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Material delivery problems in construction projects: A possible solution

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Received 16 April 2004; accepted 21 December 2004

Abstract

Emerging project management methods for construction projects generate new kinds of challenges for the delivery process of materials. The rationale of such methods is to create short-term schedules, based on a constraint analysis of resources, for project tasks. This approach has two requirements for material deliveries: transparency of material availability and short response times in the supply chain. We propose a potential solution for managing the material logistics of construction projects. The empirically validated solution proposes a shipment tracking-based approach to provide inventory transparency, and a pro-active delivery approach for efficient material deliveries.

Keywords: Supply chain management; Logistics; Inventory transparency; Construction; Tracking; Project management

1. Introduction

New project management methods that address the shortcomings of traditional methods by adding flexibility to the execution of construction projects, create additional challenges to material delivery processes (e.g. Ballard, 2000; Choo et al., 1999; Chua and Shen, 2001; Koskela and Howell, 2002). The new methods acknowledge the challenge of creating an exact schedule beforehand for a large, complex project. Instead, such methods use continuous planning on a single construction task level. The basic philosophy underpinning the methods is to create short-term schedules for project tasks based on a constraint analysis of project resources. Such an approach places two requirements for the material deliveries: the analysis of material constraints requires transparency of material availability for site inventories and other stages of the supply chain, and the short time-span of planning demands short response times along the supply chain.

The aim of this paper is to present a potential solution for managing the material logistics of construction projects. The solution consists of a

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0925-5273/$ - see front matter
doi:10.1016/j.ijpe.2004.12.027

shipment tracking-based approach to provide inventory transparency, and a pro-active material delivery approach for timely material availability. In the first section, we will review literature related to the new project management methods and the implications for material replenishments of construction projects. In the second section, we present our research problem and discuss our research design. The proposed solution for material replenishments of construction projects is presented in the third section; with the final section proffering concluding remarks and direction for further research.

2. Literature review

2.1. Challenges in prevalent project management practice

The prevalent project management methods have recently been stated as inadequate for controlling the progress of construction projects (e.g. Ballard, 2000; Choo et al., 1999; Chua and Shen, 2001; Koskela and Howell, 2002). Some of the strongest opinion has been presented by Koskela and Howell (2001, 2002) in their argument that the underlying theory of project management is obsolete and that no explicitly stated theory exists on project management. Their main objection is that planning, execution, and control are not utilised in practice as suggested by PMBOK Guide of Project Management Institute.

In a similar vein, Johnston and Brennan (1996) have argued that an embracing interpretation of project management is ''management-as-planning'', based on a strong causal connection between generating a plan and the resulting operational activity. They conclude that such a straightforward coupling is not feasible, since no plan can ever be detailed enough to enable the mere execution without feedback from the environment. Koskela and Howell (2002) note that reliance on a general plan leads to poor short-term planning. These observations are confirmed, for example, in a study of six construction projects sited in the United Kingdom and Brazil (Santos et al., 2002).

Koskela and Howell (2002) recognise that maintaining a comprehensive up-to-date plan is problematic. Therefore, due to an out-of-date plan, the tasks pushed to execution cannot often be performed as they lack either predecessor tasks or other inputs. As Johnston and Brennan (1996, p. 382) state, ''That this approach works at all is largely attributable to tacit knowledge and improvisation at the operational level''. From the point of view of the supply chain, however, this management approach and last-minute improvisation, leads to inefficient practices to guard against material shortages. Materials are often ordered either very late; invariably leaving the supplier with uncertain demand and high material buffers to guarantee service level; or too early leading to buffering at the site (Vrijhoef and Koskela, 2000).

