INTEGRATED INWARD LOGISTICS AND CONSTRUCTION WORK AND ITS IMPACT ON EFFICIENCY IN PRODUCTION

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ABSTRACT

We address a main contractor's implementation of organising logistics, as part of the contractor's transition to lean construction. Our research question is 'How to identify improvements in production, on the basis of different external logistics and material flows?' Engineering logic is applied in the paper, which builds on data from a case study. We discuss how to measure changes in production workflow efficiency, and relate this discussion to different external logistics arrangements. We only partially succeed at answering our research question in this paper, but useful experience for increasing the reliability of future measurements has been gathered, and means of improving validity have been identified.

We expect practitioners to find the paper useful because of our logistics focus and method for measuring impact of logistics on production. Academics are expected to find value in our conceptualisation of the relationship between external logistics and construction work.

KEY WORDS

External construction logistics, production, construction work, workflow efficiency.

INTRODUCTION

Improved logistics solutions is one of the ways in which construction projects can be made leaner, by increasing efficiency and thus reducing waste. Identified issues in this context include the need to increase reliability; reduce inventory; reduce lead time; and reduce waste, damage and injury (Koerckel and Ballard 2005). Elfving and Ballard (2010) claim that production reliability is a main prerequisite for expedient logistics. Hence, production planning could be regarded as a process that needs to be an integral part of logistics, and vice versa. Construction in physically constrained sites with intensified focus on logistics (e.g. in city centres), seems to achieve cost reduction, safety improvements, better utilisation of prefabrication, and other efficiency savings. However, even the design process is then focussed on seeking

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more easily constructed solutions, which includes exploiting the benefits of prefabrication (Mossman 2008).

Establishing logistics centres has been described as an approach with potential benefits for construction industry (Hamzeh et al. 2007). Logistics centres may be configured in several ways, which provides the opportunity to find the best possible match with company strategies. When efficiently designed, such logistics centre solutions can lead to improvements across a wide spectrum of conditions and activities, including storage, transport, distribution, assembly, kitting, consolidation, sorting, breaking bulk, cross-docking, and e-commerce. For high-volume low-cost made-to-stock materials, using vendor-managed inventories (VMIs) has been found to represent an effective and cost reducing solution (Elfving and Ballard 2010). According to the same authors, a number of reports have been written on how to improve logistics at the level of the individual project. However, there seems to be a lack of ability to generalise these findings. Logistic solutions need to be a corporate-level duty in order for their benefits to reach beyond the test projects in which they are tried out, according to Elfving and Ballard (*2010*).

To achieve improved logistics, quantifying improvements or results is important. Kalsaas (2010) refers to a Finnish study of a high-rise construction project measuring the effect of different ways of organising the packaging of doors and windows delivered to the construction site. Significant efficiency savings were documented when components were packaged according to storey of mounting, rather than as batches containing components of the same type.

We expect improvements to logistics and its organisation to result in a better production workflow. Furthermore, decisions made on a strategic level should aim at achieving a good production flow. Cheaper procurement is not a satisfactory measure if the sub-savings made, lead to higher total costs by negatively influencing the construction sites. In this paper we focus on how improvements and changes to the logistics of a construction site can be measured in the shape of improved production flow.

The case studied is a residential building project undertaken by Skanska Norway in an area called Østensbulia B, on the outskirts of Arendal. The project involves the construction of 54 residential units, at a total cost of some 105 million NOK. Skanska is both owner and main contractor of this project. The project focuses on green building techniques, and some of the units are constructed to meet a Norwegian standard for "passive houses". "Passive houses" are buildings where the net consumption of energy is close to zero. The Skanska Group has a department in Arendal that covers both small single residential homes and larger residential building projects. According to Skanska, the company is known for its high quality and stable workforce, and this, in addition to sound economic results probably accounts for its survival in a tough domestic market dominated by small local firms. At Østensbulia, the company employs its own carpenters and skilled workmen within concrete and tile work, whereas the rest of the work is outsourced to subcontractors. The carpenters are divided into different teams at the Østensbulia project. Each team is paid according to its performance, based on production volumes (piecework contract).

The paper is organised as follows: First, Skanska's strategy and ideas about improved logistics at the industrial group level in Norway are described. This is followed by an account of ways of measuring logistics impacts on the production, and

a discussion of these. An account is then given by a series of such measurements before, finally, conclusions are offered.

