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Just-in-Time application and implementation for building material management

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Materials constitute a huge proportion of the cost of construction. Materials are sometimes ordered weeks or even months ahead of requirement leading to uneconomical inventory on construction sites or contractors' warehouses. Building material inventory represents cost to procure, cost to store and insure, cost to guard against theft and cost incurred when inventory becomes obsolete. This paper presents an overview of the Just-in-Time (JIT) production system and discusses application and implementation issues for the control of material inventory in building construction. JIT ensures that suppliers deliver directly to the production floor to achieve either a reduction in inventory or zero inventory and consequently a reduction in production costs. Implementation of JIT building material management in construction has the potential to realize the same far reaching benefits experienced in manufacturing. Relevant factors to consider in JIT implementation for material inventory management in construction are implications for construction output and quantities, production planning, design planning, construction contractor and suppliers' relationships, material sourcing, and education and training.

Keywords: Just-in-Time, building material management, inventory, purchasing, suppliers, electronic data interchange.

Introduction

'Material management is the system for planning and controlling all the necessary efforts to ensure that the right quality and quantity of materials and equipment are appropriately specified in a timely manner, are obtained at a reasonable cost, and are available at the point of use when needed' (Business Roundtable, 1983).

Material constitutes a huge proportion of the cost of construction. A study by Marsh (1985) shows the cost of materials and equipment constitutes approximately 60% of the project's cost. Bernold and Treseler (1991) commented that material represents a large proportion of construction costs and may even represent a larger portion in the future. Nonetheless, few materials management systems are presently being used effectively in the construction industry. The lack of use of material management systems is unfortunate for the construction industry given Bell and Wooten's (1985) claim that a material management system could produce an improvement by almost 12% in craft labour productivity. Obviously, improved labour productivity results in reduced construction cost which is beneficial to contractors in terms of profitability and competitive position; to construction clients in terms of reduced bidding price and to the construction industry in terms of the increase in construction that can be procured for the same amount.

Construction is characterized by complex communication and coordination environments involving a large number of individuals and interacting functions, and the assembly of many components varying from low to high cost. Apart from this, construction environments are characterized by problems related to production, general quality of work, design changes, material quality and availability, material handling and movement, safety, labour availability, capacity utilization, etc. Generic procedures for material acquisition in construction include material inspection, delivery, handling and storage before installation (Bell and Wooten, 1985; Stukhart and Bell, 1986). Some of these activities have been described as waste; they do not add value and hence should be minimized (Schonberger, 1982; Shingo, 1986; Hay, 1988). One of the concepts in the manufacturing environment developed to address similar complex communication, coordination and waste minimization is Just-in-Time (JIT).

This paper presents an overview of the JIT production

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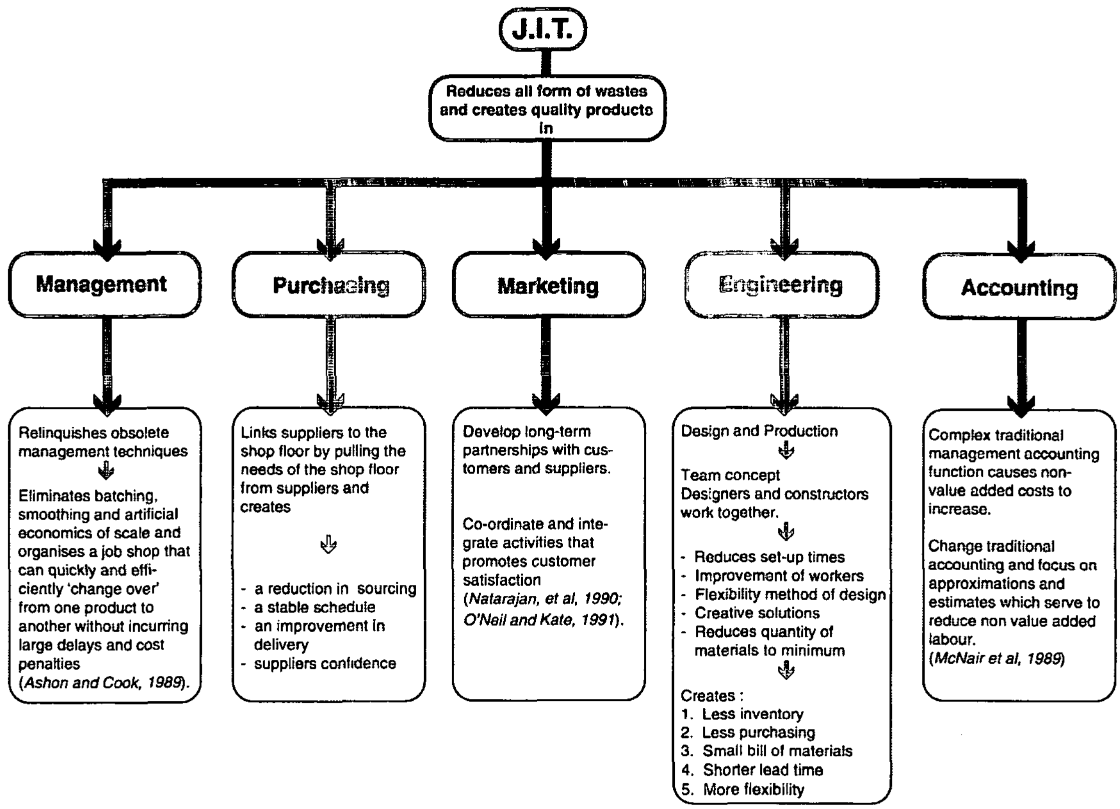

