LAST PLANNER SYSTEM INNOVATION EFFORTS ON REQUIREMENTS FOR DIGITAL MANAGEMENT SYSTEM

Rein Terje Thorstensen[1], Bo Terje Kalsaas[2], John Skaar[3] and Sigmund Jensen[4]

ABSTRACT

The plans and on-going efforts of a major Scandinavian construction company to digitalise their LPS-inspired planning processes have provided the focus in this paper.

A management system designed to reduce uncertainty by ensuring that soundness criterions are met, is proposed and discussed. The proposal involves predefining "process trains" and introducing tollgates and a traffic light system to visualize the soundness status.

Our conclusion is that such a system is possible and desirable provided that the user threshold is low and that the system is low-maintenance. The latter is achieved by as far as possible making it an automatic part of other, already existing processes. If successful, the system could also provide additional support for decision-making in relation to principals and engineering issues.

KEYWORDS

Last planner system (LPS), digitalising, tollgates for sound activities, visualising

INTRODUCTION

Last Planner System (LPS) has proved its value as a tool for making realistic plans with a high degree of realisation capability. A construction process can be regarded as a flow-process where a series of prerequisites must be met for each activity in order for it to be realised according to plan, that is making each activity "sound".

In order to ensure that all activities are made sound in time, each activity in the lookahead- and production plans is checked against seven defined prerequisites. This clearance is based on trust, and involves that the responsible party reports that the situation will be sorted as required within the given time limit. Experience shows that participants in LPS-processes show increased responsibility towards each other. The challenge addressed in this article is thus not lack of credibility, but uncertainty tied to unforeseen events and lack of overview among the participants.

The aim of this article is to contribute to constructing specifications that should be met by management system, to improve realisation capability of plans. Next step will

[1] Senior Lecturer, Dept for Engineering Science, University of Agder, Jon Lilletunsvei 9, 4879 Grimstad, NORWAY, Phone +47 37 23 30 00, rein.t.thorstensen@uia.no

[2] Professor, Dept for Working life and Innovation, University of Agder, Jon Lilletunsvei 9, 4879 Grimstad, NORWAY, Phone +47 37 23 30 00, bo.t.kalsaas@uia.no

[3] Lean Construction Manager at Skanska Norway, Skanska, Rigedalen 15,4626 Kristiansand, NORWAY, Phone +47 45 86 91 78, john.skaar@skanska.no

[4] Supply chain manager at Skanska Norway, Skanska, Rigedalen 15,4626 Kristiansand, NORWAY, Phone + 47 98 21 02 76, sigmund.jensen@skanska.no

be to evaluate existing software towards these specifications, and if necessary to induce improvements. The work is based on discussions on experience and theory between academics and construction company, aiming at improving the company's profitability through less waste in execution of constructional works.

The solution sought, is a computer-based management system informed by existing routines, and as far as possible made an automatic part of these routines by utilising tollgates to gain increased certainty about soundness.

UNDERSTANDING THE CONSTRUCTION PROCESS

A construction project is often understood as an ordered, linear process, where the project manager's task is to manage the series of on-site operations. It is claimed that commonly occurring failure to meet time schedule and budget can be attributed to the inadequacies of such models (Bertelsen 2003).

An alternative approach is to see construction as a flow process reliant on a number of prerequisites being met and provided according to expectations by everyone involved, in order for the construction activity to be realised as planned (Bertelsen et al. 2007). A common visualisation is the «river model» taken from manufacturing. Its weakness here is that this model is intuitively comprehended as a traditional production process, where the unit under production moves linearly along from one part of its production to the next. This is obviously a modeling error that can lead to misinterpretations in the work of understanding and influencing the process. By adjusting the model, the construction process can be seen as a place-based phenomenon. This provides a more correct representation of the construction process.

