LINKING PRODUCTION-LEVEL WORKFLOW WITH MATERIALS SUPPLY

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ABSTRACT

In traditional construction practice, work is done through functional silos such as planning and logistics. Typically, the planning department (or team) creates baseline schedules that drive procurement and logistics operations. Ensuring that materials are available for installation when scheduled is traditionally the objective of buyers or procurement personnel, members of another functional silo. The material management process is decoupled from work flow, potentially affecting the overall project delivery process. Lack of materials on site when required, lack of the 'right' materials on site, and accumulation of material inventories are just some of the types of waste generated by these practices, hampering performance through delays, low quality workmanship, cost overruns, and poor safety levels on sites.

This paper presents a solution that uses Strategic Project Solutions' (SPS) lean tools for production control (SPS Production Manager) and material management (SPS Material Manager) to improve transparency and performance across value streams, minimizing waste through the link of production-level work flow with material supply. Case studies are presented reporting better reliability of supply and demand due to a greater visibility across the value stream. Further benefits include a reduction of inventories on site, increased collaboration in the supply chain, realization of just-in-time material deliveries, and significant cost benefits.

KEY WORDS

Inventory, Just-in-time, Material management, Production control, Pull, Value stream, Workflow.

INTRODUCTION

In traditional construction practice, work is done through functional silos such as planning and logistics. Typically, the planning department (or team) creates baseline schedules that drive procurement and logistics operations. Ensuring that materials are available for installation when scheduled is traditionally the objective of buyers or procurement personnel, members of another functional silo. The material management process is then decoupled from workflow, potentially affecting the overall project delivery process. Lack of materials on site when required, lack of the 'right' materials on site, and accumulation of material inventories are just some of the types of waste generated by these practices, hampering performance through delays, low quality workmanship, cost overruns, and poor safety levels on sites.

This paper presents a solution that uses Strategic Project Solutions' (SPS) lean tools for production control (SPS Production Manager—SPS|PM) and material management (SPS Material Manager—SPS|MM). The main objectives are to (1) improve the accuracy of site demand (increase workflow reliability) by enabling a better planning and production control process where constraints are identified and removed, (2) increase transparency across value streams by working with web-based production management software tools, and (3) manage physical and information

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flows in real time by linking production-level workflow with material supply.

Case studies present the benefits and applicability of the proposed solution. The first case study focuses on the management of concrete supply including the design of a just-in-time material delivery system using the SPS|PM and SPS|MM concurrently. The second case study focuses on the management of the value stream for expanded polystyrene panels, a made-to-order product with 5-day lead time.

CONTROL OF PRODUCTION-LEVEL WORKFLOW

THE PROBLEM

Traditional construction practices do not control workflow at the production level. Ballard et. al. (1998) highlighted that the construction model of control is a model of project control, not production control. Production control is the missing link in the project management process forcing contractors or subcontractors to measure success based on pre-defined contractual commitments.

Effective control of production-level workflow implies breaking down the work into manageable chunks for daily control. The use of schedules to monitor and control production progress does not guarantee improvements in workflow reliability due to the level of detail at which they are created. Up to a certain point, controlling production relies on people's experience working closely to the production unit instead of process-driven approaches like the one presented in this paper that will help project teams to achieve better reliability of workflow. 'Workflow reliability in the industry has been repeatedly measured at levels ranging from below 30% to 60%, with rare exceptions above those levels. Improving [Percentage Plan Complete] PPC is expected to significantly improve project performance because it allows the application of planning to production' (Ballard, 2000).

Improving workflow reliability is synonymous with increasing the accuracy of site demand. Demand and supply are very close to each other and 'any type of variability will be critical to effective project management and will impact the total production system performance increasing cost and time and reducing quality and safety' (Arbulu and Ballard, 2004).

THE APPROACH

Improving reliability of production-level workflow requires the implementation of a systematic approach to production management. Based on lean manufacturing techniques and modern project management concepts, this paper introduces the SPS Production Manager as a software tool to achieve improvements in workflow while simultaneously reducing project delivery time and cost, and improving safety and quality.

