WHAT KIND OF PRODUCTION IS CONSTRUCTION?

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ABSTRACT

Applicability of lean principles to construction might seem to require that construction's differentiating characteristics be softened or explained away. This is the strategy employed by those who advocate making construction more like the manufacturing from which lean thinking originated. Following that line of thought, successive waves of implementation would leave ever smaller remainders that are not yet reduced to manufacturing, and consequently not yet capable of being made lean. This approach offers tremendous opportunity for reducing the time and cost of constructed facilities. However, for our part, we are interested in that remainder, in understanding its peculiar characteristics, and in learning how to make it lean. Our interest is founded on the belief that construction is a fundamentally different kind of production; i.e., that there is an irreducible remainder. We also suspect that learning how to make construction lean will help show the way to the manufacturing of the future. Manufacturing is becoming more like construction. Far from being the most backward, in our view, construction can be among the leading edge industries in lean thinking. Adopting a single-minded strategy of transforming construction into manufacturing would be precisely the wrong thing to do. This paper explains the need to develop lean thinking for dynamic construction and lays the groundwork for a subsequent paper "Implementing Lean Construction", in which these strategies are further developed.

KEY WORDS

Construction, production theory, uncertainty, strategy, lean thinking.

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INTRODUCTION

What we call “construction” covers a spectrum ranging from slow, certain, and simple (stodgy) projects on one end to quick, uncertain, and complex (dynamic) projects on the other. For the former, a manufacturing strategy is appropriate; i.e., making construction more like manufacturing through such initiatives as standardization. For dynamic projects, however, a manufacturing strategy is insufficient. We must learn how to manage uncertainty and complexity and quickness within the characteristic construction conditions of site production, unique product, and temporary organization.

What kind of production is construction? Lauri Koskela lists these differentiating characteristics: “one-of-a-kind nature of projects, site production, and temporary multiorganization” (Koskela 1998). However, other types of production also possess one or several of these characteristics. The uniqueness of projects is obviously a relative matter, extending from mass production of prefabricated housing on one end of the spectrum to the Chunnel on the other. Product uniqueness is becoming ever more characteristic of manufacturing as it strives to realize the vision of instantaneously producing custom products. ‘Site production’ differentiates construction from shipbuilding and airplane building, fellow members of the ‘fixed position manufacturing’ category. However, construction shares this site production characteristic with agriculture and extractive industries such as timber, mining, and fishing, which are at the very beginnings of manufacturing’s value streams. ‘Temporary multi-organizations’ are not peculiar to construction. Indeed, the tendency to ‘projectize’ appears to have no industry bounds. Koskela emphasizes the extent to which construction is not unique and suggests actions that can be taken to reduce its uniqueness; e.g., standardizing components, utilizing modularization and prefabrication, use of enduring teams, etc.

It is apparent that construction does not possess a unique, defining property. However, uniqueness can also result from a combination of properties. We suggest that construction’s objects possess two characteristics which together uniquely define them: (1) they belong to the category “fixed position manufacturing”, and (2) they are rooted in place. The objects of fixed position manufacturing are wholes assembled from parts. In the assembly process, the parts become too large to move through assembly stations, so the stations move through the emerging wholes, adding pieces as they move. Some degree of site production, at minimum final assembly, is a necessary aspect of construction.

This rootedness-in-place brings with it uncertainty and differentiation. For example, soil conditions can vary widely from place to place and are often difficult to determine precisely prior to actual production. Wind loads and seismic conditions differ from place to place. The physical surroundings, both natural and artificial, differ from place to place. Different locales often have different codes and regulations. The discretion implicit in the application of such codes and regulations adds the uncertainty of approvals and the additional difference in requirements actually enforced.

Because construction’s objects are rooted in place, the relationship with customers is different than perhaps for any other type of production. The customer is not intimately involved in the extraction of minerals or the production and harvesting of timber. But construction’s customer often walks through the construction site as the object is being produced. Because the objects are rooted in place, it is much more difficult to find alternative customers. A television set may have value for someone who lives 20 or 200 or even 2000 miles away from the would-be seller, but an office building must have value for a prospective buyer in the place it occupies.

