KANBAN IN CONSTRUCTION

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ABSTRACT

Kanban is a lean approach developed in the automotive industry to pull materials and parts through production systems on a just-in-time basis. A particular type of kanban is called supplier kanban which transmits a replenishment signal to outside suppliers.

This paper presents a material management strategy that uses supplier kanbans to signal the need for replenishment of selected products from preferred suppliers to site. The objective of this strategy is to accomplish material management functions with least waste; e.g., unnecessary inventories and processing time, waiting time, and physical waste. The primary means for achieving the objective is to simplify the processes of acquiring, storing, distributing and disposing of selected made-to-stock products on site. The kanban strategy is being implemented in the construction of a major international transportation hub in the U.K. The paper highlights one of the most important findings from the implementation phase of the strategy: the need to rationalize stock profiles.

KEY WORDS

Inventory, just-in-time, kanban, lean construction, made-to-stock, material management, pull, supply chain integration, value stream, waste.

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INTRODUCTION

Construction projects are known as temporary production systems that require temporary flows of resources (e.g., labour, materials, equipment, etc) to achieve project milestones. The flow of materials includes thousands of different types of products needed to complete daily tasks. Failing to allow a continuous flow of materials will have a negative impact on labour productivity and project costs. The lack of materials on site is also one of the most frequent causes of construction delays (Stukhart and Bell, 1985). As delays are waste and lean construction advocates the systematic eradication of waste, the integration of lean and material management techniques to create customized strategies to smooth the flow of materials into site seems to be a beneficial application.

Materials management serves the purpose of providing the right materials when needed at an acceptable cost. Doing so, involves specifying what materials are required, acquiring those materials from suppliers, and distributing them to construction users. Traditional ways of performing these functions were replaced, at least theoretically, by 'modern' materials management (Stukhart and Bell, 1985). However, lean techniques such as kanban have not previously been incorporated into construction materials management.

This paper presents an application of lean concepts and techniques to management of certain types of materials on a construction project. Concepts and techniques include: (1) value, value-adding, value stream, (2) waste, (3) just-in-time, and (4) kanban. The paper describes a material management strategy developed to manage the replenishment of certain types of materials to site on a just-in-time (JIT) basis. The strategy uses kanbans to pull materials from preferred suppliers to meet site demand. The paper reviews construction material management concepts and highlights the need for an important shift from a tactical view with emphasis on order placement and price savings to a more strategic view with emphasis on value-adding activities and total cost waste reduction throughout the value stream. The term 'value stream' refers to the set of interdependent activities and operations that are executed to bring materials to the final customers on site. "A value stream perspective should look across individual functions, activities, departments, and organizations, and focus on system efficiency rather than local efficiency within any one of these. Elimination of this waste will contribute to improving supply chain performance" (Arbulu and Tommelein, 2002b).

The paper provides an overview of kanban based on experiences in the manufacturing industry. This paper then defines the kanban strategy, its components, processes, and the expected benefits. It highlights the importance of supplier integration as key to the success of the strategy and supports the creation of a new role named supply chain integrator with a strong focus on the value stream rather than the traditional myopic view of a single stakeholder.

The paper presents some observations from practice and concludes by presenting one of the most important findings during the implementation of the strategy: the need for product rationalization.

CONSTRUCTION MATERIAL MANAGEMENT

Material Management is a vital part of the production system for a construction project. "Up until the 1980s, procurement in construction was achieved through purchasing processes based mainly on the concept of one-to-one transactions between a buyer and a seller in order to meet individual project needs. Construction companies at that time had been focusing their efforts on developing in-house resources and processes, creating internal organizational boundaries based on functional specialization. In the late 1980s, this focus changed and internal integration was adopted as a new goal. Subsequently, external integration became the new goal, and was achieved by engineering and construction firms integrating their materials management practices with their first-tier suppliers" (Arbulu and Tommelein, 2002a). The kanban strategy presented here is an example of external integration with first-tier suppliers.

