

MEASUREMENT OF WASTE AND PRODUCTIVITY IN RELATION TO LEAN THINKING

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ABSTRACT

In the Swedish construction sector there have been debates concerning what can be done about the current low productivity and the high levels of wastes. During the last few years it has become more common to utilize principles from lean construction as a way to enhance the problems concerning the levels of productivity and waste.

The aim of this paper is to do a literature review on measurement of waste and productivity. Terms waste and productivity will be compared and discussed in relation to lean construction. Furthermore this paper will highlight the use of lean philosophy to reduce waste and improve productivity in the Swedish construction industries. The study shows that the term 'waste' is more closely related to lean thinking than productivity is, but both terms are according to our analysis nonetheless important when striving for cost reductions. Furthermore there is a need of changing in the way of thinking in order to create a value added activities that can cut down production cost in the Swedish construction industries.

KEY WORDS

Waste, productivity, lean construction, Swedish construction industry and performance measurements.

INTRODUCTION

There has lately been a debate on how to reduce the costs for producing buildings in Sweden. The Swedish government has during the last years initiated three major investigations in order to identify various problems in the construction sector. 'Byggkvalitetsutredningen' (1997) focused on general quality-related problems, 'Byggkostnadsdelegationen' (2000) focused on the high costs, and 'Byggkommissionen' (2002) focused on general problems. These three investigations have described problems in the construction sector, but none of them have taken the opportunity to investigate the level of productivity or waste.

During 1963 to 1998, labour productivity within the Swedish manufacturing industries improved by 2.9 % per year, where as the construction sector has improved labour productivity by only 1.7 % per year (Lutz & Gabrielsson, 2002). Lutz and Gabrielsson explain the low productivity to be caused by the low level of competition existing in the Swedish construction sector, which is highly dominated by three major companies. Furthermore, worker unions in Sweden have a strong influence on

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Swedish construction. A plumber hardly cooperates with a carpenter in a building construction project, which leads to an inflexible production process.

Borgbrant explains that the Swedish construction industry has no experience of taking lesson from prior projects (Borgbrant, 2000). Detailed documentation of performance from a prior project is very low (Forsberg, 2007). A problem that comes up in projects and how the problem is solved is neither documented. According to the Japanese production philosophy “Andon”, a problem in a production line is to be solved so that the problem does not appear again. Unfortunately the Swedish construction industry lacks this type of production philosophy.

Production cost in the Swedish construction industries has increased faster than consumer price index (Jonsson, 2005). Production cost in the Swedish construction industry for multi-storeyed building has risen by 65% between the years 1995 to 2001 (Statistics Sweden, 2006). Many reports show that there is a major need of improving efficiency in the construction industries (Jonsson, 2005). Bygghälsögruppen³ (2000) has criticized the Swedish construction industry and states that the industry structure within the building construction has very low competition due to vertical integration, weak competition in the field of import, and high barriers of entry to the market. These factors cause high prices, low productivity and poor quality.

Contractor’s cost is 61 % of the total production cost and of this 36% is wages (SCB, 2003). As labour productivity is the ratio between the output and labour input, it is important to produce more per hour in order to reduce contractor’s cost.

Two principally different ways of reducing the production cost is to either increase the productivity or to reduce waste. These two concepts – productivity and waste – are therefore central when considering improvements. This means that it would be of great importance to compile the present knowledge of the two concepts. The aim of this paper is to do a literature review on measurement of waste and productivity. The terms waste and productivity will be compared and discussed in relation to lean thinking and will highlight the use of lean philosophy to reduce waste and improve productivity in the Swedish construction industries.

HOW PERFORMANCE MEASUREMENTS ARE VIEWED UPON IN LEAN LITERATURE

Measuring performance is not very highlighted in the lean concept, although there are exceptions. Womack et al (1990) did one of the largest benchmarking studies ever when they compared the performance of automotive companies in Japan, Europe and the USA. Later on Womack and Jones (1996) have however come to the conclusion that it is not worthwhile to execute such measurements and comparisons of performance. Instead they advocate companies to focus on improving their processes by implementing lean techniques. This focus on lean implementation without much emphasis on measurements has been common in the lean literature. What usually is measured is the lead-time. In traditional construction lead-time can be compared with production time. Measurements of waste and productivity are more unusual.

The literature of lean construction has similar tendencies, although suggestions of performing measurements are more common here than in the literature of lean production. Koskela (1992) points out that a requirement for continuous improvement in lean construction is that the system can measure waste inherent in the process.

