DESIGN AND PRODUCTION INTERFACE IN LEAN PRODUCTION: A PERFORMANCE IMPROVEMENT CRITERIA PROPOSITION

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ABSTRACT

Failures on transferring Japanese production techniques to West countries point out the need for a more in-depth comprehension of concepts and principles that support such techniques. In the construction industry, the abstraction and adaptation of those concepts and principles started in 1992 with the publication of the report "Application of the New Production Philosophy to Construction", by Lauri Koskela. However, since the publication of that study little further discussion has been made on other Japanese production models, such as the one proposed by Shigeo Shingo and adopted at the Toyota Motor Company.

This paper intends to compare Koskela's and Shingo's production models and the possibilities of amalgamating them. It is also proposed an application of those models for establishing performance improvement priorities, considering a hierarchy of decisions (market level, product level, process level, and operation level).

KEY WORDS

Lean construction, Toyota Production System, production improvement.

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INTRODUCTION

Most of construction modernisation efforts in the last decades have been made through industrialisation and, more recently, through the rationalisation of production processes (Farah 1992). In both approaches we can observe a great degree of influence from other industries, as they are usually viewed as more advanced, representing a stereotype where construction industry looks for skills, techniques and heuristic principles that can guide its modernisation actions. Discussions that occur along this process are basically oriented towards the contextualization of those skills and techniques, without taking into consideration the principles and the philosophy that support that industrial model (Shingo 1988).

That conventional production model can be characterised by being strongly based on the industrial engineering theories proposed by Taylor, Gilbreth and Ford at the beginning of this century, when products and process were very simple, with most of industrial plants producing a single or very few products. Although such conditions were very plausible at that time, they are not suitable for the contemporary industrial scenario.

Nowadays, the adoption of new and complex products and processes, as result of technology innovations and market changes, has been driving industrial firms in a more complex management environment (Johnson and Kaplan 1987). On the other hand, as the competition increases, other factors, besides cost and price, have become critical for companies' success, such as production and delivery time (Stalk 1988), creating a new pattern of competition among industrial actors.

All of these changes tend to drive the "conventional" production model to a state of obsolescence, pointing out the need of a more in-depth comprehension of assumptions, paradigms and basic concepts that support this model.

Taichii Ohno and Shigeo Shingo, from the Toyota Motor Company, made an early effort in that direction. Their studies resulted not only in a "new production philosophy" proposition, but also in its successful implementation in the automobile industry context, which was named "Toyota Production System" (TPS).

As a consequence, many trials were made by Western companies in order to copy some elements or the entire TPS, most of them unsuccessfully. Some of the first implementations of such "new production philosophy" in the West were reported by Schonberger (1982), who pointed out the need for some kind of adaptation in order to improve effectiveness on implementation, such as the consideration of regional, cultural and industrial characteristics.

One of the first studies aiming at a better understanding of the application of those points and principles to the construction context was made by Lauri Koskela in 1992 (Koskela 1992). In that study, Koskela presents an in-depth analysis of the JIT/TQC foundations. He discusses its application to the construction industry environment through the identification of the bases of the "new production philosophy", also known in Western countries as "lean production".

LEAN PRODUCTION CONCEPTUAL MODELS

The lack of a theory based on JIT/TQC philosophy that can be applied to production systems in construction is not well recognised by construction companies. Lean production has usually been perceived at a very practical level in the West, rather than a theoretical one. In spite of the relevance of practitioners viewpoint to implement lean production in a new environment, the formulation of a theory is very important since the practice of lean production can only be partially applied to construction (Koskela 1998). Lillrank (1995) states the need of some degree of abstraction in order to transfer and apply Japanese practices to Western countries. This can be made only through the formulation of a theory that comprises the core principles and concepts that are the basis of those practices.

An important step to accomplish that task is to compare the conceptual models that support the conventional and the new production philosophies. Such comparison can reveal differences between principles and concepts that are adopted by them.

THE CONVENTIONAL PRODUCTION MODEL

According to Koskela (1992), the conventional philosophy implies the adoption of what he calls the “conversion model” and concepts that are related to it. The conversion model may be defined as follows:

1. A production process is a conversion of an input into an output;
2. The conversion process can be divided into subprocesses, which are also conversion processes;
3. The cost of the total process can be minimised by minimising the cost of each subprocess;
4. The value of the output of a process is associated with costs (or value) of inputs of that process.

Another characteristic of the conventional production model is presented by Shingo (1988), who states that traditional industrial engineering has been considering the production phenomena as linear. Consequently, processes and operations are viewed as having the same nature. Therefore, the difference between process and operation are only related to the scope of analysis that is considered when studying production, being the concept of operation related to smaller units (time and movement studies, for example) and process related to larger ones.

