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MAKING-DO – THE EIGHTH CATEGORY OF WASTE

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ABSTRACT

The seminal authors on the Toyota Production System present a list of seven wastes. Even if many subsequent authors have suggested additions to this list, it is usually presented in its original form. This paper contends that there is a very common, generic type of waste that should be added to the list, because it can be justified using the same conceptualizations as used by the seminal authors.

Making-do as a waste refers to a situation where a task is started without all its standard inputs, or the execution of a task is continued although the availability of at least one standard input has ceased. The term input refers not only to materials, but to all other inputs such as machinery, tools, personnel, external conditions, instructions etc. Especially in production situations where there are several uncertain inflows to the task, making-do is a common phenomenon, and requires explicit attention.

In conceptual analysis, making-do is the opposite of buffering. In buffering, materials are waiting for being processed. In making-do, the waiting time of one type of material – or other inputs – is negative: processing is started before the material has arrived. However, both forms of waste are used for accommodating the impacts of variability in production. Making-do is applied especially for maintaining a high utilization rate or for avoiding schedule slippage. Thus, making-do is another penalty due to variability, and it should be added to the conceptual arsenal of queueing-theory based analysis of production (Factory Physics).

INTRODUCTION

The seminal authors on the Toyota Production System present a list of seven wastes[2]. Even if many subsequent authors have suggested additions to this list, it is usually presented in its original form. Of these seven wastes, inventory or work-in-progress has been presented as the *primus inter pares*, which should be attacked before other wastes.

But is this list of seven wastes, and the predominance of inventory, appropriate for the wide range of situations found in the universe of production? This paper contends that there is a very common, generic type of waste that should be added to the list, especially when it in some production situations seems to take the dominant position held otherwise by inventory. This eighth category of waste is here called making-do[3].

There are three sources of inspiration for this standpoint. The phenomenon of making-do first puzzled the author in a discussion with Glenn Ballard in 1992 on the requirements to be

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[2] Ohno (1988) identified the following seven wastes, of which the first five refer to the flow of material, the two last ones to work of men: overproduction, correction, material movement, processing, inventory, waiting, motion.

[3] To make do: to get along or manage with the means at hand (Merriam-Webster online dictionary)

set to production control. Glenn urged that tasks are to be sound before they should be taken into a weekly plan. By soundness, he meant that all inputs and prerequisites of the task should exist. It must be admitted that the author had difficulties in seeing the justification of this self-evident (as he thought) requirement. A second point of inspiration was provided by the writings of Ronen (1992), where the method of the complete kit was introduced. In his seminal contribution, Ronen analyzed the causes and impacts of the phenomenon of making-do (even if he did not use this term) as a generic issue in operations management. A third stimulus came in the observation, made in framework of empirical studies, that working in suboptimal conditions is one of the most important wastes in construction (Koskela 2000).

However, even if the phenomenon of making-do has been discussed in the literature, it cannot be said that this concept would have consolidated its place in the doctrine of construction management, or more generally in that of operations management or of project management. It is characteristic that there are very few references to Ronen's seminal papers[4]. What might be the reason to the sluggish uptake of this idea? One possible reason is that the concept of making-do has not yet been orderly related to the body of the knowledge in these areas. Ronen says: "The complete kit does not introduce any new theory to the field". Here the diametrically opposed standpoint is taken: making-do represents an uncharted piece of theory. The lack of theory has hindered wider understanding of this phenomenon. Thus, this paper represents an attempt to clarify the conceptual and theoretical position of making-do both in the classical categorization of waste and in the Factory Physics framework. The seminal insights of Ronen are taken as the starting-point, but they are extended, revised and re-interpreted as necessary.

The plan of the paper is as follows. First, an attempt to consolidate the conceptual and theoretical position of making-do is carried out. The causes and consequences of making-do are charted and discussed. The specific appearance of making-do in design is discussed. Next, the occurrence of making-do in construction is considered. The ways of eliminating making-do are outlined. Finally, the suggested additions to knowledge are discussed.

MAKING-DO – CONCEPTUAL ANALYSIS

WHAT IS MAKING-DO?

