Past Perfect: Historical Antecedents of Modern Construction Practices

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Abstract: This paper describes initial research on a project designed to understand the experiences of past generations of constructors and make that knowledge accessible to future generations of engineering students and construction practitioners. Much in the same way as medical students can trace their lineage back to Hippocrates, this project aims to provide architecture, engineering, and construction students, and professionals alike, a sense of their professional history. The project was developed around five time epochs, four geographic regions, and three different project types. We investigated issues such as the flow of money, training of workers, sharing of design knowledge, and nature of contracts and agreements. The central question posed by this work is how should knowledge of the history and evolution of construction practices be incorporated in the dialog that educators have with students and with the larger professional community? This research has led to multifaceted results. On the one hand, the message to students should be pride in their professional heritage because throughout time constructors and designers have used knowledge, perseverance, and innovation to accomplish remarkable projects. On the other hand, we have shown that much of what is considered new in the industry (alternative project delivery methods, worker safety programs, public private partnerships, and globalization) have historical antecedents and are not new at all.

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Background

"Who knows only his own generation remains always a child" (Norlin 1940). These words by George Norlin, the president of the University of Colorado from 1917 until 1939, appear above the doorway to the main University of Colorado library that bears his name. It is certainly true that all can benefit from the wisdom and experience of past generations. This paper describes initial research on a project designed to understand the experiences of past generations of constructors and make that knowledge accessible to future generations of engineering students and construction practitioners.

The concept for this paper started with the reading of a popular book entitled *Brunelleschi's dome* (King 2000). King's book is the story (politics, architecture, and construction) of the dome of Santa Maria del Fiore in Florence, Italy. This Renaissance dome was completed in 1436 and was then the largest dome in the world. Today it is still the largest masonry dome in the world with a span of 137 ft. It was built as a freestanding dome, unsupported by centering during its construction. One section in the book describes Brunelleschi's actions to counteract the fears of the masons who worked high on this freestanding dome. Brunelleschi designed and constructed a platform to protect the masons from falls and to prevent them from "looking down." In addition, Brunelleschi fashioned leather safety harnesses for the masons. This 14th century master builder's actions were perhaps one of the first documented instances of someone attending to workers' safety concerns in the construction industry. Brunelleschi's actions demonstrated a sophisticated understanding of labor relations.

This one innovative action on the part of Brunelleschi gives rise to a number of questions:

1. How often have the actions of past master builders, designers, and constructors presaged our current construction practices?
2. What other innovations lie buried in the historical record?
3. What should universities be telling architecture and engineering students about their intellectual and professional heritage?
4. Can the understanding of our construction heritage encourage appreciation of modern construction practices?
5. Can the understanding of our construction heritage promote new innovations?

Current curricula provide students of architecture and engineering little information on how the construction industry evolved over the centuries. Likewise, current curricula do little to help students appreciate how resourceful and creative members of the industry have been during its entire history. Much in the same way as medical students can trace their lineage back to Hippocrates, this project aims to provide architecture, engineering, and construction students and professionals alike, a sense of their professional history. Although many authors have documented the history of technology (Strike 1991), e.g., the change from iron to steel in buildings, there is little in the literature to document the changes in the processes that we use today to produce the built environment.

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Historical Construction Projects

How does one survey a subject that is so broad, that covers so many centuries, that transpires everyplace on the globe, and that encompasses so many different types of projects and structures? This work begins to understand historical construction practices by focusing on historically significant buildings and structures. A fundamental premise behind this work is that the richest historical record exists for significant and monumental buildings. Since monumental buildings and structures played an important role in the politics, social interactions, and economics of the day it is likely that a more detailed historical record would exist for them than would exist for vernacular architecture. Historians, in the process of preparing other studies involving historically significant buildings, have often inadvertently documented information about construction practices. For example, a historian working on the labor economics of medieval Europe may have observations that contribute to an understanding of labor guilds, working conditions, and worker training.