We grant that a key for making construction lean is to capture for traditional manufacturing some of the work that is now done in construction mode. We also grant that amelioration of construction's differentiating (and apparently lean-resistant) characteristics should be done where appropriate. However, there is another strategy that applies lean principles to "dynamic" construction projects; a strategy the development of which may require extending and developing lean thinking beyond where it is now.

TYPES OF MANUFACTURING

There are at least three different ways to categorize types of manufacturing. The first uses product mix and process pattern as variables in a rectangular coordinate system with projects, job shops, batch flow, line flow and continuous flow as types along the diagonal (Figure 1, from Schmenner 1993). In this categorization, construction belongs to the project type and is characterized by a "very jumbled flow; process segments loosely linked" and also by the relative uniqueness of its product.

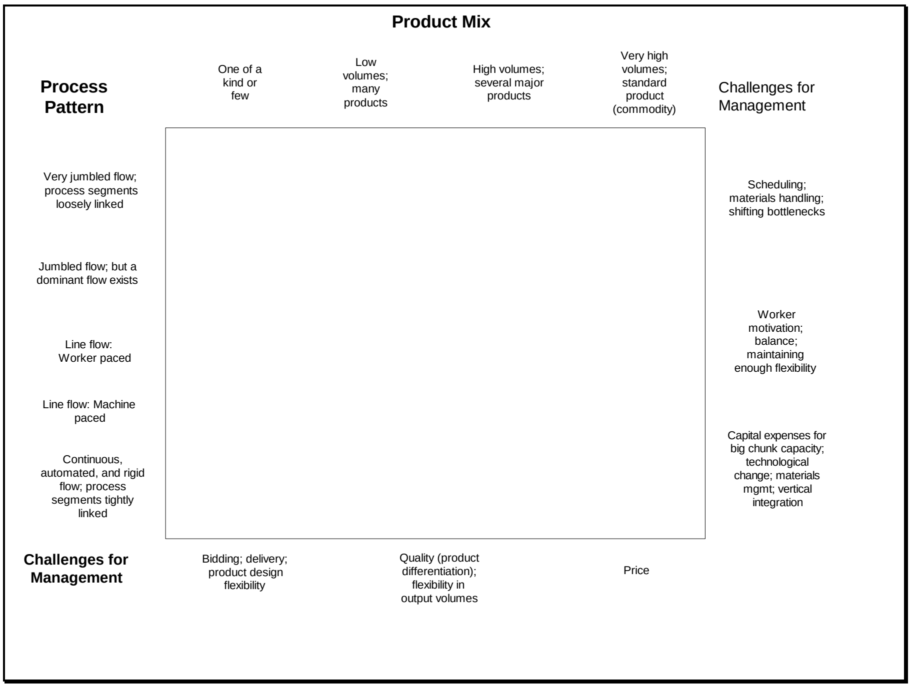

Figure 1: Types of Production (from Schmenner 1993)

A second method differentiates types of manufacturing in terms of the primary determinant of flow through the process. Factories that produce one or a few products have flows designed specifically for those products. A paper machine is a prime example and obviously is very inflexible. It would be difficult and perhaps economically impossible to adapt a paper machine to produce cans or bottles. Indeed, paper machines are designed to produce specific types of paper; e.g., linerboard, newsprint, or fine paper. By contrast, process-based flow would be found in factories organized to perform certain types of operations (grinding, milling, boring, etc.) on many different products. The third type identified by this method is fixed position manufacturing, in which the product being manufactured eventually becomes too large to be moved through work stations, so the work stations (work crews) have to move through the product. Construction, ship building, and airplane manufacturing belong in this category. Unfortunately, there appears to be little written on fixed position manufacturing.

Types of manufacturing are also sometimes categorized as extraction, fabrication or assembly; i.e., collecting materials, shaping materials, or joining materials together. Job shops and batch flow shops tend to be fabricators, while line flow and continuous flow shops tend to be assemblers, although the alignment of these different typologies is far from perfect.

