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MİMAR SİNAN FINE ARTS UNIVERSITY
INSTITUTE OF SCIENCE AND TECHNOLOGY

MATERIALS MANAGEMENT APPROACHES IN CONSTRUCTION SECTOR & A MODEL PROPOSAL

Graduate Thesis By

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MİMAR SİNAN GÜZEL SANATLAR ÜNİVERSİTESİ
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İNŞAAT SEKTÖRÜNDE MALZEME YÖNETİM YAKLAŞIMLARI VE BİR MODEL ÖNERİSİ

YÜKSEK LİSANS TEZİ

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Tez Danışmanı: Doç. Dr. Sema ERGÖNÜL

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Tahir AKKOYUNLU tarafından hazırlanan İNŞAAT SEKTÖRÜNDE MALZEME YÖNETİM YAKLAŞIMLARI VE BİR MODEL ÖNERİSİ adlı bu tezin Yüksek Lisans Tezi olarak uygun olduğunu onaylarım.

Doç.Dr. Sema ERGÖNÜL

Tez Danışmanı

Bu çalışma, jürimiz tarafından Mimar Sinan Güzel Sanatlar Üniversitesi Fen Bilimleri Enstitüsü Yapı Mühendisliği Anabilim Dalı, Yapım Proje Yönetimi Programında Yüksek Lisans Tezi olarak kabul edilmiştir.

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ÖZET

İNŞAAT SEKTÖRÜNDE MALZEME YÖNETİMİ YAKLAŞIMLARI VE BİR MODEL ÖNERİSİ

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İnsanlık her an değişim ve gelişim halindedir. Hayattaki tek statik değişimdir. Kaçınılmaz olarak, insanlığın en eski uğraş alanlarından olan ve içerisinde en köklü meslekleri barındıran inşaat sektörü de durmadan gelişmekte ve değişmektedir. Bu değişimin belki de en belirgin olduğu alanların başında inşaat yönetimi gelmektedir. İnşaat projelerinin günümüzde, gerek ekonomik büyüklükleri gerekse sosyolojik ve insan hayatı bakımından çok daha önemli hale gelmesiyle birlikte adı çok daha fazla duyulur hale gelmiştir.

Bilişimin gelişmesi ve tecrübelerin artmasıyla inşaat proje yönetimi (İPY) büyük bir ivmeyle günden güne gelişmektedir. İPY genel olarak bir projeyi, sorumlu olunan kısım ya da tümü için, insan hayatı ve insan sağlığını gözeterek, istenen en üst kalitede ve en ekonomik şekilde yapmak için gerekli parametreleri ortaya koyup bu doğrultuda işi teslim etmeyi amaçlayan bir kavramdır. Doğası itibarıyla İPY bir projedeki tüm süreçlere akreditedir ve tüm aktiviteler onu ilgilendirir. Bir başka deyişle, tüm aktiviteler İPY'nin tanımladığı şekilde yapılmalıdır. Bu, projenin doğru ve sağlıklı bir şekilde devam etmesi açısından hayatidir.

Elbette ki, bu kadar geniş etki alanı olan bir uzmanlığın da kendi içerisinde departmanları ve kısımları olacaktır. Bu tez İPY nin içerisindeki başlıklardan birisi olan "malzeme yönetimi" kavramını irdeleyecektir.

Malzeme yönetimi, genel olarak İPY içerisinde inşaat üretiminin hammaddesi olan materyallerin operasyonel anlamda; zaman, kalite, imalat gibi parametrelerinin yönetimiyle ilgilenen bir koludur.

Bu minvalde, çalışmada malzeme yönetimi kavramının teorik olarak açıklanması ilk öncelik olacaktır. Malzeme yönetimini tüm proje yönetimine aplike edebilmek için gerekli olan argümanlar, proje tipi ve detayına göre izlenecek yöntemler araştırılmıştır. Ayrıca, organizasyonun, malzeme yönetim kanadının niteliği ve niceliği gibi, malzeme yönetim felsefesini doğrudan ilgilendiren düşünsel ve fiziksel altyapının nasıl olması gerektiği de araştırılmış ve sorgulanmıştır.

Çalışmanın birinci ve ikinci bölümlerinde şu an dünyada uygulanmakta olan malzeme yönetim sistemleri araştırılmış, uygulanan yöntemlerden bazıları kıyaslamalı olarak değerlendirilmiştir. Teoride belirlenen unsurların pratik düzeyde ne denli uygulandığı da araştırılmış, ortaya çıkan sonuca göre yeni bir modele ihtiyaç olup olmadığı belirlenmiştir.

Tüm bu araştırmalarla birlikte, dördüncü bölümde, gerçekleştirilen büyük çapta projelerle bağlantılar kurulmuş anket düzenlenmiş ve seçilen büyük projelerin malzeme yönetimine bakışları ve malzeme yönetimiyle ilgili uygulamalar saptanmıştır. Beşinci bölümde şu an uygulanmakta olan bazı malzeme yönetim modellerinin eksikleri görülerek bu eksiklerden arındırılmış yeni bir malzeme yönetim modelin önerisi yapılmıştır. Önerilen modelin işleyişi bir örnek proje üzerinde açıklanmıştır.

SUMMARY

MATERIALS MANAGEMENT APPROACHES IN CONSTRUCTION SECTOR
&
A MODEL PROPOSAL

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Humanity is in constant change and development. The only static in life is change. Inevitably, Construction Sector, humanity's oldest occupation field incorporating many well established professions is constantly changing and developing. Perhaps, Construction Management is the most distinctive field among the ones involved in this change. This field, the name of which was rarely spoken 15 to 20 years ago, is a well known field now, as construction projects with their economical magnitudes and sociological significance by means of human life gained more importance.

Construction Project Management (CPM) is rapidly developing as informatics develops, and more experiences acquired. Generally speaking, CPM is a concept aiming at figuring out the necessary parameters required for obtaining the best quality and economical solutions for completing a project entirely or partially, and considering human life and human health. Due to its nature, CPM is accredited with all procedures in a project. It is involved in all activities. In other words, all activities should be carried out as specified by CPM. This is crucial for implementing a project correctly and seamlessly.

Definitely, a specialization with such a wide range has departments and sections. The concept of "Material Management" that CPM must include is studied in this thesis.

Generally speaking, material management is a management branch in CPM involved in managing parameters like time, quality, and manufacturing, which are raw materials of construction production, by means of operation.

In this context, defining the concept of material management theoretically comes first. Ideological and physical infrastructure required for practicing material management easily such as arguments required for adapting material management to entire project management, methods to be used according to project type and detail, and quantity and quality of material management wing in an organization are also studied and examined.

Practical material management systems are looked into, and some applicable methods are given comparatively in the first and seconds parts of this study. Applicability of the theoretically specified elements is assessed, and results figured out whether a new model is necessary.

Besides, links with big projects around are established; questionnaire has been made, and material management practice and material management approach in selected big projects are identified in the fourth part. Handicaps of some applicable material management models are seen, and thus an improved new model is offered. The proposed model is tested hypothetically and results are explained.

To My Mother & Father

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This study has been carried out under the supervision of Assoc. Prof. Dr. Sema ERGÖNÜL in the Institute of Science and Technology, Division of Structural Engineering, Construction Project Management Programme at Mimar Sinan Fine Arts University.

I want to gratefully thank to Assoc. Prof. Dr. Sema ERGÖNÜL , without whom I would not be able to complete my thesis, for her unconditional guidance, supervision, encouragement, motivation, support, patience and tolerance at each step of this study.

I would like to express my gratitude to my wife Canan AKKOYUNLU, my mother Şenol AKKOYUNLU , my father Şefik AKKOYUNLU my sisters Ülkü İNCETÜRKMEN and İlke BAYIR -who have never left me alone- for their endless love, support, patience and inspiration.

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LIST OF ABBREVIATIONS

ADC	:	Automated-Data-Collection
BL	:	Bill of Lading
CII	:	Construction Industry Institute
CPM	:	Construction Project Management
EPC	:	Engineering-Procurement-Construction
JIT	:	Just In Time
MM	:	Materials Management
MMS	:	Materials Management System
PC	:	Personel Computer
PM	:	Project Management
PO	:	Purchase Order
SCM	:	Supply Chain Management

INTRODUCTION

Materials management (MM) is a management system that integrates the traditional areas of purchasing, expediting and controlling the progress of the vendor. It is an essential part of project management. It can be integrated with engineering to provide an end product that meets the client's needs and is cost effective (Kini, 1999).

The importance of materials management and control has long been established emphasize the importance of monitoring the flow of materials and the data associated with them, such as their quantities and inventory levels (Poon et al. 2004).

Materials management problems occur with almost routine frequency in the best-managed companies, but they a rarely called by that name. Instead, management think in terms of the functional activities concerned with materials management: purchasing, production or material control, traffic, shipping and receiving, Thus, a materials management problem involving scheduling or inventory control becomes a 'production control problem,' and one concerned with supplier relations becomes a 'purchasing problem'. This is quite proper, since most companies divide materials management responsibility among several distinct functional departments. In most companies, the production control, purchasing, and traffic departments are not directly linked organizationally, even though each is performing part of the materials management job (Messner et.al, 2005).

A successful engineering and construction project fulfils the customer's needs while profiting the engineering company. In the current business environment, money is tight and clients are looking for engineering companies that can provide the best product at the lowest cost. Engineering solutions to this problem include using complex analytical tools to quickly create efficient designs, utilizing composite materials and custom designing equipment for optimum output. However, the area most often overlooked in this effort is materials management, which is generally considered to be a support function in engineering companies. Considering that for a typical industrial facility 10% to 15% of the total cost is for engineering design and 50% to 60% is for equipment and materials, it is obvious that obtaining the equipment and materials at the lowest possible cost will provide the greatest savings (Kini,1999).

Focusing on materials management for engineer/procure/construct projects will provide significant benefits to the engineering company and its customer in several ways. The customer will get exactly what he or she specified, leading to satisfied customers and repeat business. The engineering company will profit through a clear focus on the items that drive the costs, equipment and materials. The company's workforce will be more motivated as part of a project that has a well-defined organization and mission (Kini,1999).

Materials management involves an integrated coordination of such materials-related functions as takeoff, vendor evaluation, purchasing, expediting, shipping, receiving, warehousing and distribution. These functions can be carried out efficiently only when sufficient emphasis is placed on early project planning, personnel training and communications (Bell and Stukhart, 1986).

The current trend in construction materials management is toward developing computer-based data systems that provide the type of information needed to prevent materials shortages, surpluses, cash flow problems, and labour delays. The cost of developing and executing the computer programs has been qualitatively justified through the results they provide and the lack of control apparent in their absence (Stukhart et.al 1987).

Aim Of The Study

A construction project cost is affected by several items such as materials, labours, machine, equipment, transportation. Cost of each item must be controlled to keep the project cost within the project budget. Materials, used in construction are approximately 50 percent of whole project cost. Therefore, materials management plays an important role in Project success and should be considered at all stages of the Project. Materials management not only reduces the costs but also helps to provide project quality.