As a result, processes are recognised as a sum of many operations (Antunes Junior 1994) and process efficiency can be achieved just by making improvements on its subprocesses or, at a more detailed level, on its single operations. In other words, “it results that doing improvements on operations (micro level) can automatically assure improvments on a process (macro level) which includes those operations” (Antunes Junior 1994).

PRODUCTION AS A NETWORK OF PROCESSES AND OPERATIONS

This conventional view of production was strongly criticised by Shigeo Shingo, who considers that it is a fundamental mistake to consider processes and operations as having the same nature.

Shingo (1988) proposes a completely different interpretation of production phenomena, considering them as composed by two orthogonal axes, each one with a different nature. According to such model, industrial and service production analysis must consider the distinct observation of the object of the work (raw material) and the subject

of work (men and machines/equipment) along time and space. The former determines the processes and the latter the operations. So "Production constitutes a network of processes and operations, phenomena that lie along intersecting axes. In improving production, process phenomena should be given top priority" (Shingo 1988).
Thus, according to his point of view, processes and operations are two distinct ways to observe a single phenomenon. This can be illustrated by the following example, where items are processed with a machine (Shingo 1988):

Here, processes and operations intersect. The change that occurs in the object as the machining procedure moves ahead is a *process*. The change occuring in the machine and in the worker doing the machining is an *operation*. In this sense, processes and operations are opposite sides of the same coin. However, when the task using this machine ends, the vertical flow separates from the horizontal flow in the following manner: (1) the material (object) flows to the next machine (subject), and (2) the machine (subject) receives the next item (object).

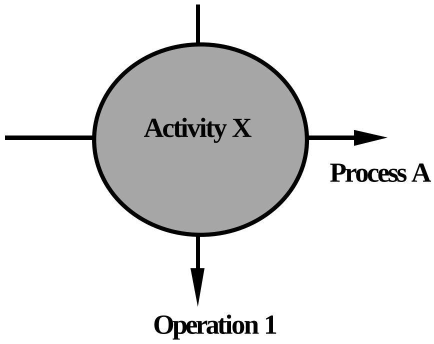

Figure 1: Activity as process and operation (based on Shingo 1988)

So, all production activities can be seen as composed by *operations* (workers and machine flow in time and space) and *processes* (material flow in time and space), arranged as two orthogonal axes crossing along production, as shown in Figure 1.

PRODUCTION AS FLOW

As a starting point of the analysis of the new production philosophy, Koskela corroborates Shingo's point of view as he affirms that the conceptual basis to distinguish conventional and new production philosophies relies on the way that production processes are seen. Thus, the new production philosophy sees the conversion model as incompatible with the complexity that characterises contemporaneous productions systems, resulting in the need of a new production model, defined as follows (Koskela 1992):

- Production is a flow of material and/or information from raw material to the end product ... In this flow, the material is processed (converted), it is inspected, it is waiting or it is moving. These activities are inherently different. Processing represents the conversion aspect of production; inspecting, moving and waiting represent the flow aspect of production (Figure 2).
- Flow processes can be characterised by time, cost and value. Value refers to the fulfilment of customer requirements. In most cases, only processing activities are value-adding activities. For material flows, processing activities are alterations of shape or substance, assembly and disassembly.

- In essence, the new conceptualisation implies a dual view of production: it consists of both conversions and flows.

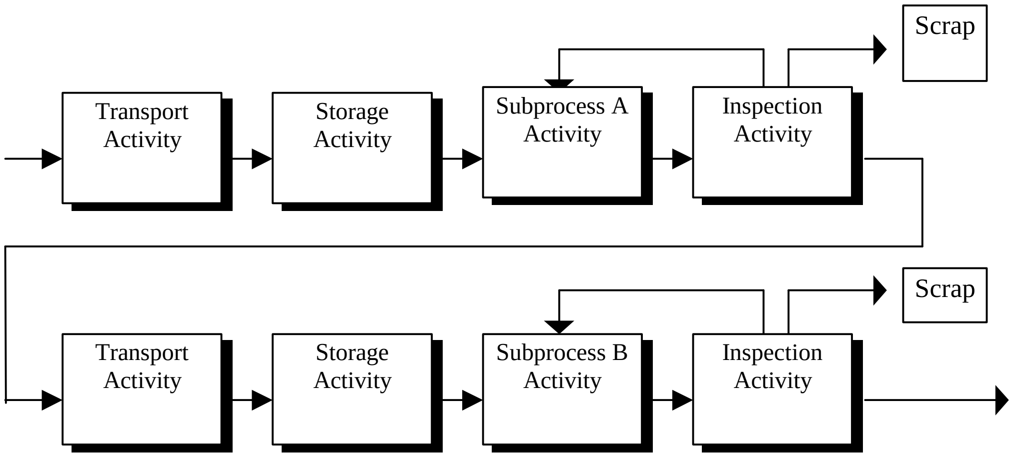

Figure 2: Production as Flow (Koskela 1992)