This paper demonstrates that construction material management goes beyond procurement limits. Traditional material management practices comprise the processes of "planning and controlling all steps necessary to insure that the objectives of price, quality, and quantity are met when and where required" (Stukhart et. al 1985). Material management therefore includes functions like identifying, acquiring, distributing, and disposing of materials on construction projects (CII, 1988). The strategy proposed in this paper simplifies the operations within these functions as well as proposes a shift from a tactical view with emphasis on order placement and price savings to a more strategic view where the emphasis is on value-adding activities and total cost savings throughout the value stream.

Previous studies (e.g., CII, 1998) have demonstrated that poor materials management can result in large costs during construction. For instance, if materials are purchased early, capital may be tied up and interest charges incurred on the excess inventory of materials. Also, product quality may be affected during storage. Stukhart and Bell (1985) recommend the following goals for material management: (1) obtain the best value from the perspective of the customer (not necessarily the best price) for purchased materials, (2) assure materials are in place when and where required, (3) reduce inventory and surplus, (4) assure quality requirements are met, and (5) provide efficient low cost movement of materials to site and within site storage areas.

In this paper, the kanban strategy emphasizes site material management and the processes of receiving, storage, control and distribution of selected made-to-stock products to the installation areas.

THE KANBAN STRATEGY

BACKGROUND

Kanban is a lean approach developed in the automotive industry as a mechanism to pull materials and parts throughout the value stream on a just-in-time basis. "In Japanese, the word kanban means 'card' or 'sign' and is the name given to the inventory control card used in a pull system" (The Productivity Press Development Team, 2002). The aim of a 'pull' system is to produce only what is needed, when it is needed, and in the right quantities.

In a lean manufacturing environment, kanban is an advanced visual control system focused primarily on eliminating overproduction, increasing flexibility to respond to customer demand, and reducing costs by eliminating waste. In this environment, two different types of kanbans have been developed: (1) transport kanbans, and (2) production kanbans (The Productivity Press Development Team, 2002). Transport kanbans are used to either signal the need to replenish materials from a preferred supplier (supplier kanbans) or to signal the movement of parts or subassemblies produced within the factory to the production line (in-factory kanbans). Similarly, production kanbans are signals to either initiate production (production-ordering kanbans) or to communicate the need for machinery changeovers (signal kanban).

In the construction industry, the evidence of the use of kanbans of any type is very limited. This paper then proposes the use of supplier kanbans to signal the need for replenishment of made-to-stock products.

CUSTOMER NEEDS

The kanban strategy is currently being implemented in the construction of a major international transportation hub in the U.K. The strategy is developed based on five key principles established by the owner: (1) materials must be pulled through the supply network as needed at workface, (2) materials must arrive at the right place, at the right time, in the right quantity, (3) the supply network is achieved at the best value for the customer, (4) all necessary actions are taken to minimize vehicle movements on site, and (5) all necessary actions are taken to increase workflow reliability on site.

DEFINITION AND SCOPE

The kanban strategy is developed to manage the replenishment of certain types of made-to-stock products[4] from preferred suppliers to site. The focus is primarily on consumables, personal protective equipment, hand tools, power tools and consumables for power tools. The delivery of other made-to-stock products (e.g., bricks, tiles, pipes, etc) is not included as part of the scope of the kanban strategy. The kanban strategy has the following goals: (1) give users what they want when they want it by pulling materials from suppliers, (2) support the reduction of material inventories, (3) reduce the paperwork necessary to order new products or to increase stock quantities, (4) facilitate product rationalization, (5) reduce purchasing cycle times, (6) eliminate expediting, (7) contribute to continuous improvement, (8) act as a catalyst for change in procurement methods, and (9) simplify site material management processes for acquiring, storing, distributing, and disposing of made-to-stock products by eliminating waste and reducing information processing.