The aim of this study is firstly to discuss the fundamental principles of materials management for the succeed of the project. and Then, to present current materials management approach is in Turkish construction. This will be achieved by analyzing several construction projects and collecting data through interviews with project managers, chiefs and materials procurement staff. Finally, a conceptual MM model is proposed to be used in construction projects.

Research Method

In order to achieve the aim of the study, the research method is as follows;

- Literature review on materials management fundamental principles and attributes. The common terms used in MM like Supply chain management, just in time and lean construction will be discussed.

- MM concepts in construction projects will be discussed and their applications will be investigated. Benefits of materials management will also be examined through the analysis of some examples around the world.

- Interviews will be held in order to analyse the current MMS status in Turkish construction sector.

- Data will be collected through interviews with project managers, chiefs and materials procurement staff to develop a MM model.

1. MATERIALS MANAGEMENT

Materials management is the planning and controlling of all necessary efforts to ensure that the correct quality and quantity of materials and installed equipment are appropriately specified in a timely manner are obtained at reasonable cost and are available when needed (Business Round Table 1982).

The materials management function is always a major concern to management of any industrial organization, since high inventory and an inefficient procurement process significantly affect profitability. Problems multiply due to the current dynamic business environment in many countries (Dey, 2002).

1.1 Materials Management Function

Materials management is one of the least-understood activities in business. If one were to ask a hundred top managers in industry to define the term "materials management," one might get a hundred different answers. There is no general agreement about precisely what activities are embraced by materials management. Some managers would associate materials management with their material or production control departments, which schedule materials requirements and may also control inventories of both raw material and in-process material. Others would associate it with the activities of their purchasing departments in dealing with outside suppliers (Ammer, 1962).

The conventional method of materials management is no longer effective with respect to today's business perspective. An overall organizational approach is required for a successful materials management function for the organization (See Fig.1.1) (Dey, 2002).

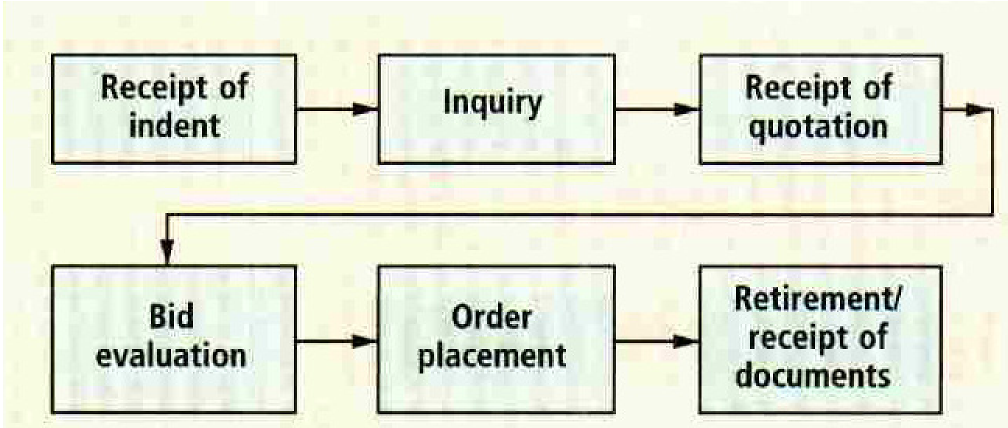


Figure 1.1 Material Planning And Procurement Process (Dey,2002)

Materials management is a basic function of every business. It is just as essential to survival and profit as the other basic functions: marketing, engineering, finance, manufacturing, and personnel. The materials management job, however, does vary substantially from industry to industry. In the chemical industry, for example, it is largely concerned with the buying, transporting, and storage of basic raw materials. Once satisfactory materials are available for production, there are few, if any, materials management problems in this industry. In the aircraft industry, on the other hand, materials managers rarely are concerned with basic raw materials. Their major job is providing an adequate supply of components made to precise specifications. Problems often arise in this industry after material has been delivered to the production line. Design changes or manufacturing problems cause previously acceptable material to be rejected, and the materials manager must exercise ingenuity to prevent a shutdown because of lack of material.

Materials management is an important job even when the end product of the organization is a service. For example, governments and educational institutions could not operate without materials management. They spend billions of dollars for thousands of different items—ranging from police cars and complex pieces of experimental equipment to printed forms and paper clips—and each must be purchased and stored until it is needed (Ammer, 1962).

There are two basic concept is being used prevalently for an effective materials management systems as Just In Time (JIT) & Supply Chain Management (SCM).

1.2 Supply Chain & Just In Time

The supply chain has been defined as 'the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer' (Christopher, 1992).

Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies. (Council of SCM professionals, 2006)

Supply chain management (SCM) is a concept that has flourished in manufacturing, originating from Just-In-Time (JIT) production and logistics. Today, SCM represents an autonomous managerial concept, although still largely dominated by logistics. SCM end eavors to observe the entire scope of the supply chain. All issues are viewed and resolved in a supply chain perspective, taking into account the interdependency in the supply chain. SCM offers a methodology to relieve the myopic control in the supply chain that has been reinforcing waste and problems. (Vrijhoef and Koskela, 1999).

Supply chain management (SCM) is a concept originating from the supply system by which Toyota was seen to coordinate its supplies, and manage its suppliers (Womack et al. 1990). The basic concept of SCM includes tools like Just-In-Time delivery (JIT) and logistics management. The current concept of SCM is somewhat broader but still largely dominated by logistics (Lamming 1996).

As presented in Fig.1.2, SCM looks across the entire supply chain rather than just at the next entity or level, and aims to increase transparency and alignment of the supply chain's coordination and configuration, regardless of functional or corporate boundaries (Cooper and Ellram 1993).

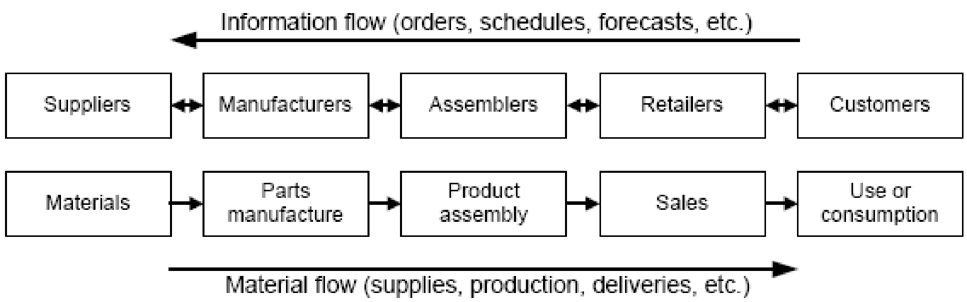


Figure 1.2 Generic Configuration Of A Supply Chain In Manufacturing (Cooper and Ellram 1993).

In the literature on SCM, many supply chain methods have been proposed. Most methods address logistical issues of the supply chain, e.g., quality rates, inventory, lead-time and production cost.

The traditional way of managing is essentially based on a conversion (or transformation) view on production, Table 1.1 shows the differences between traditional supply chain and SCM. whereas SCM is based on a flow view of production. The conversion view suggests that each stage of production is controlled independently, whereas the flow view focuses on the control of the total flow of production (Koskela 1992).

Table 1.1 Characteristic differences between traditional ways of managing the supply chain and SCM (Cooper and Ellram, 1993)

Element	Traditional management	Supply chain management
Inventory management approach	Independent efforts	Joint reduction of channel inventories
Total cost approach	Minimize firm costs	Channel-wide cost efficiencies
Time horizon	Short term	Long term
Amount of information sharing and monitoring	Limited to needs of current transaction	As required for planning and monitoring processes
Amount of coordination of multiple levels in the channel	Single contact for the transaction between channel pairs	Multiple contacts between levels in firms and levels of channel
Joint planning	Transaction-based	Ongoing
Compatibility of corporate philosophies	Not relevant	Compatibility at least for key relationships
Breadth of supplier base	Large to increase competition and spread risks	Small to increase coordination
Channel leadership	Not needed	Needed for coordination focus
Amount of sharing risks and rewards	Each on its own	Risks and rewards shared over the long term
Speed of operations, information and inventory levels	"Warehouse" orientation (storage, safety stock) interrupted by barriers to flows; localized to channel pairs	"Distribution center" orientation (inventory velocity) interconnecting flows; JIT, quick response across the channel

Besides assessing and improving the supply chain, other elements are essential to the methodology of SCM. A generic methodology of SCM can be deduced combining and generalizing the commonalities of different SCM methods. In a way, the SCM methodology bears resemblance to the Deming Cycle as shown Fig. 1.3. Generically, the methodology of SCM consists of four main elements: (1) Supply chain assessment, (2) Supply chain redesign, (3) Supply chain control, and (4) Continuous supply chain improvement.

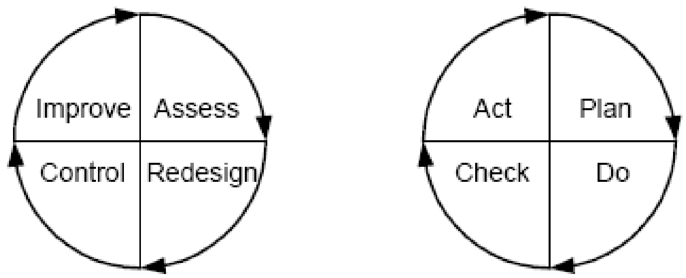


Figure 1.3 Generic SCM Methodology Compared To The Deming Cycle

The first step is to assess the current process across the supply chain in order to detect actual waste and problems. The issue here is to find the causality between the waste and problems, and locate their root causes. Once the causality is understood, and having found out about the root causes, the next step is to redesign the supply chain in order to introduce structural resolution of the problems. This includes redistribution of roles, tasks and responsibilities among the actors in the supply chain, and a review of procedures. The next step is to control the supply chain according to its new configuration. An important part of the control is the installation of a monitoring mechanism to continuously assess how the supply chain operates. This includes systems to measure and estimate waste across the supply chain process, and feedback systems to discuss and evaluate underlying problems. The objective is to continuously identify new opportunities, and find new initiatives to develop the supply chain. In fact, this continuous improvement implies the ongoing evaluation of the supply chain process, and the recurring deployment of the previous three steps: assessment, redesign and control as seen Fig.1.3 (Vrijhoef and Koskela, 1999).

In construction, initiatives belonging to the domain of SCM have been rather partial covering a subset of issues (e.g., transportation costs) in a limited part of the construction supply chain (e.g., the construction site). In most cases, the issues are regarded from a main contractor's point of view (Asplund and Danielson, 1991).

Statistical figures show that main contractors are purchasing more labour and material than previously. For instance, in 1994, in Dutch construction industry (i.e. residential, commercial and industrial building), the main contractors' share in the total national turnover had decreased to 24%. Thus, suppliers and subcontractors represented about 75% of turnover. Currently, this is expected to be more (Scholman 1997).