Figure 1 JIT approach to total business functions

system and examines application and implementation issues for material inventory management in building construction.

An overview of JIT

JIT is a set of philosophies developed in Japan designed for efficient and quality production. Although perceptions of JIT vary enormously, it is generally agreed that it improves quality, preventive maintenance, employee motivation and morale, worker involvement and commitment and decreases inventory level, lead time, throughput or set-up times, defects and ultimately costs. The JIT approach represents major changes in management philosophy to reduce slack resources, create more fluid and responsive organizational systems in place of highly structured, formal organizational systems, and involve people at all levels in operations management and decision making (Joshi, 1990).

Dale and Cooper (1992) have argued that JIT is one of the management techniques which falls under the umbrella of Total Quality Management. Although JIT practices contribute directly or indirectly to quality and productivity improvement, it is not a programmable module system that one can purchase from a vendor for installation. However some general rules of implementation can be identified and specific JIT implementation procedures are tailored to an organization's characteristics and environment.

Im and Lee (1989) have argued that all JIT practices contribute directly or indirectly to inventory reduction. JIT is often regarded as an inventory reduction philosophy, whose aim is to reduce inventory that manufacturing firms have no room to store. It has developed into a set of objectives leading to reduction of many other forms of waste. JIT seeks to provide its users with the benefits of eliminating waste. Waste in JIT is any action/process that does not add to value.

Ohno (1988) and Suzaki (1987) have outlined detailed analyses of sources of waste in manufacturing that are considered invaluable inputs to JIT. These wastes are overproduction, waiting, transportation, processing, stocks, motion and making defective products.

Lea and Parker (1989) described JIT as dealing with the creation of a manageable environment – in which participants in production process seek to eliminate waste and keep things simple – to effect a continuous improvement in overall business. Schonberger (1982) explained the idea of JIT in a simple fashion: to produce and deliver finished goods just in time to be sold, sub-assemblies just in time to be assembled into finished goods, and purchasing materials just in time to be transformed into fabricated parts. Willis and Suter (1989) pointed out that JIT simply means to provide exactly what is needed when it is needed. Scott (1986) described this as a 'wasteless' programme. Ptak (1991) summarized the by-product of JIT implementation as a major reduction in lead time, inventory and required manufacturing space yielding a more competitive company.