MATERIAL MANAGEMENT

THE PROBLEM

Previous studies (e.g., CII 1998) have demonstrated that poor materials management practice can result in large costs during construction. Delays and extra expenses may be incurred if (1) materials required on site are not available when needed; (2) materials delivered to site are not the right materials, and (3) large amounts of material inventories are accumulated on site (e.g., if materials are purchased early, capital may be tied up and interest charges incurred on the excess inventory of materials). Considering that the cost of materials may represent more than half of the total cost of a construction project (Stukhart and Bell, 1985), the definition, design, and implementation of material management solutions becomes critical to realize efficient and effective production systems.

Based on our experience, traditional thinking in construction suggests that people operate as if they cannot control materials supply. In some cases, material management practices are reduced to just telephone conversations with suppliers, primarily to confirm final delivery dates for large quantities of materials (cheaper by dozen!). This paper proposes that supply can be controlled like site activities and it supports this statement through two case studies.

THE APPROACH

To avoid results like excess of inventories on site or lack of materials, the proposed approach relies on the application of a just-in-time approach to supply. The realization of just-in-time in construction depends on the ability of project teams to control supply and accurately forecast demand. Controlling supply starts with understanding the different types of materials that project teams will be dealing with and continues with the understanding of the different lean techniques that can be applied to make this control more efficient.

This paper considers the existence of three general types of materials[4] in construction: (1) made to stock (MTS), (2) made to order (MTO), and (3) engineered to order (ETO). Independent of the physical characteristics of these materials, this paper proposes a particular approach for each type.

1. For *made-to-stock* materials usually characterized by short lead times, the proposed approach is the definition, design, and implementation of physical control systems using kanban techniques where replenishment points are driven by minimum and maximum levels of inventory. Arbulu et. al. (2003) proposes a detailed strategy to implement this type of approach.
2. For *made-to-order* and *engineered-to-order* materials commonly characterized by long lead times, the proposed approach is the definition, design, and implementation of material management systems to pull materials through the value stream with appropriate work-in-process levels in the supply chain (CONWIP[5]) or each step in the supply chain (pure pull). These options are depicted in Figure 1.

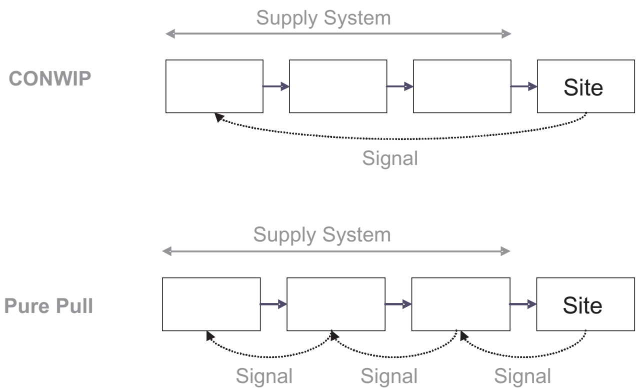

Figure 1: Material Management Approaches for MTO and ETO Materials

LINKING PRODUCTION-LEVEL WORKFLOW WITH MATERIAL SUPPLY

This paper proposes SPS|MM as a solution to manage MTO and ETO supply systems based on a CONWIP type of control. SPS|MM enables the management of information and physical flows across the supply chain[6] assuming the capital flow has been decoupled from both the information and physical flows so system performance is not constrained by purchase orders, approvals or any other type of support work required. The combination of SPS|PM and SPS|MM will make possible the link between workflow and material supply. The overall process to achieve this can be described as follows:

1. *Implement SPS|PM for production management*—the main purpose is to manage production-level workflow and start a continuous improvement process that will contribute to an increase in demand accuracy.
2. *Identify target value streams*—due to the diversity of construction materials, project teams will need to define priorities for target value streams e.g., based on project progress.
3. *Create detailed supply chain and value stream maps*—once a target value stream is identified, the next step will be to understand how it is configured to evaluate potential improvements.
4. *Determine generic material type (MTS–MTO–ETO)*—this will be one of the outputs of the value stream analysis.
5. *Evaluate potential implications of proposed improvements in relationship with supplier (Transactional, Supply Chain, Partner)*—project teams will be required to verify if improvements across the value stream will impact on existing commercial agreements with suppliers. If so, a new supplier relationship may need to be defined.
6. *Implement SPS|MM*—control of information and physical flows across the selected value stream.
7. *Monitor performance across the value stream* -—make necessary improvements or adjustments once new approach is operational.

