

WHY HASN'T WASTE REDUCTION CONQUERED CONSTRUCTION?

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ABSTRACT

Waste and waste reduction are some of the main concepts that differentiate lean thinking from other approaches to production planning and control. Since its introduction in the West in the 1980s, the concept of waste reduction has had a major impact in manufacturing. But not so in construction. This paper raises the question of why this is the case. Possible answers are sought not only in the mainstream theories of production and construction management but also in the specific characteristics that distinguish construction from manufacturing. Eight possible answers to the question are identified and discussed. The paper concludes by arguing that many of the identified reasons are in fact being addressed by newly developed Lean Construction concepts.

KEYWORDS

Waste, Construction, Manufacturing.

INTRODUCTION

In lean production theory, the concept of waste derives from the Toyota Production System (Ohno 1988, Shingo 1988 and 2005). It has proven worldwide to be a powerful approach to improving productivity in manufacturing. It is used at the macro level of business models and value chains, at the mid-level of production system design, and at the micro level of task execution. The original list of seven wastes presented by Ohno (1988) is still in broad use, but a substantial number of changes have also been proposed, particularly as a result of adapting the concept of waste to types of production other than manufacturing (Koskela et al. 2013, Bølviken et al. 2014).

Construction is one of the major industries worldwide, and is commonly recognized as having high levels of waste. It can therefore be viewed as something of a paradox that waste reduction has not become a dominant strategy with regard to improving productivity in this industry. The topic of the present paper is to identify possible explanations as to why this is the case.

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We have not identified any literature explicitly addressing the question put forward in the present paper. There are however some contributions on the related, but more general question of barriers to implementing “Lean” or “Lean Construction” in the construction industry (Mossman 2009, Bashir et al. 2010, Sarhan & Fox 2013, Wandahl 2014). Based on a review of literature on barriers to the take up of lean practice, Bashir et al. (2010) find that these barriers can be grouped in the following six categories: management, financial, educational, governmental, technical and human attitude issues. (Sarhan & Fox 2013) is the only of the identified contributions with specific references to waste reduction. These references are however to sources of waste, rather than barriers to waste reduction.

METHOD AND STRUCTURE

The approach of this paper is theoretical. Eight possible answers to the question raised in the title of the paper are identified and discussed. The paper concludes by looking at how existing Lean Construction concepts relate to those answers.

OUR THEORIES AND THE WORLD

In contrast to Plato’s idealistic view that the world of ideas is more real than the material world, which is only an imperfect image of the former, lean thinking reflects Aristotle’s philosophy of understanding the relationship between the real world on the one hand and our ideas and theories of this world on the other, as a two-way connection. The world influences us, and we influence the world. In this perspective, our ideas, values, terms and theories can be seen as a lens between the world and us. On the one hand, this lens influences how we experience the world, on the other it also influences how we choose which actions to take and how we view the consequences of these actions.

When trying to understand why waste reduction has conquered manufacturing but has not got off the ground in construction, our approach will therefore be to seek the answers to this question from two approaches:

1. *Answers related to our theories on the world.* The theories relevant to our topic are the mainstream theories of production and project management. The mainstream theory of project (or production) is provided by the transformation view on operations. In this view, a project is conceptualized as a transformation of inputs to outputs (Koskela 2000). In turn, the understanding of management is based on three theories: management-as-planning; the classic communication theory; and the thermostat model (Koskela & Howell 2002).
2. *Answers related to what the world is like.* The world in question is construction. The question of what the world is like can therefore be reformulated to what features distinguish construction from manufacturing, or: What kind of production is construction? These questions have been discussed by several authors (among others Ballard and Howell 1998, Koskela 1992 and 2000, Vrijioef and Koskela 2005, Bølviken 2012, Bertelsen 2003 and 2015), focusing on topics like temporary organization, one-of-a-kind products, site production (the product is rooted to the ground), heavy regulatory framework, and high level of complexity.