COMPONENTS

The components of the kanban strategy are: (1) marketplaces or main site stores, (2) collection vehicles or 'milk runs', (3) supplier kanbans, (4) satellite stores, and (5) an inventory management system. Figure 1 provides a graphical representation of these components.

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[4] The management of made-to-order products will be reported in future papers.

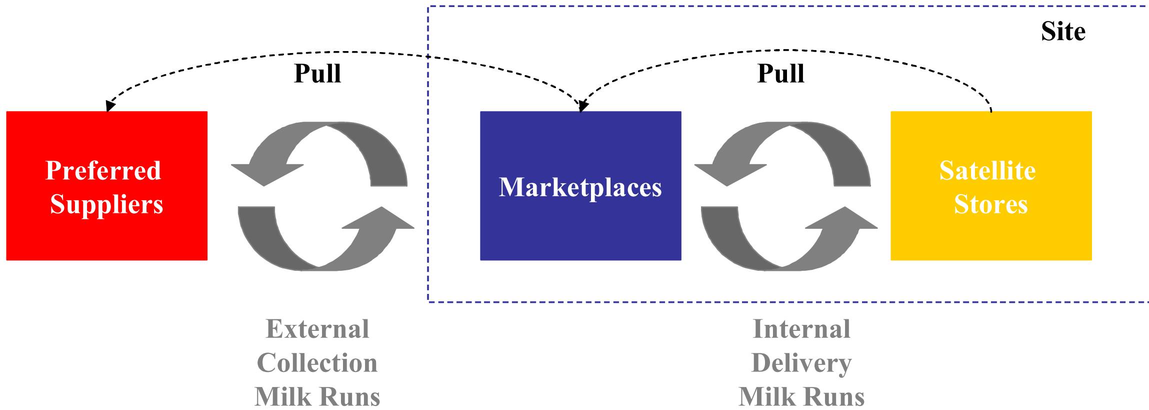

Figure 1: The Kanban Strategy: Components and Pull Mechanisms

Marketplaces

Marketplaces are site warehouses for distribution of consumables and small tools replacements. The kanban strategy involves the use of three marketplaces each with an estimated area of 2153 ft^2 ($200m^2$). A special racking configuration is adopted to facilitate the replenishment operation.

Satellite Stores

The project has a large number of workers (5000 at peak) and covers a large area. Construction teams use satellite stores on site as collection points to get products from marketplaces. The location of these stores is based on the progress of construction during the project. Portable cargo containers are used to allow relocation when necessary.

External Collection Milk Runs

'Milk runs' are routes through preferred suppliers to collect products. A special fleet of vehicles called milk run vehicles collect materials from preferred suppliers and replenish marketplaces on a daily basis. Up to three or four collections per day per milk run vehicle will ensure the right amounts of stocks on site. To reduce the collection cycle time, dedicated supplier depots are established in two consolidation centres between 2 and 5 miles from the main site. These consolidation centres are part of the logistics management solution for the project. The replenishment operation is performed using milk run vehicles with a capacity of 7.5 tonnes. Milk run vehicles have a tail lift to facilitate load and offload operations and use roll cages to transport the bins (or kanban signals). We elaborate on this later in this paper.

Internal Delivery Milk Runs

Although marketplaces do issue products to individuals through a service counter, they primarily function as site warehouses from which satellite stores are supplied. An internal milk run system links satellite stores to marketplaces just as the external milk run system links marketplaces to suppliers. Costs are allocated to users based on head count, thus avoiding the need to account separately for each transaction.

Supplier Kanbans

Plastic bins are used as kanban signals to pull materials from preferred suppliers to site on a just-in-time basis. Request forms are used as kanban signals between satellite stores and marketplaces. To standardize bin sizes, three different types are used to accommodate the variety of products in terms of sizes and shapes: (1) small bin (280mm depth x 210mm width x 130mm height), (2) medium bin (375d x 210w x 180h), (3) large bin (375d x 420w x 180h). Each bin is identified through a label placed on the front of the bin. If a product does not fit in one of the bins, plastic cards are prepared to serve as a signal. The information on the card is similar to the information on the bin label (see Figure 2).