Results and benefits of the application of this process are presented in the following case studies.

CASE STUDY 1: CONCRETE

BACKGROUND

The Channel Tunnel Rail Link (CTRL) Contract 105 consists of multiple inter-connected portions of work focused around the refurbishment of the 140 year old St. Pancras station (the 8th most significant historic building in the UK). The construction is being delivered by a contracting joint venture of Costain, Laing O'Rourke, Bachy Soletanche, and Emcor Rail (CORBER). The packages of work include renovation and structural modifications to the existing station and

4 MTS materials are commodities (e.g., consumables). MTO products are usually standard products made once customer orders have been placed (e.g., concrete - no stocks should be expected). ETO products are specially made for the customer following detailed specifications (e.g., pre-assembled rebar components).

5 Constant Work-In-Process, a concept introduced by Hopp and Spearman (2000).

6 There are three different flows on every supply chain: (1) physical, (2) information, and (3) capital.

Barlow Shed including fit out, the deck extension with associated roof and services, plus the complicated civil works including the Thameslink Box (underground metro line and station), Fleet Sewer diversion, and West Side buildings construction. These heavily inter-related works are occurring on a highly congested site in central London.

CORBER engaged SPS to develop tools and processes to improve the concrete supply system by developing a just-in-time material delivery system using the SPS|PM and SPS|MM (aka ProjectFlow at CTRL) concurrently.

THE CHALLENGE

The initial step was to define the problem and understand the challenges with the existing approach to concrete supply. Investigation indicated the following key features of the existing ordering process:

- All concrete orders were requested by the site teams, filtered through the concrete coordinator, and fed to the concrete supplier via phone and fax.
- Concrete orders were planned one week in advance and revised one day ahead, but deliveries were made only in response to call offs on the day required, making the weekly forecast unreliable.
- The on site concrete coordinator revised the provisional weekly lookahead on a daily basis and provided updates to the off site batch plant to inform them of revised pour times and quantities. These updates typically happened at the last minute, forcing the batch plant to react quickly.

Several key issues were highlighted by the project team and suppliers:

- The lack of transparency between the site teams and the concrete supplier was causing unbalanced concrete supply across the day (i.e. no concrete being placed in the morning, and a backlog of concrete supply in the afternoon), leading to overlapping pours late in the day causing delays and thus overtime for the concrete crew and batch plant.
- Concrete ordering reliability varied from 50% - 80% with the supplier losing the ability to sell concrete to other projects.
- The existing process was highly dependent upon the concrete coordinator, who acted as a physical conduit of information between the various parties involved, and kept much information in his head. When the concrete coordinator was absent, the process tended to falter.
- The existing system was only partially transparent. Progressively updating the plan and having it posted on the network and faxed to the concrete supplier provided a more realistic picture of what was going on, but real-time information was still lacking.
- The existing system did not systematically promote learning and improvement.

THE RESULTS

The results obtained on CTRL were immediate. Within the first three months of transferring to the new system, concrete deliveries became more reliable as the constraints between site and the supplier were better understood. This was the result of the site teams improved planning and production control process (SPS|PM), coupled with the integration of concrete ordering and control through SPS|MM.

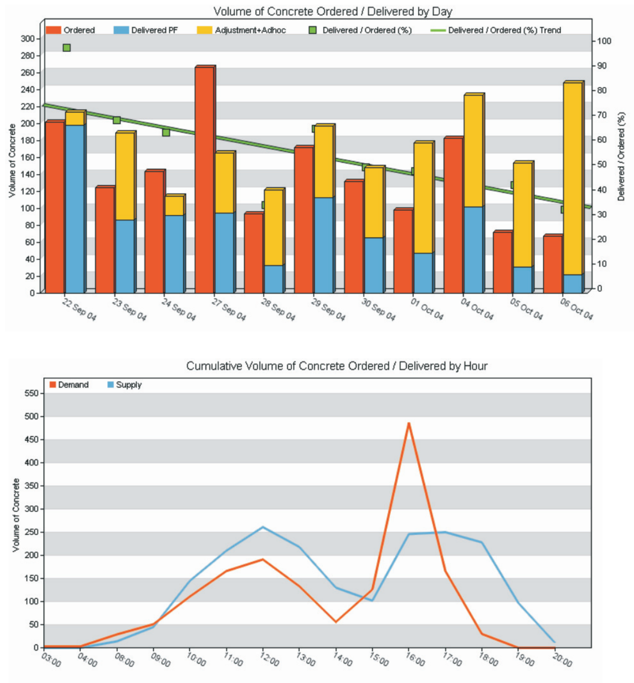

Figure 2: Initial concrete reliability (left) and daily supply vs. demand (right)