The first task of this work was to identify a list of significant buildings and structures on which to base the study. This list was initially organized as a simple matrix of three time periods and three geographical locations. In the course of populating the matrix with projects, it was soon apparent that a more complex $5 \times 4 \times 3$ matrix was needed. Five dimensions are needed to contain five time epochs: [ancient (to 1000 CE), Middle Ages (1000–1400 CE), Renaissance (1400–1700 CE), Industrial (1700–1900 CE), Modern (1900–present)]. The demarcations between the various time periods are somewhat arbitrary as there are no precise standards for these dates among historians. The expanded matrix contains four dimensions for geographic locations: (Asia/Australia, Middle East/Africa, Europe, the Americas). Finally, three dimensions are needed for three different project types: (civil/military works, religious buildings, and monumental structures). This final dimension is needed to recognize the different motivations behind different types of structures.

This matrix structure was populated using university libraries, interviews with historians, the World Wide Web, and other sources. Currently, the matrix has more than 150 significant historical projects. Tables 1–4 show representative samplings of the projects. Each table covers one of the geographical units in the study and organizes the projects by type and time period. For clarity of presentation only a handful of the projects identified in the study are included in these tables. We endeavored to ensure that the number of projects in each time period and in each geographic location is representative of the comprehensive project set. Selecting projects included in the matrix, as well as their placement in geographical regions, admittedly allows some degree of judgment. For example, Hagia Sophia is included with the Asian region even though it is located on the European side of Istanbul. The Great Wall in China is placed in the medieval period even though many sections of the wall date to much earlier periods.

Judgmental selection and categorization of individual projects notwithstanding, organizing a construction project in this manner produces interesting observations.

Construction Practices and Their Historical Context

The principal purpose of this research is to develop understanding of how fundamental construction processes and practices have developed and evolved during their long history. We approached this problem by treating each combination of a time domain and a location (i.e., medieval Asia or industrial Europe) as a "building culture." Differences in cultures can be used to understand variations in construction practices. This cultural understanding of construction has two levels; first relative to the dominant culture of the day and then relative to the culture of the project.

Investigation of a "building culture" must first develop an appreciation of the larger culture in which the construction project occurred. Understanding at this level helps explain the major societal forces that shape construction practice. Davis (1999) suggests that answers to the following questions will help understand a historical building culture:

Table 1. Asian Construction Projects Various Time Periods

		Time period				
Region	Project type	Ancient	Medieval	Renaissance	Industrial	Modern
Asia/Australia	Civil/military works	Du Jian Yan Irrigation Project, China	Great Wall, China			Hong Kong Airport, China
		Grand Canal, China				Three Gorges Dam, China
						Petronas Towers, Kuala Lampur
						Akashi Kaikyo Bridge, Japan
						Kansi Airport, Japan
	Religious	Angkor Wat, Cambodia		Potala Palace, Tibet		Jade Buddha Temple, China
				Temple of Heaven, China		
	Building and monuments	Easter Island		Taj Mahal, India		Bank of China Building, China
				Forbidden City, China		HSBC Building, China

Table 2. Middle East Construction Projects Various Time Periods

Region	Project type	Time period Ancient	Medieval	Renaissance	Industrial	Modern
Middle East/ Africa	Civil/military works					Suez Canal, Egypt
	Religious	Hagia Sophia, Turkey	Blue Mosque, Turkey			
		Dome of the Rock, Jerusalem				
	Building and monuments	Pyramids, Egypt		Topkapi Palace, Turkey		Burj Al Arab Hotel, Dubai
		Library of Celsus, Turkey				

1. What was the relationship between the building culture and the society, the larger culture, in which it existed?
2. What were the major institutions of the building culture?
3. What were the major human roles with those institutions?
4. What kinds of agreements did people enter into with each other in the building activity?
5. How did money and materials flow?
6. How was building activity regulated?
7. What was the building operation itself like?
8. What were the typical built results of the building culture?