Main contractors become more and more reliant on other actors in the construction supply chain (e.g., suppliers and subcontractors). Therefore, they need to revise their supply strategies and trading relations with subcontractors and suppliers (Vrijhoef and Koskela, 1999).

1.3 Materials Management Objectives

Almost every materials department has at least nine primary objectives. These are low prices, high inventory turnover, low cost of acquisition and possession, continuity of supply, consistency of quality, low payroll costs, favourable relations with suppliers, development of personnel, and good records (Ammer, 1962).

- Low Prices.

This is the most obvious materials objective and certainly one of the most important. If the materials department reduces the prices of the items it buys, operating costs are reduced and profits are enhanced. This objective is important for all purchases of materials and services, including transportation.

- High Inventory Turnover.

When inventories are low in relation to sales (inventory turnover = sales ÷ average inventories), less capital is tied up in inventories. This, in turn, increases the efficiency with which the company's capital is utilized, so that return on investment is higher. Also, storage and carrying costs of inventories are lower when turnover is high.

- Low-Cost Acquisition and Possession.

If materials are handled and stored efficiently, their real cost is lower. Acquisition and possession costs are low when the receiving and stores departments operate efficiently.

- Continuity of Supply

When there are disruptions in the continuity of supply, excess costs are inevitable. Production costs go up, excess expediting and transportation costs are likely, and so on. Continuity of supply is particularly important for highly automated processes, where costs are rigid and must be incurred even when production stops because of lack of material.

- Consistency of Quality

The materials department is responsible for the quality only of the materials and services furnished by outside suppliers. The manufacturing department is responsible for quality control of manufacturing processes. When materials purchased are homogeneous and in a primitive state (e.g., sand and gravel), quality is rarely a big problem for materials personnel. But when the product is in a highly advanced stage of manufacture and specifications are a tremendous challenge for suppliers to meet consistently (e.g., components of interplanetary missiles and rockets), then quality may become the single most important objective of materials management.

- Low Payroll Costs

This objective is common to every department in the company. The lower the payroll, the higher the profits—all other factors being equal. But because no department can do its job without a payroll, the objective of low payroll must be viewed in proper perspective. It pays to spend $1.00 on additional payroll if earnings can thereby be boosted $1.01 through achieving other objectives.

- Favourable Supplier Relations

Manufacturing companies rely on outside suppliers to a far greater degree than is generally recognized. This makes favourable relations with suppliers extremely important. A company's standing in the business community is to a considerable degree determined by the manner in which it deals with its suppliers. A company with a good reputation in supplier relations is more likely to attract customers than one with a bad name. Suppliers also can make a direct contribution to a company's success. Their product development and research efforts can be of tremendous assistance to their customers.

- Development of Personnel

Every department in the company should be interested in developing the skills of its personnel. And each department head should devote special effort to locating men in junior posts who have the leadership potential the company needs for continued success and growth. They should try to develop these high-potential men as the company's future executives; the company's future profits will depend on the talents of its future managers.

- Good Records

Paper work is a means to an end, not an end in itself. So it may be surprising that good records are considered a primary objective of materials management. How can they contribute to the company's survival and profits? The fact is that records and paper work contribute only indirectly to the materials department's contribution to profits (Ammer, 1962).

2. MATERIALS MANAGEMENT IN CONSTRUCTION

Construction materials management is generally recognized to be the integrated coordination of materials takeoff, purchasing, expediting, receiving, warehousing and distribution. When these functions are not properly managed, materials shortages, surpluses, and cash flow problems are likely to occur. Costly labour delays result when the required quantity or quality of materials is not available when needed. The attributes of materials management systems are discussed and the essential elements of a successful system identified. Owner-contractor, engineer-contractor, and home office-project site communications appear to be critical to the success of the materials management effort. Preconstruction materials planning and personnel orientation and training are also important. The complex on-line computer programs that are used to coordinate the materials management effort are costly, but essential, if the desired degree of control is to be exerted to prevent potential shortages, surpluses, and cash flow problems (Bell and Stukhart, 1986).

Materials management is a process that how a building is designed and how materials are estimated. It is how materials are acquired and even how the packaging is specified. It is how the delivery schedule is designed. It is how contractors plan materials use and how they manage previously used materials and cuts. It is how waste is managed for use elsewhere or recycling rather than being discarded in a landfill (Kini,1999).

An effective management system can be vital for the success of a construction company. It has been estimated that the lack of effective materials management has resulted in work hour overruns of 18% (Thomas et al. 1989). It was also reported that a basic material management system can be expected to produce a 6% improvement in craft labour productivity. When a sophisticated system is installed, an additional 4–6% increase in craft labour savings can be achieved (Construction Industry Institute 1986).

Considerably MM should be considered as a part of whole project management system. According to numerous researches on MMS (Bell and Stukhart 1986, Kim 1999, Navon and Berkovick 2005, CII 1987), an effective MMS may consist of following processes;

- Planning & organisation
- Engineering interface & quantity survey
- Vendor Evaluation & Material Control
- Procurement
- Expediting
- Site materials management
- Waste material management & Lean construction

2.1 MM Planning & Organisation

A construction project's purpose is to create a product-producing facility that will generate revenue for the customer. The materials management focus on the mission statement must be clear when defining how the facility will be completed: Lowest cost for completion is the mission. While the best design is not the mission, the facility must meet the customer's specified requirements. The key word that describes the customer's needs is ''specified,'' because the most common reason for exceeding the project budget is the addition of enhancements not required by the customer's contract. If the project is based on a firm price contract, the cost of such enhancements will reduce the profit for the engineering company (Kini, 1999).

An effective organization essential for materials management to succeed on a construction project should define the project management team, show the functional relationships and develop a cohesive project team (see Fig. 2.1). There should be a materials management department for an effective project management. Moreover Materials management department should be connected to project manager directly. There is a typical project management organisation chart (Kini,1999).

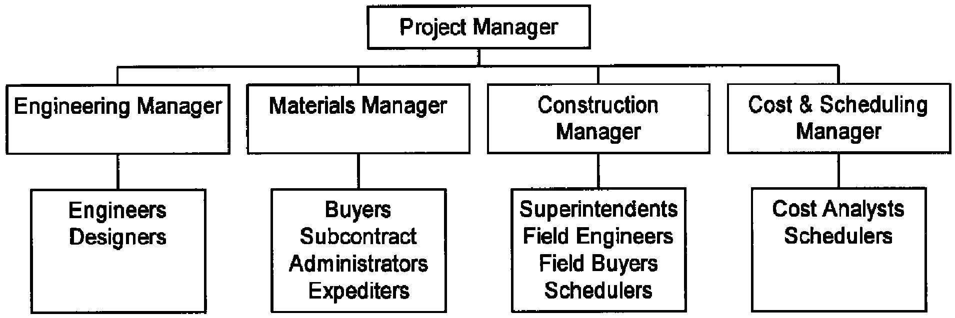


Figure 2.1 Typical Organisation Of Construction Project (Kini, 1999)

Job site materials personnel must be trained in all aspects of material classification, inspection and computer data entry. A core of trained materials personnel should be in place on the site before the first material deliveries are anticipated. Placing craft superintendents on the site at an early date can also help resolve problems with respect to material items that are not always specified on a bill of materials (Bell and Stukhart, 1986).

Generic work flow diagrams of the materials management process provided the framework for communicating in common terms within the construction industry. The role of these diagrams was to illustrate and communicate the functional boundaries of the process. The diagrams also illustrated the flow of data, information, and materials between primary and secondary suppliers and customers. Separating the materials management process into functions allowed the flow of data to be illustrated in a simple, graphic format, and for the measurement point(s) to be depicted for each measure. The materials management process and the integrated functions for a typical industrial construction project are shown in Fig. 1. Expanded diagrams of each function were then developed. An expanded diagram for the purchasing function is shown in Fig. 2.2 (Plemmons et.al, 1995).

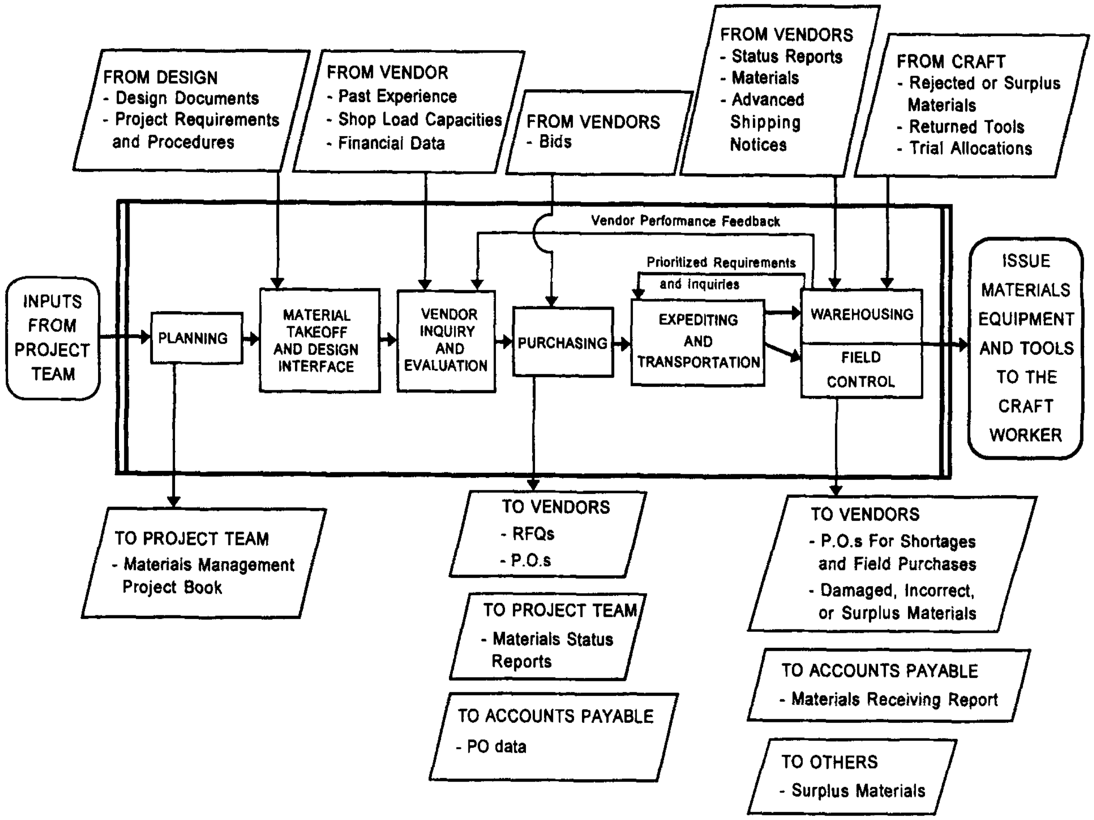


Figure 2.2 Materials Management Process (Plemmons et.al, 1995)

Deciding how construction will be accomplished is crucial in achieving the materials management goals on any engineering-procurement-construction (EPC) project. One method is to use the engineering company's own personnel for construction without subcontracting any work, while the other extreme is to subcontract all construction and perform construction management only. A mix of the two approaches is commonly used where some of the work is subcontracted to utilize the special expertise of certain subcontractors or to spread the construction risk among several subcontractors (Kini, 1999).