Plenert (1990) identified three different concepts of JIT: kanban, production planning and global management philosophy. Kanban allows the scheduling of inventory movement through the shop floor with the use of a material-movement-tracking device. Figure 1 shows JIT implications for various functioning aspects of manufacturing. To realize its potential and achieve total quality, Schneider and Leatherman (1992) have maintained that JIT must involve all aspects of organization (total business approach) leading to excellent communication and inter-functional cooperation. The main features of JIT (Schonberger, 1982; Hutchins, 1990) can be described as:

Minimum inventory
Minimum work-in-progress
Information driven 'pull' system
Close knit team
Close relation with suppliers
Operator responsibility
Quality
Responsiveness
Reorganized work space

JIT material inventory

JIT materials inventory is intended both to optimize material delivery timing and to minimize inventory quantities. It specifies delivery of materials to work stations as needed to implement production scheduling.

In JIT, inventory is 'demand' pulled into and through the process on a part-by-part basis in small quantities. In other words, materials are provided only when required by the next work station and, ultimately, by the suppliers. These are often called Kanban quantities. The movement of material is from supplier to work position direct, rather than traditional practice: from supplier to company site or store to work position. This tends to minimize lot size, queues and work-in-process inventory control. The pull system minimizes the time that a material spends in the production process and means less rework when a quality problem is discovered.

Since the materials are supplied in small quantities depending on the quantity required to complete a specific work over a short period possible, the inventory flow in JIT resembles a pipeline, where the pipeline is a production process. Willis and Suter Jr (1989) likened the JIT material flow in a production to the water flow in a river. This is required to be as smooth as possible to achieve minimal or zero inventory.

Apart from describing inventory flow in JIT as a pipeline, it is sometimes referred to as 'four-wall system' (Schonberger, 1986; Tatikonda, 1988). Once material enters the four walls of production, it is not recorded until it leaves as part of finished goods. This is possible because the material is supplied in small quantities directly for a specific application within a short time in the production process. The difficulty in tracking the location of such material in the production process is minimal.

Related aspects of JIT material inventory are purchasing and supply management. Manoochehri (1984), Ansari and Modarress (1988) and Freeland (1991) have all described JIT purchasing as a set of techniques and concepts for eliminating waste and inefficiency in the purchasing process. In contrast to the conventional purchasing practices, Romero (1991) and Freeland (1991) identified the basic characteristics of JIT purchasing or JIT policies in supply management.

JIT material inventory and purchasing rely on partnership approach relationships between a company and its suppliers or vendors. These relationships are based on a different philosophy from the usual manufacturing operations. As opposed to the selection of suppliers based on multiple sourcing of materials and selection of the supplier with lowest cost, JIT thrives on local and sole-source vendors. These vendors are accepted as partners in a joint effort with the company and the company's vendors responsible for high-cost items (parts, materials or services) are encouraged to undergo the company's programme of JIT indoctrination.

JIT application for building material management

Various materials are required for construction, ranging from low-cost items like nails to high cost components like steel beams. Relatively large numbers of components and materials are purchased and delivered to construction sites to achieve the end product.

A typical materials flow for building construction is characterized by convergence to the end product – the completed building. Many materials are processed, fabricated and combined to make sub-assemblies or prefabricated under a factory based environment before being brought to site for installation. Some are processed and assembled on construction sites as part of work-in-process.

Application of JIT to building material management demands that some preliminary questions be addressed:

1. What material?
2. Who supplies these materials and components to construction site?
3. What would be the best distribution system?

What material?

This should address questions of type, volume, quantity and location or distance from site of parts, materials and components required for a contract. This information is extracted from the contract documents such as the contract bill of quantities from which bills of materials and components are produced. The materials and components must be classified into ordering systems. It may be possible to classify each of the materials and components, in terms of massiveness and criticality to construction programme and quality control into four ordering systems (after Hiraki *et al.*, 1994):

Synchronized system
Prescheduled ordering system
Periodic ordering system
Non-periodic ordering system

The synchronized system is applied to large volume components like air conditioning units and fabricated steel work. The prescheduled ordering system is applied to big-volume (but not as big as synchronized system) such as panels, doors etc. The periodic ordering system applied to materials like cement, gravel, paint etc., which are required at various stages during construction. The non-periodic ordering system would apply to small-volume and large quantity materials such as nails, bolts etc., which are obtained as occasion arises.

Who supplies these materials and components to construction site?

Three ways of supplying materials and components to construction sites are:

1. In-house supply – parts and component fabricated from contractor's workshop and material such as quarry products produced by a division of the construction firm
2. Fabrication of parts and components by subcontractors
3. Supply of parts and materials out-house by vendors

Each of the parts, materials and components required for the construction contract must be classified to be supplied by one of these supply systems.