Ronen (1992) did not define making-do but rather the ideal situation where no making-do is required: the complete kit. A complete kit is, according to Ronen, the set of components, drawings documents and information needed to complete a given assembly, subassembly or a process. Thus, the suggestion is that work should not start until all the items required for completion of the job are available.

Our observations especially from construction indicate that whether all items required are available or not is not a question with only two answers: yes or no. Rather, there are inputs that may be available, but on a non-optimal or non-standard basis[5]. For example, the space needed for a given work may be also in demand for another, simultaneous work. Thus, we

[4] According to the ISI Web of Science (March 17, 2004), the paper is referred to in two later papers (self-referrals excluded).

[5] This includes the substitution of materials, labor or equipment due to the lack of a prescribed resource.

generalize the original idea of Ronen to cover also available, but non-optimal or non-standard inputs.

Our definition is thus as follows: Making-do as a waste refers to a situation where a task is started without all its standard inputs, or the execution of a task is continued although the availability of at least one standard input has ceased. The term input refers not only to materials, but to all other inputs such as machinery, tools, personnel, external conditions, instructions etc.

Conceptually, making-do is the opposite of buffering. In buffering, materials are waiting for being processed. In making-do, the waiting time of one type of material – or other inputs – is negative: processing is started before that material has arrived.

It is noteworthy that both buffering and making-do are invisible in many process modeling methods that start from the total process and decompose it further to sub-processes (like IDEF0). The process modeling methods originated in industrial engineering, which show what is happening in the time line, model buffers explicitly, but even they fail to model making-do.

WHY DOES MAKING-DO OCCUR?

Ronen (1992) mentions three basic causes of making-do: the efficiency syndrome, the pressure for an immediate response[6] and improper division into levels of assembly. Let us consider and comment each in turn.

According to Ronen, the efficiency syndrome is the urge to have the resources utilized as much as possible.

The pressure for an immediate response provides a less straightforward case. One motivation lies in the belief that by starting early, even if with an incomplete kit, the task will also be completed earlier. Another motivation is to start the work just for getting the job. On the other hand, if the customer does not trust the supplier, the only way of ensuring that his order is delivered at due time is to require that the work is started immediately.

The improper division into levels of assembly refers to a situation where the number of components per kit grows to an uncontrollable level.

While agreeing with Ronen's conclusions, we would like to present a deeper explanatory framework for the occurrence of making-do. First, regarding the efficiency syndrome, of course this is the utilization rate used as a performance measure, an intrinsic feature of the transformation model of production (Koskela 2000). And similarly to the case of buffering, making-do is invisible in the conceptual framework of the transformation model.

Second, the way production is managed has an influence on the occurrence both of the pressure for an immediate response and of the situation of an incomplete kit. As it has been elsewhere argued, the conventional method of operations management is characterized by approaches of management-as-planning, the classical communication theory and the thermostat model (Koskela & Howell 2002a).

In management-as-planning, management at the operations level is seen to consist of the creation, implementation and revision of plans. This approach to management views a strong causal connection between the actions of management and outcomes of the organization.

[6] This is extended in a later paper (Grosfeld-Nir & Ronen 1998) to a prisoner's dilemma based analysis.

Materials and other prerequisites are pushed according to the plan towards the workface, and it is expected that each task, with all inputs available, can thus be started according to the plan. Unfortunately, the discrepancies between the plan and the real world are not taken into account, resulting in situations where making-do provides a solution.

In execution it is assumed that planned tasks can be carried out by a notification of the start of the task to the executor. Such one-way communication is covered by the classical communication theory. The whole focus in execution is getting a task started. Again, making-do seems to provide the ready solution.

The thermostat model is the cybernetic model of management control that consists of the following elements: there is a standard of performance; performance is measured at the output; the possible variance between the standard and the measured value is used for correcting the process so that the standard can be reached. However, this control requires that the progress is presented in non-discrete terms: time, money, area, etc. This makes the starting of a task seem inviting, even if only, say, half of it can be realized with the inputs at hand. Making-do is thus applied especially for trying to avoid a slippage from the plan.

Thus, remarkably, all parts of the conventional managerial system seem to cause or to invite, or at least to fail to reject, making-do. It can be concluded that making-do is not due to a failure of implementing the conventional managerial system, but rather inflicted by that system.