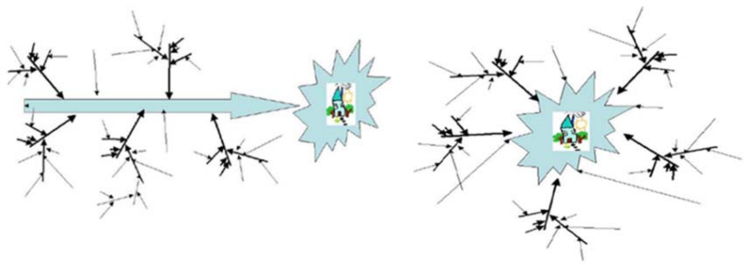

Figure 1: The traditional river model (left) and the suggested localized model (right) represent two different solutions to flow-view modeling (Bertelsen et al. 2007).

Modeling the construction process thus means that project management is no longer a question of managing a linear chain of operations, but of managing the flows that provide the construction site with prerequisites for production. The task becomes a question of managing social processes rather than of simply applying traditional planning tools.

Koskela suggests a division into seven different prerequisites: Construction design (information), Components and materials, Workers, Equipment, Space, Connecting (previous) works, and External conditions (Koskela 2000). Ballard suggests a model containing three flows (Ballard et al. 2002). Ballard's model can be seen as collecting Koskela's seven categories into groups, and there is no contradiction between the two models. Ballard's version can be regarded as a simplification suitable for theoretical understanding of the construction process, whereas Koskela's version is well suited for operational work and case comprehension. For our purposes here, we choose to pursue Koskela's seven prerequisites.

The success of the Last Planner System (LPS) (Ballard 2000) has been demonstrated in countless implementations and case studies all over the world, for instance by Kalsaas et al 2009. How the LPS actually works has received less attention. It has been suggested that its success is due to the user involvement built into the LPS turns the planning itself into a social process (Bertelsen et al. 2007). Our purpose is to increase the reliability of these social processes by introducing tollgates.

PROJECT MANAGEMENT

A commonly used planning tool is the Gantt chart. The Gantt chart shows activities and time along the two axes of a traditional axis system, with the additional possibility of defining dependences between activities. A clear strength of the Gantt chart is its pedagogic simplicity, as it is easily understood in terms of the division of activities, their dependences, and progress.

It also has its weaknesses. Some of these are that it is inadequate for showing repeated activities in different locations, and subsequent activities in one location – in other words, flow. Bertelsen et al. (2007) pinpoint the inadequacy as the Gantt chart (and other methods such as the Critical Path Method - CPM) regarding the construction process as a series of operations, thus missing important elements which appear when the construction process is regarded as a series of flow mechanisms. These flow mechanisms must be dealt with by the project manager in the day-to-day management of the project. One study points to corresponding lack of understanding of flow, as a general weakness associated with the use of 4D-CAD systems (Cooper et al. 2004).

Line-of-Balance (LOB) is a better suited tool for understanding the construction process as one of flow. The LOB diagram shows time along the x-axis, location along the y-axis, and individual activities appear as diagonal lines in the span between the two. The line shows the flow of each activity through zones, as a function of time. This makes the LOB particularly suitable for projects with repeated activities at different locations. For example, in a building containing identical apartments, each apartment can be a separate zone. Thus the plan will show how repeated activities flow through the different locations. If two diagonal lines cross, it means that two activities are taking place in the same zone simultaneously. This represents a potential conflict, which rescheduling can then prevent from occurring.

The LOB is advantageous because it allows planning both with respect to how specialised work teams should be employed throughout the zones, and with respect to avoiding simultaneous activity in individual zones; in other words flow in terms of the prerequisites of Workers, Equipment, Space and Connecting works. A further strength of the LOB is that it improves logistics by making it possible to plan delivery of the exact volume of the needed materials for each location. Hence better control of flow is achievable also in terms of Components and materials.

LOB also has its limitations in an understanding of the construction process as flow, in that it is (usually) limited to the activities on the actual construction site. In the greater picture, the activities on the construction site represent only a limited part of the many sub-processes, in which flow is required in order to realise the project.