There has been a clear need for a more interactive management method, where the subsequent steps to be taken in a construction project, are determined from the *current status* of the project, not from predefined and outdated schedules which are obsolete for controlling practical actions. To overcome the challenges of traditional project management, flexible project management practices have been developed (e.g. Ballard, 2000; Chua and Shen, 2001). In the following, we review the Last Planner System of Ballard (2000) as an example of such approaches. The Last Planner System has been used in the production control of construction projects in the United States (Ballard, 2000), Brasilia (Conte, 2002; Soares et al., 2002), Chile (Alarcón et al., 2002), Ecuador (Fiallo and Revelo, 2002), Peru (Ballard and Howell, 2003), the United Kingdom (Townsend et al., 1999), Denmark (Bertelsen and Koskela, 2002), and Finland (Koskela and Koskenvesa, 2003).

2.2. Last Planner—a novel method for managing projects

The Last Planner System commenced development in 1992 by Ballard (2000). It is a project execution system that uses the overall project plan as the general framework, but suggests that the day-to-day activities of the production should be managed by a more flexible approach that is cognisant of the actual progress of the project. The underlying philosophy is to ensure that all the prerequisites needed for performing a distinct construction task are in place before it is assigned to a work group. This is the task of the "last planner"; and therefore Last Planner has been used to mean both the system and the person responsible for the final preparation of tasks (Ballard, 2000).

The four main categories for any executable project task are SHOULD, CAN, WILL, and DID (Fig. 1).

- SHOULD: tasks that need to be performed in the near future according to the overall project plan,
- CAN: tasks that have all their prerequisites ready: e.g. previous project steps are completed, necessary materials are at hand, and work force is available,
- WILL: the tasks that are commenced before the next planning round,
- DID: the tasks that are completed.

From the perspective of the supply chain, the most important feature of the Last Planner System is the way that the logic generates a backlog of viable construction tasks by undertaking a constraint analysis. Traditionally project tasks are pushed to execution, based on what SHOULD be done in the near future. However, within the Last Planner System, the upcoming tasks are evaluated in greater detail. To create the buffer of tasks that CAN be done, the last planner places tasks that SHOULD be done on a near-term schedule and analyses various constraints for each task (e.g. prerequisite tasks, available workforce, equipment and materials). If the planner thinks that any of the constraints of a specific task cannot be removed in time, then the task is shifted to a later date on the schedule. Only when all constraints are removed, is the task allowed in to the workable backlog. The objective is to constantly have a backlog of work that CAN be performed, and based on the backlog the actual work plan (WILL) is created.

The aim of the constraints analysis of Last Planner is to ensure that all resources are available for a given project task at the time of the execution. Therefore, from a material replenishments perspective, information regarding the availability of the relevant material is crucial for the constraints analysis to function. Case studies on Last Planner implementation show that defective material deliveries account for 8–25% of the non-completed tasks (Koskela and Koskenvesa, 2003; Fiallo and Revelo, 2002). This indicates that in practice it is difficult to ensure that all tasks allowed into the CAN backlog have the needed materials.

2.3. Material flow management challenges of the Last Planner method

There are two distinct material flow management challenges with the Last Planner methodology that have not previously been addressed in detail. First, the last planner needs to have access

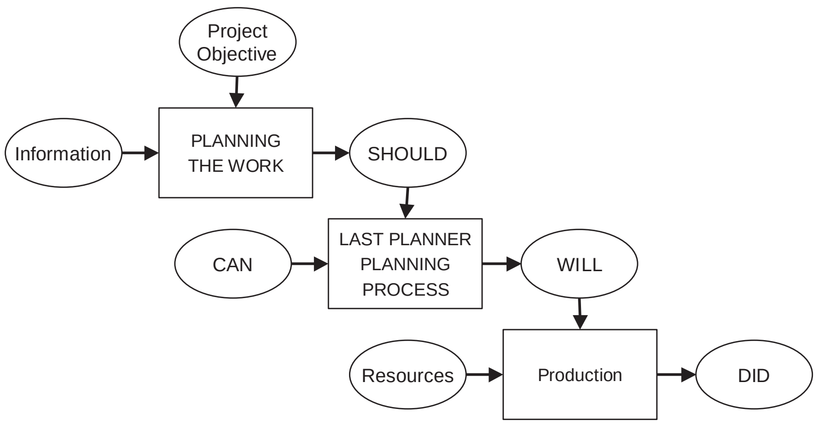


Fig. 1. The Last Planner System (Ballard, 2000).

to comprehensive information on materials availability for individual project tasks; and second, the materials should be reliably available without excessive inventory build-up at the project site.