Figure 2 shows a graph from the SPS|MM of the project's daily concrete reliability and demand vs. supply. The left column for each day shows demand as ordered through the SPS|MM. The right column is broken into two sections for each day. The bottom section represents concrete supplied based on orders placed in the SPS|MM. The top section represents concrete that was supplied ad-hoc. The line graph shows the balance of concrete demand vs. supply across the hours of a day. The large peak indicates a time when several members of the project were requesting concrete at the same time. This led to the other line extending farther to the left and represents overtime work for the concrete batch plant and concrete crew.

Initial estimates from the project indicate a 19% reduction in concrete productivity rates (during the first 12 weeks of SPS|MM implementation, concrete productivity rates improved from 2.0 hrs/m3 to 1.62 hrs/m3). Based on a conservative estimate of labor rate including all costs of employment, overtime, management supervision, facilities and plant (£20.00/hour), this equates to a productivity improvement of 5,000 man hours or £100,000. Figure 3 shows the same graph as above with the current data for the project. Note that there are less ad-hoc orders and the overall reliability is higher and less variable for a greater daily supply of concrete. Also note the better balanced supply vs. demand graph with virtually no overtime work, even during the busiest phase of the project.

Assuming that the calculated average production rate will continue to be achieved over the remaining concrete forecast, this suggests an additional productivity improvement of 12,600 man hours or £250,000, although data will need to be continuously collected and used as verifiable evidence that this trend is being sustained.

Figure 3: Current concrete reliability (left) and daily supply vs. demand (right)

DETAILED APPROACH

The process to develop this solution required the careful definition of the initial ordering process.