Third, regarding levels of assembly, it has to be noted that there are production situations where tasks systematically have several intrinsically unreliable inflows. As the author has elsewhere argued (Koskela 2000), construction is one such domain. There are usually seven or more inflows to any construction task, all more or less unreliable. The total unreliability for a task tends to grow to an impressing level. Thus, the question is not only about choices on assembly levels but also about intrinsic characteristics of various production situations.

The analysis of Ronen does not comment on whether there are more fundamental, underlying causes for making-do. We argue that making-do is fundamentally caused by the phenomenon of variability in production. Making-do is usually[7] applied when there is unexpected unavailability of a (standard) input. Thus, making-do is another penalty, besides buffering, added capacity and lost production (Hopp & Spearman 1996), due to variability. It should thus be added to the conceptual arsenal of "Factory Physics", the queueing-theory based analysis of production.

WHICH ARE THE CONSEQUENCES OF MAKING-DO?

Ronen (1992), with his co-author (Grosfeld-Nir & Ronen 1998), present two broad areas of consequences: technical and behavioral. Regarding technical consequences, the starting point is in an *increase in processing time* and its *variability* caused by making-do. The increased variability leads to *more work-in-process*, or equivalently to *longer lead times*. The increased processing time leads to a *decline in productivity* and to *more operating expenses*. Increased work-in-process necessitates *increase in complexity of controls*. An intrinsic consequence of making-do is also *poor quality* and *more rework*. To this analysis by Ronen, only the *decline*

[7] Surely, making-do may be planned and deliberate, if the unavailability of some standard input is known in advance. Likewise, making-do may occur just for lack of effort to ensure the availability of inputs.

in safety, caused by making-do, can be added here. This decline in safety is explained by the abnormal conditions of work in making-do.

Behavioral consequences of making-do, as presented by Ronen (1992), include *decline in worker's motivation* as well as *lessening of effort to ensure arrival of the missing kit items*. While these behavioral consequences are plausible, it must be pinpointed that a strong theoretical or empirical backing[8] for them is still lacking.

MAKING-DO IN DESIGN

The discussion above has concentrated on making-do in the physical production phase. In design and engineering, the causes, nature and impacts of making-do are slightly different. Regarding a design task, making-do generally relates to the lack of complete input information. Empirical studies indicate that the problem of lacking input is chronic, for example, in building design. However, this lack of inputs is not only due to bad control of the design process, but may also reflect the inherent characteristics of design. Namely, first, design can also be seen as a mutual learning process between the client and the design team (Green 1996), or, in other terms, as an oscillation between criteria and alternatives (Ballard 2002). It is thus natural and inevitable that some input data evolve gradually. Second, there are situations of interrelated design tasks (called blocks in a design structure matrix) where the task input is inherently incomplete at the beginning of an iteration cycle, but is perfected in the next cycle(s).

There are several methods for allowing the design to progress in spite of lacking input (Koskela 2000). One typical way to cope is to make assumptions, with the intention to check their validity later. Unfortunately, this leads to rework[9] if assumptions, and thus most often even the design solution, have to be corrected after checking. Also, checking is easily forgotten or there is no time for it, and thus a discrepancy between different design disciplines possibly emerges.

Other coping methods have an even more direct impact on the design (or construction) solution. However, almost every method brings about additional costs or an added risk of these, or reduced functionality:

- Design iteration is eliminated through an alternative construction method.
- Interface between design tasks is prearranged.
- Design solution is over-dimensioned to absorb all possible future decisions.
- Design solution is selected based primarily on the consideration of design progress (i.e., it prevents the progress of other design tasks as little as possible).

Given these peculiarities of making-do in design, it is natural to assume that contextualized means for eliminating or reducing making-do are needed in design. However, this line of discussion cannot be followed further here.

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[8] However, this situation is shared by many other popular constructs in operations management.

[9] Ronen (1992) comments that this is one of the reasons why most development activities are carried out twice or three times.