IDENTIFIED EXPLANATIONS TO THE RAISED QUESTION

In the following we will present eight possible explanations to the question raised in the title of this paper. The first four address how we see and understand the world (i.e. consequences of the mainstream paradigm of production and construction management); the last four address how the world is (i.e. what kind of production and industry construction is).

CONSTRUCTION MANAGEMENT IS SEEN AS THE MANAGEMENT OF CONTRACTS RATHER THAN THE MANAGEMENT OF PRODUCTION

Waste is a concept embedded in the concepts of production. However, construction is not always viewed as production. Rather, since the mid-20th century, the organization and management of construction has increasingly been influenced by the view of construction as procurement, or buying, of the different inputs.

Pre-war construction was often an in-house activity. Bigger industrial companies had their own construction departments. Contracting companies hired labour directly. Along with changes both in construction technology and management thinking, the use of subcontractors gradually became prevalent, eventually arriving at the current situation where subcontractors perform the vast majority of the work.

However, this has also influenced construction management. Whereas earlier contracting companies had been keen to carefully manage production to avoid any unnecessary costs (indeed, waste), their attention was now turned to contract management, to ensuring that the agreed output was being provided by the subcontractors. A witness of this evolution writes (Allen 1996):

Suddenly there was a contract between the manager and the production process and yet we still acted as if we directly controlled the work face. The contractual problems that inevitably arose required a fix, and we started down the road to managing contractors, not production.

Although the main contractor continued to provide a master schedule, its efforts towards careful production management were reduced. The unnecessary costs of the subcontractors were not visible to the main contractor, and thus the waste in the production process failed to attract its attention. Of course, each subcontractor endeavours to avoid unnecessary costs, but as the work in many ways is usually intertwined with the activities of other sub-contractors, these pursuits are constrained at the outset.

THE CULTURE IN (PARTS OF) THE CONSTRUCTION INDUSTRY

It has been widely observed that the mindset and the culture of construction are oriented to firefighting, to solving problems as they occur rather than prevent them arising in the first place. This may be due to the endemic weakness of management in construction but perhaps also to the weakness of managerial ideas. This situation is also common in project-based industries, as shown by the results of Wearne (2014):

...the results indicate that more than 75% of the problems are due to institutional practice within organizations rather than inherent in their projects. Many of these problems of project management could therefore be avoided, or at least reduced by early attention to their causes. As a result, much of what is called “fire- fighting” in project management—

urgent actions on problems that should not have been allowed to occur—could be prevented.

The firefighting mentality implies little interest in proactive avoidance of problems, leading to waste. Rather, the rapid and efficient solution of the problems is appreciated.

IN CONSTRUCTION THE FLOW PERSPECTIVE IS UNDERSTOOD FAR LESS THAN THE TRANSFORMATION PERSPECTIVE

In the 1960s, the critical path method (CPM) rapidly diffused as a modern method of construction management (Moder & Phillips 1964) and, indeed, the whole discipline of project management evolved based on CPM. The notion of task is central in CPM: it is tasks that are comprehensively identified through a Work Breakdown Structure and then planned, executed and controlled. Conceptually, task is based on the transformation model of production. This is a black box model, abstracting time away, which depicts only the input and the output of the transformation, rather than the transformation itself (of course, in CPM, time is included but it is external to the conceptualization of tasks). Waste occurring inside the productive transformation is not visible in this concept.

Through the diffusion of CPM as well as wider project management ideas into the teaching and training of construction management, and progressively also into practice, this task-centred view on construction has effectively directed attention away from waste.

THE CLASSIC LIST OF SEVEN WASTES IS NOT FULLY RELEVANT FOR CONSTRUCTION

The success of the famous classic list of seven wastes in manufacturing is founded on its practical and intuitive qualities, and neither Ohno nor Shingo present theoretical arguments for the list. In manufacturing, the list has been instrumental in clarifying the concept of waste and also in identifying waste. Among the seven wastes, Ohno pinpoints overproduction (essentially, producing something too early) as the most important type of waste. The elimination of overproduction ideally requires that the production cycle is compressed to be the same or shorter than the ordering cycle of the customer so that the pull principle can be used. This, in turn, requires the elimination of all slack, in the form of inventories, from the production cycle time (Koskela et al. 2013).