What would be the best distribution system?

Available distribution systems include:

1. Direct from component and part fabrication workshop or material production factory to site
2. Direct from contractor/supplier depot or warehouse to site
3. Travelling pickup of materials from several suppliers to site

The delivery system of the materials and components must be selected with reference to the ordering system.

Figure 2 shows the relationship between all these stages and the JIT application to building material management. It shows that materials and components which are classified under the synchronized, prescheduled and periodic ordering systems can be subjected to JIT inventory and purchasing.

The next question that will readily come to mind is 'How can JIT be applicable to the management of the various building materials and components?' JIT unlike various material management systems such as materials requirement planning (MRP), manufacturing resources planning (MRP II), optimized production techniques (OPT) and computer integrated manufacturing (CIM) is not a computer system (package) which can be purchased for installation. It is a principle, or good practice guide, which strives to achieve discipline in the work place and demands some reorganization and reorientation of the production process and participants.

The application of JIT philosophy in construction, in relation to material inventory, aims to minimize all waste. Practically, the ultimate goal is to have direct receipt of materials into construction work-in-process, replacing the traditional receiving, inspection and storage functions. These traditional procedures for material acquisition do not add value and should be minimized to

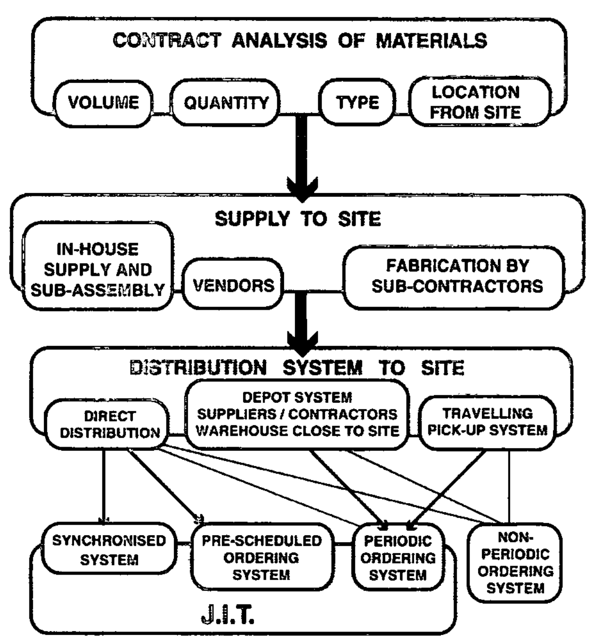

Figure 2 JIT application for building material inventory

achieve inventory reduction in the construction process. In relation to the inspection of building materials for quality, JIT deals with quality as an integral part of production process whereby the contractor and his suppliers have to conform to an agreed quality management system. By so doing, the waste (time and cost) associated with expenditure on quality control and inspection of building materials is eliminated.

JIT application to building material management should ensure that materials are purchased in small quantities with frequent deliveries to the construction site just in time for usage. Under this system, materials required on each particular day and the sequence in which they are to be used in a construction process must be known by site workforce. The supplier must be provided with this information and must be willing to comply to the scheduled demands.

Application of JIT material inventory should not mean that a contractor transfers his own problems or pushes inventory back to the construction supplier, where the supplier is asked to maintain inventory to buffer against demand changes. If a contractor does this, there is tendency for the supplier to pass back the extra cost of carrying this inventory to the contractor in form of an increase in price of purchased building materials. JIT material management should expose material management problems in the production process on the construction site, search for the causes, and correct them as closely as possible to the source(s) of the problem.

Implementation of JIT for building material management

Various factors have been proposed for effective implementation of JIT philosophy. Empirical work by Im and Lee (1989) show that the most important factor is top management commitment, followed by worker participation, education and training, level scheduling, reorganization, proximity to suppliers, supplier participation, reduction of set-up time, new accounting practices and quality. Apparently, these factors are relevant to JIT management of building construction material.