CONSTRUCTION – THE PROMISED LAND OF MAKING-DO

How common is making-do? Where does it occur in the product realization cycle? Let's consider construction as an example, looking primarily at the major stages[10], and if the data allow, inside them.

The first major interface is between the client decision-making and design. Ample evidence indicates that design generally starts in a making-do mode due to the failure of the client to gather and decide on the requirements (Koskela 2000).

Next comes the interface between design and procurement. It is quite common to procure tailored products before their design has been finished. One reason, related by Elfving (2003), is the tendency of procuring in large batches, in spite of that only a part of the products in question have been completely designed at the moment of procurement.

The interface between procurement and prefabrication is, again, strained by the late completion of design drawings. On the other hand, in the hope of negotiating an even better deal, the contract may be agreed on so late, that the prefabricator has no time for orderly production planning and preparation (Koskela 2000).

All the problems that have remained without consideration in the prior stages end up at the site and provide concrete hindrances for progress. In addition, the traditional push type planning easily fails to take into account the deviation between the planned and real progress, causing problems in input availability. The natural response is making-do in a massive scale. This is evidenced in the seminal finding of Ballard (2000) regarding the outcome of weekly plans: only about half of the tasks get realized as planned during the week. Some tasks are not even started, but a considerable share of tasks started must be abandoned before completion due to lacking inputs, or their execution takes longer because of the suboptimal conditions. The observations by Jaafari (1984) on productivity in a construction task are illuminating[11]:

> While the size of samples is not large enough to yield conclusive results, the general pattern remained similar. Productivity showed a gradual build-up at the start (often associated with unavailability of specific tools or materials at the time required, or lack of foreman instruction, or absence of key craftsmen). Steady progress in productivity continued unless interrupted externally, then followed by unexplained drag at the end, or often unfinished 10-15 % for a variety of reasons such as urgent start elsewhere, technical problems, or breakdown of tools.

This variability in task execution causes a further situation of lacking inputs for subsequent tasks – and further making-do.

Finally, there is the interface between construction and the operations intended to take place in the constructed facility, handover. In view of the prior discussions, it is not

[10] This discussion does not imply that each stage in a construction should be fully completed before the next can start. Rather, appropriate batches of completed work in one stage can be released to the subsequent stage, which can start without essential needs for making-do before the total completion of the previous stage. For an insightful discussion of the significance of batching, see (Reinertsen 1997).

[11] Note that all problems described by Jaafari do not necessarily (or always) represent making-do. Especially, the "often unfinished 10 – 15 %" may be due to problems emerging during the task execution, such as a sudden breakdown of a tool. However, probably more often unfinished work is caused by issues that either were known at the start of the task or could have been caught and rectified during the planning of the task, i.e. explicit or implicit making-do is the root cause.

surprising to realize that even here often the operations are moved in and started before the constructed facility is fully complete. Womack and Jones (1996) give an illustrative example, where the performance measurement system prompts construction managers to bribe house buyers to accept and move into houses with long punch lists.

Indeed, it seems that in construction, making-do has been cultivated to an art[12], with the related can-do attitude as a cherished characteristic of everybody involved (Howell & Ballard 1994). Maybe this is one reason for Schonberger (1990) to comment that construction does not fit the usual categories of industries: "One industry, construction, is so fouled up as to be in a class by itself. Delay, lack of coordination, and mishaps (especially return trips from the site to get something forgotten) are normal, everyday events for the average company."

HOW TO ELIMINATE MAKING-DO?

The basic advice given by Ronen (1992) on the implementation of the complete kit is to introduce it as a part of a major change in the organization, such as JIT, TQM or TOC implementation. On the other hand, he also presents the possibility of basing the planning and control system of an organization on the complete kit concept, which would thus be the lead idea for improvement.

While not disagreeing with the positions taken by Ronen, the theoretical considerations carried out above make it possible to sharpen and augment them. First, it is necessary that the conventional theoretical foundation of production management, which contributes to making-do, is rejected, and the production management system is based on wider theory. Thus, besides the transformation model of production, especially the flow model of production should be adopted (Koskela 2000). In doing so, the attention is turned towards reducing waste and its major cause, variability.