In car manufacturing, overproduction manifests as large intermediate inventories and as cars produced without an order from a customer. Barring speculative building of housing or offices, the situation is different in construction: it is engineer-to-order production at the outset. Indeed, in general a construction project is completed late rather than too early.

Thus, as Koskela (2004) and Koskela et al. (2013) argue in more detail, the concept of overproduction as the most important waste does not hold in construction. Rather, as Koskela et al. (2013) explain, the characteristics of construction lead to an erosion of the integrity of tasks, both at their start and end: making do and task diminishment. In order to have an effective grip on waste in construction, these two phenomena need to be understood and controlled.

As a contextualized analysis of waste in construction has only recently emerged, it can be argued that the mismatch between the manufacturing waste theory, widely popularized, and the factual situation in construction has hindered the uptake of the notion of waste in this industry.

THE COMPLEXITY OF THE CONSTRUCTION PROCESS RESULTS IN WASTE BEING A MORE COMPLEX PHENOMENON

The complexity of construction projects has been explored by many authors (among others Bertelsen 2003 and Rooke et al. 2008). It appears likely that the high complexity in construction will result in waste being a more complex phenomenon (Formoso et al. 2015). Indeed, the very complexity of construction establishes relationships that generate a complex network of chains and cycles of waste.

On the other hand, the simple and intuitive quality of the classic waste list has been essential when uniting entire manufacturing organizations in continuous improvement processes that remove waste in production. If the wastes and their interconnection are in fact more complex and less intuitive and predictable in construction, this might also explain the slow uptake of the notion of waste.

THE LOW DEGREE OF STABILITY AND REPETITIVENESS IN CONSTRUCTION FLOWS

Waste can be found both in the transformation, flow and value perspective on production (Bølviken et al. 2014). However, the concept of waste as presented by Ohno (1988) and Shingo (2005) is tightly linked to the flow perspective. They focus on waste in the product flow and in the workflow.³ Their point of reference is manufacturing, and one of Shingo's (1988 and 2005) main points is that the product flow (the flow of the product through production) should have priority over the workflow. Shingo's goal for manufacturing is a continuous one-piece flow, and he sees all deviations from this goal as waste. In this conceptualization the product is flowing through a constant production set up (factory lay out, etc.) and waste is something that can be observed in the flow. It is present over time: Buffers of intermediate products between workstations, products being processed more than necessary, workstations waiting for intermediate products, etc.

In construction, the situation is somewhat different. Here production is moving through the product. There are no permanent workstations and the physical work situation is continuously changing. Waste is therefore also constantly changing and is not necessarily observable over time. First example: A worker is waiting for a drawing and receives it after two hours. The two hours of waiting are waste and can be observed, but only in these two hours. When the drawing arrives and the worker starts working, the waste disappears. If you come back and observe the same worker at a later moment, he will be in a different location and he might be waiting for another drawing, or he might have the drawing he needs. Second example: A piece of work is not done with the proper quality and has to be remade. The working hours and the materials used to produce the insufficient quality are waste⁴. Also in this example we see that the waste is observable at one point in time, but ceases to exist when the rework is completed. Later, new quality problems might occur in other

³ Shingo (1988 and 2005) calls these two flows processes and operations.

⁴ The waste can be quantified as equal to the rework needed to establish the proper quality.

places, or they might not; and if new problems occur, they might be similar to the first quality problem, but they also might not be.

So, we find that while waste in the permanent production layout of manufacturing tends to be something that is constantly present over time, in construction waste tends to be a *parade of singular (unique), evanescent events*.