During the planning stage, the subcontracted work must be clearly defined so that the project schedule and engineering design can be tailored to fit the subcontracting needs. The general scope of the subcontracts should be developed, including a list of the equipment and materials to be furnished by subcontractors. Usually, the equipment with longer delivery lead times is procured by the engineering company, while the minor equipment and bulk materials may be furnished by the subcontractors. The project schedule is then developed to combine subcontracted work with the delivery and installation of the long lead equipment (Kini, 1999).

An effective materials management system encompasses more than a set of computer programs. It involves complex communication mechanisms, education activities, and training programs that must be established early in the project. Decisions that are made early in the planning stages of the project appear to be critical to the overall success of the project (Bell and Stukhart, 1986).

2.2 Engineering Interfaces & Bills Of Quantity

During the process, design needs to be developed to a point where sufficient information is available for starting detailed design. During this stage of the project, materials management focus requires a concentrated effort on the definition of materials and equipment while minimizing the cost of design. In order to achieve this objective, there are several critical steps. The engineering manager needs to ensure that the process flow diagrams and preliminary definition of major equipment conforms to the specified requirements of the customer's contract (Kini, 1999).

The materials takeoff process may be repeated as more definitive design information becomes available. Initial takeoffs may be executed from plot plans or flow sheets so bulk material orders can be placed as soon as possible. The secondary or final takeoff equates required material quantities to specific drawing numbers. Before storing the bill of materials information in a computer file, a "construction category" (underground electrical, lighting electrical etc.), a work area, the system identification number, the field need date, and the name of the subcontractor who will receive the material may be added to each file entry. This information can be attached to all items on the drawing or, for maximum flexibility, attached separately to each line item in the bill of materials (Bell and Stukhart, 1986).

Project model database which stores, processes, and transfers all the data relating to the project at all stages of the construction process. It includes up-to-date information relating to the physical description of the building, construction planning information, schedule, quantities and resource-input data, as well as catalogues and vendors' price lists. The project management (PM) is a dynamic database and all the stored data are updated frequently by automated or manual methods (Navon and Berkovich, 2005).

At the conclusion of preliminary design, the engineering manager should compare the result with the project mission and the contract with the customer to ensure that it fully conforms to the previously set objectives. The design should be frozen at this time, with only minor revisions allowed to add specific equipment characteristics when vendor data become available during final design. The challenge for the project manager and the project management team is to hold firm to the process design completed during the preliminary design stage while completing drawings, specifications and other final design documents (Kini, 1999).

Ideally, an effective MMS should be linked to design and scheduling systems. The design process obviously makes much use of computer systems for engineering calculations. The process is highly iterative, due to the number of different engineering analyses (pressure, thermal, and seismic) that can require changes in the size, geometry, and the material specification. Geometric conflicts, such as interferences with structures or with other piping components, can also generate design changes Integration with design ensures that updates of design data are rapidly reflected in the takeoff file, thereby eliminating problems related to material availability and surplus (Reinschmidt 1991).

The project team uses the information from the preliminary design to prepare the drawings, specifications and other data required for construction and for the procurement of equipment and materials. The project team will need to concentrate on the following to ensure a materials management focus:

- Develop performance specifications for equipment to obtain competitive proposals from several vendors so that the best fit can be selected at the lowest price. This should be feasible because the layouts were developed and process conditions established during preliminary design based on vendor input. The objective is to encourage vendors to provide standard models that meet or exceed the required performance while avoiding custom-designed features. Utilizing standard models will result in lower costs for spare parts and better technical support from the vendor for maintenance. It may even be feasible to eliminate warehousing costs for the spare parts if the manufacturer can supply these standard spare parts in a timely manner (Kini, 1999).

- Avoid fine-tuning or improving the preliminary design. The project team must remember that the design was frozen at the conclusion of the preliminary phase and that it meets the needs of the customer (Kini, 1999).

- The engineering manager, the materials manager and the construction manager need to work together to ensure that the construction drawings show sufficient information, defining the boundaries between subcontracts that were planned earlier in the project. This step ensures that the minimum number of drawings needed to define any particular subcontract can be separated and provided to the bidders. It also reduces bidding time and questions about the scope of work by the bidders.

- Prepare the construction specifications tailored to the subcontracts planned. For example, if the steel erection and equipment installation are to be included in one subcontract, the appropriate specifications can be packaged in one document. This type of packaging helps reduce the documentation that bidders need to review and results in reduced bidding time (Kini, 1999).

2.3 Vendor Evaluation & Control

Competitive bid laws do not usually apply to privately owned industrial construction so the contractor-owner-engineer team is free to submit inquiries and evaluate proposals as it wishes. Inquiries are forwarded to approve vendors, and both technical and commercial evaluations of vendor proposals are performed by the team. The evaluation of vendor proposals should include an examination of vendor performance on past and present projects. Computer program modules that summarize the dollar value of materials committed, the dollar value received, the number of partial deliveries per purchase order and the number of late deliveries, can provide valuable information. Purchasing managers often examine this type of on-line data for the current project prior to telephoning or meeting with a vendor. Vendor evaluation should be a company-wide effort. The owner or contractor’s status with respect to a particular vendor must be known for all owner or contractor offices if maximum leverage is to be applied to the vendor. Although not as yet implemented as a formal procedure, many of the firms contacted by the writers favoured establishing a "cost of quality" algorithm to assist with bid evaluation. The algorithm would apply modifiers to vendor bids according to the vendor's history of late or nonconforming materials deliveries (Lansford and Stukhart, 1986).

Vendor control's of the project, it is very easy for unintentional vendor scope changes to occur through comments on the vendor drawings. Simple comments can result in significant changes to the equipment and subcontractor scope. It is essential for the reviewer of vendor data to keep comments to a minimum, especially when the use of performance specifications makes the supplier responsible for the design. As long as the equipment meets the performance criteria and space boundaries, no comments should be necessary. The materials management objective during this stage of the project is to minimize the time spent on vendor drawing review and to ensure that all required submittals are received from the vendors in a timely manner (Kini, 1999).

The materials management focus for expediting is twofold. First, critical data from vendors have to be expedited and received as early as possible after order issue to avoid delaying the design. Second, fabrication and deliveries need to be expedited to meet the construction schedule. The amount of shop expediting is likely to be less owing to the use of standard equipment models with established manufacturing practices. For complex equipment, construction personnel should visit the manufacturing facility to become familiar with the details of field assembly and installation. Contacting the vendors and obtaining the status of progress at frequent intervals are essential to ensuring that commitments will be met. Setting up a transportation agreement with one carrier to ship all equipment and material will reduce costs and allow greater shipment control. With a single party responsible for transportation, it will be easier to make temporary arrangements to hold equipment for short periods of time until the applicable foundation or support is ready. This will avoid the costs of handling the same equipment more than once (Kini, 1999).

2.4 Procurement

The best way to procure equipment and materials is through a competitive bidding process that culminates in a negotiated price to meet all specified requirements. The price might not be the low bid, but would be the best price that included the cost of such factors as maintenance and operating costs. Competition is best achieved through performance specifications that define the requirements for the equipment in a generic manner so that all qualified manufacturers in the market have an equal chance of getting the order. This is facilitated by obtaining vendor input during preliminary design to ensure that the design does not favour any particular manufacturer (Damadora,1999).

Further steps to maintain a materials management focus during procurement are as follows:

- The request for proposal should state that the bidder must propose a standard model that meets or exceeds the performance requirements in the specifications and should explicitly discourage custom designs.

- Because standard models are to be used, data submittals from the vendor should be kept to a minimum. This will reduce vendor costs for the preparation of the data and engineering costs to review the data. It will also reduce incidental costs, such as those for data control, for the engineering company.

- Critical information, such as foundation details, should be submitted early to facilitate finalization of the design. Vendors shouldn't have problems with this requirement because details for standard models are usually readily available. The fabrication schedule should also be required early for input into the construction schedule.

- Bidders should provide the best possible deliveries to meet the schedule, including the storage of equipment if completed earlier than needed.

- Installation support and start-up assistance should be solicited as part of the proposal. This ensures that construction or start-up will not be delayed by uncertainties regarding vendor instructions.

- Brief, specific proposals should be encouraged to reduce the time for proposal evaluation. Crisply written performance specifications during final design will make this possible.

- Comparison of the proposals should focus on conformance to the performance requirements stated in the request for proposal and avoid inclusion of any enhancements. The project team must focus on meeting the customer's specified needs defined in the performance requirements. (Kini, 1999).

The purchasing function (see Fig.2.3) must be fully integrated into the overall materials management system. For cost reimbursable construction contracts, the owner is frequently tempted to assume control of purchasing while holding the contractor responsible for the other materials-related functions. When executing either cost-reimbursable or fixed-price contracts, the owner may wish to purchase the engineered and fabricated materials and assign other purchases to the contractor. Owners are accustomed to purchasing materials in small quantities for normal plant maintenance. Major plant construction involves purchasing activity that builds to a peak and then rapidly falls off. Therefore, the owner's purchasing system, which may be effective for controlling plant operations, is often inadequate for major plant expansion construction. Whereas the bills of materials define the project materials requirements, the resulting purchase orders define the actions that were taken to meet those requirements. When an approved requisition is converted into a purchase order, the purchase order information is entered into a separate purchase order computer file. Information typically entered includes the purchase order number, the item stock number, item description, order quantity, received quantity, vendor name, need date, promise date, requisition number, the status with respect to partial delivery and expeditors remarks. If the takeoff bulk materials are at some point increased to account for waste, the original takeoff and the increased quantities may both be entered into the purchase order file. Once the purchase order file is created,. the status of any purchase order or group of purchase orders can be examined. It is convenient to be able to print reports that

summarize purchase order data by vendor, by type of material, by status (whether the purchase order is open or
closed) and by the material need date (Bell and Stukhart, 1986).