The search for answers to each question requires a detailed examination of the role of construction in a historical culture and improves understanding of the motivations for a given construction practice. Considering the relationship between the building culture and its society leads to consideration of the impact of individual projects on society. For example, large religious projects (Ankor Wat, Cambodia; Chartres Cathedral, France) were often the major enterprise of the local community for decades. They were both the source of livelihood for many and the object of monetary donations by affluent citizens of the community. These projects were the source of pride for rich and poor alike.

Understanding the larger culture requires an appreciation of the role of churches and kings, as opposed to commercial interests, in major construction endeavors. Historically, most projects had religious, military/civil works, or monumental motivations (St. Paul's, United Kingdom; Great Wall, China; Roman Aqueducts, Rome; Pyramids, Egypt) and only very recently have projects been developed as purely commercial ventures.

Consideration of the major human roles in a construction culture helps understanding transitions from a master builder culture to the more specialized division of labor common in modern construction. Rapid changes in construction practices are seen during those periods that experienced profound cultural changes, e.g., agrarian to industrial economy, changes from royal to democratic governments. For example, the rise of democratic, industrial economies allowed the growth of specialized contracting firms and increased autonomy for workers' organizations.

Table 3. European Construction Projects Various Time Periods

Region	Project type	Time periods Ancient	Medieval	Renaissance	Industrial	Modern
Europe	Civil/military works	Roman Aqueduct, Italy		Ponte Vecchio, Italy	Tower Bridge, United Kingdom	Chunnel, United Kingdom–France
					Forth Rail Bridge, United Kingdom	StorBælt Bridge, Denmark
						Dutch Sea Barrier, Holland
	Religious	Pantheon, Italy	Chartres Cathedral, France	Santa Maria del Fiore, Italy	St. Paul's, United Kingdom	
		Parthenon/ Acropolis, Greece	Salisbury Cathedral, United Kingdom	St. Peter's, Italy	St. Mark's Basilica, Italy	
	Building and monuments	Stonehenge, United Kingdom		Versailles, France	Eiffel Tower, France	La Defense, France
		Coliseum, Italy		Alhambra, Spain	Hermitage/Winter Palace, Russia	Crystal Palace, United Kingdom
				Louvre, France	Palace of Westminster, United Kingdom	Pompidou Center, France
						Guggenheim Museum, Spain

Table 4. Americas Construction Projects Various Time Periods

Region	Project type	Time periods				
		Ancient	Medieval	Renaissance	Industrial	Modern
Americas	Civil/military works			Palace of the Governors, New Mexico, United States	Eads Bridge, Missouri, United States	Panama Canal, Panama
					Hoosac Tunnel, Massachusetts, United States	Hoover Dam, Nevada, United States
					Brooklyn Bridge, New York, United States	Golden Gate Bridge, California, United States
						Alaskan Pipeline, Alaska, United States
						Big Dig, Massachusetts, United States
	Religious		Chichen Itza, Mexico		Mission San Xavier del Bac, Arizona, United States	Washington National Cathedral, United States
						Cathedral of St. John the Divine, New York, United States
	Building and monuments				U.S. Capitol, Washington D.C., United States	Chrysler Building, New York, United States
					Statue of Liberty, New York, United States	Empire State Building, New York, United States
					Washington Monument, Washington D.C., United States	World Trade Center, New York, United States
						Sear's Tower, Illinois, United States
						Superdome, Louisiana, United States

On the other hand investigation of "project culture" helps us to understand the growth and motivation for specific construction practices. Issues such as the flow of money, training of workers, sharing of design knowledge, and nature of contracts and agreements are central to defining fundamental construction practices. There are myriad related questions imbedded in understanding the historical development of modern practices. How, for example, were workers trained? How were designers trained? How was the design recorded and communicated with the project's patron? In short, how did the process of conceiving, designing, and constructing the built environment change over time and across different geographical areas? Finally, how should such knowledge, of the history and evolution of our practices, be incorporated in the dialog that educators have with students and with the larger professional community? To help guide this aspect of the research the following list of questions, covering seven specific areas, was developed (Table 5). These questions provided a discipline and organization for scrutinizing the practices used on each project.