GUIDELINES TO IMPROVEMENTS ON PRODUCTION SYSTEMS

The idea of *improvement* is a fundamental aspect of lean production: keen attention has to be paid on waste reduction as a continuous improvement driver rather than waste measuring. Thus, it is extremely important to define a criterion that can be used to determine improvement priorities, enabling the establishment of an effective improvement sequence to assure such continuous waste reduction.

In spite of the differences between Koskela's and Shingo's models, it is important to observe that JIT/TQC philosophy is a fundamental basis of Koskela's and was strongly influenced by Shingo's ideas and propositions. So, there must be some common element between both models, as both conceptual bases are thought to be the same.

According to Shingo's model, improvements that only take into consideration the operation axis cannot assure global process improvement. To achieve such improvement, both process and operation axes must be considered when analysing production to design specific actions oriented to assure effective results on each one (Ishiwata 1991). In order to do that, Shingo (1996) states that process improvements must precede operation improvements, since the nature of the relationship between process and operation relies fundamentally on a necessity created by the process to be satisfied by the operation. This assumption implies that priority actions have to be oriented towards the causes which generate the necessity (processes) and only then towards the way that the work is done (operations).

Beyond this, a more in-depth analysis of Koskela's view of production shows that it is highly linked with the process axis, as can be seen in Koskela's words (Koskela 1992): *"Production is a flow of material and/or information from raw material to the end prouct"*. In this sense, Koskela is extremely clear when providing an improvement criteria at the process dimension, as he says: *"the overall efficiency of production is attributable to both the efficiency (level of technology, skill, motivation, etc.) of the conversion activities performed, as well as the amount and efficiency of the flow activities though which the conversion activities are bound together"*.

Thus, both Koskela's and Shingo's models can be seen as complementary. While Shingo identifies the priority of process improvement rather than operation improvement, saying nothing about where the improvements in the process must start, Koskela proposes a balance between flow and conversion activities improvements, as shown in Box 1.

Guidelines to Improvement Prioritisation
1) Improvements of processes, balancing flow improvements (eliminating/reducing/improving efficiency of flow activities) and conversion improvements (improving efficiency of conversion activities); 2) Improvements of operations.

Box 1: Guidelines to improvement on production systems
(based on Koskela 1992 and Shingo 1988)

It is important to observe that starting improvements by processes does not mean that such improvements will give the best possible return on investment. Often times this can be achieved through operation improvement. Since there is a cause-and-effect relationship between processes and operations, small changes on processes can result in radical changes on operations, thus affecting operation improvements that have already been implemented.

IMPROVEMENT CRITERIA APPLIED TO THE DESIGN/PRODUCTION INTERFACE

Additionally, there is an important difference between the points of view of Koskela and Shingo. The model proposed by Shingo focuses mainly on production when guiding improvement-making efforts, thus considering a narrower scope than Koskela's, which considers not only production aspects but a whole company and its environment. However, this difference reveals a choice in focusing <u>where</u> the improvements must be done rather than in <u>how</u> the possible ones are identified. Therefore, there is no reason not to extend the cause-and-effect logic of Shingo's model beyond production, as discussed ahead.

According to Shingo, not only operations are subordinated to processes but also the product design has absolute priority over both of them. So, product improvements must be made in advance to both process and operation improvements since the product definition will substantially affect subsequent choices related to processes and operations. Such link amongst product, process and operation can be clearly identified in Shingo (1988) due to the importance placed by him on the use of Value and Engineering Analysis to product design.

The same logic can be applied in linking product and market, as can be seen in Quality Function Deployment (QFD) through the deployment of customers' needs into production standards and practices (Akao 1990).

So, a cause-and-effect relationship can be established from market to operation, as: **market → product → process → operation**, which can be represented as shown in Figure 3.