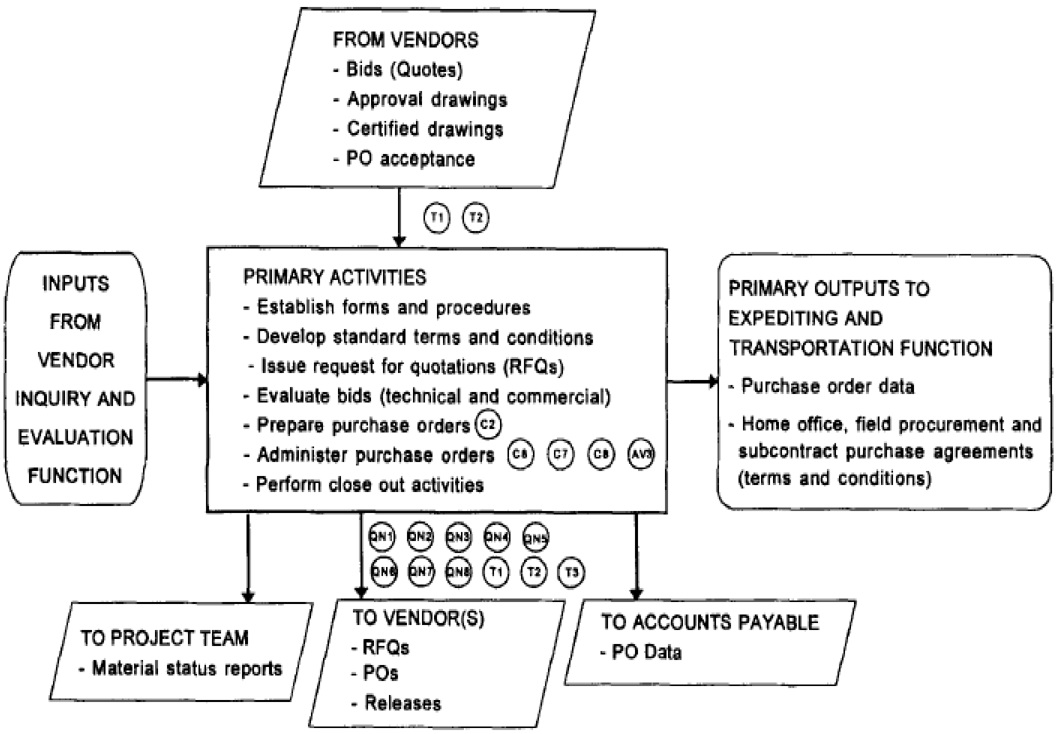


Figure 2.3 Purchasing Function (Plemmons, et. Al.)

2.5 Expediting

Expediting is an extremely important materials management function that does not always receive its proper emphasis. The purpose of expediting is to provide timely information regarding anticipated materials deliveries to all concerned project personnel (Bell and Stukhart, 1986).

The materials management focus for expediting is twofold. First, critical data from vendors have to be expedited and received as early as possible after order issue to avoid delaying the design. Second, fabrication and deliveries need to be expedited to meet the construction schedule. The amount of shop expediting is likely to be less owing to the use of standard equipment models with established manufacturing practices. For complex equipment, construction personnel should visit the manufacturing facility to become familiar with the details of field assembly and installation (Kini, 1999).

To maximize expediting efficiency, the project expeditors should receive information pertaining to projected or actual material shortages in some order of priority. This priority can be conveyed from scheduling reports, from an open purchase order report, or from a trial allocation report. (A trial allocation report arranges drawings in some priority ordered then allocates the materials on hand to the drawings with the highest priority. Materials not yet received are then assigned a priority in the order in which they will be needed.) The expeditors' estimate of materials delivery dates must then be communicated back to materials management and other project personnel. This communication is accomplished by issuing an expediting report or inserting projected delivery dates and comments into the purchase order file (Bell and Stukhart, 1986).

2.6 Site Materials Management

Site material management is defined as the allocation of delivery, storage, and handling, spaces and resources for the purposes of supporting the labour force and minimizing inefficiencies due to congestion and excess material movement (Thomas et al. 2005).

The objective during this stage of the project is to properly account for the equipment and materials delivered to the site and locate it within the warehouse so that it is readily available when needed by construction. This will avoid duplicate orders for materials already on hand. Regulating how much material is issued for construction will also minimize waste (Kini,1999).

Material management involves storage, identification, retrieval, transport, and construction methods. Each is indelibly linked to safety, productivity, and schedule performance (Thomas et al. 1989).

Several principles are important as they relate to transporting materials from the storage or staging areas to the workface areas. The first relates to projects with below grade excavations such as basements. The use of earthen ramps should be avoided as these often impede the completion of basement walls that may in turn affect the entire project schedule. The interference between wall construction and the ramp has been observed on several projects (Thomas and Sanvido, 2000).

Herein, site materials management system can prevent these undesirable conditions in the site.

- Materials arriving to the site at the wrong time, or in the wrong
- quantity;
- Materials whose specifications do not match the ones in the purchase order;
- Forgetting to order materials
- Unavailability of information regarding the status of the
- orders;
- Lack of complete and up-to-date information regarding arrival of materials to the site and, or, regarding on site stocks
- Surplus of, or missing, materials
- Lack of storage space for materials on site
- Waste of man hours searching for materials and tracking them.
- Whenever possible, erect deliveries directly from the delivery trucks.
- Assure deliveries are properly sequenced to be consistent with the work plan.
- Make sure the delivery rate from vendors is compatible with the installation rate of the field crew (Navon and Berkovich 2005).

The main duties of the site materials management team according to academic researches (Plemmons, J. K., and Bell, L. C. _1995_. "Measuring effectiveness of materials management process." Bell, L. C., and Stukhart, G. _1987_. "Costs and benefits of materials management systems." J. Constr. Eng. Manage., Construction Industry Institute _CII_. _1987_. Project materials management handbook, Austin, Tex.) are :

- Material Receiving
- Warehousing (Storage) & distribution
- Material Inspection

2.6.1 Materials Receiving

When material is received at the warehouse, it is inspected and a formal material-receiving report is completed. This report is often computer generated so the quantity and quality of the received material can be checked and that information entered into the computer system. If a warehouse or lay down area location has not yet been assigned to the received material, an area assignment is made and that information is entered into the computer system. Nonconforming materials may be photographed upon receipt to document back charge claims (Bell et.al, 1986).

2.6.2 Warehousing

Storage areas are areas where materials are stored for an extended period of time, say several weeks or more (Riley et.al, 2005).

The materials warehouse plays a critical role in the materials management system. Because constructing temporary warehouse facilities at the site can be costly, there is a tendency to allocate insufficient warehouse space for a project. A wide range of warehouse costs were encountered during the research carried by Bell and Stukhart (1987). Adequate warehouse space can probably be supplied in the form of a temporary building on a small project for about $20 to $30/sq ft.

The owner and contractor should work together to establish the warehousing and material lay down requirements. Piping, electrical and instrumentation materials are usually segregated in the warehouse and stored on shelves or in bins according to a material code or stock number. Warehouse and lay down area access should be controlled for security reasons and environmental protection provided for materials that require it. When material is received at the warehouse, it is inspected and a formal material-receiving report is completed. This report is often computer generated so the quantity and quality of the received material can be checked and that information entered into the computer system. If a warehouse or lay down area location has not yet been assigned to the received material, an area assignment is made and that information is entered into the computer system. Nonconforming materials may be photographed upon receipt to document back charge claims (Bell and Stukhart, 1986).

2.6.3 Material Inspection

The reviewers have indicated that the integration with scheduling systems is necessary to perform JIT scheduling of procurement which improves cash flow. Improving cash flow is especially important when purchasing major engineering equipment because the cost of major installed equipment is high compared with that of bulk materials. JIT scheduling of procurement also eliminates double handling and reduces the required warehouse space. Traditionally materials are handled twice: as the are received in the field and stored in the warehouse, and as they are issued to the crafts. During JIT procurement, materials are received when needed. The materials are checked for specification compliance and forwarded directly to the work area.

The control function also extends to the warehouse inventory. All items may be inventoried periodically, or spot inventories may be performed on selected items each day. Inventory adjustments may be required to reconcile differences between quantities shown on computer reports and the quantities that are actually on hand. Inventory adjustments should be performed such that an audit trail is maintained (Bell and Stukhart, 1987).

2.7 Waste Management & Lean Construction

In recent years, many researchers have championed lean construction as offering principles related to material management. Unfortunately, many of these principles are vague, difficult to comprehend, and hard to implement at the site level (Thomas et al. 2002b). However, one aspect is clear. Any interruption to the normal flow of materials will result in causing serious degradations on performance and labor productivity .In studies involving more than 125 projects, the most frequently documented cause of disruption was problems associated with material management (Thomas et al. 2002).

Lean construction much like current practice has the goal of better meeting customer needs while using less of ever him. But unlike current practice, lean construction rests on production management principles, the “physics1” of construction. The result is a new project delivery system that can be applied to any kind of construction but is particularly suited for complex, uncertain, and quick projects (Howell, 1999).

The concept of lean construction is concerned with the application of lean thinking to the construction industry. It is about improved delivery of the finished construction project to meet client needs. Its principles were suggested as part of the Latham (1994) and Egan (1998) reports.

Despite the fact that construction operations and supply chains have inherent differences to those deployed within manufacturing, the principles of Lean can equally be applied. It must however be noted that Lean is as much a philosophy and culture as a set of principles or approaches. Regardless of whether one takes the perspective of the client/developer, the contractor or the supplier, the end-to-end supply chain must be engaged. The contractor is in a unique position to be able to co-ordinate downstream activities within the supply chain (Egan Report, 1998).

2.8 Cost & Benefits Of MMS

Construction professionals are recognizing the need to focus on the materials management process as a proactive, identifiable entity that has a significant impact on the cost of construction. In recent years construction contractors have developed integrated, or "total concept," materials management systems (MMS) that combine and integrate the takeoff, vendor evaluation, purchasing, expediting, warehousing, and distribution functions. These materials management systems produce tangible benefits in the areas of improved labor productivity, reduced bulk materials surplus, reduced materials management manpower, and cash flow savings. The cost of developing and implementing these systems can be substantial, but the benefits outweigh the costs, particularly when the system is used by the crafts for scheduling their work around bulk material availability (Bell and Stukhart, 1987).

Many researhers (Hendrickson and Au 1989; Akintoye 1995; Choo et al. 1998; Formoso and Revelo 1999; Thomas and Sanvido 2000;Bell and Stukhart 1987; Formoso et al. 2002; Poon et al. 2004) reveal the main benefits of efficient Materials Management and Control System as:

- Increased productivity and avoidance of delays: Estimates of increased productivity vary from 8% (Akintoye 1995) up to 12% (Bell and Stukhart 1987). This is mainly due to the availability of the right materials prior to work commencement and the ability to plan the work activities according to he availability of materials (Akintoye 1995) and (Choo et al.1998). assert that the biggest problem field workers face is coping with discrepancies between anticipated, actually needed, and available resources (materials included).

- Reduction in man hours needed for materials management: Bell and Stukhart (1987) show that on projects lacking materials management systems craft foremen spend up to 20% of their time hunting materials and another 10% tracking purchase orders and expediting (time that they could devote otherwise to supervising workers). The writers add that leaving the crews unsupervised has a detrimental effect on labor productivity.

- Reduction in the cost of materials This is due to reduction in waste caused by manual and inefficient materials management and control (Formoso et al. 2002; Poon et al. 2004), which causes errors in purchase order and reduced shipping costs (Li et al. 2003).