³ Autonomous Commission appointed by the Swedish Construction Industries

Despite that measuring waste is labelled as a requirement, it is rare with these types of measurement systems both in practice in the Swedish construction industry and among the work done by international researchers. The types of measurements that are most commonly referred to lean construction are PPC, i.e. percentage of planned and concluded work tasks (Ballard, 2000). The amount of PPC is to some extent in practice correlated with the level of productivity, although the two types of measurement units in theory are separate. A high level of PPC does not automatically imply high productivity. The reason for this is that high PPC can be reached with lowly set goals. On the other hand, the level of PPC can be low even if the productivity is high if the goals have been too ambitious or if several tasks are completed to 99 %, which would give the same result as if the same work tasks only would be completed to 50 % compared to the plan. However, when scrutinizing what measurements have been performed in research related to lean construction it appears that they, besides measuring PPC, have been scarce.

MEASUREMENTS OF WASTE

In lean production the term 'waste' is often used synonymously with the term 'non-value adding costs' (e.g. Buzby, et al, 2002). Womack and Jones (1996) define waste as "any activity, which absorbs resources but creates no value". Formoso et al (1999) use a construction terminology when defining non-value adding costs as "any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client".

A study which sought to capture the amount of all types of waste in construction projects was done by Josephson and Saukkoriipi (2005). The data gathering consisted of direct observations in four Swedish construction projects mixed with interviews, group discussions and studies of project documentation. The inventories showed that the amount of waste was around 30-35% of a project's production cost. The study did, however, not include any waste appearing in the use phase of the buildings. Waste was divided into four main groups (Josephson & Saukkoriipi, 2005):

- *Defects and checks.* Besides defect costs, this category also included costs for checks, insurance, theft and destruction of property. Waste in this group accounted for more than 10% of the projects' production cost.
- *Use of resources.* This category included inefficient use of labour, machines and materials. This waste corresponded to more than 10% of the projects' production cost.
- *Health and safety.* Waste associated with work-related injuries and illnesses represented about 12% of the projects' production cost. The greatest portion of the cost was for rehabilitation and early retirement, which indirectly add extra cost to projects via taxes.
- *Systems and structures.* Waste related to the structure of the construction industry, such as long land use planning processes, extensive purchasing processes and a great deal of documentation, together corresponded to approximately 5% of the projects' production cost, although this category was thought to be underestimated in the inventory to a high extent.

Another major study of waste has been done by Alwi (2002), who studied the Indonesian construction industry. Several types of waste were identified through

questionnaires and in a second stage the causes to the wastes were identified. The measurements of waste were, however, limited to the use of resources (labour, machines and materials) on site.

Other studies of waste or non-value adding costs in construction have only investigated the activities in the design phase and at the site with research methods that have not been as detailed and precise as the two studies mentioned above (Lee et al, 1999; Hall & Tomkins, 2001; Zhao & Chua, 2003). In addition to these studies there are several examples of research on single part of the overall waste in construction. Such parts are material waste (Lindhe, 1996; Bossink & Brouwers, 1996; Garas et al, 2001; Formoso et al, 2002) waste in labour time (Agbulos & AbouRizk, 2003; Orth & Jenkins, 2003) and poor-quality costs (Burati et al, 1992; Nylén, 1996; Abdul-Rahman et al, 1996; Josephson & Hammarlund, 1996; Barber et al, 2000).

A conclusion that can be drawn when reading publications of previous studies is that their measurements of waste have mainly been limited to production at site. Is this a relevant view of wastes in construction? Since a large part of the resources are consumed in the production at site, it is naturally important to consider waste among these resources. But if the measurements are limited to these parts, it means that wastes occurring at other parts are overlooked. Such other parts which usually are overlooked are: work done in the supply chain of the material suppliers; the use phase; work done in supporting activities such as administration; and other activities which are financed by construction projects, e.g. all activities in the public sector, trade organizations, insurance companies, etc. Since the concept of 'lean', and thereby the term 'waste' as well, in the past primarily has dealt with factory physics (i.e. how the production should be structured) it is perhaps not very surprising that measurements of waste also primarily have focused on production. But this should be no excuse for not considering waste being present in other parts of the involved organisations.

