NATURE OF CONSTRUCTION TECHNOLOGY

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ABSTRACT

Construction management studies address mostly the phenomena of construction problems. Few studies explore the nature of construction technology or production systems.

Technologies in manufacturing are classified into unit, mass and continuous process productions and their characteristics are examined. Construction fabrications and activities are contrasted to classify construction technology as unit production. Furthermore, technical change is studied and limitations to the change of construction technology are proposed.

Although the efficiency of construction technology as unit production is low, it has many advantages such as flexibility and zero stocks. The appearance of new production systems will not replace the old unit production. Although the final construction products could not be standardized entirely, we can standardize their components, and rethink their assembling and integrating methods to increase production efficiency.

KEY WORDS

Construction technology, production system, unit production, mass production, continuous process, product, automation, technical change

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INTRODUCTION

Construction is the major process in the construction project life cycle and many parties are involved. For a long time construction productivity has not been satisfactory. Improvement studies mostly focus on construction activities, while few studies explore the nature of construction technology or production systems (Howell 1999).

Since industrial revolution, people keep looking for efficient production systems. Departing from the earliest built-to-order production, manufacturing and industrial process plants adopted mass, continuous process, flexibility, and even advanced IT production systems to gain advantages in efficiency and effectiveness. However, the construction process has none of the characteristics of the modern manufacturing (Bertelsen 2002).

Most construction projects are still built under the traditional way of one-of-a-kind production. The use of IT in construction has often failed to produce the results intended. These inefficiencies of operations may largely result from particular complexity factors owing to industry specific uncertainties and interdependences (Dubois and Gadde 2002). Therefore, it needs to understand the nature of construction technology more to explain these phenomena, and a theory of construction production to solve the problems (Koskela 2000).

This study contrasts construction practice with technology theory. It defines construction technology, compares characteristics of different technologies, discusses technical change and construction technology's limitation, and finally presents improvement strategy for the construction industry.

DEFINITION OF TECHNOLOGY

Technology has different meanings and definitions. In manufacturing, technology has often been used interchangeably with the production system. Daft (2004) defines technology as the tools, techniques, machines, and actions used to transform organizational input (materials and information) into output (products and services). Slack et al. (1995) also see production as a transformation process. In addition to the transformation process, Koskela (2000) sees the production as a flow to reduce waste and a value generation process to meet customer needs. These definitions are shown in Figure 1: the core circle is the transformation process, the input-process-output is a flow, and the output products or services have to meet customer needs.

Technology includes hard machinery and soft work procedures. Most literature of technology emphasizes the hardware aspect such as machine and techniques but neglects the software aspect such as methods of working and managing. Technology influences performance and achievement of strategic objectives. The software of the transformation process is like tacit knowledge that is worth exploring in depth to supplement hardware to achieve better performance.

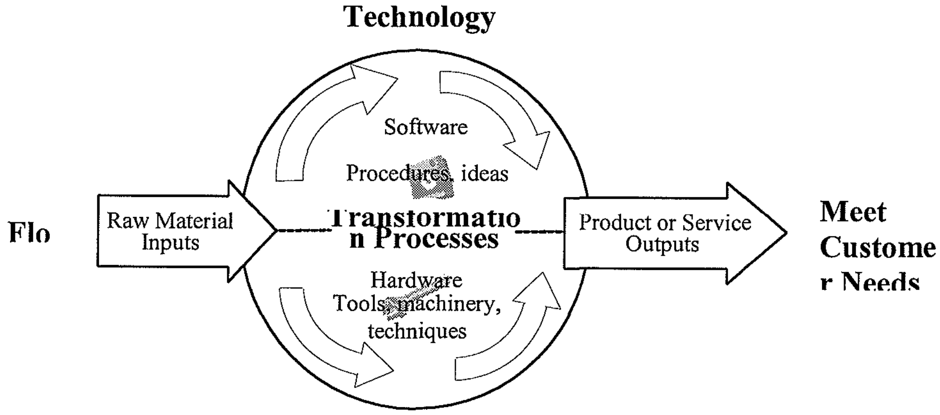

Figure1. Definition of Technology

CONSTRUCTION TECHNOLOGY

Woodward (1994) classified production systems into unit and small-batch production, large-batch and mass production, and continuous process production according to technical complexity of the manufacturing process. Technical complexity represents the extent of mechanization of the production process. Similarly, Schmenner (1993) divided manufacturing processes into a spectrum of five major types: project, job shop, batch flow, line flow, and continuous flow.