THE SOUNDNESS CHALLENGE

An activity is considered sound if, and only if, all the prerequisites have been cleared prior to its commencement. The sum of all actions preceding each prerequisite is described here as «process trains». Each activity involves consequently seven process trains. Each process train can also have side tracks and loops.

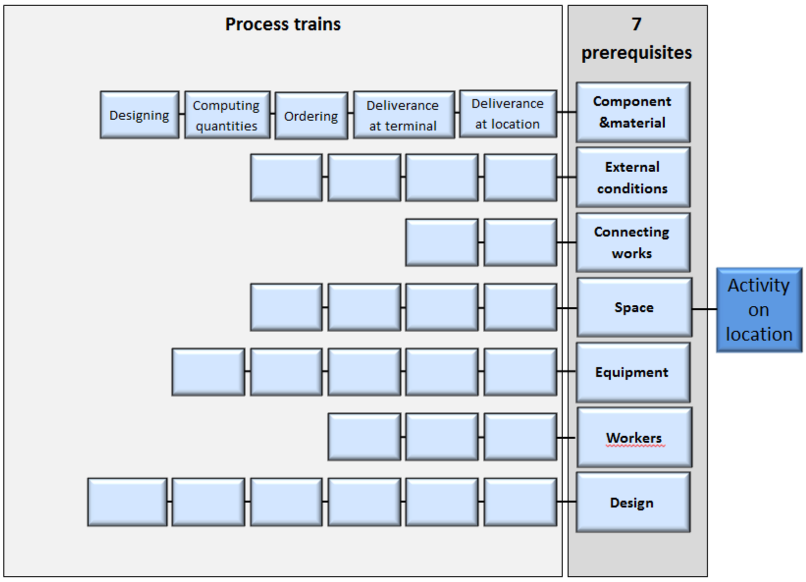

Figure 2: "Process trains" (each activity has process sequences, sets of actions, which must be completed in order for each of the seven prerequisites to be sound)

The vulnerability of the production process can be made apparent by a simple probability observation: The probability of the seven prerequisites n=[1,7] being settled when the activity on the construction site is set to begin, is described as P(n). The probability that the activity in its entirety is sound P(sound)=P(1)*P(2)…*P(7). Assuming 95% probability that each of the prerequisites is met, the probability that the activity is sound at the point of implementation is $P(sound)=(0,95)^7=70\%$. Thus, even when the uncertainty associated with each prerequisite is very low, the uncertainty tied to the overall soundness of the activity is nonetheless significant.

If the uncertainty tied to one single prerequisite increases, this will imply great consequences for the whole activity. For example, if the uncertainty tied to one prerequisite increases from 5% to 30% (leaving the other 6 at 95% probability), the probability that the activity will be sound decreases to $P(sound)=(0,95)^6*0,7=51\%$.

Based on this knowledge about vulnerability, it is vitally important that the project manager monitors the process trains for all of the prerequisites for each individual activity. But when can the prerequisites be assumed to be met?

In most cases, it is desirable to minimise storage on the construction site, both in order to reduce capital binding and storage costs, and to avoid deterioration. Thus it is undesirable for this prerequisite to be met any sooner than «just in time». Workers should not be sitting around waiting for the activity to commence; they should be used for other tasks in the meantime. Designers should work on other and more pressing tasks up to the point when «our» task must take priority, etc. If the prerequisites are reported met only at the point when everything is ready for the construction activity to commence, the activity often cannot be classified as «sound» until immediately prior to its implementation. This would be an impractical classification system, as it is devoid of any information value. The system must rather be able to show whether or not the prerequisite can be expected to be met. Thus it seems sensible to characterise the prerequisites too as sound or unsound. They are sound if they are «on schedule». Traditionally this means that the person responsible for the delivery confirms that it will be delivered as agreed.