The challenge in providing the last planner with materials availability information is due to the site inventory control methods. Frequently, the materials on site are not registered in any inventory control system, and so need to be visually controlled to ensure that they are available (Halmepuro and Nystén, 2003; ISI Industry Software, 2003). In some cases, site inventories are monitored with a spreadsheet application. But the inventory records tend to be flawed due to manual processes and inconsistent registering of the material movements (Harju-Jeanty and Jäntti, 2004). This is a serious problem for the constraint analysis of the Last Planner approach, as it dramatically increases the workload of the planner. More effective means for creating visibility to site inventories are therefore needed.

In an endeavour to reduce the risk of not having the materials at hand when needed, project materials are often ordered well in advance. However, excessive site inventories create problems for materials handling at the site and there is a risk that materials get lost, broken, or stolen (Alves and Tommelein, 2003; Bertelsen and Nielsen, 1997; Kärkkäinen et al., 2003). When using Last Planner, such issues increase the probability of faulty material constraint analyses that rely on inventory records. As a consequence, orders that are raised too early for site use may in fact increase the risk of not having the task materials available at the time of executing a task.

The challenge with excessive material buffers at the site can be addressed by shifting the inventory responsibility upstream to suppliers and by accurate scheduling of material orders when creating the initial project plan, as suggested by Bertelsen and Nielsen (1997). However, this approach is not feasible with the Last Planner approach, and its flexible near-term project schedule. The timing of the deliveries needs to be adaptable to respond to the inevitable changes in the near-term schedule. Therefore, the suppliers need to stay informed on the progress of the project, so that they can react to the actual needs of the construction project and, proactively, inform the last planner of potential disruptions that may lead to material constraints for future tasks.

However, providing tools for communicating site inventory levels and updating project schedules among the project participants is not without problems. The most significant challenge of implementing transparency tools in project supply networks, is that the networks are mostly created for a single project, and disbanded after the project is completed (Dainty et al., 2001). This has resulted in low long-term commitment, which is needed for most information technology development projects (Voordijk, 1999). Thus, due to the short time span of the usability of the solution that seek to increase inventory transparency in project supply chains, they should be speedy and easy to take into use, and not demand significant investment (Cheng et al., 2001). Supply networks of construction projects are also usually characterised by the inclusion of several small- or medium-sized enterprises (Dainty et al., 2001), which further increases the need for low-cost, easy to implement tools (Anumba and Ruikar, 2002; Elliman and Orange, 2000).

3. Research problem and solution design

Based on the identified management challenges in material flow, the following research problem is proffered: How to develop an effective material delivery model for construction projects with near-term task-level scheduling?

The literature identified that specific requirements were required for any solution; hence two more detailed research questions were developed:

(RQ1) How to gather and convey material availability information to project task scheduling?

(RQ2) How to organise efficient material deliveries for projects with near-term scheduling?

The methodology used in the research is based on the "Innovation Action Research (IAR)" approach (Kaplan, 1998). The aim in IAR is to initially document major limitations in contemporary practice, identify a new concept to overcome the limitation, and to continually develop the concept through publication, teaching and active intervention in companies. Holmström et al. (2004) have recently developed the framework with the aim of providing clearer support for studying the role of new technology in supply chain management.

When working with a group of project supplier companies, we identified extreme difficulties in building transparency in project supply chains. The companies were not able to inform their customers on the availability of the goods they were supplying. One of the major difficulties was to identify what goods had already arrived at the project site, as well as locating goods at site inventory. During the project, a simple tool for tracking the goods was developed by Främling (2002). The tool is freely available at http://dialog.hut.fi/.