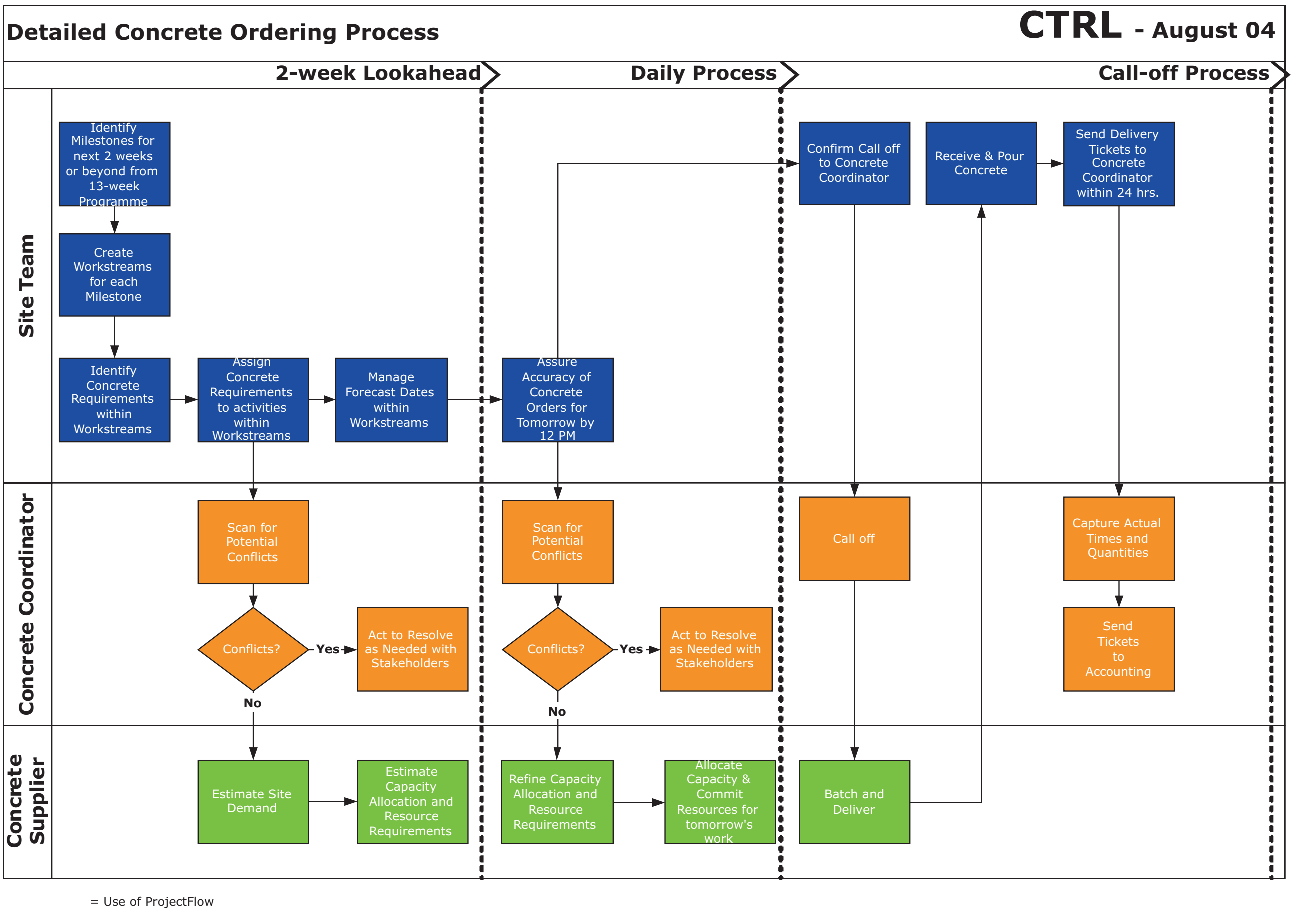

Figure 4: Concrete Ordering Process after collaboratively created and agreed by primary stakeholders

Using just-in-time principles, rules were developed and agreed with all the primary stakeholders (site teams, concrete coordinator, and concrete supplier) and captured in the process map below highlighting the steps in three phases: 2 weeks ahead of a concrete pour, the day before the pour and the day of the pour.

To illustrate the overall supply system, a diagram similar to the one shown in the case study for expanded polystyrene panels (Figure 6) was produced showing information, material, and money flows from one stage to the next. As the solution has become embedded across the project, the overall process has improved and given the project measurements upon which to base further improvement efforts.

CASE STUDY 2: EXPANDED POLYSTYRENE PANELS

BACKGROUND

British Airport Authority (BAA) engaged SPS in collaboration with Laing O'Rourke, one of the largest major contractors in the U.K., to develop tools and processes for the management of selected supply systems during the Civils Phase of the construction of Heathrow Terminal 5 in London. The concurrent use of SPS|PM and SPS|MM (aka ProjectFlow at T5) was part of the strategy for just-in-time material delivery during the Civils Phase. The strategy also considered the use of Logistics Centers (LC) to buffer variability in value streams.

Project teams identified expanded polystyrene panels as critical for the completion of Civils works. Expanded polystyrene panels are used to alleviate the effects of ground movement on ground floor slabs, pile caps and ground beams in areas where clay abounds (clay heave is the main cause of ground movement and overload recovery represents a technical challenge for engineers). These panels may vary in density and thickness and are designed to collapse at a pre-determined load to avoid structural damage. Most expanded polystyrene panels are made-to-order materials, not available in stock.

THE CHALLENGE

Similarly to the concrete case study, the first step was to identify the current state and associated challenges with the existing supply system. Key issues were identified as follows:

- Project teams were not looking ahead. Forecasts were inaccurate creating a tidal wave of demand on the horizon. The supplier was not able to know with certainty what materials were required, in which quantities, and by when, however, the factory kept producing based on delivery schedules.
- Work-in-process (inventories) at the LC increased due to demand variation from site (panels were unique, they were not interchangeable). This created an additional problem related to the availability of trailers for panels that were really needed (*Note*: due to its physical characteristics, the expanded polystyrene panels could not be double handled so they needed to remain on trailers until final delivery to site from LC).
- Doubling handling of unwanted materials (already sent to site) was required to make way for wanted materials.
- Due to demand variability, large quantities of panels were backing up the factory.
- Poor visibility across the value stream. Project teams did not always know what type of panels and how many were waiting at the LC ready for delivery to site.
- Real lead times for panel fabrication and delivery were not understood. Last minute orders were common, expecting prompt delivery (assuming the panels were made-to-stock products!). Due to long lead time, immediate deliveries were not possible constraining planned activities on site, and therefore affecting workflow reliability and work progress.
- Considering panels were delivered to LC first and then transported to site based on call-offs, the communication between project teams and the responsible party for transportation was very poor causing delays and continuous misunderstandings.

RESULTS

The most important results are:

- Materials inventories at the LC were reduced to 1 day. Previously, inefficiencies in the supply system generated important amounts of WIP in the way of trailers full of panels. Due to variability in the supply systems, more than 15 full trailers were waiting at the LC for more than 3 weeks. Each trailer carried the equivalent of £14,000 of expanded polystyrene panels, which means that an estimated £200,000 of materials inventories was held at some point.
- The level of transparency increased once the new solution was implemented. Project teams immediately provided positive feedback (voice of the final customer): "*The old system was a nightmare. Since site was involved in the development of the new method*

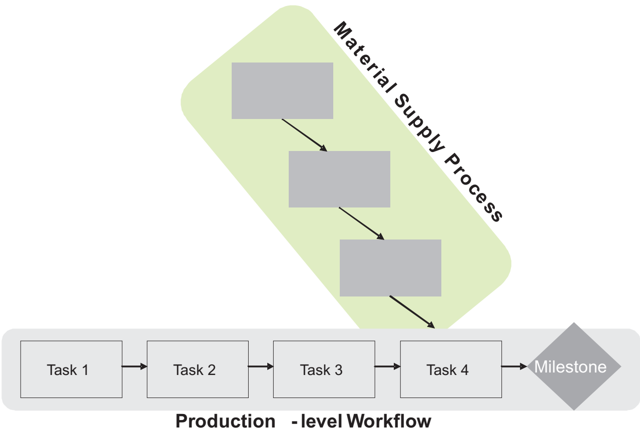

Figure 5: Integrating Production-level Workflow with Materials Supply

using SPS|PM and SPS|MM, there were few surprises when it was rolled out, and it worked! This will be the norm rather than the exception for future materials orders."

- Project teams and the supplier used the new solution for a period of 13 continuous months. 430 different orders were placed through SPS|MM during this period (approximately 8 orders per week) for a total 230 different site activities on daily production plans created in SPS|PM. This is an example of "external" integration with suppliers for supply chain improvement. This type of integration is depicted on Figure 5.

DETAILED APPROACH

The first step was to gain a holistic view of the value stream for the panels (value stream map showing current state is not presented on this paper due to space constraints) to understand the impact of the problems/challenges described above on the overall value stream performance. Working in collaboration with main stakeholders (project teams, transportation team, logistic center team, supplier), the supply system was re-designed focusing on overall performance rather than local optimization of resources (myopic view). Lean techniques like pull and kanban (kanban signal = empty trailer) were implemented to improve the management of physical flows supported by the use of SPS|PM to improve workflow reliability (demand accuracy) and SPS|MM to manage the information flow and track status of physical flows.

As part of this approach, rules across the value stream needed to be created to guarantee a win-win situation for all stakeholders. Some of these rules included: (1) supplier will make to a 5 day lead time (e.g. Monday → Monday), (2) project teams take what they order and once ordered it will be delivered, (2) project teams break orders up into smaller chunks based on trailer size (reduce order batch size), (3) project teams keep a rolling 2 week lookahead of orders in SPS|MM to improve demand forecast, (4) trailers are allocated to each project team giving them full control