The implementation of JIT for building material control in construction will need reorientation and change in attitudes of construction management and workers. JIT requires flexibility and demands workers' participation in the decision making process. Current practice in the construction industry gives little or no opportunity to workers, particularly at the lower level, to participate in decision making. On the implementation of JIT in the construction industry, Low (1992, p. 8) concludes that 'The very nature of construction activities suggests that the JIT concept, which has been adopted successfully for raising productivity in manufacturing, can only be applied gainfully if appropriate structural modifications are made in the construction industry'. For JIT to be implemented successfully in building construction material management, the following bottlenecks need considerations.

Construction process output and material quantities

There are various factors that the construction process output and quantities of materials delivered to construction site must conform with for JIT to be applicable. The level of process output in JIT determines the quantity of and the rate at which materials are delivered. It is essential, therefore, for the contractor to maintain stable productivity so that material can flow smoothly into the production system. The quantity of material which is delivered on a daily or periodic basis is determined by the requirements of work-in-process. This must be exact and delivered in small and variable finite quantities to ensure zero or near zero inventory on construction sites. The implication of this is that the contractor will need to determine the exact quantities of construction materials in relation to production plan and schedule, and communicate this information to suppliers.

Communication of contractor with suppliers

Effective links must be established with suppliers for efficient communication. The suppliers must know and monitor each stage of work-in-process. This can be achieved with ease by contractors giving authority to their site management to communicate directly with their suppliers on site material requirements. An increasing number of companies are introducing Electronic Data Interchange (EDI) with their suppliers. The critical success factor in JIT for material inventory control on site will be direct link information system from site to suppliers via EDI links or other management information system techniques.

Suppliers need to be involved at both pre-contract and post-contract stages in construction planning. They must have the bills of materials and a copy of the master schedules of construction and materials to know the material types and quantities to deliver and the precise time that they are required on site. Through EDI links direct from site, suppliers may be reminded of the timing, exact quantities and types, and any rescheduling of delivery times to site. This procedure in reality eliminates waste associated with time and paper work required for purchase orders and requisitions by contractors.

Production planning

Construction work is characterized by poor planning and associated project time overrun. Construction has high level of wastage due to lack of planning (Harris and Olomolaiye, 1992). JIT requires an accurate work programme. It must show clearly the specific time that material is needed. The construction schedule needs to be developed by providing only the quantities of material required for a specified time period. This means that contractors need more discipline and that they must strive to achieve an accurate construction plan and to ensure that construction is carried out as planned. What may result in delays in work progress should be foreseen far ahead of time, dealt with on time and communicated to the supplier in sufficient time to allow programme adjustment. Harris and Olomolaiye (1992) observed that construction materials, with the exception of ready-mix concrete (this is ordered when needed as this cannot be stored), are ordered weeks or even months ahead of requirement due to bad scheduling and changes in plan. This must change if JIT philosophy is to be useful to the construction industry. JIT is not practical when a supplier delivers material to the construction site and it cannot be used immediately as planned due to delays in work progress. This material then becomes an inventory which is contrary to one of JIT's goals – to reduce work in progress inventory.

Design planning

The interaction between design and construction process is important to the total JIT effort. The contractor can provide vital input to project simplification, standardization of specification, design for buildability and building quality into the design. JIT philosophy performs efficiently when a production process is standardized. For the production process to be standardized, the design input is paramount. Project designers have contractual responsibility to design projects to meet clients' requirements intelligently. The project design strategy for JIT calls for flow-based construction process which need not sacrifice the clients' expectations. To facilitate the flow-based construction, strategies such as modularization or simplification of design elements are useful. Modular design allows flow-based delivery to site by suppliers of materials that are required for mass-scaled production of commonly used modules and simplification in design allows for short lead times for material assembly. These encourage the use of standardized materials which can be procured from suppliers on a JIT basis and there is an associated increase in productivity of the site workforce.

Traditionally, construction design and production are carried out by different organizations. Where these two functions are performed by different independent organizations, this may pose a problem for standardization of production process. The current use of the design and build method in construction procurement means that the design and production gap can be bridged to accommodate design and production standardization. Cooperation between the design and production teams means that construction technology, sequence of construction operations, construction materials etc. can be standardized to meet the construction client's requirement. A standardized construction material provides room for long-term agreement between contractor and supplier.