From	**To**
Supplier	Marketplace
Product Description	
Boots XYZ	
Location	**SKU N°**
1C4-1	03015322
Kanban Signal	**Kanban Qty**
Bin or Card	100

Figure 2: Bin Labels and Card Template

The amount of inventory is controlled by minimum and maximum levels determined by forecasts of site demand. Forecasting site demand is not an easy task. Construction teams may not be able to provide this information at the level of detail required to determine the min and max levels. Therefore, labour histograms and historical consumption rates are being used to estimate future demand for these products.

Inventory Control System

Warehouse management systems are not always implemented 'as is' in their initial package form. It is unlikely that the package perfectly matches customer requirements. In this particular case, the inventory control system is designed to (1) support the kanban and milk run operations, (2) improve inventory accuracy, (3) decrease order processing time, (4) eliminate picking errors, (5) improve the use of human and warehouse resources, (6) reduce inventory carrying costs, (7) improve customer (construction teams) service levels, and (8) eliminate costly physical inventories.

THE KANBAN PROCESS

The kanban strategy has five major tasks: (1) order placement, (2) product request, (3) picking, (4) dispatching (including delivery milk runs), and (5) replenishment (collection milk runs).

Order Placement

Suppliers receive what is called an open order which basically means that the site can pull materials from the supplier up to a certain monetary limit. The open order reduces information processing time. Without an open order, the pull mechanism would be constrained by procurement or purchasing procedures.

Product Request

A request from site arrives at the marketplace in a verbal or written communication. A typical request does not necessarily include a technical description of the requested products, therefore, the ability and training of the store man combined with a standard way to request products is essential. Samples of fast moving products are kept at the serving counter in the marketplace to facilitate the product request task. An updated stock list is also kept at the serving counter as a reference. This list includes the supplier's product code, product descriptions, and product locations within the marketplace. If the requested products are not in stock, the team managing the marketplace has to evaluate the need to incorporate this new product into the stock profile. If the requested products are in stock, the picking operation is the next step.

Picking Operation

This operation includes all actions needed to get products from the bins. In order to follow certain rules for the picking operation, one of the bins is denoted as the 'working bin' and the rest as 'back up bins'. Once empty, the working bin is sent to the loading areas and placed on a roll cage. One of the back-up bins then becomes the working bin. After this, the cycle is continuously driven by demand. Reorder points (minimum levels) and maximum levels are reset periodically in accordance with replenishment lead-times and forecast consumption rates to avoid lack of stock. The reorder point depends on the product consumption rate expressed in terms of bins per time unit, together with the number of milk runs in a day. Consequently, assuming that bin size and milk run frequency stay constant, both minimum and maximum levels are changed by changing the number of bins in the system. That number of bins is assigned to the supplier and to the marketplace(s). For example, if the demand for a certain type of product is forecast to be 1000 per day, and the bin for that type of product holds 250, the number of bins might be increased from the 4 required to meet forecast demand to 5, allowing for forecast inaccuracy. Then, 5 bins are assigned to the supplier and 5 bins to the marketplace(s) handling that product.

Dispatching Operation

After the picking operation, the next step is to dispatch the requested products to the final customer. Marketplaces can get either a request from an individual via the serving counter located in the marketplace or a request from satellite stores for delivery to site through an internal milk run. The dispatching operation through the serving counter is the continuation of the picking operation described above and it comprises all actions required to give the products to the individual waiting behind the serving counter. If the goods are to be delivered to satellite stores, a different fleet of milk run vehicles performs this operation. In this case, the kanban is a material requisition form that is collected by the milk runs at each satellite store as part of their daily routine.