In Woodward's scale of technical complexity, the three groups are originally consolidated from ten categories. Typical construction component fabrications and jobsite activities are compared with the ten categories as shown in Table 1.

It can be seen that most construction jobsite activities belong to unit production. For the first of the ten categories, the production of single pieces of customer orders means build by project. When the project is divided into jobsite activities, concrete pouring belongs to this category because its activities are arranged into pieces following finished steal bar and formwork. The steal bar and formwork are prepared as technically complex units one by one such as beams and columns, which is one level up in the technical complexity and belong to the 2nd category. Precasting, a kind of standardization work learned from manufacturing, belongs to the 3rd category of fabrication of large equipment in stages.

Hence, construction is a kind of unit production based on the majority of jobsite activities. Although some component fabrications reach the mass or continuous process production level such as cement plant and building materials, they are mostly done by suppliers or fabricators, not constructors in the construction supply chain (Ballard and Howell 1998).

Fabrications of construction components are better performed than construction jobsite activities. The challenges for construction management are to assemble or integrate these fabricated components into better planned and executed construction activities.

Table 1. Construction Activities in Technology Categories

		Technology Classification	Component Fabrications	Jobsite Activities
Small-batch and unit production	1	Production of single pieces of customer orders	Build by project	Concrete pouring
	2	Production of technically complex unit one by one		Steel bar tying, formwork
	3	Fabrication of large equipmment in stages		Precasting
	4	Production of pieces in small batches		Excavation
Large-batch and mass production	5	Production of components in large batches subsequently assembled diversity	Concrete batch plant	
	6	Production of large batches, assembly line type	Assembly house	
	7	Mass production	Cement plants	
Continuous process production	8	Continuous process production combined with the preparation of a product for sale by large-batch or mass production methods	Building materials	
	9	Continuous process production of chemicals in batches	Paint plant	
	10	Continuous flow production of liquids, gases, and solid shapes		

TECHNOLOGY CHARACTERISTICS

Service and manufacturing are the two main types of technology in organizations. Their characteristics are compared in Figure 2. Service technology emphasizes the process and manufacturing addresses the product. The construction industry is in the middle, characterized by a combination of the two. For example, the contractor needs to interact with the owner very closely, just like the service. She also builds tangible structures, the same as manufacturing.

A number of construction studies expect to copy successful experience from manufacturing. However, lessons can be learned only to certain extent since their characteristics are not the same (Ballard and Howell 1998). That is, construction needs to find out its own nature and develop its own stories.

Service Technology	Construction Technology	Manufacturing Technology
1. Intangible output		*1. Tangible product*
2. Quality is percieved and difficult to measure		*2. Quality is directly measured*
3. Labor and knowledge intensive	**Service**	*3. Capital asset intensive*
4. Customer interaction generally high	**and**	*4. Little direct customer interaction*
5. Rapid response time	**Product**	*5. Longer response time is acceptable*

Figure 2. Characteristics of Services and Manufacturing

The characteristics of three technologies are compared in Table 2. Unit production tends to be job shop operations that manufacture and assemble small orders to meet specific needs of customers. It relies heavily on the human operator and is not mechanized. Although machinery is used for part of the produciton process, final assembly requires highly skilled human opertions to ensure reliability of products. Mass production is characterized by long production runs of standardized parts. Output often goes into inventory from which orders are filled. Examples include most assembly lines. In continuous process production, the entire process is mechanized and there is no starting and stopping. Examples include chemical plants and refineries.

Table 2. Technology Characteristics

Technology / Characteristics	Unit Production (Construction)	Mass Production	Continuous Process Production
Process predictability	Low (High uncertainty)	Medium	High
Mechanization	Low (Labor intensive)	Medium	High
Batch	Small (Pieces)	Medium	Large
Product complexity	Integral (Heavy integration)	Assembly or components	Dimensional
Standardization	Low (Less duplication)	Middle	High (less types)
Sale	Production to orders (by contract)	Inventory	Some inventory difficult to store

The characteristics of construction technology are similar to those of unit production. Construction's process predictability is low because of high uncertainty that resulting in actual deviation from planning. Mechanization is low because of labor intensive. Many activities are operated in small batches or pieces. Products are highly complex that requires heavy integration. Standardization is low because of unique design, less duplication, or little repetitiveness. And the construction project is operated by contract.

