surveying. Likewise, the General Administrative Office set up in the Tang Dynasty (618-907 AD) was in charge of workmen engaged in civil engineering projects. Separate departments within this office were responsible for the procurement of woodwork, surface rendering, logistics support, stone carving and earthenware-making. In the Yuan Dynasty (1279-1368 AD), the emperor, queen, and princes all had their own men and organizations for procurement of engineering construction works, a practice which is quite akin to the modern-day practice of nominated or term contractors for development projects. In the Ming Dynasty (1368-1644 AD), officials were put in charge of the supply of timber. Their duties included noting down the varieties, sizes, quantities and location of usable trees and reporting them to the central procurement authority.

The above comparison between ancient and modern-day project management practices suggests that much emphasis have been placed by the ancient Chinese on the quality aspects of prominent building projects and that much of the bureaucratic and administrative frameworks put in place have been to help assure that quality standards were not compromised in anyway during the building process.

This probably explains why many historical structures of good workmanship and material quality standards still remain intact today in China, for example, the Great Wall of China and the Forbidden City in Beijing. This is one facet of building processes which modern-day project managers and clients can certainly learn from. One area recommended for future research would, therefore, be to compare the *Yingzao Fashi* with modern-day codes of practice for building works to determine which of its "ancient" provisions relating to quality management are still relevant today.

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