There is no guarantee of a component being delivered in correct condition and at the correct time even if it has been ordered within the stated processing time, but it must be assumed to be sound because the schedule is followed. When a component has been ordered within the stated deadline, the prerequisite Components and materials must temporarily be considered to be sound. Nevertheless, unexpected events may occur and prevent the prerequisite from being met – for example production stoppage or obstructions to the delivery of goods to the production site. In such cases the status of the prerequisite changes from sound to unsound. Such information can easily disappear on its way from informant to construction site implementation – provided that the information is given in the first place.

In order to reduce construction process uncertainty it is essential to handle large quantities of information about soundness status on all three levels from actions in process trains to implementation on the construction site, and to have a clear visualisation of the information about these factors. This involves large quantities of information. Gaining and maintaining an overview of all the information, and ensuring that it is up-to-date at all time, therefore represents a great challenge. Dave et al. (2010) pinpoints the same fragmentation of knowledge, suggesting using web services for aggregating and distributing knowledge from/to stakeholders.

AUTOMATION

The paper-based LPS system offers simple handling of the seven prerequisites for soundness in terms of each activity. The planning form consists of a matrix where the lines indicate the activity and the columns indicate the soundness prerequisites. If the underlying activities in each process train are «on schedule» and the delivery is considered by the person responsible as sufficiently likely to go ahead as planned, the box is ticked as being sound. This perception of soundness is often based entirely on cognitive assessment. Our argumentation is that much of the “trust” of the person responsible is tied to the likelihood of the assessment turning out to be correct. In practice, his/her capacity or system is rarely good enough to produce sufficient overview. The paper-based system does not contain information about the schedule of the process train, and it does not give any notification when additional follow-up or checks are needed to ascertain that the process train is still sound.

The status statement sound/unsound contains more information than a Boolean variable (true/untrue), as it also involve a time perspective that pronounces everything to be in order now, but the process train has yet to reach its destination. In terms of programming and visuals, a «traffic light» can be used to model this information. The significance of the different lights is of course open to discussion, but in the following, we use the significance illustrated in figure 3 as our basis.

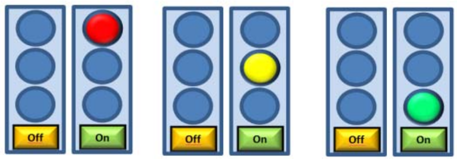

Figure 3: Traffic lights with Boolean switches. When switched on, the possible signs are red="unsound – action needed"; yellow="action soon needed"; or green="sound"

Such lights marking the status of each activity on the lookahead plan and the production plan, is a pedagogical, intuitively graspable system for informing those in charge of when they need to take action.

The status light for each activity is automated to representing the sum of the seven prerequisites. Only when all of the seven prerequisites are sound does the green light appear for the activity. A red light signals that something is wrong with at least one of the prerequisites, and that immediate action is needed. A yellow light signals that everything is on schedule, but that further follow-up will be needed soon.

It is conceivable that one might want to «switch off» the system for individual actions or whole process trains, for example if a standard solution is chosen rather than a planned special design. This situation could be solved by reprogramming the plan, but this might prove difficult when the plan has been partially carried out already. One might also choose to set the status light to «green», but it would then contain false information. A good solution would be to enable the status light to be switched on or off – that is, introducing the Boolean variable in addition to the light.

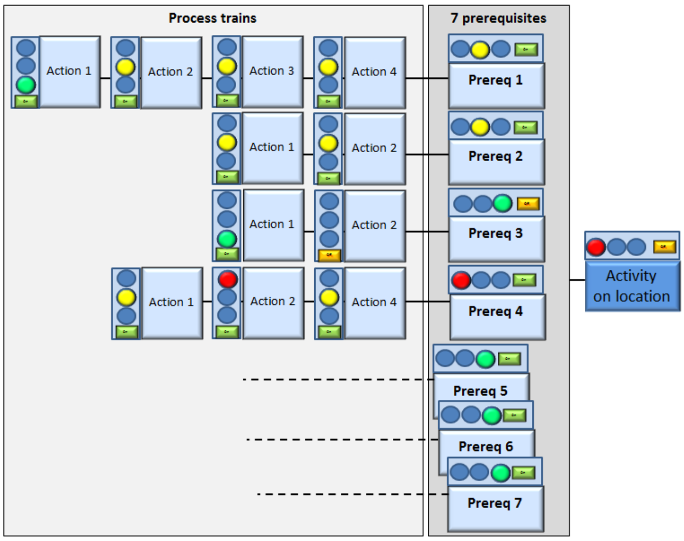

Figure 4: Status lights applied to process trains, seven prerequisites (visible on lookahead plan and production plans), and activity in the work breakdown structure