Observations on Historical Construction Practices

By way of review, this research is based on these concepts:

1. Constructors throughout time and in all geographic regions have produced extraordinary projects;
2. Historically significant and monumental projects possess the most detailed historical record of construction practices that we know of;
3. This investigation focused on key practice areas, namely; (1) labor; (2) design; (3) development and financing; (4) project management; (5) contract issues; and (6) innovations;
4. It is useful to understand how and why construction practices adapt to correspond to changes in the prevalent culture; and
5. It is important for design and construction professionals and especially for students to have knowledge of historical practice and appreciate the choices available to them.

It has been said that, "the more things change, the more they stay the same." The findings of this study prove the wisdom in

Table 5. Guiding Questions for Research on Historical Construction Projects

Guiding questions for research on historical construction projects			
1.	***Project specific information***	***5.***	***Project management and performance***
1.1	Where is the project?	5.1	What was the safety performance?
1.2	What is the current state of the project (ruin, functioning, etc.)?	5.2	What was the quality performance?
1.3	When was it built?	5.3	What was the cost/schedule performance?
1.4	How long did it take?	5.4	Where there construction/design failures?
1.5	How much did it cost?	5.5	How was the project organized?
1.6	Why was it built?	5.6	How was the design presented and documented?
1.7	Who was in charge?	5.7	Who supplied the material?
1.8	Why is it a noteworthy project?	5.8	How was quality control/quality assurance accomplished?
		5.9	How was the project managed and delivered?
		5.10	How was the contractor selected?
2.	***Labor***	***6.***	***Contracts and legal issues***
2.1	Who were the laborers? Were they paid? Were they paid well?	6.1	What was the law that regulated the commercial exchange?
2.2	How many specialties/trades/guilds were involved or how many subcontractors?	6.2	What codes or standards were used to regulate design or construction?
2.3	How were workers trained or apprenticed?	6.3	How were disputes negotiated?
		6.4	What kinds of contracts were used?
3.0	***Designers***	***7.***	***Innovation***
3.1	Who did the design?	7.1	What technical innovations were involved?
3.2	How many design specialties?	7.2	What design innovations were involved?
3.3	How were designers trained?	7.3	What material innovations were involved?
3.4	How was the designer selected?	7.4	What construction organization and management innovations were involved?
4.	***Project development and financing***		
4.1	Who provided the financing?		

this saying. The next sections provide examples of some of our findings on project organization (Table 5, question 5.5), labor issues (Table 5, questions 2.1 and 2.3), and design (Table 5, questions 3.1 and 5.6).

Construction Project Organizations

For the past several decades, construction has moved away from split responsibility, i.e., separate design and separate construction project delivery, toward more integration of design, construction, and project management. Authors often state that these more integrated forms are a movement back toward a master builder approach. The conventional wisdom is that historically control of a project was in the hands of a master builder. This seems to be the case in Egypt where records indicate that as early as 2800 BCE there was a "chief of the works" for major construction projects (Garrison 1991). Likewise, in the 5th century CE, Greek builders ("architektonas") were in charge of designing and building, and they worked independently under a contract system (Garrison 1991). However, some early construction was not under the unilateral control of a master builder. During the construction of the Coliseum in Rome, the amphitheatre was divided into sections, each under the control of a separate contractor (Elia 2003). Likewise, construction of most cathedrals in the Middle Ages made a clear distinction between the control of the funds by the "owner's representative" the master of the works, and the master builder who served as the architect. Specialization in design and construction skills was clearly developed by this period wherein "masters" of various trades were in charge of their own designs and workshops (Icher 1998). By the time St. Paul's Cathedral in London was built, specialization in the trades was firmly established. More than 14 contractors, from quarrying to finishing, were used during its 40-year construction period (Parkyn 2002). Construction of the Suez Canal, in approximately 1869, was an international joint venture that presages today's globalization and public-private partnership trends. Thus, organizations and delivery methods have always been mutually shaped by the needs of the culture and of the project.

