IMPROVING THE MAKING READY PROCESS - EXPLORING THE PRECONDITIONS TO WORK TASKS IN CONSTRUCTION

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ABSTRACT

Scheduling in construction is complex. Before an activity can be conducted, a number of preconditions first have to be fulfilled. In Last Planner System this removal of constraints is referred to as the making ready process. To ensure that this process is running, the preconditions need to be known. Therefore, in an attempt to bring these preconditions into light three construction projects have been followed. Here reasons for non-completed activities have been collected. In total 5014 activities have been registered whereof 1279 was not completed according to schedule. Afterwards the non-completed activities were sorted into nine main categories. The six of the categories are basically corresponding to the ones presented by Koskela (1999), while the last three are an expansion of Koskela's external condition category. The preconditions are as follows: 1) Construction design and management. 2) Components and materials are present. 3) Workers are present. 4) Equipment and machinery are present. 5) Sufficient space for conduction. 6) Previous activities must be completed. 7) Climate conditions must be in order. 8) Safe working conditions in relation to national "Health and Safety at Work Act" have to be present, 9) Known working conditions. Often a problem during excavations or refurbishment assignments where existing conditions first has to be examined. One of the major and underlying reasons to non-completed task is insufficient and even bad scheduling. Often non-sound and out of sequence activities are selected to the Weekly Work Plans. When conducting the schedule it is important to notice as described in Lindhard and Wandahl (2011) that the soundness of an activity can vary over time. By focusing on all nine preconditions a more robust schedule can be achieved. A more robust schedule induces an increased percent planned completed level and moreover and increased productivity.

KEYWORDS

Lean Construction, Preconditions, Constraints, Last Planner System, Making Ready,

INTRODUCTION

Lately production in construction is undergoing a transition from traditional construction to Lean Construction. This includes among others the implementation of Last Planner System (LPS). Since LPS is based on Lean-thoughts, these thoughts gains acceptance in the industry. One of the central elements in lean is the focus on

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product flow and the elimination of non-value adding activities; in other terms removal of waste. Ohno (1988) stated that the total capacity of a production system equals the sum of work and waste, he furthermore identified seven different types of wastes. These are showed at the list below. In the list the first five elements refers to the material flow while the last two refers to the human work flow (Koskela 2000).

- Waste of overproduction
- Waste of stock on hand (Inventory)
- Waste of transportation
- Waste of making defective products
- Waste of processing itself (Over-processing)
- Waste of movement
- Waste of time on hand (Waiting)

Waste can be categorized into both necessary and unnecessary waste, where necessary waste still is necessary for production. Necessary waste is still waste and should be minimized. An example on waste which sometimes is necessary could be transportation (Choo and Tommelein 1999). Choo and Tommelein (1999) furthermore claims that transportation sometimes can be cost-saving for instance when transporting materials to more effective off-site production facilities.

Additionally both Christiansen and Ahrengot et al. (2006) and Koskela (2004, 2000, 1999) suggests extra sources to waste. The suggestions include: not to fully utilize the mental capacity of the employees, making-do where assignments are started when at least one input is ceased, and work performed in suboptimal conditions. Koskela (1999) lists a number of conditions which leads to suboptimal working conditions: Congestion, out-of-sequence work, multiple stops and starts, inability to do detailed planning in advance, obstruction due to material stocks, trying to cope without the most suitable equipment for the task, lack of planning and preparation, interruptions due to lack of material, tools or instruction, overtime, oversizing crew.

Implementation of Last Planner System (LPS) on construction sites has induced a growing interest in construction constraints. If the constraints are not removed they will lead to unnecessary waste which will surface as waiting, movement, transportation etc. Therefore, construction constraints do have a central role in the making ready process (Lindhard and Wandahl 2012). The purpose of the making ready process is to make activities sound. The making ready process starts when activities enter the Look-ahead window. Here, focus is on the individual activity where constraints are identified and removed (Jang and Kim 2008).

When all preconditions are fulfilled an activity is moved to a backlog of sound activities. When conducting the Weekly Work Plans only activities from the backlog are selected. This secures that only sound activities are moved to the Weekly Work Plans (Hamzeh et al. 2008; Steyn 2001; Ballard 2000; Howell and Ballard 1994). According to theory the backlog should be kept at minimum two weeks (Ballard 2000). This is to ensure that enough sound activities can be moved to the Weekly

Work Plans to match capacity and moreover enough ready work to buffer against unexpected constraints in the sound activities (Ballard 2000; Ballard 1997).