FORCES OF TECHNICAL CHANGE

Competitive pressures often drive firms to adopt new technologies to differentiate from competitors or to gain a cost advantage (Porter 1985). Market pull and technology push are two forces that strongly influence the adoption of new technologies (Mowery and Rosenberg 1979), as shown in Figure 3. Market pull forces come mainly from customer needs. Technology has to change when the market changes and the old technology can not meet customer needs. The market pull drives organizations to change from top down to modify strategic objectives and adopt more advanced systems. For example, a unit production is changed to mass production when the difference of customer needs in the market decreases.

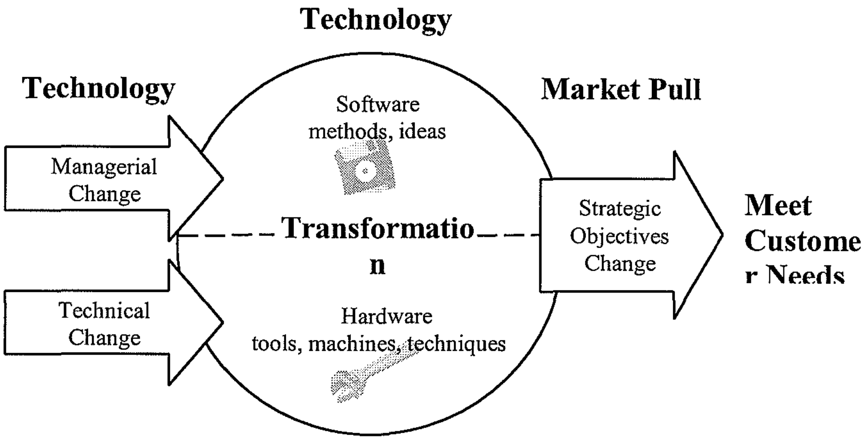

Figure 3. Driving Forces of Technical Change

Technology push causes a bottom up change. This change occurs when hardware and software techniques develop that enables organizations to use new and more effective means to achieve organization goals. Technology push includes the hard technical change and soft managerial change, in which management methods, processes, and procedures have to be compatible with the machines, tools, and techniques.

Market pull forces are the primary influence on the technical change compared to technology push (Mitropoulos and Tatum 2000). Studies of new product and process development also support the argument that market pull forces are the primary influence on innovation compared to technology push (Myers and Marquis 1969; Langrish et al. 1972). That is, customer needs drive the transformation process change.

CHANLLEGES FOR CONSTRUCTION TECHNICAL CHANGE

It is important to have good precognition of problems when leading a technical change. The challenges of construction technical change are illustrated in Figure 4. Three major problems are the broken junction, jumbled jobsite process, and vague demands from unclear customers. In the front component fabrication part, mass or continuous process production approach is allowed to generate steady work flow. Once reaching the junction with jobsite activities, the flow becomes turbulent that requires the unit production to handle subsequent jumbled processes. We can see many construction supply chain endeavors design material supply or web-based bidding well, but stop at the jobsite activities. Customer needs are indeed important to know. But customers of construction projects are unclear. Are they users? Where are they? What are their needs? The needs are usually vaguely explained by owners and/or designers in the front and change afterwards (Bertelsen 2002).

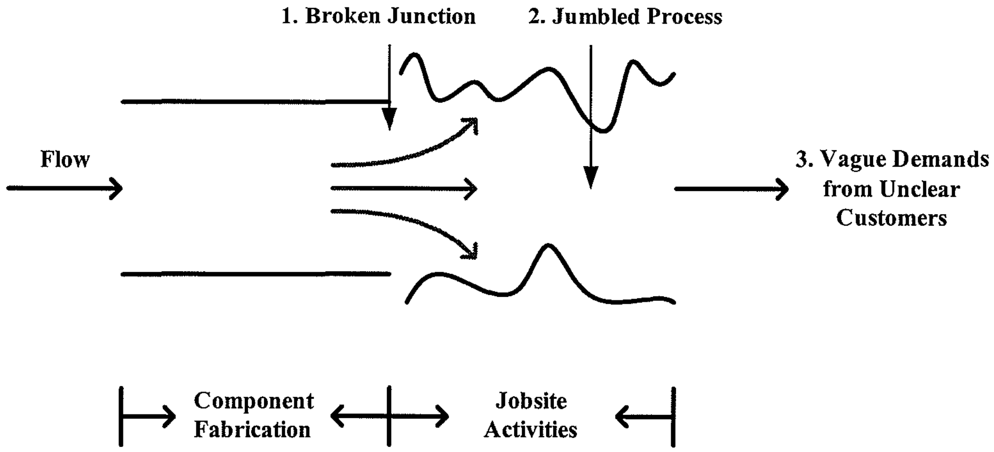

Figure 4. Challenges of Construction Technical Change

Combination of two processes is common for many productions. The reason for the hybrid process is that one part such as batch flow is not as nimble as the other part such as continuous flow (Schmenner 1993). In most hybrid processes, the second part is more nimble than the first to quicken the whole process (Schmenner 1993). However, in the construction hybrid process in Figure 4, the second part of jobsite process slows down the whole process.