Construction Labor

Much is written today about labor availability, worker skill, and productivity. So too throughout history labor has been important to construction projects. Records of a small medieval project indicate that approximately 70% of the project cost was in labor (Davis 1999). Labor is a domain where the culture of the day is of utmost importance. Kings and princes have much more latitude in compelling workers to work than is found in an open labor market. Slavery was commonplace in the ancient world and mines and quarries were often worked by slaves (Florman 1987). At Angkor Wat, nobles pledged workers under their control to the king's grand project. Military organizations, for example the Roman legions, used soldiers to perform construction work during periods of peace (Rae 1993). Kings in England had the power to order the sheriff to conscript men and order them to work in a castle workshop (Gimpel 1961). However, throughout history most workers were not slaves. Although it is generally assumed that slaves built the Pyramids, Egyptologists now believe that peasants worked on the Pyramids on a rotating basis in exchange for food, clothing, and shelter. The barracks area at the Great Pyramid suggests that 4,000 men worked on the project at any given time (Garrison 1991). Just as today, construction work was a seasonal affair. During the winter season, skilled workers remained in the workshops and other less skilled workers went to quarries or returned to their homes to work their farms. Not only were Egyptian workers free men, there is evidence of competition between work gangs. Inscriptions extolling the prowess of a work gang or its lack of injury or sickness are found on ancient stone workings.

Many aspects common in today's labor market are found during construction of the major European cathedrals. For example, traveling workers (boomers) going from major project to major project are found throughout Europe. Interestingly, women were sometimes found on the payrolls of medieval cathedrals in lower paying trades, plasters, and cementers (Gimpel 1961). On large projects, there is evidence that project sponsors set up lodging for the workers so they could stay close to the project (Decri and Boato 2003).

Labor Organizations

Labor regulations and work rules developed early. By the 12th century workers formed artisan guilds (Parsons 1939). Renaissance guilds generally set working rules but not specific wages (Davis 1999). The length of the working day for medieval cathedrals was generally from daybreak to sunset (Icher 1998). French regulations set the workday at 14 h in the summer and 12 h in the winter (Parsons 1939), and 14th century English regulations called for a 1 h lunch break and a 15 min break in the afternoon.

During the era of the great cathedrals there were two classes of workers, guildsmen, and day laborers. Guildsmen wages were higher, commensurate with their skill and bargaining power. Day laborers received lower wages or they were compensated on a piecework basis (Icher 1998). It was desirable to be a guild member but guilds were tightly closed. No one could work as a mason or carpenter unless they were a "companion" of the guild or were apprenticed to the "master." The guilds were the closed shop unions of the day. In France, during the late 13th century and early 14th century, the growing power of the guilds prompted ordinances that are very similar to modern "right to work" statutes. The difference in wages between skilled and unskilled workers was quite large. A 14th century master mason was paid five or six times more than a regular mason (Rae 1993). At the end of the 13th century in France, a stonecutter's wages were three times that of a laborer and twice that of a mortar maker. Guilds were abolished by decree in France in 1791, in Rome in 1807, in England in 1837, in Spain in 1840, in Austria and Germany in 1859–1860, and in Italy in 1864 (Sebestyen 1998). History demonstrates the same forces and counter forces caused a shifting balance of power between labor and management then as they do so today. The more things change the more things stay the same.