MEASUREMENTS OF PRODUCTIVITY

There is disagreement about the proper definition of productivity within the construction industry. Jergeas et al. (2006) describe productivity as a comparison of input and output. They furthermore mention that an increase of productivity is when the input is reduced to achieve the same output. Calvert et al. (1995) describe work measurement or labour productivity as the determination of the time required for an average operative to carry out a particular task in accordance with a specified method and standard of performance.

Productivity or lack of it is a major challenge facing in the construction industry (Adrian, 1999). Construction is a labour-intensive process and in absolute terms labour is the only productive resource in construction (Jergeas et al., 2000). As we mentioned earlier 36% of total contractors cost is to cover labour wages. Therefore construction productivity greatly depends on human performance (Laufer et al., 1982). But unfortunately labour productivity in the Swedish construction industries is very low compared to other industries (Lutz & Gabrielsson, 2002). Time used by a worker on productive activities averages about 30% of the total time available for construction work (Alinaitwe et al., 2005). Hammarlund and Rydén (1988) performed a similar study in the field of HVAC. According to their research, a worker in this

field produces value to the work during 3.5 hours of his 8 hours shift. Strandberg and Josephson (2005) show that less than 20% of the workers' time is spent on directly value-adding activities. It can be questioned about their methodology in measuring labour productivity.

Thomas argues that the amount of time spent in direct work is not related to productivity (Thomas, 1991). Causes to low productivity are default management of machines, wrong material, delayed material delivery, high reserve stock and ineffective distribution of workforce and material costs. Contractors often aim at short-term high revenue, "*It is important to remember that productivity is often more of a marathon, not a one hundred yard dash!*" (Adrian,1999). Substandard working organization is a possible cause to this low labour productivity (Lutz & Gabrielsson, 2002).

RELEVANCE OF MEASURING WASTE

There are several problems with measuring waste. It is difficult to measure the cost of some negative aspects that do not have a clear monetary value, e.g. drawbacks of the structure of the construction industry, the mental and physical pain due to ill health and environmental costs. Besides, there can be a demoralizing effect on employees if they hear that their work tasks are wasteful.

There is also a problem with using the term "waste", since it does not give an accurate description of the cost reduction potential. First of all, there can be cost reductions by rendering the value adding tasks more efficient. Secondly, there are costs that do not add any direct value, but which indirect value can be significant, e.g. some managerial tasks and non-value adding activities that result in increased knowledge. Thirdly, the focus on costs is one-sided. A total economic analysis should as well consider the revenues and the costs for alternative solutions in order to know what actions to take.

With all these problems with measuring waste one could question whether these kinds of measurements are relevant? It is most likely not meaningful to conduct complete measurements in every building project since this would cost too much and thus increase the amount of waste. However, this does not mean that there never should be any measurements. Measuring waste leads to facts that can be used when a company, an industry or the entire society decides how to render activities more effective. Without this kind of facts it is difficult to know what measures to take. Thus it is important that some measurements are performed. In addition, it can be valuable to think about which activities are wasteful without actually doing any detailed studies. Just considering about activities in terms of value and non-value adding could be helpful when trying to achieve cost reductions.

RELEVANCE OF MEASURING PRODUCTIVITY

Since construction is something that concerns most people and labour cost is a large part of the contractors cost, labour productivity has become a subject for debate (Jonsson, 2006). Manufacturing industries has taken the advantage of reducing production cost by improving productivity; the question can be asked whether the

construction industries can do so. SBUF⁴ has started a project to find out whether the Swedish construction industries measure labour productivity or not (SBUF, 2005). Borgbrant and Lugnegård state that there is a major difference between how the site managers and workers measure labour productivity (Borgbrant and Lugnegård, 1994).

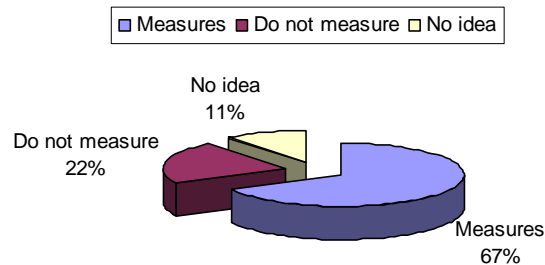


Figure 1: Proportion of Swedish companies that measure labour productivity (Forsberg, 2007)

According to an ongoing survey among 85 site managers and high officials in four construction firms in Sweden that has a traditional way of building, 67 % state that they perform labour productivity measurement (Forsberg, 2007). On the other hand, 11 % state that they have no idea whether they measure productivity or not (see figure 1). It is to be mentioned that these respondents state that they measure labour productivity but Forsberg (2007) is not clear about what they really meant by measuring labour productivity. The survey shows that these respondents measure labour productivity in order to pay salary to their craftsmen, not as a purpose of improving productivity (Forsberg, 2007).