TEMPORARY ORGANIZATIONS AND A FRAGMENTED VALUE CHAIN

The produce to order logic of the project-based construction industry results in low levels of value loss in the form of products being produced but never used (Bølviken et al. 2014). However, the flipside of the coin is temporary organizations and a fragmented value chain. Often the client is the only party following the entire project, and sometimes even the client can change (e.g. when the project is sold after the development phase). Through his role in the value chain, the construction client should be seen in many ways as an integral part of the construction industry. However, many clients do not see themselves as part of the industry but, as the term indicates, as clients of the industry. Unlike many other industries, the construction industry then finds itself in the situation in which nobody takes the holistic perspective on the total value chain, including a holistic perspective on waste reduction. With the holistic perspective gone, waste reduction becomes something the individual actors in the chain have to handle alone. Reduced to local achievements, waste reduction becomes both less relevant and harder to achieve.

INTEGRATED MANAGEMENT OF INCOME, COST AND RISK

In manufacturing, product development is done with the intent to maximize profit. This implies an integrated dual perspective: the product is developed and designed to be possible to sell at a high price, and possible to produce at a low cost. With regard to production, on the other hand, the management of income and cost is typically divided. Price strategies, sales channels and marketing are the responsibility of the commercial departments of the company, whereas cost, quality and delivery on time is the responsibility of production. Thus, production is to a large degree shielded from design and commercial issues, making it possible for production management to concentrate on production alone.

In construction, as in manufacturing, project development is done with an integrated perspective on price and cost. However, in construction, design, price and cost are also managed in an integrated way in the production phase. The project organization has to manage design issues, the income side (including change orders) and the cost side (payment to suppliers, etc.). This means that the project management has to make a trade-off between how much attention is to be given to each of these different issues. While a factory manager can focus full attention on production, cost and quality, and thereby on waste, a construction project manager will in addition have to focus also on the client, the design process and the income side of the project. In total, this creates a situation where cost management and waste reduction not only appear to be, but actually are, of less overall importance for management in construction compared to management in a factory (in manufacturing). This provides part of the answer to the question raised in this paper: One of the reasons why waste reduction has not conquered construction, is that it is relatively less important for management.

DISCUSSION

Among the topics discussed, one stands out as a particularly different in comparison to the manufacturing-originated discussion on waste: construction waste tends to be a *parade of singular, evanescent events*. This raises some fundamental questions that merit to be initially commented:

1. Is the present conceptualization of waste fully relevant to this *parade of singular events*? And if not, what conceptualization would be relevant?
2. How is *making do* linked to the *parade of singular events*?

Let us start with the last question. Making do refers to starting or doing a task although not all preconditions are present (Koskela 2004). Making do is locally and at the singular point in time a rational strategy to reduce waste, the argument being that “it is better to do something than to do nothing”. However, from the perspective of the production system as a whole, making do can be counterproductive and increase the negative impacts instead of reducing them. It can result in root causes not being addressed and thereby increase rather than decrease negative consequences (Bølviken et al. 2014). In other words: It is the singularity of the waste phenomena in construction that establishes the rationale behind making do as a phenomenon with a dual character, being both rational and irrational at the same time. And it is this dual character that makes making do so difficult to defeat.

Answering the first question, we find that the conceptualization of waste from manufacturing is not fully relevant for construction. Because the waste in manufacturing is present and visible over time, it can be categorized and understood directly and concretely: “This worker is waiting two hours a day”, “there is always a pile of raw materials in front of this machine, etc.”. Because wastes in construction are singular, often evanescent phenomena, they will have to be handled either one by one, i.e. by firefighting, or they have to be grouped into categories with similar features or similar root causes. These categories will, by their nature, have to be more abstract than the classic seven wastes (from manufacturing). Bølviken et al. (2014) categorize the wastes of construction based on the transformation-flow-value (TFV) theory of production (Koskela 2000). In the transformation perspective, waste has the form of material loss, in the flow perspective of time loss⁵, and in the value perspective of value loss. Transformed to a waste reduction strategy, this would mean identifying the main material losses, time losses and value losses, and then launching improvement initiatives that address these wastes.⁶

CONCLUSION

In this paper we have identified and discussed eight reasons why waste reduction has not got off the ground in construction. These reasons show us that the explanation is not simply lack of talent or interest in the industry, but is deeply rooted both in how

⁵ There can be time losses both in the product flow and in the workflow (Bølviken et al. 2014).