Designers

Little is known about early architects and engineers; some sources make little distinction between the architect and craftsperson, noting only that architects would work with their hands on difficult pieces. On the other hand, others note that Egyptian engineers were the first people, other than rulers and warriors, to gain a distinct historical identity (Garrison 1991). However, controversy about the designer's role in the construction process has been constant through the years. Even medieval master builders were criticized for not getting their hands dirty (Erlande-Brandenburg 1995).

What is clear is the slow transition from an experiential and empirical knowledge base to the scientific knowledge base of today's designers. By the 13th century, architect Villard de Honnecourt produced a sketchbook of current design knowledge (Bowie 1959). The specific divisions of knowledge in the book are:

1. Mechanics;
2. Practical geometry and trigonometry;
3. Carpentry;
4. Architectural design;
5. Ornamental design;
6. Furniture design; and
7. Other special knowledge.

In the early 15th century, Filippo Brunelleschi attended a conference of architects and engineers on the method of erecting the dome of Santa Maria del Fiore, demonstrating the growing professionalism of the design professions (Garrison 1991). In France military engineering gradually migrated into civilian projects (civil works) and in the early 18th century a civilian engineering corps was established as the Corps des Ingenieurs des Ponts et Chaussees. In 1747, the Ecole des Ponts et Chaussees started to apply mathematical theory to construction that had heretofore been designed by rule of thumb convention (Florman 1987). The first professional body for engineering was formed in 1818 and for architecture in 1834 (Louw 2003). The concept of a Principal Engineer arose in England in the mid-18th century (Rudkin 2003). Nevertheless, the transition from an experiential-empirical knowledge base to a mathematical-scientific base was a very slow process. The role of the engineer in the project has changed dramatically during the course of construction history. Design knowledge has become scientifically based and codified, and this fostered a fundamental separation between designer and constructor. As previously mentioned, today there is a trend toward more integration between design and construction. This is an instance of a technology enabled adaptation. Early in construction history design and construction were inseparable for the design was based on the empirical knowledge of the builder. Later, as design became more codified and scientifically based, design tasks were separated from construction for those with the scientific knowledge also did not have the empirical knowledge of the builder. Now market forces and technology are causing a reintegration of (scientifically based) design and construction activities.

Designs

The growing professionalism of the design process meant that at some point the thing to be built did not arise in a master builder/craftsperson's head, but rather in the engineer or architect's mind. The designer had to have some means of explaining the design and the intent to the workers who would construct it (Ferguson 1992). Gradually, as projects became larger and more complex, the need to represent the design became more important. At first, designs were made to help the patron visualize the project; this is a use of today's designs as well (Rae 1993). Sometimes designs were used to help the patron raise funds for the project: a type of medieval marketing. Often papier-mâché, wood, wax, or plaster models were used to present the design (Icher 1998). Brunelleschi used a model to demonstrate his concept for the dome of Santa Maria del Fiore (Parsons 1939). Eventually, designers started using drawings to clarify the design and to communicate the design to those who would execute it. In Renaissance Florence, Italy, there were two distinct kinds of drawings: general drawings used in the initial conception and layout and the detailed drawings

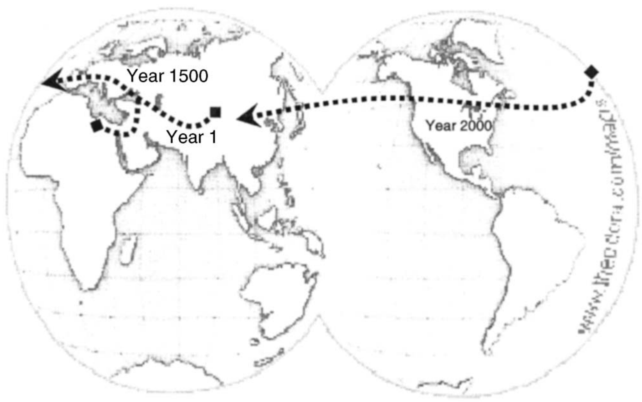

Fig. 1. Progress of construction over time (Reprinted from ⟨Theodora.com⟩, with permission)

used to communicate with the craftspersons (Davis 1999). For construction of the Sant' Antonino chapel in St. Mark's two surviving formal drawings show a plan view and an elevation (Codini 2003). Today technology allows us to design in 3D; it is even common to talk of 4D or of building integrated models (BIMs). However, the fundamental uses of our designs have remained constant: (1) communication with patrons; (2) design clarity and visualization; and (3) communication with craftspersons and contractors.