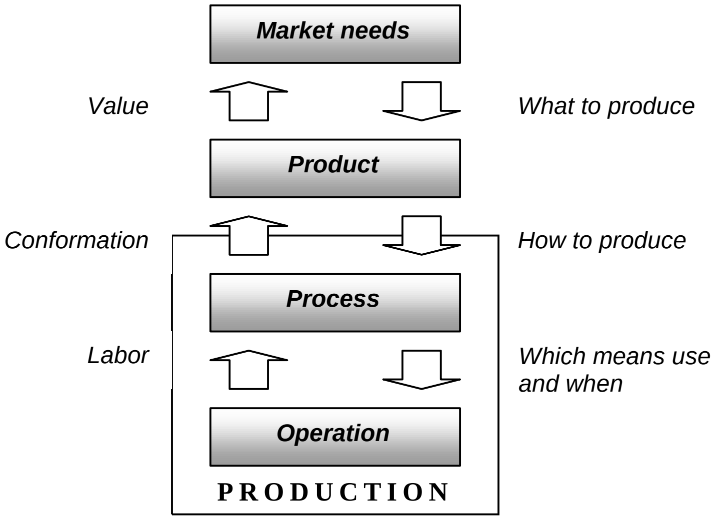

Figure 3: Cause-and-effect Conceptual Model

DISCUSSION

The conceptual model presented in Figure 3 shows not only a priority order but also some similarities with the PDCA cycle. The top-down flow represents the design process, according to the deployment logic of QFD, which is the equivalent of the "Plan" phase of the PDCA cycle. It can be divided into three steps: product design ("what to produce"), process design ("how to produce") and operation design ("which means to use and when"). The same priorisation rules are applicable to all, meaning that design must be done in the same order (product → process → operation). Obviously, there may be some exceptions such as, for example, through product standardisation. Nevertheless, all of them have some speculative elements, thus representing some kind of inventory of decisions that are made beforehand.

In contrast, the bottom-up flow represents the value generating process (including production and delivery, and also considering the product-service pack), which is the equivalent of the "Do" phase of PDCA cycle. The "Check" phase take effect between "Plan" and "Do" at all considered levels (market, product, process and operation). Occasional discrepancies must be corrected through redesigning, representing the "Act" phase.

There are two reasons that justify the consideration of such similarities with PDCA cycle. The first is to integrate the priorisation logic with continuous improvement methods used by CWQC (QC Story and 5W, for instance), since it may provide guidelines for conducting the investigation of relevant causes.

The other one is to emphasise the cyclic interdependence amongst market, product, process and operation, which can be explored in order to diminish development time. For instance, by testing the concept of a product with customers before the process and operation design. This also can be done by standardising products, process or operations, resulting in shortening the development time.

FINAL CONSIDERATIONS

The difference between the construction environment and the one that originated the Toyota Production System is usually considered to be a major constraint to applying the new production to construction. However, the application of new production philosophy does not imply—and must not suppose—either an integral or a partial copy of skills and methods from TPS without a critical consideration of structural and environmental factors of the industry.

This study tried to point out some basic characteristics of the new production philosophy. Some fundamental concepts and principles were presented as identified by Shingo, Ohno, and Koskela. Also, it was proposed a conceptual model aiming at representing the cause-and-effect nature of the link amongst market, product, process and operation, which enables a systemic understanding of the improvement-making process in production.

Without the discussion and consolidation of such concepts, there is the risk to make the same mistake made when the conventional production model was conceived: to ignore constraints and implicit paradigms that support the production system. In this respect, it is expected that this paper will contribute as another element of discussion to define a new understanding of the concept of waste in construction context according new production philosophy.

REFERENCES

Akao, Y. (ed.)(1990). *Quality Function Deployment: Integrating Customer Requirements into Production Design.* Productivity Press: Cambridge, Mass.

Antunes Junior, J. (1994). Mecanismo Função Produção: A análise dos sitemas produtivos do ponto de vista de uma rede de processos e operações. *Revista de Engenharia de Produção* (4)1.

Farah, M. (1992). *Tecnologia, Processo de Trabalho e Construção Habitacional*. USP: São Paulo. (Tese de Doutoramento em Sociologia).

Ishiwata, J. (1991). *IE for the shop floor: Productivity through process analysis*. Productivity Press: Portland, Oregon.

Johnson, H. and Kaplan, R. (1987). *Relevance Lost*. Harvard Business School Press: Boston, Mass.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction***.** Technical Report #72, CIFE, Stanford University.

Koskela, L. (1998). "Lean Construction." In: Silva, D. et al. (ed.). ENTAC 98: *Qualidade no Processo Construtivo*, (1), 3-10. ANTAC: Florianópolis, Brasil.

Lillrank, P. (1995). "The Transfer of Management Innovation from Japan." *Organization Studies*, 16 (6) 971-989.

Schonberger, R. (1982). *Japanese Manufacturing Techniques: Nine Hidden Lessons of Simplicity.*

Shingo, S. (1988). *Non-Stock Production: the Shingo System for Continuous Improvement.* Productivity Press: Cambridge, Mass.

Stalk, G. (1988). Time—The Next Source of Competitive Advantage. *Harvard Business Review*, Jul-Aug, 41-51.