INTEGRATING LOGISTICS AND PRODUCTION PLANNING AT SKANSKA NORWAY

Skanska's strategy is to increase its operational efficiency by making improvements in the areas of procurement and logistics. It is argued that the attention needs to be widened from a one-sided focus on the cost of materials,to the complete installation costs. The current status is that the integration between production planning and logistics planning is very limited, and that the control over the logistics process, information and physical handling is perceived as insufficient. The result is assumed to be batch sizes that are uneconomical, unnecessary on-site waste, and low productivity. The lack of standardised logistics solutions also hampers the possibility of a possible supplier development program.

Make-to-stock (MTS)[7] products are an important factor in Skanska's projects. The company strategy is to develop logistics solutions for each product group on a corporate level rather than rely on project-specific customised solutions. The idea is to deliver the correct quantity of MTS products directly to the place of installation. The coordination of deliveries will be taken care of by a consolidation centre (terminal).

The Reversed Phase Scheduling (RPS) method is considered to be an adequate tool for informing logistics. When the RPS is completed, it provides the information needed to calculate accurate volumes of the different products directly linked to the location involved.

A possible disruption to the planned start-up date for production will be monitored through the lookahead-plan up to 3 weeks prior to the set date. The monitoring of the need for materials 3 weeks to 7 days into the future is followed up by the foremen and their weekly plan. The main principle behind coordinated deliveries is that the materials will not be transferred from the terminal to the construction site until they are needed. The evaluation of total costs is part of the procurement process. Deviation from planned start-up times may mean that deliveries need to be held back from suppliers or terminals.

Diversion of blue-collar workers at shorter than one week's notice has been a challenge since both activities and coordinated deliveries are planned for one week at the time. The consequence has been a shortage of materials needed for the buffer activities, and a corresponding need to place rush orders in to get the materials needed at the site. Pre-cutting, attention to packaging details, and improved predictability will have a direct impact on production efficiency.

Standardised processes for the reception of goods and the on-site handling of materials can reduce the non-value adding activities, cut the waste which occurs through damaged materials, and improve safety levels. This is achieved as a result of the materials being handled by people dedicated to and trained for that particular job, and of reducing the relocation/moving of materials to a minimum..

[7] Based on a portfolio analysis Skanska has pro procurement purpose grouped construction material into 'make-to-order' 'make-to-stock', 'frame agreement' and 'spot buying'.

THE ØSTENSBULIA CASE

The Last planner system is not used at Østensbulia; hence the described logistics solution is not activated. Rather, the foreman draws up a plan for the next 3 weeks, which he then presents to and discusses with the different internal teams. The subcontractors are given a couple of days' advance notice when their work is needed. The foreman feels that it is difficult to set specific dates for the accomplishment of each task. He feels the plan unreliable, and waits to inform the subcontractors until as close to the date of their involvement as he considers reasonable. The foreman performs a variety of tasks to help with the production, including shopping for materials and equipment.

The project management at Skanska believes that the faster production might be achieved by having each team perform a single task across several buildings. Nonetheless, they have chosen to give each team the responsibility for a specific building from start to finish. This is both to reduce the risk of strain injuries as a result of monotonous work and workdays, and because it results in greater involvement in the finished product – plus it creates a certain amount of internal competition between the different teams.

An interview with the subcontractors (Grepperud and Hinlo 2011) indicated that they wanted greater involvement in the project, and that they felt that their work should be less fragmented.

HOW TO MEASURE IMPACT FROM LOGISTICS ON PRODUCTION

The method of measurement – or instrument – which is applied is designed to measure changes to the time spent on different activities in the production process at the level of details. An exhaustive description of the method is given in Kalsaas and Bølviken (2011). Briefly, the method is to make a detailed record of the workmen's time-use before and after implementation of changes. A registration of activities is made every 5 minutes over the course of several full working days, and involving several workmen as objects of study. The categories guiding the data registration are grouped, among others, into the following categories: Direct work; Indirect work, Planning and HSE; Visible waste; Personal time, coffee and meal breaks. Furthermore, Indirect work is sub-divided into Rigging and cleaning and Material logistics. These categories are shown in detail in Table 1, which also shows anticipated changes to the variables before and after implementation of logistics improvements. In addition, making the indirect work more efficient can be expected to result in more time being available for performing direct work, unless other factors cancel out the savings. In this project, there is a particular emphasis on developing categories of measurement that capture logistics-related activities. An attempt to calculate workflow was performed before and after introduction of changes.