Later, in another project case study, a supplier company had problems with the accuracy of project materials deliveries. This caused significant difficulties in the management of the construction activities. It was even claimed that material shortages occurred far too often for successful operations to be possible. Consequently, our research group developed a potential solution model to these challenges: namely, to adopt a near-term project scheduling approach that took into account the constraints proposed by the material delivery problems. To link our proposed solution to the current body of knowledge, we performed an extensive literature survey; and this resulted in identifying the Last Planner project management approach. Moreover, we recognised that our replenishment model was a valuable complementing element for the Last Planner System, as our model addressed the transparency and delivery accuracy requirements posed by the material delivery process.

In this paper, we present the delivery model and its linkages to Last Planner type project management. The tracking-based transparency approach has been validated in two pilot installations (Kärkkäinen and Ala-Risku, 2003), as proposed by the IAR framework. As yet we do not have experiences of the delivery-scheduling model in a real commercial setting, but the model has been validated by expert group discussions in one supplier and one installation company operating with construction projects, following the IAR guidelines.

4. The proposed material delivery solution

We will present our proposal in two parts. First, we address the transparency needed for determining material constraints. Then we demonstrate how the near-term scheduling of project tasks can be used to help the supplier to provide timely deliveries. Finally, we provide an overview of the whole material delivery solution.

4.1. Visibility to material constraints

An initial challenge of the material delivery process for the task-level project management approach, is to provide the task planner with reliable information on material availability. However, as previously discussed, creating transparency to the materials has proved complex in construction projects, whether the inventory is located at the site or elsewhere along the supply chain.

We addressed this challenge by developing a tool for creating inventory transparency based on shipment tracking. The tool has been designed for site inventories and short-term storages that are the most critical ones for the task-level constraint analysis of a project, and where traditional inventory transparency solutions are extremely difficult to apply. The material inventory information is established using the tool by tracking the incoming shipments (materials received at the site/warehouse) and outgoing materials (materials installed/sent from the warehouse) (Kärkkäinen and Ala-Risku, 2003). The tool is also suitable for building transparency to inventories located in any other section of the supply network (e.g. at the suppliers or sub-suppliers).

Building tracking-based inventory transparency requires that deliveries are equipped with an identifying code (e.g. order number or a delivery number), which can be used to link the shipment that arrived to the materials it contains. When packages arrive at or are taken out of a given storage location, these codes are registered with a tracking system. The tracking software then conveys the tracking code, the location of the inventory and the time to a tracking database as illustrated in Fig. 2.

Using the inventory information with the material constraint analysis to determine task-level materials availability requires that there is also a link between the materials and tasks, i.e. the material needs of each task are known. The materials needed for a task can be thought of as a bill of materials (BOM) for a task. An example BOM for a project task 29 is illustrated in Fig. 3.

If the planner is provided with availability information on all the identified task materials, the material constraints for the project task can be determined. The linking of project tasks and the respective material availabilities can be visualised as illustrated in Fig. 4. When equipped with the material availability information, those project tasks in which materials availability acts as a constraint can be detected, and rescheduled to a later date where the material needs are satisfied.

If the inventory transparency is based on shipment tracking, the following information can be interrogated from the tracking database:

- the location of the different goods needed for a certain project task,
- materials that are at a given location (e.g. site inventory or intermediate storage inventory),
- the location of a certain shipment,
- the dwell times of materials in a specific location.

This information is sufficient for checking the availability of material for the project tasks; and it can also be used to optimise inventory allocation in the supply chain.

If further database tables containing the delivery dates promised by the suppliers, the ordering date, and shipping date is also connected to the tracking database, then the following performance measures can be generated:

- the on-time delivery rate of a supplier,
- the lead-time of orders (from ordering to receiving of the goods),
- the lead-time of deliveries (from the dispatch to the receiving of the delivery),
- and, if the packages are traced in several locations, the de-constructed lead-times can be used for performance analysis of the supply chain (Jahnukainen et al., 1995).