Although lean engineering and manufacturing is based on standardization (GM 1997), the essence of jumbled construction jobsite activities restrict process standardization. Gibb (2001) pointed out that houses are not cars and maximum standardization is not always the answer. It is also difficult to standardize construction products because each project, owner, or designer demands differently. Automation is achieved through continuous standardizing and optimum production process. If not standardized, it will be even more difficult for construction technology to change to automation.

The construction market usually reflects customer needs on the front-end materials and final products. Specifications specify requirements mostly on material quality and safety standards. The technology is usually not the focus. Therefore, it may not raise competitiveness but cause problems if a firm adopts new technology for the sake of technology push, without knowing the real market needs.

Another limitation to change is the work availability. The initial investment cost of standardization or automation is high. Construction firms are unwilling to take risks under the uncertain market. Unless a large number of work orders are available in the market and in the future, few construction firms will have long term plans. However, the construction markets in many countries are mature. Many firms are developing overseas markets in the developing countries.

STRATEGY BASED ON CONSTRUCTION TECHNOLOGY

Table 3 compares the technical complexity with product complexity. Although the technical complexity of unit production is low, it demands integral products so the product complexity is high. Since the integral products are created with low mechanization, people working in the process have great discretion (Dubois and Gadde 2002). At the same time the manual integration brings tremendous interaction between people. These distinct features satisfy social needs as well as imply the importance of individual experience and interpersonal skills. In contrast, technical complexity is high and products are simple for mass or continuous production. The repetitive production process and early product planning tend to make people in work feel bored and less challenge.

Table 3. Technical and Product Complexity Comparison

	Technical Complexity	**Product Complexity**
Unit Production	Low	High (Integral Product)
Mass Production	Medium	Medium (Components)
Continuous Process Production	High	Low (Dimensional Product)

Every kind of technology has its pros and cons and suitable applications. The appearance of new technology does not mean that the old one is out of date. Lessons from construction technology can be learned by other industries. In the automobile industry, the firms gradually perform only the core tasks and adopt outsourcing. Production systems also change from large-scale plants on pursuing maximum economic scale to small-scale plants in order to be close to customers and response production demands (Economist 2002). In construction, outsourcing (i.e. subcontracting) is widely used and closeness to customers (owners) is common.

Construction should take advantage of the flexibility instead of over-standardizing. Each construction project has distinct characteristics, location, period, and aesthetics demands. These flexibilities do not give up pursuing efficiency and effectiveness. Although it is unlikely to standardize the very end products, their components are possible. In this regard, lessons can be learned from the mass or continuous process productions. Precast construction is an efficiency example. Design for manufacture or constructability is another effectiveness example (Fox et al. 2001).

The ultimate construction products depend largely on the collaboration of project participants and integration of tasks during the construction process (Peña-Mora and Tamaki 2001). The very techniques needed for the construction industry would be the coordination mechanisms across organizations and participants to integrate construction supply chain activities.

CONCLUSION

Construction technology produces products at the same time providing services. It is a kind of unit production and highly customized. Projects are constructed to orders with zero stock. The construction process is highly uncertain and predictability is low. Although technical complexity is low with the production system, it can make the highly complicated products. Many intermediate products are created and integrated by human operators with low mechanization, standardization, and automation.

Limitations should be considered when pursuing construction technical change. It should be out of market pull driven by customer needs; address standardization of construction components only; and base on market work availability. The advantages of construction technology include zero stock, high flexibility, and satisfactory social needs. With these advantages appreciated, the construction industry should pursue the integration improvement of construction jobsite activities.

Construction automation had been promoted to advance production efficiency for past years. Moreover, the issue of electronic business also has been included recently. The automated construction systems are poorly progressed compared with those in the manufacturing industry. It may largely be limited by the nature of construction technology. Thus, we should understand and examine the construction technology fundamentally before pushing successive construction automation and e-construction programs.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the National Science Foundation of Taiwan for the research grant of NSC92-2211-E-006-101.

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