Table 1 Construction activities and expected impact from improved logistics

DIRECT WORK ACTIVITIES	Possible impact of improved logistics
Direct work	A greater proportion of the working day can be spend doing direct work
Crane operation etc. as part of direct work	The expected impact depends on whether the decision is to increase or decrease the use of a crane, and on the type of crane

Collecting materials within a radius of 12 metres	A certain reduction can be expected if the materials are placed even closer to where they are needed, thus allowing the other types of direct work to increase.
Inspections and control	No expected impact as a result of logistics changes
INDIRECT WORK ACTIVITIES	
Rigging (up and down)	Improved logistics may help reduce the recourse to 'making do' solutions, thus also reducing the rigging work
Rigging, weather-related	Reduced storage of materials can be expected to reduce the man-hours needed for tasks such as recovering materials after snowfall and protecting them against the weather.
Clearing to allow access to materials and workplace	Reduced storage of materials on the building site will make it easier to get access to the workplace.
Cleaning up after work	No expected impact as a result of logistics changes, but important for the overall flow
General tidying-up work	Reduced storage of materials on the building site can reduce the time spent tidying.
Receiving materials and procedures related to this	A reduction of the time spent receiving materials can be expected to result from increased reception precision and predictability, more adequate packaging, etc.
Unpacking materials	Adequate packaging can be expected to reduce this factor
Collecting materials using a trolley or similar	The expected impact depends on whether the decision is to increase or decrease the use of a trolley
Collecting materials beyond a radius of 12 metres	Considerable savings can be made by improving the way materials are distributed across the construction site
Carrying waste to skip/container	Adequate building site layout and a reduction in damage to materials can be expected to lead to a reduction in this activity
Transferring between places of work	If improved logistics lead to a great degree of predictability, an reduction in the use of 'making do' solutions can be expected, thus reducing the number of transferrals between places of work. See also the comments under 'Rigging'
Moving and fetching tools	Ditto
Moving to/from saw with mitre gauge, and similar	Layout improvements can be expected to have a positive impact
Moving excess materials (not included in Table 2)	Considerable improvement can be expected as a result of better logistics solutions with better adaptation of material volumes and more careful consideration of the on-site storage of such materials
Crane operation etc. as part of indirect work	Improving the adaptation of the material volumes to the production needs at any given time can be expected to reduce the need to use a crane to move such materials.
SECURITY AND COORDINATION	
Securing work, outside	Reducing the volume of materials stored on the building site can have a positive impact on safety, but is not expected to be measureable in terms of a reduction in the time spent on securing the site
Planning meetings	A greater integration between logistics and procuring and production can increase the time needed for meetings and coordination somewhat.
HSE meetings and similar	The need for meetings may be somewhat reduced as a result of a tidier construction site, but the impact is not expected to be measurable

Construction site coordination	An indirect impact can be expected, in that the coordination work is made easier by a greater degree of predictability in relation to the delivery of materials, and through the reduction of 'making-do' solutions.
COUNTERPRODUCTIVE WORK ACTIVITIES AND UNUTILISED TIME	
Correcting mistakes	Logistics impact expected to be negligible
Correcting mistakes made by different team/trade	Ditto
Waiting/downtime	Greater predictability in relation to the delivery of materials can reduce the time spent waiting
Unutilised time	Not directly related to logistics, but greater predictability in relation to the delivery of materials can have a motivating effect on the workmen
PERSONAL TIME	
Coffee and meal breaks	Unrelated to logistics
Essential/necessary personal time	Ditto

EMPIRICAL ANALYSIS

Based on the observations made at a construction site during the first series of measurements, a number of possible approaches to increasing the proportion of direct work were identified in dialogue between researchers and main contractor:

1. Marking and delivery of building materials straight to the right building
2. Lifting of building materials by crane up to the storey where they will be needed (before the closing of the building)
3. Introducing backward planning in cooperation with the subcontractors
4. Introducing team-specific tool containers
5. Ensuring that each building has waste skips/containers nearby
6. Ensuring that each building is connected to electricity sooner
7. Introducing VMI (Vendor Managed Inventory) (Elfving and Ballard 2010)
8. Pre-cutting materials

In dialogue with the main contractor a decision was made to try out the first three of these possible approaches. The second series of measurements was performed to uncover any detectable changes in the time-use at the building site that might be attributed to the implemented changes.