Replenishing Marketplace Stocks

Milk run vehicles follow pre-determined routes (milk runs) for collection, each visiting specific suppliers on each run. Empty bins are collected from each marketplace. Milk run vehicles arrive at supplier warehouses and exchange empty bins for full bins. By keeping their allocated bins full, ready for loading onto milk run vehicles, preferred suppliers maintain sufficient inventories to meet project demand. Milk run vehicles then either return to site or continue their journey to the next supplier warehouse. To reduce the exchange time of bins, suppliers agreed to first load full bins and then input the order into their own system after the milk run vehicle has left their facility. A special team works closely with suppliers to verify that the right products and stock quantities are in place throughout the life of the project. Each vehicle makes multiple milk runs per day, thereby reducing the amount of inventory required to be held on site.

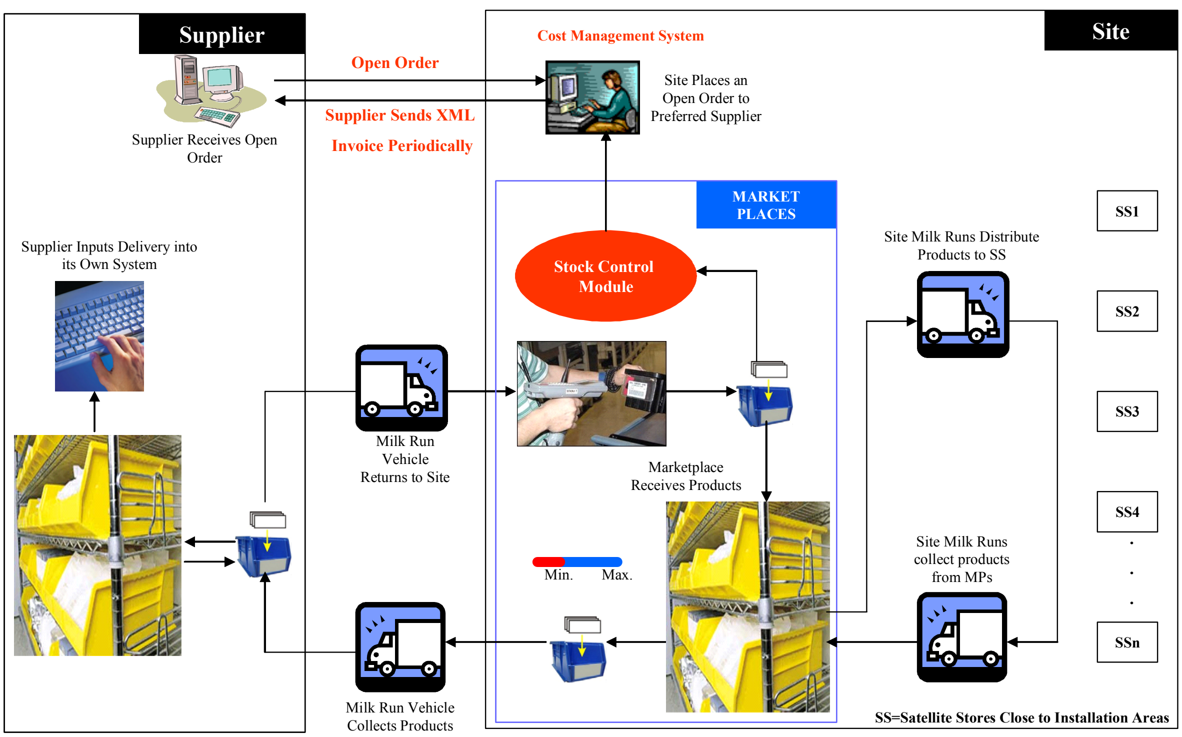

Figure 3: The Kanban Process

THE NEED FOR SUPPLIER INTEGRATION

Each marketplace contains hundreds of different products that are collected daily from suppliers, each of which belongs to a very complex supply network. Traditionally, one of the most important communication links between construction and suppliers is the transmission of information related to what type of products, in what quantities, and when and where construction teams expect the products to be delivered. The kanban strategy proposes a different way to manage these communication links. The strategy requires suppliers to change the way they work and adopt new processes (Figure 3). If suppliers do not understand the kanban process, the replenishment operation will fail. Therefore, to implement the kanban strategy successfully, the integration of first-tier suppliers is a 'must'.