DIRECTIVES-DRIVEN PRODUCTION

Yet a fourth categorization might be useful; i.e., the division of production types between those in which flow is governed primarily by the alignment of machines and those in which flow is governed primarily by directives. This distinction somewhat parallels that made between product and process-based flows. However, construction poses some subtleties. Construction operations can be conceived in terms of assembly chains; e.g., excavate-form-rebar-pour-cure-strip-finish-backfill. In tightly coupled assembly chains, the work to be done by the next work station (e.g., rodbusters) is released to them by the upstream work station. They have little or no discretion about what work to do next. However, not all assembly chains are tightly coupled. Consider the relationship between installing piping and electrical materials in a unit of an industrial plant. The completion of piping work in a subarea can be deemed to release that subarea to the electricians, but the sequence of electrical work in that subarea is not predetermined simply by that release. One might argue that rodbusters also can decide on which end of a trench to begin installing rebar, but the typical sizing of rebar releases requires that all the rebar for that trench be on hand when installation begins. That is not the case for the electrical work because the size of its releases is usually greater and because there is less structural integrity of the electrical installation itself as opposed to the rebar. The rebar is part of a single foundation, while electrical materials are parts of different control or power circuits to different items of equipment, even though the conduit or cable may lie adjacent to one another.

Construction at the site is now a combination of fabrication and assembly. Industrialization initiatives advocate simplifying site construction to final assembly and testing in order to shift as much work as possible into shop conditions where it can be done more efficiently. Given that construction is essentially site production, final assembly will always be done on site, although the extent of that work will vary with the stage of development and the facility being assembled. The key to efficient site assembly is planning and control, the processes that produce directives, thereby conditioning discretionary work choices and coordinating flows so those choices can be closer to optimal.

PRODUCT DEVELOPMENT PROCESS

We have long advocated that construction look to manufacturing's product development process rather than to the factory for its inspiration and analogies (Howell and Ballard 1994). An automobile manufacturer does not only make cars, it also designs them. Product development begins with a decision to modify an existing model or create an entirely new one. It ends when factory production begins. This exactly parallels the scope of industrial construction. When Chevron decides to upgrade or expand a refinery, the 'construction' process begins. When 'construction' ends, the upgraded/expanded refinery is ready to go into production. So, far from construction being like factory production, it is actually parallel to product development. Admittedly, this is a best fit for industrial construction, whose customers are themselves manufacturers. However, it works also for the building and infrastructure sectors. Indeed, lean production itself is best conceived as including lean design and lean supply, and perhaps the lean enterprise as well (Womack and Jones 1997).

Design-build offers the possibility for construction to realize its product development potential. Traditional design-bid-build parallels mass production's wasteful sequential method, making it virtually impossible to achieve global improvement and to avoid suboptimization. However, design-build thus far has been conceived and practiced as an alternative procurement method favored by owners who wish to shift risk onto the design-build team. Little thought has yet been given to the potential of design-build for revolutionizing the production system from design through turnover and beyond.

We propose that construction is essentially a design process, but one in which the facilities designed are rooted-in-place, and thus require site assembly. Understanding the design process is vital for making both stodgy and dynamic construction lean, but is especially important for the latter. Complexity, uncertainty, and quickness are first met in design, the structuring and management of which can either exacerbate those characteristics, when traditionally conceived and executed, or can contain and adapt to them through practices such as those advocated by Laufer (1997), Tommelein (1997), and by the authors of this paper (Ballard and Howell 1998).

WASTE AND VALUE

Koskela and Huovila (1997) have proposed three ways of conceiving design: as a process of converting inputs to outputs (conversion process), as a flow of information and materials (flow process), and as the generation of value for customers. All are necessary, but the conversion process model has dominated thinking and practice about both manufacturing and construction until recently. The lean revolution is essentially a conceptual revolution, at the heart of which are the flow and value models. The flow model facilitates waste reduction. The value model facilitates value maximization. To date, most lean thinking in construction has concerned waste reduction.

Value is generated through a process of negotiation between customer ends and means. The first role of the designer is to make explicit to customers the consequences of their desires, subsequent to which customers may choose to modify their ends. This way of conceiving the design process is quite different from the conversion process model, according to which it is the customer's responsibility to provide the designer with a clear, complete, and unchanging design brief. If design were adequately conceived as a conversion process, it would be appropriate to demand such inputs from a customer. However, facilitating an internal negotiation is quite a different matter. Customers can and should define the 'business' need and provide that definition as an input to the design process. However, such definitions of business needs invariably make assumptions about means; e.g., that the need can be met within a certain time and for a certain cost.