Gangs of workers were rearranged between measurements, hence measurements were not performed on the same gangs twice. Two experienced workers were measured from each gang. Measurement duration was 8 days in the first measurement, and 5 days in the second. Due to practical limitations, the activities executed during the two periods, were not exactly the same. This is a weakness to the method, and as commented below it is anticipated to have influenced the measurements. The data was collected and partly processed by Grepperud and Hinlo (2011).

The most striking change from the first to the second measurement is the reduction in direct work (line 1), and a corresponding increase in the figure showing

indirect work (line 5 and 21). However, this change is not the result of any of the new approaches that were introduced. It was caused by major indirect work performed during the second period of measurements. This was partly due to heavy snowfall, which meant that the snow had to be cleared before ordinary work could resume (line 8); and partly, it was due to the building of a large scaffolding structure which will benefit the direct work category for the rest of the construction period (line 9). This exemplifies that making measurements at an actual construction site is not exact science, as registrations made at two different points in time are influenced by a number of variables in addition to the implemented changes one wants to monitor the effects of.

Table 2. Comparison of the measurements made before and after the intervention

		1st measurement percentages	**2nd measurement percentages**
1	Sum Direct work	58	50
2	SUM Counterproductive work activities and unutilised time (Visible waste)	8	8
3	SUM Safety and Coordination	5	3
4	SUM Personal time	11	10
5	SUM Indirect work	19	28
6	**SUM**	**100**	**100**
7	**INDIRECT WORK:**		
8	Rigging, weather-related	0	2
9	Rigging (up and down)	5	10
10	Clearing to allow access to materials and workplace	2	1
11	Cleaning up after work	0	1
12	General tidying-up work	0	3
13	Receiving materials and procedures related to this	1	0
14	Unpacking materials	1	0
15	Collecting materials using a trolley or similar	0	0
16	Collecting materials beyond a radius of 12 metres	4	5
17	Carrying waste to skip/container	1	0
18	Transferring between places of work	0	1
19	Moving and fetching tools	3	5
20	Moving to/from saw with mitre gauge, and similar	0	1
21	**SUM Indirect work**	**19**	**28**

The analysis of the three implemented approaches is conducted below.

Approach 1: Marking and delivery of building materials straight to the right building. The figures show that recovery of materials from central storage sites constitutes a significant share of the worked total (4%), allowing the identification of a potential for considerable improvement in material logistics. If this approach proves successful, the time spent collecting materials within a 12-metre distance from the building should increase and consequently reduce time for collecting materials from the central storage site (12m-limitation set according to rules for piecework contract).

Demands towards the suppliers were made stringent. When the second series of measurements was conducted, we observed a significant increase in the amount of materials stored in the immediate vicinity of the buildings. The measurements also show that the time spent collecting materials within the 12-metre radius had more than doubled, even though the figures are small (from 1.1% to 2.6% - Table 2 does not show details under the main category of Direct work; the figures are therefore taken from logged measurements underlying the listed category). The increased figure for collection within the 12-metre radius seems to indicate that collection within each building has replaced collection from the central storage site.

Opposite to expectations, the measurements show that the time spent collecting materials from the central storage site also increased somewhat over the same period (from 4.1 % to 4.9%). The increase can be attributed to the fact that the work conducted during the second series of measurements was of a different nature from the work conducted during the first series. The total need for materials was larger for the work conducted during the second round of measurements. This explains why there was an increase for both short and long distance collection of materials. Yet, the relative increase of time spent on collection within the 12-metre radius is large enough to indicate that such handling of materials has at least in part replaced the indirect work of collecting materials from a more distant central storage area.

Appr 2: Delivery of materials by crane directly to the storey they were needed (before closing the building). An agreement was made between the building site management and the management of the main supplier. The idea was that this would reduce the man-hours spent on vertical manual transportation of materials. However, the communication about this approach was insufficient, both in relation to the supplier's driver and the construction workers. Consequently, this measure was not implemented within the period covered by the measurements.

Appr 3: Introduction of backward planning in cooperation with the subcontractors was expected to contribute significantly to improving the coordination between the different contractors (turned out unsuccessful). This should help ensure the following:

- That each place of work is made ready and available for the next team at the agreed time – thus allowing each trade to utilise the working day in a rational way, and preventing conflicts with other trades over the same physical area.
- That materials are delivered at the correct time and to the correct place in relation to assemblage work – thus reducing temporary storage and waiting.

- That errors are avoided – thus reducing the need to spend time correcting such errors.