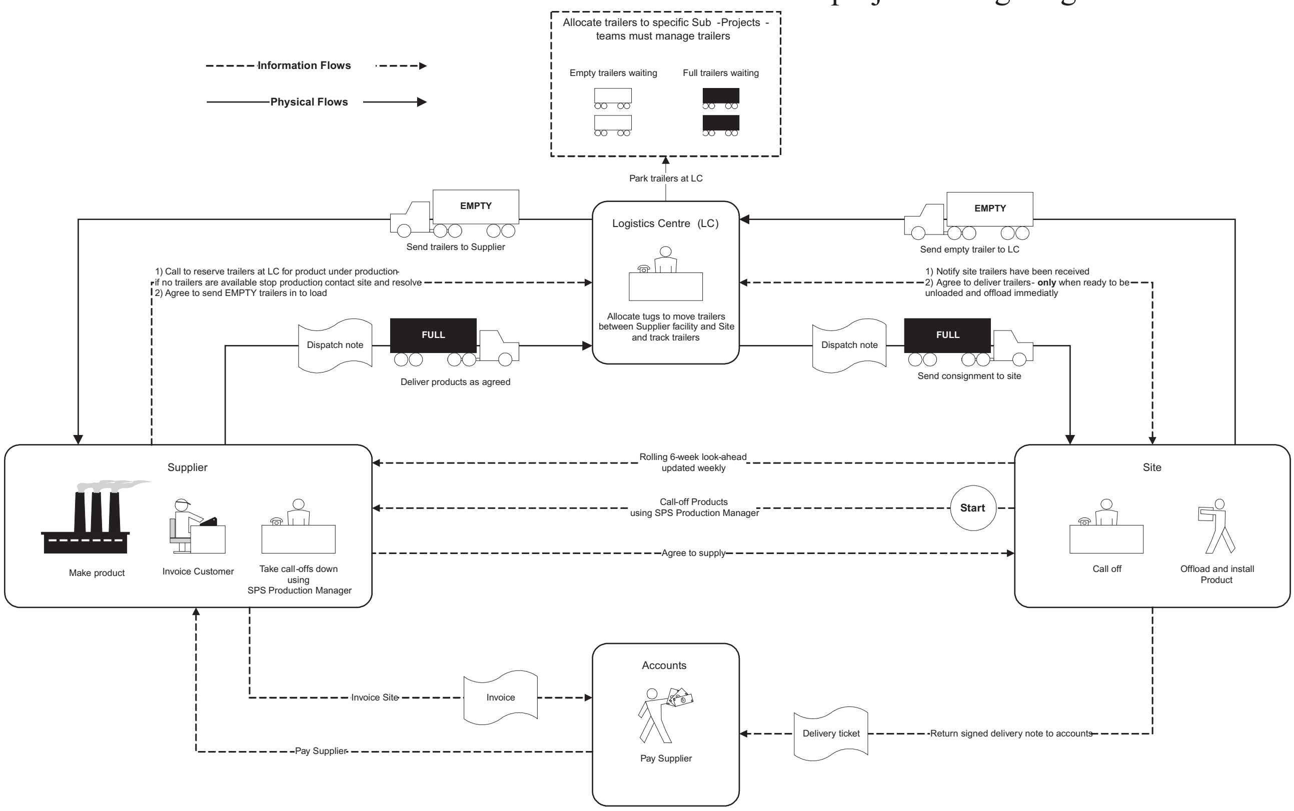

Figure 6: Supply System Diagram for Expanded Polystyrene Panels

of the use of the fleet according to their needs, (5) supplier does not have to fabricate more panels if a trailer is not available when they start production (trailer availability triggers the start of production), and (6) trailers are reallocated across project teams on a weekly basis if necessary, according to demand forecasts.

To illustrate the new supply system, the above diagram (Figure 6) was produced showing information, physical, and money flows incorporating the rules described above.

CONCLUSIONS

This paper has presented a systematic approach to link production-level workflow with materials supply. The paper has demonstrated through case studies that the management of supply can be controlled and incorporated into workflow management practices on site creating an integrated approach to value stream management. This approach proposes pulling materials to project sites according to site demand on a just-in-time basis reducing the possibility of accumulating physical inventories on site. Case studies have illustrated the application of this approach and the related benefits for made-to-order materials with different lead times. It has presented a solution to manage physical and information flows simultaneously across value streams while money flows are de-coupled. De-coupling money flows from physical and information flows reduces the possibility of having transactional bottlenecks that will hamper value stream performance increasing cost and time. The authors are constantly working in multiple implementations of this approach and will present new case studies in future papers that, together with this one, will contribute to the body of knowledge about applying lean concepts in construction value streams.

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