How to do it? Supply chain integration is not an easy task in any circumstances, much less in a complex environment like construction. To move towards this type of integration, this paper supports the creation of a new role named 'supply chain integrator' whose main focus will be on the value stream rather than on a traditional myopic view of a single stakeholder. Arbulu and Tommelein (2002b) suggest that supply chain integrators could provide the glue to bring people and organizations together. Parker and Anderson (2002) proposed that supply chain integrators must possess business and interpersonal skills, complementing technical skills that will allow them to maintain the integrity of the final product. In addition to these skills, this paper supports the idea that construction supply chain integrators should focus on (1) evaluating suppliers' capabilities and level of flexibility to adopt new processes, (2) identifying and eliminating waste in the supply chain focusing on creating value for everyone involved and not only the final customer, (3) working with suppliers to understand the root cause of a particular problem and the corresponding solution, and (5) acting proactively to identify potential improvements to the supply chain as a whole. During the implementation of the kanban strategy, a small team was in charge of performing some of these tasks focusing only on made-to-stock supply chains. At the time this paper was written, the team had started other supply chain integration initiatives focused on made-to-order supply chains and delivery of bulk materials. The results of this work will be reported in future papers.

IMPLEMENTATION CHALLENGES AND FINDINGS

Five suppliers are expected to serve the marketplaces. All have the status of preferred suppliers to the contractor. Each supplier handles more than 1500 different products. The capacity of each marketplace is approximately 800 different products with an average of three bins per product. Therefore, one of the most important implementation challenges is to match the demand with capacity in terms of the number of different products and their quantities. The contractor, which does work in excess of $750 million per year, provided data regarding purchases from preferred suppliers during previous years. Figure 4 shows the results of the analysis of this data for one supplier only. 97.6% of the total number of different products has an average demand of less than 100 items per month. Further analysis of this 97.6% (see Figure 5) reveals that 91.2% (0.924 x 97.6%) of the total amount of different products have an average demand of less than 20 items per month. The root cause of this problem is that construction teams are selecting products directly from supplier catalogs (more than 2000 different products) rather than from project-specific catalogs in which product types have been consolidated and standardized. Additional analysis using different data from other preferred suppliers show similar results.