⁶ The construction company, in which one of the authors works, has actively used the concept of working-time losses in the implementation of the Last Planner System (Ballard 2000).

we conceptualize production and management (how we see and understand the world) and in what kind of production and industry construction is (how the world is).

The aim of the paper has been to identify reasons. The next step should then be to propose implications in the form of possible actions to take. There are four possible ways to approach these actions. In regard to the explanations based on how we see and understand the world, we can either aim at changing these understandings, or we can seek actions within the present understandings. Similarly, in regard to the explanations based on how the world is, we can either accept the world as it is, and seek options within this framework, or we can try to change the world.

With the danger of oversimplifying, we consider that the solution we seek is most likely to be found by challenging the present (mainstream) understanding and, in so doing, also the fundamental features of the construction industry. Indeed, we contend that in regard to all the eight reasons, progress towards resolution has already started and has for many reasons already provided encouraging results, while initial research and development is needed for some. This is discussed next for all the eight reasons.

Construction management seen as management of contracts. As a countermeasure to this, new production control methods have emerged, based on the idea of construction management as management of production. The prime example is Last Planner System, which strengthens the production management capabilities, even across contractual borderlines.

The culture in construction. Obviously in lean, the thrust is in avoiding variability and variation instead of tackling with realized variability and variation. The Last Planner System contains many features geared towards avoiding problems and mishap. The idea of lean leadership, originating from manufacturing, similarly endeavours to switch the attention to problem avoidance.

The flow perspective understood far less than the transformation perspective. Along with the diffusion of lean philosophy and methods, education and training based on the flow perspective has recently gained foothold in construction. On the other hand, the flow perspective has been emphasized in certain methods, such as location based site management, the Last Planner System, and Takt time.

Classic list of seven wastes not fully relevant. As a countermeasure to this, construction-specific concepts of waste have been developed. The waste of making-do provides one example (Koskela 2004), the proposed understanding of waste based on the TFV theory another (Bølviken et al. 2014).

Complexity of the construction process. Here two directions can be envisaged. First, there is the argument that at least part of the perceived complexity of construction is self-inflicted through inappropriate principles and tools in use (Kenley 2005, Pennanen & Koskela 2005). The associated prescription is to simplify construction management through more appropriate principles and tools. Second, it can be argued that even if causality of waste formation is difficult to identify and predict, it could still be possible to identify patterns of waste formation (Formoso et al. 2015).

Low degree of stability and repetitiveness in construction flows. As argued above, this issue, construction waste tending to consist of evanescent phenomena forming *a parade of singular events*, would seem to be one of the most important, and simultaneously least understood hindrances for waste-based management. This conceptualization raises several questions, among others: Does the term waste have

the same intuitive qualities in construction as it has in manufacturing; and if not, what terms could have the necessary intuitive qualities? Does the removal of this *parade of singular events* demand strategies other than those relevant to waste reduction in manufacturing; and if yes, what sort of strategies could they be? Here, more research and practical development are needed.

Temporary organization and a fragmented value chain. These problems have in recent years propelled many different countermeasures, such as the alliance model, public private partnerships (especially Private Finance Initiatives), and Integrated Project Delivery (IPD).

Integrated management of income, cost and risk. As a countermeasure to this, the contractual models for IPD typically separate income from cost and risk management.

Construction is basically about making something. The fundamental components of this making are to decide what is to be made (development and design) and to actually do the making (production). Waste is part of production theory, but is not present in the mainstream approaches to management and economics. It is only by focusing on production and viewing management and economics as supports of this production (and not the other way around) that we can hope to get waste reduction off the ground in construction.

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