In addition, JIT purchasing by the contractor requires close working cooperation between the designer and contractor. Contractors need designers and specialists to provide construction detailing and specifications early enough to allow them to make satisfactory arrangements with JIT suppliers. The standardization of the sequence of construction operations also leads to a more uniform and invariable output rate.

Construction site layout and storage planning

Construction site layout and storage facilities need to be properly planned such that building materials and components are located at fixed positions on the site. The underlying planning strategy requires JIT suppliers to deliver all materials components and subassemblies to, or close to, the point of work in the proper sequence. This strategy will minimize material waste and damage on site which is caused by multiple handling of material and will also increase productivity due to the ease of access to the materials components and subassemblies.

Construction contractor and supplier's relationship

Building materials merchants or suppliers are diverse in size, geographical location, resources, building materials capable of supplying etc. For the building material merchants to be in a position to embrace JIT philosophy, they must reorientate their operations. Hale and Karney (1987) identified the service and delivery factors as the most important JIT ingredients for every supplier to have. Building materials merchants must embrace quality delivery by committing themselves to deliver the agreed-upon quantity of acceptable building materials and equipment on time, neither before nor after the agreed-upon date. A successful JIT programme requires this aspect of delivery not to be compromised. It requires discipline by building materials' suppliers, and encouragement, motivation, cooperation and coordination by construction contractors.

The JIT supply of building materials to a construction site requires good delivery planning by both supplier and contractor. In the selection of JIT building material supplier a contractor must take into account the past record of its suppliers. An agreement must be reached between the two on who will take delivery to the construction site. On a very large contract, a supplier might be encouraged to expand his fleet of trucks in order to make sufficiently frequent deliveries or to locate its warehouse close to the contractor's construction activities. Where a contractor has many JIT suppliers, the deliveries of materials from these sources could be undertaken by a third-party (JIT carrier) who can consolidate deliveries from several sources or alternatively a contractor could provide a chain collection of deliveries from these sources.

Building material sourcing

JIT purchasing requires that the material sourcing to firms is reduced as much as possible. JIT purchasing is more effective, although this is not mandatory, if suppliers locate near construction activities. A construction contract is characterized by its one-off nature and the construction industry's workload fluctuates and is not one geographical location bound. This may produce problems for a JIT supplier on what to do if a contractor it serves has limited contracts or fails to win other contracts in the same geographical location. Such risks are reduced by adopting a modified JIT programme for the construction industry where contractors in the same locality collaborate on material sourcing. This demands that contractors in the same locality use the same suppliers. This practice is not unusual in the construction industry, but requires to be formalized among the contractors. This will keep the suppliers busy in spite of fluctuating workloads for each of the contractors in the group. Although they use the same JIT suppliers, this does not limit the extent to which a group of contractors in the same locality can compete in contract bidding. Other avenues are available for them to compete, such as material usage, labour productivity, mark-up etc.

Training and education

Construction firms and suppliers from top management to the low level employee must know the basic JIT philosophy. They need to know how and why JIT could improve efficiency in the construction process. Since JIT requires an attitude change of employees, it is important that all employees in both the contractor and the suppliers' organizations understand the JIT material management programme before its implementation. JIT demands both precision and flexibility in decision making. Construction operatives will need training and education in process skills and need to understand this well enough to make suggestions for improvements. Communication and group technologies are vital to the effective implementation and on-going maintenance of JIT. This means that contractor and suppliers' employees must be trained in area of communication techniques, in the needs of JIT participants and in teamwork.

JIT benefits for the construction industry's building material management

This section addresses various key questions. Why is JIT needed for building material management? What and who will motivate its implementation? Is it the client, BS5750 or the supplier's/contractor's self-motivation? Who will bear the 'risk', if any, in turning to JIT?

JIT is beneficial to contractors, suppliers and client alike. Although its implementation involves cost, in the long run cost savings by contractors and suppliers will offset the risk and additional cost in turning to JIT.