If just one precondition is not fulfilled an activity is not sound and cannot be conducted. Without the making ready process and without proper knowledge to the preconditions there is no guarantee that only sound activities end up in the Weekly Work Plans. Thereby unreliability has entered the schedule which leads to a high level of non-conformances and results in demotivated workers and moreover productivity decrease (Ballard 1994). To secure that the sounding process is progressing, in order to maximize productivity, the site-mangers need to know and understand the preconditions in construction.

There is a need for exploring the preconditions in construction in order to understand and improve the making ready process. The preconditions to ready work were first mentioned by Koskela (1999) which found seven preconditions. Koskela's seven preconditions are listed below.

1. Construction design; correct plans, drafts and specifications are present
2. Components and materials are present
3. Workers are present
4. Equipment and machinery are present
5. Sufficient space so that the task can be executed.
6. Connecting works, previous activities must be completed
7. External conditions must be in order.

Studies indicate that implementation of LPS leads to an improvement in project productivity (Formoso and Moura 2009; Friblick et al. 2009; Ballard 2000; Garza et al. 2000; Ballard 1999). As mentioned one key element in LPS is the making ready plans which purpose is to reduce the unreliability of the schedule. Implementation of LPS has raised percent planned completed (PPC) to around 70 %. But the PPC level is right now stuck at the 70% level. To help construction in reaching a higher PPC level, it is important to understand what causes the non-completion of activities. Therefore, in order to reach the 90 % level or higher the preconditions needs to be explored to enhance the understanding of existing and reveal undiscovered preconditions (Ballard 1999; Ballard 2000; Lindhard and Wandahl 2011).

The preconditions in construction are examined through three case studies. Here causes for not started and not completed activities are registered and categorized. The result is a framework for the focus areas in the making ready process. This helps the site-manager in securing that only sound tasks end up in the Weekly Work Plans and thereby increases the quality and the reliability of the plans. The preconditions in construction are examined through the following research question:

What are the preconditions to the conduction of construction activities in onside production?

RESEACH METHODOLOGY AND METHODS

Three construction sites are followed focusing on observing and registering reasons for non-completed activities. This was done in order to map the preconditions to construction activities in onside production. The cases had to fulfill two basic requirements: Last Planner Systems must be applied, and PPC calculation must be conducted. Furthermore, since most data are from archives, reasons for non-completion or non sound activities had to be described. To secure consistency all three construction projects are with the same site manager in charge. In the selection process, mail correspondences and phone conversations with site managers and company consultants secured the fulfillment of the mentioned requirements.

Data is collected through either LPS meetings or archived summaries from LPS meetings. This is because the PPC calculation and collection of reasons for non-completion take place at the LPS meetings. The LPS meetings do furthermore involve the Look-ahead planning and the scheduling of the next weeks plans which in relation to LPS-theory are completed in collaboration. The use of archives secures collection of data from the entire construction period.

The reason to supplement the archived data with onsite observations was to get an insight to how the meeting actually proceeded and how non-completions were recorded. Therefore, the archived data was in one of the construction cases supplemented with on-site observation, meeting participation, and semi and unstructured interviews. Since all cases have the same site manager in charge, insight in the scheduling process from all projects is achieved.

The data analysis consists of categorizing the recorded causes to non-completions into main categories. This is done to get an overview to causes to non-completion and to simplify the problem to help avoiding future repetitions. Data collection from the three cases is listed in **Error! Reference source not found.** which is followed by a short case description.

Table 1: Data collection at the three case-studies

	Case 1	Case 2	Case 3
Contract form	Turnkey contractor	Turnkey contractor	General contractor
Project followed	Entire construction period	23 weeks	Entire construction period
From archives	Reports from LPS meetings	Reports from LPS meetings	Reports from LPS meetings
Construction period	53 weeks	23 weeks	60 weeks
Activites registered	1829 activities	593 activities	2592 activities
Non-competions	575 activities	134 activities	570 activities
Average PPC	68.6 %	77.4 %	78.0 %

CASE ONE - EDUCATIONAL INSTITUTION

Case one was construction of an educational institution. The project consists of two buildings in total 11000 m^2. The main building was a three-storey building plus basement, in total 8000 m^2 and has an autonomous contract value on $21.75 million. The secondary building was a two-storey building with no basement, in total 3000 m^2. In total the secondary building had an autonomous contract value on $7.36 million. The duration of the construction process was restricted to 16 months.