Case studies carried by Construction Industry Institution (2000) present the costs and benefits of MMS clearly.

2.8.1 Impact of MMS On A Structural Steel Activity

The data for this case study were collected as part of an ongoing study of construction labor productivity The goal of the research is to test a productivity measurement technique that provides a daily assessment of the problems affecting production without the need for continuous on-site work measurement methods. The technique relies upon both quantitative and qualitative data. An inependent observer visits each case study project daily and classifies the day according to a predefined set of more than 25 site factors or conditions that potentially affect productivity. These factors include disruptions, one of which is material management; work content and constructability issues; construction methods; environmental conditions; and other management aspects. The data set can then be partitioned according to the desired classifications and examined to determine the impacts of one or more factors. The measure of impacts is determined by comparing daily productivity data from the pertinent subsets of the data base. (Thomas and Mannering 1987).

To further verify the cost impacts, the cumulative productivity on the case study project (Project A) was compared with the cumulative productivity on another similar project (Project B) where material sequencing and storage of the structural steel were effectively managed. Fig. 2.4 provides summary statistics indicating the similarity between the two projects. A CPM schedule was not used on either project.

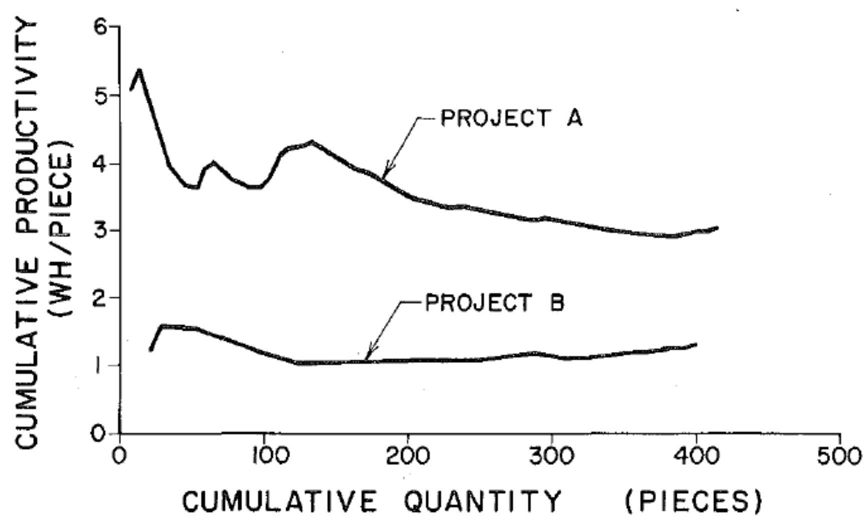


Figure 2.4 Comparison Of Cumulative Productuvity For Structural Steel Erection (Thomas et.al, 1989)

The differences in material management on Projects A and B were twofold. First, on Project B the steel was delivered directly to the job site at the beginning of each shift. Because the delivery sequence had been carefully preplanned, the steel could be erected directly from the truck. After several hours, the remaining steel was off-loaded in a nearby storage area, and the delivery truck was released. Second, when the material was stored, it was done so in a neat and orderly manner.

The difference in work-hours required on the two projects is quite substantial. At the previously quoted wage rate, this difference amounts to (1,256 - 526) 21.96 = $16,031. The addition of equipment operator wages, equipment rental, and project overhead would further widen the cost differential to about $23,000. Obviously, not all of the work-hour difference can be attributed to material management practices (Thomas et.al, 1989).

2.8.2 A MMS Implementation By Construction Industry Institute

The research project that examined the costs and benefits of materials systems was initiated in April 1985. The research was conducted jointly by Auburn University and Texas A&M University under the direction of the Materials Management Task Force of the Construction Industry Institute. As a part of the planning for the research, all owner and contractor member firms of the Construction Industry Institute (CII) were contacted and asked if they could provide data on recently completed projects that would be appropriate for case study investigations. Auburn and Texas A&M researchers selected, from the candidate projects, those that represented a good mix of facility type and size, geographical location, contracting method (lump sum versus cost reimbursable), and type of computer system as shown in Table 2.1

Table 2.1 Characteristics of case study projects (Stukhart et.al, 1987)

Project number	Facility type	Facility cost ($ million)	Contract type	Status	Computer system
1	Petrochemical	Ongoing 25/yr	Cost reimbursable	Ongoing	Contractor, home office, mainframe
2	Product manufacturer	2,17 (2 projects)	Multiple Lump Sum	Complete	Owner, home office, mainframe
3	Pulp and paper	500	Cost reimbursable	99% complete	Contractor, mainframe, on site
4	Chemical	95	Lump sum	24% complete	Contractor, leased mainframe system
5	Steel mill	500	Cost reimbursable	99% complete	Contractor mainframe
6	Chemical	3	Lump sum	20% complete	None
7	Refinery	more than 500	Cost reimbursable	Complete	Contractor, home office, mainframe

8	Chemical (overseas)	600	Lump sum	90% complete	Contractor, mainframe, on site
9	Chemical	90	Lump sum	Complete	Contractor, home office, mainframe
10	Refinery	35	Multiple	Complete	Owner, mainframe
11	Cogeneration power plant	140	Lump sum	Complete	Contractor, home office, mainframe
12	Turbine general building	Not disclosed	Lump sum	Not disclosed,	Not disclosed
13	Industrial	2000	Lump sum	Complete	Contractor, home office, mainframe
14	Power plant	1300	Cost reimbursable	Complete	Owner mainframe
15	Chemical	34	Multiple	Complete	None
16	Chemical	20	Lump sum	Complete	Partial system
17	Paper mill	350	Lump sum1	30% complete	Contractor and owner systems both on site
18	Chemical	85,124 (2 projects)	Cost reimbursable	50% complete	Microcomputer data
19	Industrial	10 typical	Not disclosed	Many ongoing	base system (dBase III)
20	Manufacturing facility	100	Lump sum	Complete	Owner mainframe

A summary of benefits after MMS application that pertain to improved craft labor productivity that were reported during the research are shown in Table 2.2

Table 2.2 Benefits related to craft labor productivity (Stukhart et.al, 1987)

project number	**Reported benefit**
1	Overall 6% reduction in craft labour costs ($34,000/mo) reported.
1	Foremen no longer spend 2 hr/day hunting materials and expediting material deliveries.
4	Installing a computer system in the warehouse has reduced the time required to check material availability for 40 isometric drawings from 3 days to less than 20 min.
4	The MMS has greatly reduced costly rework. Six crew man-hours were wasted every time a crew returned to a previous work area to replace or install an item that was incorrect or initially not available.

5	The MMS is believed to have increased labour productivity and improved craft work planning.
10	With the MMS in place, no labour delays due to material not available have been experienced.
11	A foreman delay survey indicated that 8% of direct labour savings could be attributed to the materials management effort. This savings was reported to be $725,000.
12	A comparison of two similar projects showed craft man-hours per hanger were reduced from 31.1 on the first project to 11.7 on the second project. Similarly, man-hours per pipe spool were reduced from 91.7 to 38.9, and hours/ft of pipe were reduced from 1.5 to 1.09. These improvements in productivity can be attributed to many factors, including the MMS that was put in place on the second project.
15,16	A comparison of two similar projects showed pipe fitter man-hours per unit reduced from 1.92 on the first project to 1.14 man-hours per unit on the second project. This improvement in labour productivity can be attributed, in large part, to the improved MMS that was put in place on the second project.
17	A craft foreman developed his own time-saving spreadsheet personal computer (PC) program for planning crew work packages.
18	The owner believes a forecast of 6% reduction in craft labour costs will be realized as the result of implementing a PC data base system for tracking major equipment items.

It is extremely difficult to prove the cost effectiveness of materials management systems. But there is strong evidence to suggest that the benefits far outweigh the costs, even when making very conservative assumptions. In project 1 the owner's construction manager performed a very careful analysis of the costs and benefits associated with implementing the contractor's materials management system. His analysis showed that the one-time cost to inventory materials at the site and install the system would be recovered after only five months, due primarily to improved labor productivity.

The following hypothetical project data and assumptions are representative of the project data and subjective opinions that were gathered as part of the research.

- Assume a 12-month project involves 500,000 man-hours and the purchase of $5,000,000 in bulk materials.
- Implementing effective field material control will require one-time costs (for secure materials storage, data loading, administration, and personnel training) of $200,000.

- Implementing an effective materials management system will require computer charges (that include all hardware ownership or lease costs, as well as software development costs) of $10,000/month.
- These measures will result in a 6% savings in craft labor costs. Craft labor costs are assumed to be $20/man-hour, including direct overheads.
- These measures will result in reducing the bulk materials surplus from 5% of the bulk materials purchased to 2%, producing a net 3% surplus reduction. Surplus materials will be sold for scrap, at 1/10 their original cost.
- Other tangible benefits (cash flow, reductions in management manpower, etc.) will result, but will be ignored for the purpose of the cost benefit comparison. The costs and benefits for this hypothetical project can be compared as follows:

Project costs:

Computer: $10,000/month x 12 mo = $120,000

Warehouse, training, etc. = $200,000

Total costs = $320,000

Project benefits:

6% labor savings = 0.06 x $20/man-hour x 500,000 man-hours = $600,000

3% surplus reduction = 0.03 x $5,000,000 X 0.9 = $135,000

Total benefits = $735,000

If the assumptions in this scenario are representative, then it can be concluded that even a 6% savings in craft labor costs far exceeds the costs of implementing a materials management system.

3. CONSTRUCTION MATERIALS MANAGEMENT MODELS

Construction professionals are recognizing the need to focus on the materials management process as a proactive, identifiable entity that has a significant impact on the cost of construction. In recent years construction contractors have developed integrated, or "total concept," MMS that combine and integrate the takeoff, vendor evaluation, purchasing, expediting, warehousing, and distribution functions. These materials management systems produce tangible benefits in the areas of improved labor productivity, reduced bulk materials surplus, reduced materials management manpower, and cash flow savings. The cost of developing and implementing these systems can be substantial, but the benefits outweigh the costs, particularly when the system is used by the crafts for scheduling their work around bulk material availability (Bell and Stukhart, 1987).

3.1 Automated Materials Control Model

Materials resources constitute a large portion of a project's total cost and this makes them an important and attractive subject to control. Proper control and management of materials can meaningfully increase productivity by 6%, or more. A model based on automatic, or semiautomatic, data collection for materials management and control was developed by Navon & Berkovich (2005) as shown in Fig.3.1. Based on project plans, the model initiates and manages the ordering of materials automatically and monitors both the actual flow of materials and the current stock at the construction site. The model permits real-time control, enabling corrective actions to be taken. In this manner, costs and unnecessary handling of materials are reduced. In addition, up-to-date information regarding materials flow is available and different statistical analyses are enabled: materials acquired from a specific supplier; materials used for a specific activity; and materials used during a specific month, etc. The information generated by the model enables the updating of a historical database to be used for planning of future projects (Navon and Berkovich, 2005).