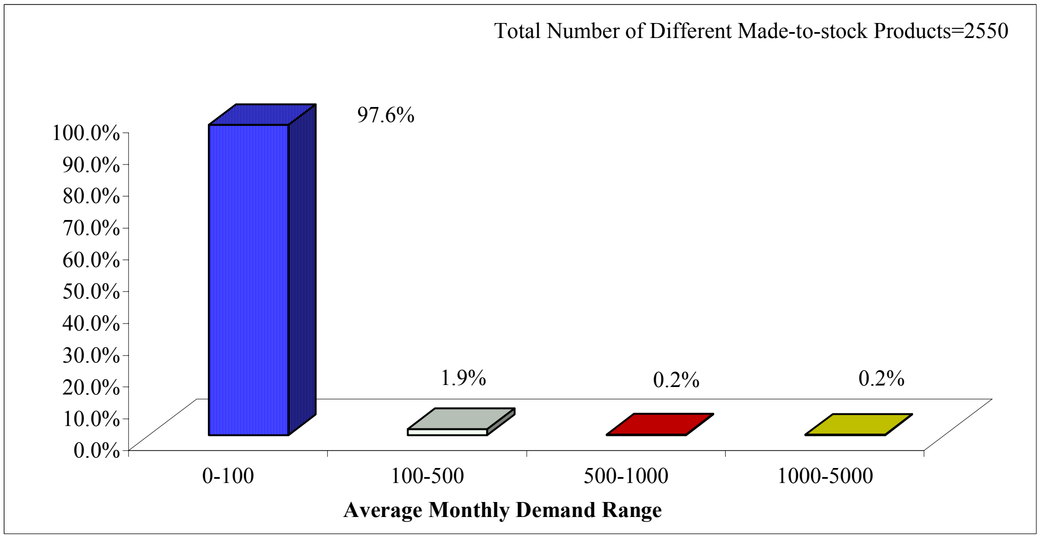

Figure 4: Analysis of Material Purchasing Behavior

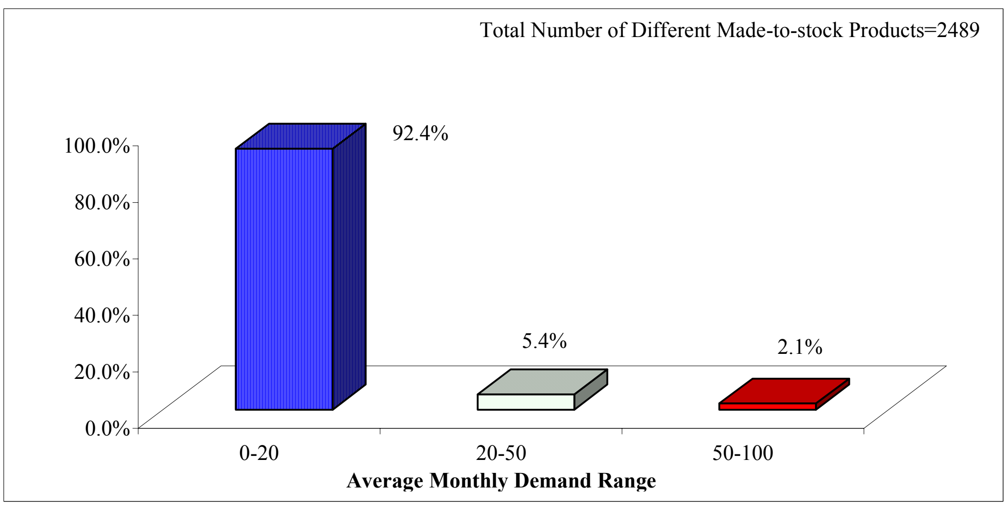

Figure 5: Analysis of Products with Average Monthly Demand less than 100 items

The conclusion from this analysis is that a program to rationalize product profiles is required. To rationalize means to reduce the stock profile by replacing products with others that have similar functionalities; i.e., to standardize. The rationalization initiative started at the time this paper was being written. The results will be presented in future papers.

OBSERVATIONS FROM PRACTICE

The kanban system is currently allowing construction teams to get 400 different types of products from two different suppliers on a just-in-time basis. The replenishment of these products is done within a period of 2 to 4 hours. The current plan is to increase the number of suppliers to 5 and therefore the number of different products to approximately 800 in total.

The kanban strategy has a positive impact on labour productivity since construction teams can get what they need without delaying production. In the case of an unexpected increase in daily demands from site, products can be replenished quicker than by traditional methods which rely on next day deliveries. Therefore, the kanban system guarantees same day internal deliveries for all products included in the stock profile. This is possible because preferred suppliers carry the stock levels for each marketplace product based on future site demands. The amount of inventory is determined by the number and capacity of bins in the system plus a quantity needed to respond to possible changes in the number of bins.