CONSTRUCTION VS MANUFACTURING SUPPLY CHAINS

Think of supply chains as concentric rings (Figure 2), in which raw material suppliers occupy the outer ring, fabricators occupy the middle ring, and the designer-constructor occupies the innermost ring. When you use 30% (and perhaps as little as 10%) of a raw material supplier's output, you can influence his product specifications, product delivery, and product price. With the possible exception of the very largest construction companies, none occupy such a position with any of their raw materials suppliers, those who produce lumber, steel, cement, or aggregate, not to mention trees, iron ore, or rubber.

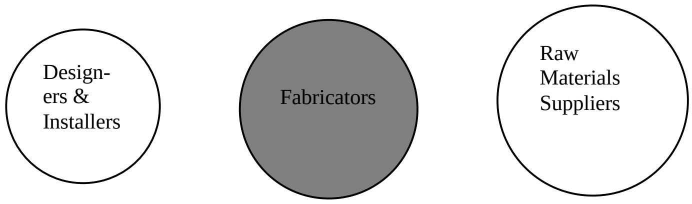

Figure 2: Supplier Integration

Move in towards those suppliers who provide manufactured products from raw materials; e.g., fabricated pipe, structural steel, reinforcing bar, concrete (batch plants), metal panels, windows, cladding, etc. Here the largest construction companies may have some leverage, and large users of construction services even more. Consider Bechtel's alliances with Fisher Valve, Shaw Industries (fabricated pipe), and Okonite (electrical wire and cable). British Airport Authority is one of 12 user companies that collectively do 40% of the construction work in the U.K. This gives them some leverage with manufacturers. In the case of localized manufacturers such as batch plants, the influence can obviously be even greater. However, a distinction must be drawn between suppliers of 'fabricated' materials. Some can make and supply whatever pipe or steel you happen to need. Others produce only a certain type of product which you may or may not need all the time. While negotiation of favorable commercial terms is hardly to be neglected, the greater potential is offered by those suppliers who can be integrated into a production system so that global and continuous improvement can occur. That is possible only with those who are not peddling solutions to problems you may not need to solve.

Move in once more towards those who design and install fabricated materials. These may also be manufacturers, but it is important to understand if a supplier is essentially dedicated to manufacturing or is really interested in improving its installation operations. Some manufacturers sell installation services in order to sell manufactured product. Those really belong in the previous ring. In this ring belong those who are designers and installers, whether or not they manufacture what they design and install. These are the specialists whose coordination lies at the heart of making construction lean.

TWO PART IMPLEMENTATION STRATEGY

What kind of production is construction? In summary, construction is essentially the design and assembly of objects fixed-in-place, and consequently possesses, more or less, the characteristics of site production, unique product, and temporary teams. Making construction lean has at least two parts: (1) Claiming from construction what actually belongs to contemporary product manufacturing and minimizing construction's peculiarities in order to take advantage of lean techniques developed in manufacturing, and (2) Developing lean techniques adequate to dynamic construction, the remainder that resists the first approach. A shared challenge for both is coordination of the specialist installers who occupy the front line, and through whom engineering and fabrication expertise is best applied.

The industrialization movement seems to have the first strategy in mind when it advocates such initiatives as manufactured housing. Examples of actions to minimize construction's peculiarities include simplifying site construction to final assembly and testing. The second part poses the greatest difficulties for lean thinking developed in manufacturing because it proposes to make lean a type of production that is explicitly *not* manufacturing.

What is dynamic construction and what challenges and opportunities does it pose for lean thinking? While product and process design can be standardized for standard products, for non-standard products it is necessary to standardize at the meta-level of planning and control. In other words, it is necessary to develop standard procedures for planning and managing the design and installation of unique facilities. The engineer/constructor firms of the industrial sector have gone the farthest in this direction. The building sector in the U.S. has only just begun to map its production (design, procure, install) processes. The industrial sector's lead seems based on their control of the entire process, as opposed to the extreme fragmentation in the building sector. This is now changing as specialists band together to pursue design-build opportunities. This social unity is a prerequisite for process mapping and streamlining that can maximize customer value and minimize waste.

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