The construction industry is characterised by various types of waste. A sizeable proportion of waste is excess inventory on construction sites or at contractors' warehouses. Inventory represents cost to procure, cost to store and insure, cost to guard against theft and cost incurred when inventory becomes obsolete. Construction material inventory is a cost requiring financing from construction contractors' scarce resources. The use of JIT by construction firms will accomplish inventory reduction and could amount to significant cost savings to contractors. Less inventory by contractors will generate cost saving by avoiding expenditure on unnecessary inventory and by saving inventory carrying costs for excess construction materials. With less inventory on construction sites, there are potentials for shorter cycle times, and smoother and faster flow of construction materials.

The cost savings for a contractor could lead to more competitive pricing for the client. Apart from this, the construction client can also benefit from considerable improvement in project quality and delivery performance.

Standardization of construction material can benefit suppliers through long-term contracts with contractor to deliver materials. This means that suppliers can invest in long-term planning and development programmes. JIT purchasing does not mean cost to suppliers, rather it means that the suppliers do not have to produce more than required by construction contractors. This saves the suppliers cost of storage, tying down of money on excess inventories etc.

Obviously, the implementation of JIT material management on site must be led by the contractor. The contractor must communicate this development to his suppliers and identify those that are willing to subscribe to JIT purchasing. On the basis of this response and past records of the reliability of these suppliers, the contractor should be able to negotiate the implementation of JIT programme with suppliers. This negotiation will involve some reorganization for both the contractor and suppliers' organizations, and must be communicated effectively and understood by all parties.

A current trend in the construction industry is that clients ask for contractors to comply with relevant quality assurance provisions. In JIT the problems of quality are integral to the overall approach. This means that the contractor and its suppliers are able to comply with quality management provisions such as the BS5750 or ISO9000 and ensures that both of them work to the same standard code of practice.

Implementation of JIT building material management could produce other advantages. JIT building material management has the potential to provide or improve communications between contractors and their suppliers, establish closer relationships among construction workers as JIT demands team work, eliminate a large number of warehouses and site stores, reduce the number of the building materials suppliers and improve supplier's delivery performance. A closer working relationship between a contractor and its supplier has many additional benefits, including a supplier understanding the contractor's delivery and quality requirements, earlier involvement of supplier in the planning of new contracts etc.

There may be some work environments where inventory build-ups cannot be avoided because of the remoteness or uniqueness of the work. A contractor should look into the possibility of using other material management techniques, like MRP, to achieve an economic delivery and avoid needless inventory of building materials.

Conclusion

The construction industry is extremely competitive. JIT building material management, as an addition to good management practices, has the potential to ensure that contractors are competitive in a tough market. Construction firms need to focus on strategies that will lead to a reduction of excessive inventory on construction sites or warehouses. Excessive inventory is not economical – it adds to production cost and the costs of the construction. To improve itself the construction industry must open itself to any strategy that leads to the reduction of the industry's cost of production.

JIT achieves inventory cost reduction in manufacturing. The incorporation of JIT in the construction process needs to be developed. Each construction firm needs to define its material management problems and goals; what can be supported by the management of the company, and what is economically practical, before JIT building material management can be implemented. Other factors that need to be considered include the company's size, resources used, the type of construction undertaken etc.

JIT implementation for building material management requires trust and discipline on the part of the contractor and its suppliers. This requires the contractor to redefine its relationships with its suppliers; for example, by developing long-term relationships and being prepared to share information with them. An indication of successful implementation of JIT in the construction sector, based on trust, commitment and cooperation, is reported by Bennett (1991, pp. 172–6) in relation to Japan where subcontractors including material suppliers 'enjoy a paternalistic family relationship with one construction firm'. The need for trust in the construction industry is one of the two main thrusts of the interim report by Latham (1993) and it has been described as one of the two 'gatekeepers to any real progress'.

Generally, JIT in manufacturing achieves a series of benefits. It improves communication, increases inventory turnover, reduces inventory, eliminates warehouse, improves service, reduces supplier base, improves quality, enhances competitive position, improves or enhances forecasting, simplifies ordering and receiving procedures, builds up long-term relationships with suppliers, provides quicker resolution of delivery problems, decreases purchasing and administrative costs, decreases carrying cost, improves sense of team spirit, decreases traffic time and achieves lower prices. Is the construction industry ready for these tremendous benefits?

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