A glance at the plan in figure 3 quickly reveals that the activity is unsound through the red colour of the traffic light, and that some of the controls have been deactivated, since the Boolean variable indicator shows «off». From the soundness prerequisites which are also shown in the plans, the following information can be found:

- The lack of soundness can be found in prerequisite 4. Further investigation shows that action 2 is the one in need of attention.

- Prerequisites 1 and 2 will soon require action
- Prerequisite 3 is sound, but one of the action controls has been switched off
- Prerequisites 5, 6 and 7 are sound

The system will contain large quantities of data on details about the construction process, visualised in a simple manner. However, a great deal of work is still needed to follow up and ensure that the information for all indicators is correct. If the traffic light is extended to the individual actions of the process train, the follow-up work can easily take on overwhelming dimensions. In order to increase the detailing level even further, for many types of action a traffic light can be placed at either end: one indicating that action has been taken, and another to indicate that the action has been confirmed. For example, the first traffic light for the action «order» can show that an order has been sent, whereas the second one can show that confirmation of the order has been received along with an acceptable date of expected delivery. As a consequence, maintaining the system will involve almost twice as much follow-up work. Given the amount of information, digital support is almost completely necessary in order to sustain such a system.

NECESSARY FOLLOW-UP

The timeframe required to follow up an activity/production line varies according to the content given to the activity. The follow-up of a process train with regard to the seven prerequisites takes place within the timeframe of the lookahead plan.

Most activities can be included in the lookahead plan when the timeframe of the lookahead plan is larger than or equal to the timeframe for commencing with the activity. For such activities the lookahead plan is a complete preparation for start-up, and there is no preparation to be done prior to the inclusion in the lookahead plan.

Some process trains will nonetheless require follow-up beyond the timespan of the lookahead plan. Process trains that require more long-term follow-up, need to be identified and prepared at an earlier stage. A good planning process will uncover these through the Reversed Phase Scheduling process (RPS) in connection with preparing the milestone plan and the phase plan. The logic used in preparing an activity can be said to be the same; thus it is the timeframe of the lookahead plan that represents the limitation. It is nevertheless a good idea to keep the lookahead plan within a practically manageable timeframe.

When activities that require earlier follow-up are identified by the RPS process, it seems natural to include these in the same planning processes. Manually handled, their follow-up will differ from that of activities prepared for start-up within the timeframe of the lookahead plan. The design of a follow-up method for such activities is not addressed in this article; we merely want to point out that the manual system must be adapted to this reality. Digital follow-up makes it easier to handle these on the basis of their natural timeframe, as the light signals must be generated on the basis of when action is required.

The step from cognitively assessing the soundness of an activity to using a set of tollgates for each process train, brings in large amounts of additional information. Manual follow-up of such a detailed system can easily become a very laborious task indeed. If the ambitions of the management systems are so high that they are not followed up, the management system becomes a hazard rather than a security, because parts of the organisation may mistakenly trust that information they collect from the system is correct. However, it is possible to make many of the controls automatic through different already existing processes.

One process that can help make the management system more automatic would be to connect it to checkpoints for scanning RFID- (or barcode-) marked deliveries. As soon as a unit has been given an RFID mark, a connection can be set up between the management system and points along the production line; for example «ready to leave production facility», «loaded onto vehicle», «arrived at construction site/terminal», and «checked and found OK».