The introduction of backward planning was also expected to have an educational effect, by those involved expected to see the advantages of this approach and therefore continue to pursue it.

One of the subcontractors was already familiar with backward planning, and was welcoming introduction of this approach at the Østensbulia project. However, the construction site management had no prior knowledge of the method, and were reserved about trying it out, pointing out own need for greater competence in the use of planning tools. This lead to a situation where even the most experienced subcontractor was unable to place his activities on the time axis, as relevant milestones was not communicated by the construction site management. Thus, the attempt at visual and well-structured planning was unsuccessful. The large increase in time spent on general tidying up (3% - line 12 in Table 2) demonstrates the need for better coordination, as it was mainly caused by an incident where unaware that delivery had been arranged for 12 noon, a team of carpenters ended up spending half a working day waiting for the roof trusses they had come to install, and carrying out sporadic tidying-up tasks while waiting.

Although the implementation of reverse scheduling (phase planning) can hardly be characterised as a success, all of the contractors participated in the planning meeting, and many factors involving the different actors were clarified. In sum, the subcontractors reported that the reverse scheduling effort was useful due to the clarification of factors which had been unclear prior to the meeting. However, it also seems clear that the backward planning approach will not be pursued any further at this particular building site.

VALIDITY AND RELIABILITY

In Table 1 we have included the category "Moving excess materials". It is not included in the actual measurements, however, and is hidden among the other categories describing indirect work. Based on the experiences from this project, it should have been included, as a significant amount of resources are tied to such activities, exemplifying the type of "hidden waste" which can be driven out of the production process by improved logistics. In terms of validity, consideration should be given to removing the category of "Collecting materials using a trolley or similar", since it overlaps with the other collection activities. Using tools for moving materials could be included as an improvement measure. Collecting materials needed for one's work is a natural part of a work process, but suggesting that the time spent "Collecting materials within a radius of 12 metres" should qualify as part of direct work might represent an exaggeration of the reasonable distance within which materials should be located. Nevertheless, we have chosen to keep this definition as it conforms with the Norwegian piece-rate agreement for carpentry work.

The measurements conducted before and after the interventions exemplify the kind of problems which can occur when measurements are not conducted in a laboratory with controllable framework conditions, and where changes to the parameters produce greater effects than the targeted interventions. Also, the interventions were not implemented according to the intentions. Moreover, we did not have the opportunity to conduct measurements on the same teams before and after the

interventions; thus, the reliability of the data is less than optimal in terms of comparability from that particular perspective.

Consequently, the result should above all be regarded as a contribution to the mapping of time-use related to the different activities. In order to optimise data reliability, thus allowing comparisons to be made between data collected during different periods of measurement, it is crucial that the measurements are made using the same teams as subjects, since different people have their individual ways of performing their work. Furthermore, it is of course optimal if the same (type of) activities can be measured before and after the intervention. However, even if these conditions are not met, measurements are not wasted as part of a continuous improvement effort where the identification of potential improvements is discussed after the first series of measurements with the workmen involved. Another alternative is to conduct measurements over a longer time span in order to correct for untypical events/activities, or to leave such untypical activities – e.g. the major rigging work taking place during the second round of measurements – out of the measurements.

CONCLUSIONS

We have not fully succeeded in providing an answer to our research question in this paper: "How to identify improvements in production, from different external logistics and material flows". However, a series of useful experiences have been gathered, and the outcome demonstrates the challenges involved in measuring the impact of targeted interventions at a building site where the parameters keep changing. In the studied project, other conditions had a greater impact than the targeted measures. We have identified the following factors as keys to improving the reliability of this type of measurements:

- If possible, measure construction activities which are approximately identical
- Increase the duration of the measurement period; however, this can be a rather resource-demanding approach
- Correct the measurements for factors which cause an obvious reduction of reliability
- Measure the same teams before and after the intervention
- Introduce the changes/intervention with great discipline, and make sure that the changes have been accepted by those who will be implementing them.

In terms of the changes which were introduced, or attempted introduced – in this case, reversed scheduling – our material demonstrates the crucial importance of having the backing of the project management. However, one might also argue that this measure had an in-built weakness in that reversed scheduling only constitutes one of several elements in the LPS approach, and that introducing it in isolation was not sufficient.

The paper helps establish a detailed baseline for time-use related to different construction activities. This is an important factor in making it possible to measure workflow and waste reduction in construction. This baseline can be used for later measurements which are part of the same project, or it can be used in the context of comparable projects.

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