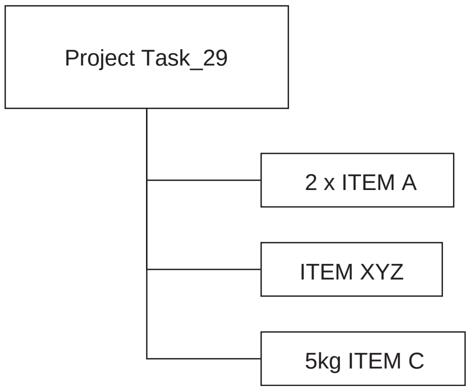
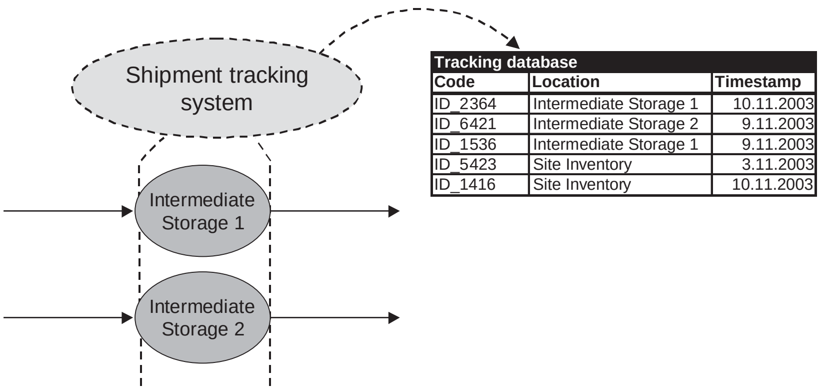


Fig. 3. An example bill of materials for project task 29.



Code	Location	Timestamp
ID_2364	Intermediate Storage 1	10.11.2003
ID_6421	Intermediate Storage 2	9.11.2003
ID_1536	Intermediate Storage 1	9.11.2003
ID_5423	Site Inventory	3.11.2003
ID_1416	Site Inventory	10.11.2003

Fig. 2. Inventory transparency provided with a tracking tool.

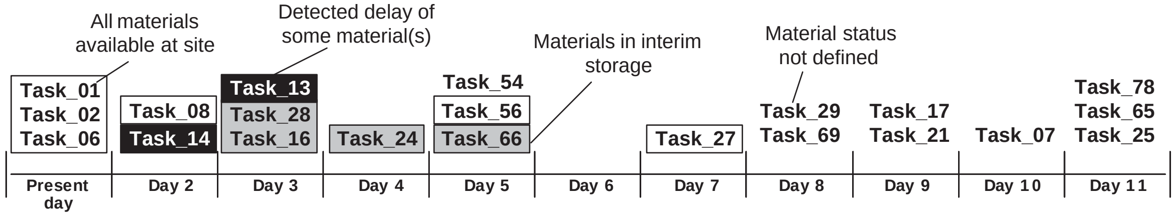


Fig. 4. Illustration of the results of materials constraint analysis.

4.2. *Material delivery triggering*

An additional challenge for construction project management with the material delivery process is to guarantee material availability for the project tasks without the build-up of unnecessary inventory. This requires effective communication and scheduling with the suppliers. Hence, we suggest the use of the near-term schedule from the Last Planner approach as a means of communication between the project site and material suppliers.

With Last Planner, project tasks are allocated on the near-term schedule and the material constraints of each task are removed by ensuring that the availability of necessary materials before the tasks are allowed to move to the workable backlog (Ballard, 2000). Since the upcoming tasks are positioned on the near-term schedule, they can also be used to communicate upcoming delivery needs to the suppliers. This is the most accurate demand information available, as the near-term schedule is continuously updated to represent the most likely timing for the project tasks; and therefore depicts the progress of the project. If the suppliers are given visibility to upcoming material needs, they are able to proactively inform the project of potential delivery problems. The task schedule can then be adjusted, taking into account the emerged material constraint.

Moreover, as changes in the task sequence are made, the supplier is informed of delayed (or advanced) material needs. Thus, the near-term project schedule can be used for enabling the suppliers to better cope with the changes in the required delivery dates of the project material.