On the other hand, the theory of management needs an overhaul (Koskela & Howell 2002a). The approach of management-as-organizing as a theory of planning allows the pull type of production control, which is instrumental for ensuring the availability of all task inputs. The language/action perspective, as a theory of execution, focuses attention to commitment towards the plan and to confirmation of the task outcome. The scientific model of experimentation, as a theory of control, likewise stresses the comparison of the task outcome to the plan, with the target of learning from the possible discrepancy. While there

[12] Sometimes the whole setting of a construction project leads to the necessity of making-do. An effort initiated and led by students to build an observatory at Stanford University in the 1970s is described as follows (Origin and history):

> Construction was an education and an adventure. According to Suntzeff, `innovative' solutions had to be found for many financial and engineering challenges. ``The dome was way too big to take on the freeway, but we crossed our fingers and the CHP never caught us." Also ``I remember one of the junior faculty with a pencil and paper trying to figure out a dual 3-way light switch from first principles." Greg Howell was particularly adept at making do: ``To erect the pier which was about 25 feet tall, he only had a crane which was about 25 feet tall. He jacked up the front end of the crane, started lifting the pier upright, and somewhere near vertical, he jerked the crane up while jumping out of the crane and ran for safety. The pier magically righted itself. He told me that he had done this before."

(The anecdote is based on the reminiscences of Nick Suntzeff from the Cerro Tololo InterAmerican Observatory) surely are other alternative or complementary theories, these examples show that it is possible to switch to theories that support the elimination of making-do.

At the practical level, these alternative or augmenting theories are embodied, for example, in the Last Planner™ system of production control (for justification, see Koskela & Howell 2002b). What seems to be important is a structured system for short term planning and execution, where the rule of not starting a task without all inputs can be transparently enforced and enabled.

Furthermore, it has to be stressed that similarly to using inventory or lead time reduction as a driver, the goal of eliminating making-do is not merely to eliminate its damaging consequences, but also to address its causes and the intrinsic penalties associated to them. This said, it must be acknowledged that there may be situations where making-do, to a controlled extent, is a perfectly feasible way of promoting some particular goal, say schedule compression.

Finally, the conceptualization of construction (or other) projects as complex adaptive systems (Bertelsen 2004) invites the question whether the elimination of making-do in such contexts necessarily is the right, or even possible, target. Here, this question must be left to be answered in future research.

CONCLUSIONS

The general conclusion from the analyses made is that making-do has been neglected not only in conventional thinking on production, but largely also in lean thinking.

Contributions to knowledge are suggested in this paper regarding four literatures, covering queueing-theory based analysis of production, lean production, lean construction and making-do itself.

Firstly, the conceptual position of making-do as an opposing category to buffering is clarified: whereas in buffering there is a positive waiting time for an input to a task, in making-do that waiting time is negative, i.e. the input arrives during the task execution (or never). The basic law of production, as suggested by Hopp and Spearman, is shown to be deficient: it should include making-do as one consequence of variability. Here, we encounter a basic weakness of the mathematically oriented operations management research, namely the lack or paucity of testing of theories against empirical facts.

Secondly, the classic list of seven wastes in lean production is suggested to be augmented by making-do. This evident gap in the classic list raises the question to which extent that list should be seen as a generic one or rather as a contextualized one, reflecting the situation in car manufacturing.

Thirdly, regarding the literature on lean construction, the explicit acknowledgement of making-do as waste simplifies the explanation of the Last Planner™ production control system. Last Planner™ is using the suppression of the waste of making-do as a driver towards reducing variability and improving the whole production system. Thus, Last Planner™, as suggested by the first principles of lean production, attacks the type of waste that is dominant in its application context.

Fourthly, while fully acknowledging the seminal and substantial contributions made by Ronen towards understanding making-do, a number of additions or revisions are suggested. Making-do is introduced as a theoretical innovation, rather than only practical. The difference of consequences of making-do in physical production and product design is emphasized. Reduced safety is added as one important consequence of making-do. For the implementation of the complete kit principle, theory-based methods are suggested.

New theory invites for its empirical testing. This applies also for making-do: empirical research is needed for charting its occurrence in different production situations and for assessing its consequences, and ultimately, for better validating the concepts and causalities suggested.

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