3.1.1 Model description

The model provides a comprehensive approach, encompassing materials purchasing aspects, their delivery to the site, and their dispatching for use in the building. The model can meaningfully reduce the time needed for materials management, reduce wastage caused by manually ordering the materials, and ensure that materials arrive to the site on time, in the right quantity, and according to specifications (Navon and Berkovich, 2005)..

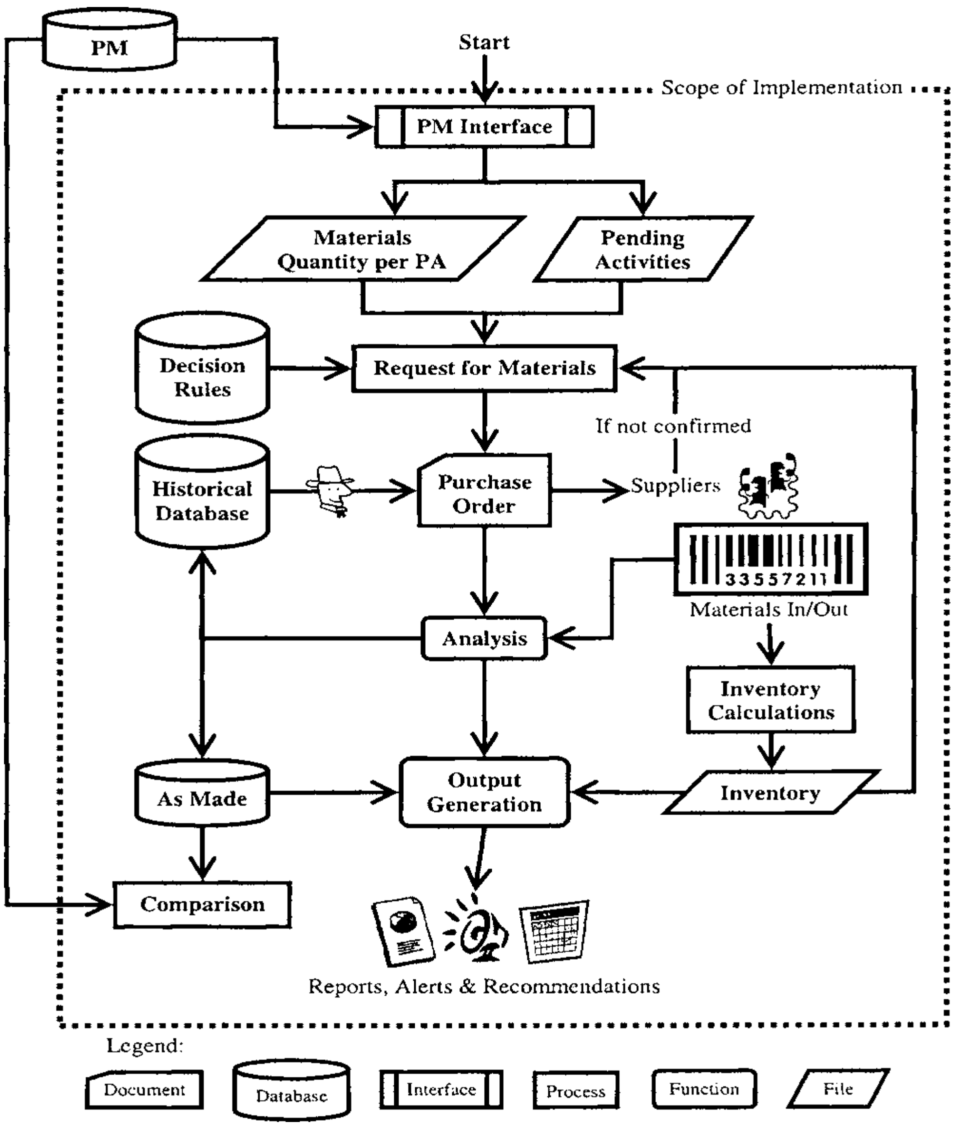


Figure 3.1 Materials Management And Control Schemetic Model

3.1.2 Development Principles

Most of the components of the model were implemented in aprototype system. The databases and the algorithm were built with *Microsoft Access* and for the Automated Data Collection (ADC) the prototype used a handheld computer. The development principles are :

- Data Entry : As described in Fig. 3.1 with the broken line, the PM was not included in the current implementation. Hence most of the input to the system was done using the Access forms. The ADC was implemented with a handheld computer for tracking the materials flow (in/out).

- Reports : The output of the system is mainly in the form of reports, which are generated either automatically, or they can be tailored by running queries. Table 3.1 depicts a cumulative materials flow report.

- Materials Ordering : The current practice of most of the companies surveyed in the field study uses similar procedures.

Table 3.1 Materials flow report

Materials Flow - summary

Description	Unit	In	Out	Stock	Acc. to Plan	Deviation (%)
Binding Wire	Kg	275	262	13	275	-4.7
Concrete	Cubic Meter	1358.5	1358.5	0	1400	-3
Fomule 1 (barrel)	Kg	3780	3780	0	3500	8
Honeycombed carton space-fillers	Piece	1516	1436	80	1500	-4.2
Honeycombed carton space-fillers (m)	Meter	135	135	0	135	0
Nails 5 kg	Package	63	63	0	60	5
Rebar	Ton	122.18	122.18	0	140	-13
Shekdarit 471 (barrel 150kg)	Kg	3060	3000	60	2900	3.4
Silica Blocks	Square Meter	816.5	809.5	7	780	3.8
Spacers 4 cm	Piece	1300	1300	0	1300	0
Twisted wire	Kg	738	738	0	550	34
Wood	Cubic Meter	60.56	60.00	0.55	70	-14.3

- Materials Handling: This function deals with the entire process of handling incoming materials, starting with their receipt on site and ending with entering the data from the bill of lading (BL) to the computer.

- Materials Availability : The model initiates materias ordering and gives an alert when they do not arrive, or if the shipment is incomplete. This minimizes teprobability of missing materials and, indirectly, contributes to increased productivity (Navon and Berkovich, 2005).

The prototype was tested in a commercial building site in Hod Hasharon. The building had two floors, amounting to 880 m2 and a total cost of about $450,000. This site was selected because the procedures used by the project personnel were typical, as observed during the first part of the field study. Moreover, these procedures were among the more advanced and relatively highly computerized. Yet, different procedures might exist in other projects, or different companies, or other countries.

The prototype bases the calculations for the report on the quantities of the materials needed for the specified period, the planned date of usage, lead times for supply, available stocks on site, and the minimal inventory. The report includes the latest time that the material needs to be ordered, the date when the material is scheduled to be used “Required” column in Table 3.2 the lead time to order, and the quantity to be ordered (Navon and Berkovich, 2005).

Table 3.2 Materials to order report

Materials to Order

Last Day to Order	Description	Unit	Required	Lead Time	Quantity
12/2/2001	Silica Blocks	Square Meter	1/1/2002	30	93
12/25/2001	Honeycombed carton space-fillers	Piece	1/1/2002	7	20
12/25/2001	Honeycombed carton space-fillers (m)	Meter	1/1/2002	7	100
12/28/2001	Rebar	Ton	1/1/2002	4	2
12/29/2001	Fomula 1 (barrel)	Kg	1/1/2002	3	150
12/29/2001	Shaklarit 471 (barrel 150kg)	Kg	1/1/2002	3	90
12/29/2001	Wood	Cubic Meter	1/1/2002	3	1 441
12/30/2001	Aashdod sand	Piece	1/1/2002	2	1
12/30/2001	Binding Wire	Kg	1/1/2002	2	387
12/30/2001	Cement	Sack	1/1/2002	2	10
12/30/2001	Concrete Block 10/20/40	Piece	1/1/2002	2	500
12/30/2001	Concrete Block 20/20/40	Piece	1/1/2002	2	500
12/30/2001	Gravel	Ton	1/1/2002	2	1
12/30/2001	Nails 10	Kg	1/1/2002	2	50

3.2 Object Oriented Materials Management Model

Materials management systems should be integrated with computer systems that are used for design and scheduling. In adition, many materials management systems would benefit from integration efforts that would facilitate rule-based reasoning. These enhancements are facilitated by the use of an object-oriented methodology (OOM) data structure for the materials-management system. Elzarka and Lansford (1985) present an OOM data model which is applied to piping commodity materials. They discuss the attributes incorporated into an OOM materials-management tutorial that was evaluated by industry professionals. Tutorial attributes include automatic commodity code generation, automatic takeoff execution, intelligent purchase order generation, and components of design and schedule integration. As part of their evaluation industry reviewers noted that OOM not only facilitates the development of more versatile systems, but also results in a computer code that is far easier to generate and less expensive to maintain (Elzarka and Lansford, 1995).

3.2.1 Model Description And Objectives

The MMS development efforts have focused on integrating the materials-related functions of quantity takeoff, requisition, purchasing, expediting, transportation, field material controland warehousing. However, MMS development effort should have another objective, which is to integrate the MMS with external computer-based systems that perform functions related to design, project scheduling, and cost accounting.

- To determine critical integration interfaces that should be incorporated into a MMS.
- To determine potential expert systems applications in materials management.
- To develop and implement an object-oriented materials management model that supports integration and facilitates the incorporation of expert systems in the materials management proces.
- To obtain feedback from industry professionls related to the concepts illustrated in the MMS tutorial.

Integrating the MMS with scheduling systems provides a critical automation interface. Schedule compression and changes will modify materil need dates. Integrating the MMS with the construction schedule also permits the procurement schedule to be construction driven. A construction driven procurement schedule effectively prioritizes the procurement activities, reduces project durations, and causes fewer delays in the field (O'Conner et al. 1987).

A construction driven procurement schedule also allows for just-in-time (JIT) scheduling of procurement. JIT improves cash flow, eliminats double handling and reduces the required warehose space (Elzarka and Lansford, 1995).

3.2.2 Implementation Of The Model

Benefits of the OOM can only be achieved if considerable effort is spent in developing a sound data model (Kim and lbbs 1992). During data modeling, classes, relationships between classes, attributes, and methods relevant to the problem domain are identified. To fully understand the proposed model, schematic diagrams are needed to represent the different classes and their interactions. The OOM graphical representations will follow the notation introduced by Coad and Yourdon (1990). In this notation, a class is graphically represented by a rectangle with rounded edges displaying the class name, attributes, and methods.

The first modeling activity involves identifying classes. Classes can be identified by looking into the problem space. Any entity in the problem domain that needs to be remembered, has more than one attribute, or is essential for the system should be considered a potential class. The following description of the piping materials-management process will be relied on to identify objects of the model. The first step of the piping materials-management process is obtaining design information. For piping systems, this information describes the piping components in terms of geometric features, metallurgy, and so on. A component class is needed to capture general information on piping components.