The efficiency of operations for the planner can be increased by removing the need for frequent material orders. If the upcoming material requirements are conveyed directly to the suppliers (e.g. via www), the suppliers can move to pro-active deliveries of the goods needed for the project tasks (analogous to Vendor Managed Inventory). The suppliers can be given the responsibility to deliver the goods in time to the project site for each task.

For the pro-active delivery, we have added an extra parameter to the task schedule—the project buffer time. The project buffer time is used to ensure that the materials arrive early enough for the tasks that are moving into the workable backlog. Hence, suppliers are given a material needs view, where the needs are advanced by the number of buffer days (illustrated in Fig. 5).

For example, in Fig. 5, the project planner has determined that the materials should be available for the project tasks that are scheduled for the next three days. A supplier with a delivery time of two days would then have to dispatch the materials for a task five days before the task is commenced. The material requirement of upcoming tasks would be shown as a forecast to ensure that suppliers are prepared to deliver according to the schedule.

4.3. *Overview of the proposed material delivery solution*

The entire operating model is summarised in Fig. 6. Incoming shipments are tracked to create inventory information for the various storage locations of the project site. This information, along with information on other relevant constraints for the project tasks, is used in updating the project near-term schedule, which represents the anticipated sequence of the project tasks. The task schedule is then converted to material needs and communicated to the respective suppliers. The suppliers either commit to the requested deliveries

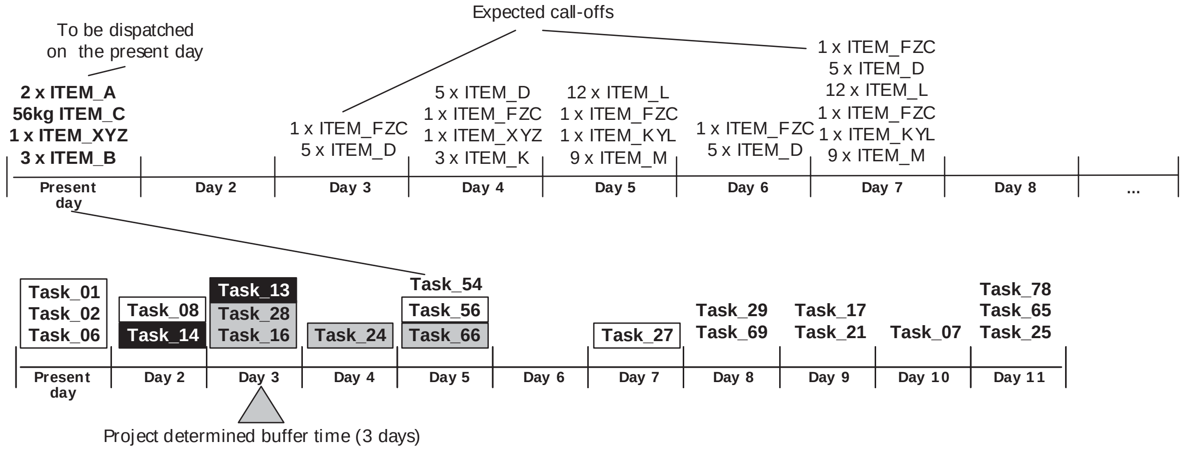


Fig. 5. Pro-active deliveries for project materials.

or notify the project planner of potential delays. Finally, the suppliers deliver the ordered materials that are then recorded with the tracking system as being available materials in the site inventory.

The experiences of the pilot installations of the tracking-based inventory transparency tool indicate that it is a suitable approach for temporary supply chain structures and for small companies as it is quick-to-implement and does not require significant investment or IT expertise (Kärkkäinen and Ala-Risku, 2003). Furthermore, if www-pages are used to communicate the project construction schedule to suppliers, no additional project-specific investments are required from any participant in a project. We therefore claim that the proposed material delivery solution can be implemented in various types of construction supply chains.

5. Conclusions and further research

A solution comprising two features was proposed for addressing the initial research problem of: How to develop an effective material delivery model for construction projects with near-term task level scheduling?