Innovation

Space considerations will not allow us to report the findings of all the facets of our work. It is important, however, to document some of the examples of innovative and seemingly modern practices embedded in historical context.

1. The 15th century contract for the Fotheringay Church in England contained a provision that was essentially a payment bond that allowed the owner to pay workers and suppliers before the master was paid. The same contract contained a very severe liquidated damage provision (Erlande-Brandenburg 1995).
2. Brunelleschi found during the construction of the dome of Santa Maria del Fiore, Italy (15th century) that too much time was lost by workers descending for their meals so he opened a canteen on the structure where food and wine could be obtained (Parsons 1939). Starrett Brothers and Eken used the same approach on the Empire State Building, New York, centuries later (Willis 1998).
3. In 16th century France, toll roads were established to build and maintain roadways. Persons who were beneficiaries for new roads were required to pay a levy for their construction and maintenance (Parsons 1939).
4. During the 16th century construction of the Rialto Bridge in Venice, Italy, a dispute arose concerning the sufficiency of the design. A panel of expert witnesses was formed; the witnesses were examined under oath for 2 days to resolve the dispute (Parsons 1939).
5. In 17th century England, lump sum, unit price, and time and material contract payment schemes were all commonly used (Heyman 2003).

Locus of Historical Construction Activity

While we were documenting historical construction practices, we noticed interesting patterns in construction activity in various geographic regions over time. Some regions experience increasing construction activity over time, while other regions see activity diminish. For example, the Asian region exhibits substantial early history activity, followed by a lull, and then by a recent significant increase in activity. It is interesting to reflect on the causes for construction activity moving from geographic region to geographic region. Starting an examination at the time of construction of the Great Pyramid, one can observe construction spreading around the world; from north Africa to east Asia, to Europe, and finally to the Americas. Now it appears that the hub of construction activity is once again returning to Asia (Fig. 1).

One might assume that historical population trends (shown in Table 6 and Fig. 2) explain differences in construction activity in different time periods. This seems to be the case in the Americas where increases in population are accompanied by increases in construction activity. It is not the case, however, in Europe which experienced a static or declining proportion of the world population but an increased level of construction activity. Likewise, population does not explain the relative lull in Asian construction during the Middle Ages.

An alternative explanation for changes in construction activity is the amount of wealth possessed by a given region at a