Corresponding routines can be established for the engineering part of the construction process. They would not involve RFID, but the various technical consultants could sign for «drawing delivered», and the project manager could sign for «checked and found OK». If the engineering is primarily done through BIM, the controls can be conducted automatically at different detailing levels in the model, as solutions are chosen and locked towards further changes.

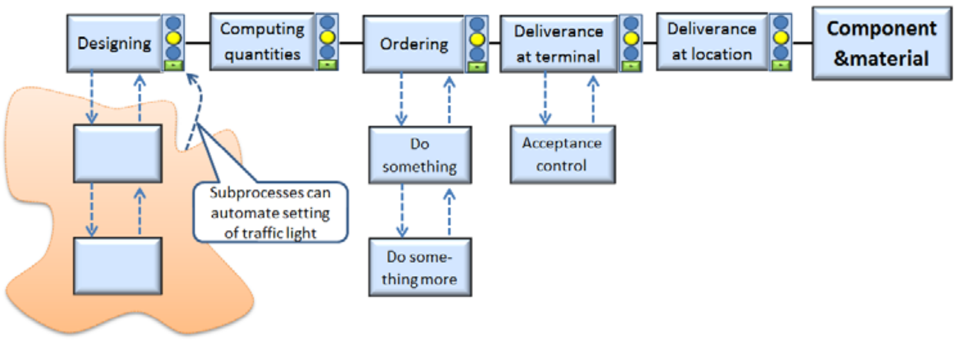

Figure 5: Prerequisite "Components and materials" used as an example of sub-processes informing and possibly automating traffic light setting.

The logistics system is a prioritised area for automation. The key to important activities being sound at the point of implementation, is that necessary materials have been ordered and delivered in the right quantities to the right location at the right time. As a prerequisite for good logistics, the person in charge of purchasing needs early access to information such as product specifications, volumes, dates of application, and lead times. By using zonal planning (such as line-of-balance) the purchaser can easily specify the necessary total quantities of batches of standard high-volume goods, which can be divided into sub-packages marked for delivery at different locations.

Separate software for logistics management and purchasing is already in use. It would make sense to connect this to the management system for the planning tool, so that when the purchaser makes his or her moves, they are automatically registered and visualised in the management system. This could, for example, take the shape of automatic registration and visualisation in the management system's traffic lights of «price quote requested», «price quote received», «contract negotiations started», «contract signed», «goods dispatched» etc.

OPERATIONALISATION

Our aim is to draw up an LPS-based management system that helps reduce the uncertainty tied to the seven prerequisites and their underlying process trains, consequently improving flow in the construction process. Because it will have to handle large quantities of information on status and needs for action, the system has to be computer based.

The management system should be linked to other processes: e.g. existing tools for logistics management; and new tools, e.g. digitalising the transition from RPS with Post-it technology, to the phase plan. With such links the work of maintaining the management system is radically reduced, and thus also the likelihood of errors.

The management system must include tools for establishing process trains as the project proceeds and the detailing level increases. It must have the ability to handle prerequisite changes, e.g. if the prioritised solution is changed from custom made to standard.

Many process trains can be predefined. Most construction activities, for example, can be carried out with a limited number of Components and materials. If the system contains pre-defined process trains for, say, the 50 most commonly used construction materials, much of the work will be rationalised for most projects. Such predefining is also likely to weed out many errors – e.g. by avoiding that the project manager fails to meet the minimum deadline for ordering materials. This could be considered to be standardization of operation – and standardization is considered to be vital to improve lean-ness.

If the predefined process trains also contain alternative solutions and their necessary lead times, this information can be used not only by the project manager during implementation of the construction process. It can also widen the principal's or contractor's basis for decision-making, and change the basis for making decisions about the engineering. For example, the designer can be alerted that the deadline for ordering pre-cast concrete elements is approaching. If the choice is made not to comply with this deadline, it comes with the knowledge that the concrete structures must be made as poured on location.