To work properly, the kanban system relies on product requests made in small quantities (small batches). This becomes a problem when traditional procedures generate orders in big batches usually in a weekly or biweekly basis. The advantage of the kanban system is that construction teams can get products from marketplaces on a daily basis according to site needs. The big batch mentality is then one of the most important challenges in the implementation of the kanban strategy. To face this challenge, the kanban implementation team has created a plan to engage construction teams one by one to help them understand the real value of the kanban system as well as to co-create new processes and procedures to support the change from big batches to small batches. This work is currently under way.

CONCLUSIONS

This paper has presented a material management strategy that uses supplier kanbans to signal the need for replenishment of a limited range of products from preferred suppliers to site. The paper has illustrated a combination of lean and material management techniques working in unison to generate value for the final customer. It has demonstrated the application of lean concepts in support of value-adding strategies. The paper has highlighted the importance of implementing a process-driven lean strategy across organizational and company boundaries. This paper has presented a real example of supplier integration through the application of supplier kanbans. The need for supply chain integration is highlighted through a proposal for the creation of a new role called supply chain integrator with a focus on the value stream bringing people and organizations together.

The authors challenge individual companies and their supply chain partners to adapt the kanban strategy to their own scenario using their own processes and project data.

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REFERENCES

Arbulu, R.J. (2002). *Improving Construction Supply Chain Performance: Case Study on Pipe Supports used in Power Plants*. Master of Engineering Thesis, Constr. Engrg. and Mgmt. Program, U.C. Berkeley, Berkeley, CA, May.

Arbulu, R.J., and Tommelein, I.D. (2002a). "Alternative Supply-Chain Configurations for Engineered or Catalogued Made-To-Order Components: Case Study on Pipe Supports used in Power Plants." *Proc. Tenth Annual Conference of the International Group for Lean Construction* (IGLC-10), 6-8 August, held in Gramado, Brazil, 197-209.

Arbulu, R.J., and Tommelein, I.D. (2002b). "Value Stream Analysis of Construction Supply Chains: Case Study on Pipe Support Used in Power Plants." *Proc. Tenth Annual Conference of the International Group for Lean Construction* (IGLC-10), 6-8 August, held in Gramado, Brazil, 183-195.

Borges da Silva, F., and Ferreira, F. (1999). "Applicability of Logistics Management in Lean Construction: A Case Study Approach in Brazilian Building Companies." *Proc. Seventh Annual Conference of the International Group for Lean Construction* (IGLC-7), 26-28 July, held in Berkeley, CA, USA, 147-158.

CII (1987). "Project Materials Management Planning Guide" *SD-27*. Prepared by the Material management Task Force, Construction Industry Institute, Austin, Texas.

CII (1988). "Project Materials Management Primer." *RS47-1*. Prepared by the Material management Task Force, Construction Industry Institute, Austin, Texas.

Parker, G., and Anderson, E. (2002). "From Buyer to Integrator: The Transformation of the Supply-Chain Manager in the Vertically Disintegrating Firm." POMS, *Journal of Production and Operations Management*, 11 (1) 75-91.

Stukhart, G., and Bell, L. (1985). "Attributes of Material Management." *SD-1.* A Report to the Construction Industry Institute, University of Texas A&M, Auburn University, April, 34 pp.

The Productivity Press Development Team (2002). *Kanban for the Shopfloor*. Productivity Press, Portland, OR, 102 pp.

Tommelein, I.D., Walsh, K.D., and Hershauer, J.C. (2002). *Construction Supply Chain Management Primer*. Work document (not a CII publication) developed by Project Team 172 on "Improving Construction Supply Chain Performance" for the Construction Industry Institute, available from Tommelein, I.D., Constr. Engrg. and Mgmt. Program, Civil and Envir. Engrg. Dept., U.C. Berkeley, CA, January version.

Womack, J.P., and Jones, D.T. (1996). *Lean Thinking: Banish Waste and Create Wealth in your Corporation*. Simon and Schuster, New York, N.Y.

Womack, J.P., Jones, D.T., and Roos, D. (1990). *The Machine that Changed the World*. Harper Collins, New York, NY, 323 pp.