On the other hand, construction firms that build houses in an indoor plant state that labour productivity measurement is an important part of their process development. It is to be mentioned that these companies are total or semi automated house builders and thus have more in common with the other manufacturing industries than with traditional construction companies. These companies are measuring labour productivity in order to reduce production cost. Älvsbyhus, a single timber house builder, has reduced manufacturing cost by 3% per year by improving labour productivity (Blomgren, 2007). Tomokuhus perform labour productivity measurement and has improved their labour productivity by 6% in the year of 2006 and succeeded to keep their sell price to a constant over 16 years (Pettersson, 2006). Lindbäcks Bygg, a multi-storied house builder, has a similar way of thinking. According to the plant manager, “*productivity is the unit of fulfilment of the company target*” (Lindbäck, 2007).

Labour productivity measurement provides useful information to contractors for scheduling and estimating purposes on future projects (Alinaitwe et al., 2005). Construction cost can be best carried out by labour productivity as labour cost is up to 36% of the total contractors cost. A conclusion can be drawn that productivity measurements are an important tool to improve overall company results. However, it is not enough only to perform measurement. The results of the measurements should also be used to improve productivity.

⁴ Svenska Byggbranchens utvecklingsfond (The Development Fund of the Swedish Construction Industry)

COMPARISON OF WASTE AND PRODUCTIVITY

One way of comparing 'waste' and 'productivity' is to see where the terms originate. The aim to reach high productivity is strongly correlated to traditional mass production or what is called the transformation concept of production. Koskela (2000) states that "it is also instructive to note that the [transformation] model is directly associated with the notion of productivity, e.g. the ratio of output to the input (or a particular part of it) in a given time period". A focus on solely productivity would therefore result in the aim to efficiently produce as much as possible with the given resources. It is such a focus on productivity alone that the literature of lean thinking strongly criticizes since this kind of focus tends to result in huge amounts of waste in the production process (e.g. Liker, 2004; Womack & Jones, 1996).

During the last 15 years the term 'waste' and its synonym 'non-value adding activity' have been used as an integral part of various concepts such as poor-quality costing (Harrington, 1999), activity-based costing (Tsai, 1996), business process redesign (Knorr, 1991), and the value-creation model (McNair et al, 2001). The term 'waste' has, however, most frequently been used in the lean literature. Even though the term was referred to already in 1921 in the "Report on Elimination of Waste in Industry" (Anonymous, 1921) it is within lean thinking that the idea of eliminating waste has grown into a fundamental cornerstone (Womack & Jones, 1996).

When trying to optimise production it is important to consider aspects of both flow and transformation. Shingo (1988) points out that processes (flow of products) and operations (transformations done by workers and machines) are both essential. Traditional mass production is usually heavily criticized in the lean thinking literature (e.g. Womack & Jones, 1996), but despite the criticism there are basic principles in mass production that are worth considering, even from a lean perspective. To reach an efficient work on the value-adding tasks is such a principle that should be important to all companies, no matter how lean they are. Likewise it should be of significance for all companies to eliminate waste.

CONCLUSION

Measurements of productivity and waste can complement each other. The fundamental reasons to study waste and productivity are the same, which is to get more information about the current state so that improvements can be achieved. Therefore considering the levels of waste and productivity can both be useful.

As the Swedish Construction Industries have been criticized for its low labour productivity and high level of waste, it is important to highlight the issue to do something about it. Expenses like labour wages and cost of material is difficult to control because of high level of construction demand caused by the strong economical growth in the Swedish economy in the recent years. Hence labour productivity can be improved by improving human performance. Tomokuhus and Lindbäcks bygg states that measurement of waste and labour productivity is closely related to lean thinking and in a near future they will apply lean philosophy in their production process for additional improvement of labour productivity.

The Swedish construction industries need to change their way of thinking. A continuous process of labour productivity measurement and an effective analysis of the measurement results are important. Furthermore these results should be used in order to improve productivity. A better level of labour productivity will automatically

upgrade the level of value added activities and thereby can reduce waste and cut down production cost. The Swedish construction industries have an old and substandard organisation structure and need an updating. A better understanding of lean thinking is necessary in the executive level so that the flow of change can reach the production level.

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