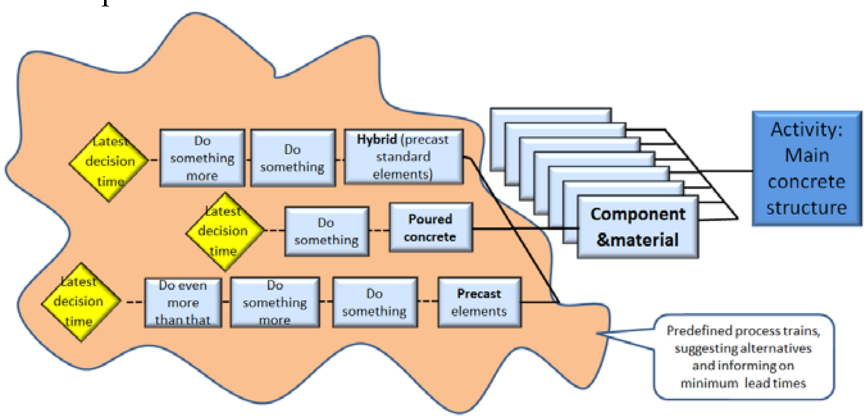

Figure 6: Using predefined process trains suggesting alternatives and specifying minimum lead times

CONCLUSION

In terms of assessing the soundness of activities on the lookahead and production plans, the traditional LPS system contains a weakness: it is highly vulnerable to uncertainty relating to all the different actions involved. A system for monitoring the actions that the soundness assessment builds on, and that visualises soundness status on lookahead and production plans, can make a significant contribution towards reducing uncertainty about the feasibility of the plans.

Such a system needs to be computer based due to the sheer amount of information to be handled and the number of necessary actions to be taken in order to keep the system up-dated. This complexity is in itself an indication of the need for an improved management system, as current solutions are based on the assessments and (limited) overviews of the different parties involved in the project. Much of the necessary information is already being generated in existing systems and routines, but the overview can be improved by including information feeds from these underlying systems in a new and automated management system.

Experience shows that mutual responsibility increases among contributing partners involved in LPS. The need for improved control does not, therefore, arise from a lack of trust in the goodwill of those involved, but from the need to reduce uncertainty linked to factors beyond their control or overview. In order for such a system to be successful, it must have a low user threshold (adapted to Last Planner), and as much information as possible must be automated against other processes that are already in place, in order to reduce the labour intensity of maintaining the system.

If this is achieved, the result will be reduced risk as a consequence of informed assessment gathered at tollgates, and of transferring information from the cognitive awareness of those involved into the management system, thus making it visible. Furthermore, important support for decision making can be provided at early stages of the construction process. The system will probably have its own errors, possibly linked to the clear break with the simplicity of the current system. However, it has the potential of contributing to greatly reducing uncertainty and increasing flow.

REFERENCES

Ballard, G., Tommelein, I., Koskela, L. and Howell, G. (2002). “Lean Construction tools and techniques” (Chapter-15). In *Design and Construction: Building in Value*, Oxford-England-UK, 227-255.

Bertelsen, S. (2003). “Complexity: Construction in a New Perspective”. *11th International Group for Lean Construction Conference*, Blacksburg, Virginia - United States.

Bertelsen, S., Henrich, G., Koskela, L. and Rooke, J. (2007). “Construction physics”. *15th International Group for Lean Construction Conference*, Lansing, MI -United States.

Cooper, R., Aouad, G., Lee, A., Wu, S., Fleming, A., and Kagioglou, M. (2004). “Process management in design and construction”. Blackwell publishing.

Dave, B., Boddy, S. and Koskela, L. (2010). “Improving information flow within the production management system with web services”, *18th International Group for Lean Construction Conference, Haifa, Israel.*

Kalsaas, B.T., Skaar, J. and Thorstensen, R.T. (2009). “Implementation of Last Planner in a medium-sized construction site”, *17th International Group for Lean Construction Conference,* Taipei, Taiwan

Koskela, L. (2000). “An exploration towards a production theory and its application to construction”. *PhD Thesis*, University of Technology, Espoo-Finland.