CASE TWO - EDUCATIONAL INSTITUTION

Case two was a renovation project of an educational institution. The project original only involved a renewal of the roofing. But as renovation progressed extra work arose. Therefore, the project ended up additionally involving renovation of windows, inner walls, and sewer. In total the project contract value ended at $4.88 million, with a fixed schedule to 9 months.

CASE TREE – HOUSING

Case three was a renovation project of 9 residential apartment blocks containing a total of 300 flats distributed at 32 stairways. The flats were, because of variation in story and size, irregular distribute in the blocks. The contract included renovation of facade and renewal of the roofing. The project contract value was $28.62 million, with a duration fixed on 25 months.

THE 9 PRECONDITIONS OF CONSTRUCTION

The collection of data from the three case studies revealed a lot of different preconditions. These are sorted in to 9 different groups of preconditions and presented in the following. In total 5014 activities have been registered whereof 1279 was not completed according to schedule. Nine different groups or categories of preconditions have been applied in an attempt to categorize the non-completed activities. The first six is basically corresponding to the ones presented by Koskela (1999), while the last three categories are an expansion of Koskela's (1999) external conditions. 1) Construction design and management; correct plans, drafts and specifications are present. 2) Components and materials are present. 3) Workers are present. 4) Equipment and machinery are present. 5) Sufficient space so that the task can be executed. 6) Connecting works, previous activities must be completed. 7) Climate conditions have to be acceptable. 8) Safe working conditions in relation to national laws have to be present, 9) Known working conditions. Often a problem during excavations or refurbishment assignments where existing conditions first has to be examined.

One of the major and underlying reasons to non-completed task are insufficient and even bad scheduling. Often non-sound and out of sequence activities are selected to the Weekly Work Plans. When conducting the schedule it is important to notice as described in Lindhard and Wandahl (2011) that the soundness of an activity can vary. By focusing on all nine preconditions a more robust schedule can be achieved. A more robust schedule induces an increased PPC level and moreover and increased productivity. The actual recorded reasons to non-ready work assignments are in the following elaborated in relation to the 9 groups.

1 CONSTRUCTION DESIGN AND MANAGEMENT

a) Sufficient and correct plans, drafts, and specifications have to be present.
    a. Drawings with wrong measurements
    b. Outdated drawings
    c. No clarification of project details

   d. Missing approval of project design or details.

b) Legal Aspects

   a. Government authorizations

   b. Building laws and Eurocodes

   c. Contracts and agreements

c) Communication, coordination, collaboration, and individual mistakes

   a. Misconceptions and oblivions

      i. High work pressure

      ii. Lacking skills/experience

d) Adjustments in the schedule

   a. Changes made to optimize the sequence

   b. The conducted schedule is not realistic, cannot be executed

   c. Changes in soundness of activities forces changes to be made

   d. A complex and changing environment forces the schedule to be rethought.

      i. Unexpected conditions causing need for adjustments

e) Incorrect time estimate

   a. Activity takes longer or shorter than expected

2 COMPONENTS AND MATERIALS

a) Correct materials
   a. Wrong materials were delivered
   b. Materials were not delivered
   c. Materials does not fit the purpose
      i. Drying of materials necessary because of moisture
b) Materials are not present when assembling
   a. Dwelling materials in the stock.
   b. Materials damaged in stock or during assembly

3 WORKERS

a) Workers need to be present
   a. Illness in the workforce
   b. Unexpected or overlooked vacation.
   c. A contractor does not keep his commitments and do not show up.
      i. Forgets the agreements
      ii. Keep his own schedule, and make adjustments
b) Workers need to be qualified
   a. Changes in the workforce.
      i. Working slower than expected.
      ii. Resulting in low quality and forcing rework

4 EQUIPMENT AND MACHINERY

a) The correct equipment and machinery are present.
   a. Equipment are not delivered or delayed
   b. Equipment used by other contractors
   c. Wrong equipment or not fitting the work task.
   d. Breakdowns in equipment

5 SUFFICIENT SPACE

a) No space for completing the activities.
   a. Not enough space
   b. Space has to be shared with other contractors.
   c. Not suitable work surroundings
      i. No stable base for assembling or driving
b) Access to workplace
   a. Work area was locked
      i. No key

6 CONNECTING WORKS

a) Completions of connecting activities
   a. Is caused by including *"at risk"* activities in the Weekly Work Plans
      i. Previous activities was not completed according to plan
   b. Rework in previous activities cased delay.
      i. Rework caused by insufficient quality of work
      ii. Rework caused by damages to completed work