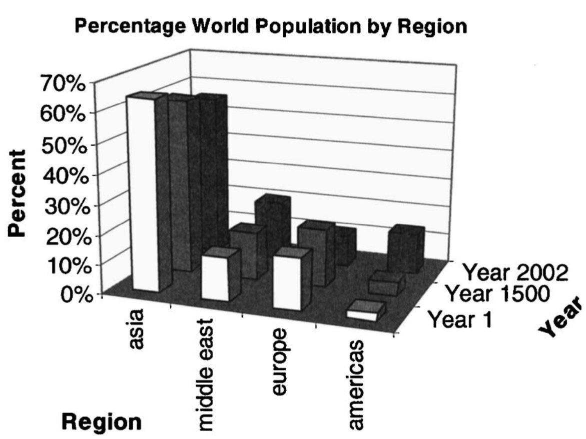

Fig. 2. World population—percent

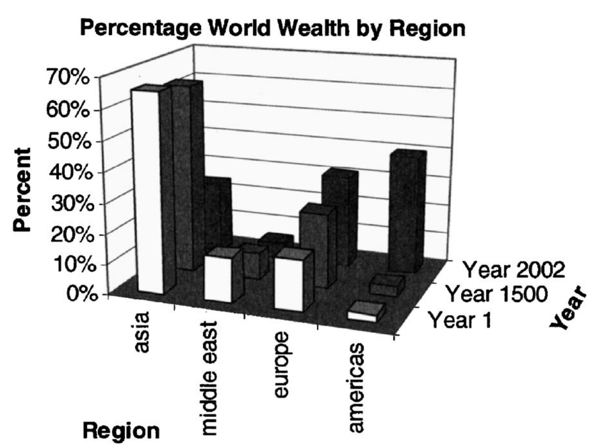

Fig. 3. World wealth—percent

Table 6. Regional Population by Year (1000s) (Adapted from SASI Group 2007 ⟨world mapper.org⟩, with Permission)

	Year 1		Year 1500		Year 2002	
Region	Population	(%)	Population	(%)	Population	(%)
Asia/Australia	148,969	65	261,005	60	3,478,751	56
Middle East/ Africa	34,748	15	71,036	16	1,253,232	20
Europe	40,784	17	86,637	20	653,599	10
Americas	6,320	3	19,750	4	856,492	14
Total	230,821	100	438,428	100	6,242,074	100

Table 7. Regional Wealth by Year (US$ Billions) (Adapted from SASI Group 2007 ⟨world mapper.org⟩, with Permission)

	Year 1		Year 1500		Year 2002	
Region	Wealth	(%)	Wealth	(%)	Wealth	(%)
Asia/Australia	67	66	148	63	7,688	24
Middle East/Africa	15	15	21	9	1,691	5
Europe	18	17	59	25	9,881	31
Americas	3	2	8	3	12,804	40
Total	102	100	236	100	32,064	100

specific time. Changes in the distribution of world wealth (shown in Table 7 and Fig. 3) are a logical explanation for increased construction activity. This explanation works very well to explain Europe and the Americas' historical increase in construction activity. Notice that although Europe and the Americas contain a small fraction of the world population (currently 10 and 14%, respectively) they posses a large fraction of world wealth (currently 31 and 40%, respectively). The "wealth" explanation also explains the early historical lull in the Asian sector that has seen its proportional share of world wealth decrease from more than half of the overall global wealth to less than one-quarter of global wealth. The declining trend in wealth has, of course, been reversed in recent years and this reversal has been accompanied by an increase in building activity in Asia. Additionally, localized concentration of wealth (Hong Kong, petro dollars) explains much of the modern era construction activity in the Asian and the Middle Eastern regions of the world.

Conclusions

This work, started on the notion that understanding the past will benefit the future, has led to a dilemma. On the one hand, as an educator, our students should understand that throughout time constructors and designers have used knowledge, perseverance, and innovation to accomplish remarkable projects. The message to students should be pride in their professional heritage. On the other hand, we have shown that much of what is considered new in the industry (alternative project delivery methods, worker safety programs, public private partnerships, and globalization) is, in fact, not new at all. This notion that there is "nothing new under the sun" could be quite dispiriting to young engineers. A more positive perspective is to present the industry as the domain of resourceful, creative, and innovative persons; persons who continually adapt their processes to the specific project and broader culture in which they work. It is this message that we should all bring to our students.

The work that led to this paper represents only the beginning. To date we have visited more than 30 projects ranging from the ancient to the modern and from Asia to the Americas. We have compiled more than 100 bibliographic entries and many more references from the World Wide Web. We have visited the collections of prominent historical museums and libraries and discussed projects with numerous historians and regional experts. For all this work, we have barely begun to understand the whole of the historical construction record regarding construction and design practices. We intend to continue this work and gather more information to allow us to "connect the dots" and gain a greater insight into the motivations and necessity for modern construction practices. Above all, we will continue this work because we believe in its relevance and immediacy for this generation of students and practitioners.

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