The solution consists of a tracking-based approach for building inventory transparency for short-term supply chains, and a pro-active material delivery model for the materials for specific project tasks. Both of these elements are central when using the Last Planner approach in production control.

The presented tracking-based method for solving the difficulties of site and intermediate inventory management and transparency can be considered a useful addition to the current body of literature. Its practical relevance is emphasised in project-oriented industries, as it is challenging and often infeasible to establish traditional inventory management systems to temporary storage locations used during projects.

We consider the pro-active delivery model for construction task materials to be a novel notion. As material delivery control has been a neglected area in project management research (Bertelsen and Nielsen, 1997; Olsson, 2000), we argue that our model is an important step in promoting the importance of this research focus.

There has also been software development based on the Last Planner approach, thereby making it easier to apply the production control system (e.g. Choo et al., 1999, Choo and Tommelein, 2001). We believe our suggestions on how to integrate materials suppliers to the near-term scheduling process would further improve the utility of such software for project managers.

The case studies on implementation of the Last Planner identified that, despite its later appraisal, the new planning and control paradigm confronts remarkable organisational resistance during the initial implementation stage (e.g. Alarcón et al.,

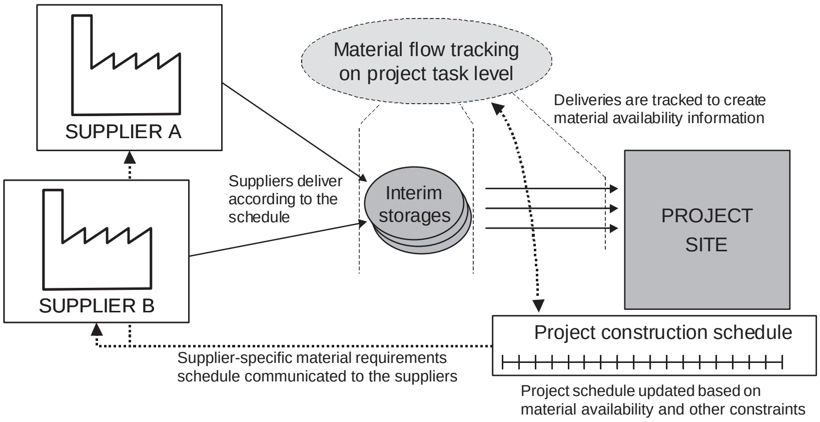


Fig. 6. An illustration of the proposed material delivery system.

2002; Fiallo and Revelo, 2002). During the expert panel discussions on our material delivery triggering approach, we also noted resistance to change related to the role of material suppliers and the project execution. The project management teams were unwilling to formally articulate that disturbances in material deliveries were a legitimate reason for re-scheduling project tasks. However, not acknowledging the possibility for material problems in task scheduling may lead to economic penalties. The installation subcontractors can make heavy claims for the idle time of their installation workers due to lack of materials (Halmepuro and Nystén, 2003). As a result, the interaction between project management and suppliers needs to be strengthened. This is what our material delivery system is designed to do.

We suggest two interesting areas for further research. A case study with a company utilising the delivery scheduling procedure for timing material replenishments is needed to examine and develop the practical applicability of the proposed solution. The study should aim to determine the most critical points of the supply chain where transparency is required (our experiences thus far have all pressed the importance of site inventories). Also, the economic effects of the near-term scheduling model and the established demand visibility on the material delivery process need to be comprehensively studied.

An additional area for future research is to identify similarities and differences of material flow challenges in construction projects of various industries to provide further insights on the general relevance of the solution. For example, if individual tasks are less interdependent, does it affect the flexibility requirements for material suppliers? This could be studied by comparing projects establishing communication or power networks (e.g. digital television network or an electric network) with civil engineering projects.

Acknowledgements

This research has been primarily supported by TEKES, the National Technology Agency of Finland. We also thank the companies who have contributed to the research results by financing the research and by providing empirical validation for our proposed material delivery solution.

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