7 CLIMATE CONDITIONS

a) Weather conditions
   a. Temperature conditions not allowing certain work task to proceed
   b. Moisture conditions in the building
   c. Rain or weather conditions forcing work task to stop
      i. Drainage of the construction causing delay
   d. Snow or frost hindering activities to start.
      i. snow clearing is causing delay

8 SAFE WORKING CONDITIONS

a) Safe working conditions needs to be present
   a. The national "Health and Safety at Work Act" is not obeyed
      i. Problems with fencing
   b. Work accidents forcing work to stop

9 KNOWN WORKING CONDITIONS

a) Unknown working conditions causes changes in plans
   a. Unexpected discovery of asbestos or rot
   b. Unexpected soil conditions
b) Drawings are incorrect or outdated
   a. Unexpected condition of existing structure

The content in the nine preconditions above, gives a picture of the most common reasons for non-sound activities in construction. It is important to state that the list is based on research from three construction projects and is not considered exhaustive. Furthermore, specifics will differ depending on the actual construction project.

DISCUSSION

It is essential in the sounding process that the site manager is aware of the preconditions which can affect the soundness of an activity. Else preconditions can be overlooked resulting in interrupted workflow and decreased productivity. The three construction case studies have revealed a number of reasons to non-sound activities. These reasons were afterwards divided into 9 main categories extending the previous conception. Koskela's (1999) external condition category was divided into three new categories respectively: Climate condition, safe working conditions, and known working conditions. Finally, the construction design category is expanded to also contain conditions caused by site management.

It can be argued that the three new categories are just subcategories to the existing 7 preconditions being a part of the external condition category. The existing external conditions category covered several fundamental different subcategories. Therefore, the three new categories are considered necessary to achieve a sufficient detail level and to bring awareness and attention to the variety of sources to not sound activities in construction. Splitting external conditions up into 3 categories: climate, safety, and unknown will help site-managers making activities ready. Awareness could be achieved by putting a concrete name on the main reasons to non-completion in onsite construction. From this follows that the likelihood of unexpected constraints in sound activities will decrease leading to an increased PPC level.

The causes to non-sound activities will vary depending of the type of construction project. Projects involving refurbishment will more often experience unexpected conditions as asbestos in the existing construction. Due to the limited number of case studies and due to variation in the causes depending on construction type the list is not considered exhaustive.

When making activities ready for conduction for instance by following the list above it is important to state that the activities should be ready for completion. By stating completion it is not enough to secure an activity can be started. This could for instance be only limited delivery of materials. Such an activity will be considered as an *"at risk"* activity because it still caries constraints and thereby increases the likelihood for non-completion (Liu and Ballard 2008).

Even though all constraints are removed preconditions change (Lindhard and Wandahl 2011). Machinery breaks down, weather changes, unexpected needs of materials etc. This changes the soundness of the activities in the Weekly Work Plans, and hinders the scheduled activities to proceed. To keep production going, LPS has implemented the 14 days buffering. PPC calculation is only measuring the quality of the schedule and neither the production stage nor productivity. To increase the PPC level, the responsible contractor should during the week follow up on the preconditions and make sure that the scheduled activities can still finish on time.

CONCLUSION AND FURTHER RESEARCH

Based on three case studies the preconditions to the completion of activities in construction were examined. The research revealed a number of reasons for non-sound activities. These were divided into 9 main categories and thereby extending the previous conception with two extra categories. Here, the external conditions category was divided into 3 categories: Climate conditions, safe working conditions, and known working conditions. Furthermore, the category including construction design was expanded to also contain constraints caused by site management.

By dividing the external condition category into three subcategories a sufficient detail level in the categories is achieved. A sufficient detail level secures awareness and attention to the variety of sources to not sound activities in construction. Putting a concrete name on the main reasons to non-completions increase the awareness and helps the site-manager not to overlook remaining constraints in the sounding process. Therefore, the three new categories will help archiving a more robust schedule. A more robust schedule induces an increased PPC level and moreover and increased productivity.

It is important to state that the list presented above is not considered exhaustive. Constraints may vary depending on the type of construction project i.e. refurbishment, housing, offshore etc. Further research need to be carried out to verify the completeness. In future research attention could be on what triggers non-completion in relation to the 9 different preconditions, for instance by applying the 5 whys.

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