The class that is connected to the straight line by several small lines represents the M side of the relationship whereas the class that is only connected by one line represents the 1 side of the relationship. In Fig. 3.2, the relationship between the line class and the pipe class is one to many. A pipeline contains (has) many pipes, while a pipe belongs to only one line.

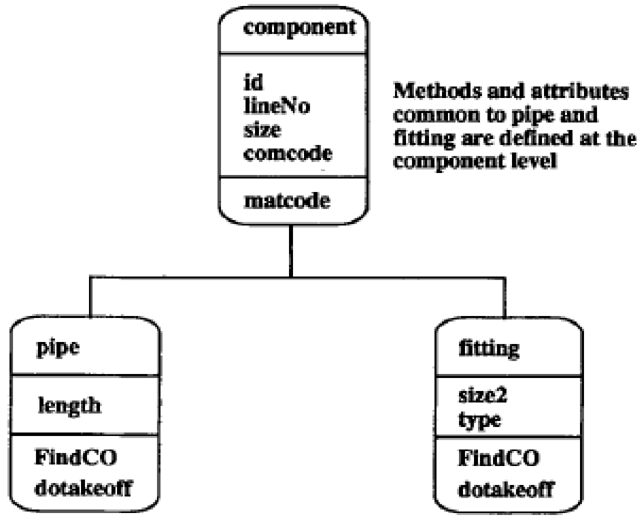


Figure 3.2 Example Of Classification Relationship (Elzarka and Lansford, 1995).

The automatic generation of commodity codes is of extreme importance. A commodity code is a part number used to specify and purchase a commodity. Thousands of unique piping entities are incorporated into a typical industrial facility. Determining the correct commodity codes of these products requires expert knowledge. The ability of the MMS to automatically generate commodity codes will reduce the time use by management personnel in assigning these codes, allowing them to focus on other aspects of the materials management process. In both classes pipe and fitting, methods pipe::FindCO, and fitting :FindCO automatically generate commodity codes after the user enters the id, size, length, and line number of the component. These methods use a commodity code scheme that is similar to one used by a large engineering/procurement/construction (EPC) firm (Fig. 3.3).

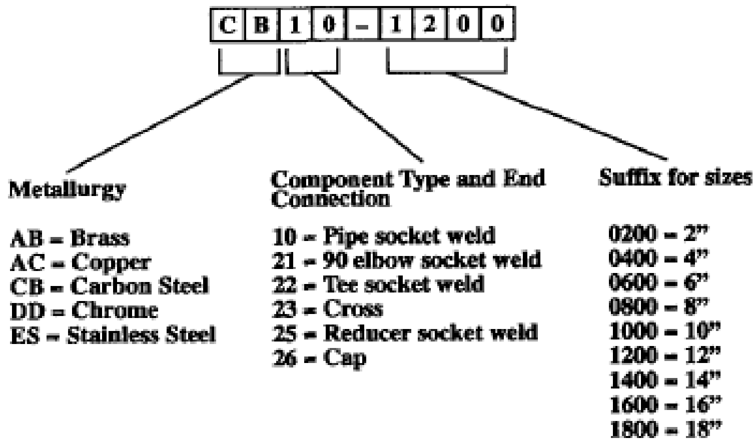


Figure 3.3 Commodity Code Scheme

3.3 Site Materials Management Model: Based On Site Division

The discipline of project management is often ill defined particularly when it comes to site operations. There is considerable knowledge about the things that go wrong and the consequences of ineffective decision making, but there is limited published information about what procedures and steps to follow to avoid cost overruns and time delays. This is particularly true of site material management practices (Thomas and Sanvido 2000).

A construction site should be portioned into three areas or zones: semipermanent (exterior) storage, staging areas, and workface (interior) storage. Each has a unique function relative to site material management. Using these areas as a framework, fundamental principles are stated and illustrated using a case study project accompanied by numerous photographs and narratives (Riley and Thomas, 2005).

The effective site management practices can have a significant affect on schedule performance The schedule slippage on the installation of windows, precast panels, and ducts ranged from 50 to 129% (Sanvido and Thomas 2000).

The principles of site material management are summarized in Table 3.3. Relative to storage of materials, a site should be divided into three areas:

1. *Semipermanent (outside) storage area* : these are areas, sometimes called laydown areas, where materials are stored prior to being used in the project.

2. *Staging area* : This area is next to the exterior of the facility. It is in this area that materials are lifted into the facility. Materials that are off loaded directly into the facility also use this area.

4. *Workface (interior) Storage Area* : This is the area inside the facility where the work of the craftsmen takes place. Each of the above areas has a different use and must be managed differently and different principles will apply (Thomas et.al, 2005)

Table 3.3 Principles of site materials management (Thomas et.al, 2005)

Semi-Permanent (outside) storage area	Do not store materials close to the building.
	Locate parking areas, tool sheds, trailers, spoil piles elsewhere or as far from the building as possible.
	Mark stored materials so they can be readily distinguished from similar materials.
	Materials should be stored to permit easy access and retrieval.
	Materials should be stored on timbers or pallets to permit easy retrieval and protected to prevent damage from mud and water.
Staging Area	Reserve areas next to the building for materials deliveries or materials being moved to the workface areas.
	Backfill around the building as quickly as is practical to permit the area to be used as a staging area.
Workface (interior) Storage Area	The amount of material stored inside should be kept to a minimum.
	Preassemble components into larger components or subassemblies.
	Integrate the sequence of work with the storage plan so interior space can be used without interfering with the work.
	Ancillary tasks like unpacking, cutting, reshaping, preassembly, etc. should be done away from the workface when practical.
	Maintain good housekeeping.
	Arrange for removal of waste from the building on a continuous basis.

Fig. 3.4 shows the productivity for the first 33 working days of the ductwork activity (Han and Thomas 2002). The work was frequently disrupted, especially after the first 2 weeks. During the first 2 weeks, the productivity was frequently in the range of 0.30–0.35 work h/ ft. Thereafter, the productivity on undisrputed days was more in the range of 0.50–0.60

work h/ ft. The case study and data from other projects form the basis for principle (see Table 3.3), that is, preassemble components into subassemblies to maximize productivity. Not being able to use subassemblies on the case study project resulted in more than a 50% loss of productivity (Sanders and Sanvido, 1989).

As it is seen in Fig.3.4, there are numerous disruptions caused by congestion, interferences, and out-of-sequence work. Overall, the labor performance of the duct installation was poor.

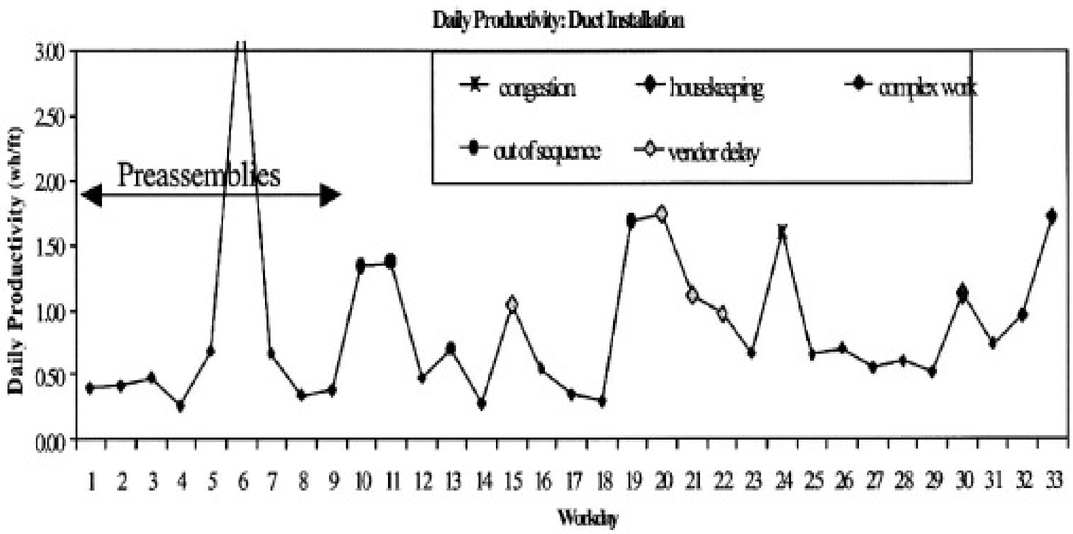


Figure 3.4 Daily Productivity (Thomas et.al, 2005)

3.4 Evaluation of The Models

Applications of the models described previously show that they have some deficiencies as far as MM principles are concerned. As mentioned in previous sections, attributes of MM system should consider following attributes and the evaluation of the models in accordance with these attributes are explained below and summarized in Table 3.4

- MM organisation
- Interfaces
- Planning & scheduling
- Warehousing

- Site MM
- Vendor Control
- Negotiating
- Waste Management
- Materials receiving
- Expediting

MODEL 1 :

Automated materials management model does not provide a clear defined MM organisation. In addition to this, scheduling & planning, site MM, vendor control, negotiating and expediting procedures haven't been mentioned. Since the model integrates automated systems which technological approaches about MM has to be considered. This is not make any sense for several studies (Construction Industry Institute Bell & Stukhart, Plemmons about MM reffered in this paper). These studies perceive the MM as a total management process.

MODEL 2 :

The second model conform with industrial projects like piping or factory construction. Variety of the materials can be divided with these MM model. Therefore, this model does not consist of the main principles of the MM except interfaces and waste management.

MODEL 3 :

The concern of the third model is site management. Since its focus is only the MM on site, the model can not be considered as a part of total management process including office as well as site.

Table 3.4 Comparison of The Models In Relation To The Attributes Of MM System

Attributes Of MM System	***Model 1: Automated Materials control Model***	***Model 2: Object Oriented MM Model***	***Model 3: Site MM Model (Based on site division)***
MM organisation	N\A	N\A	N\A
Interfaces	YES	YES	N\A
Scheduling	N\A	N\A	N\A
Warehousing	YES	N\A	YES
Site MM	N\A	N\A	YES
Vendor control	N\A	N\A	N\A
Negotiating Procedure	N\A	N\A	N\A
Waste Management	YES	YES	N\A
Materials Receiving	YES	N\A	YES
Expediting	N\A	N\A	N\A

N\A : Not Applicable

4. MATERIALS MANAGEMENT APPROACHES IN TURKISH CONSTRUCTION SECTOR

One of the main purposes of this thesis is analyzing the material management approach of Turkish contractors. In this context, 10 large scale projects (see appendix A) implemented in Turkey and United Arab Emirates by leading Turkish contractors were selected, and Project Managers were interviewed and asked some questions for understanding how the material management is practiced, and whether they have the concept of material management. In the selection of contractors following criteria are taken into account Fig. 4.1 & 4.2 show estimated costs and number of labours of the projects.

- Estimated project cost,
- Availability of consulting companies, and
- Business careers

were considered when selecting projects for interviewing.

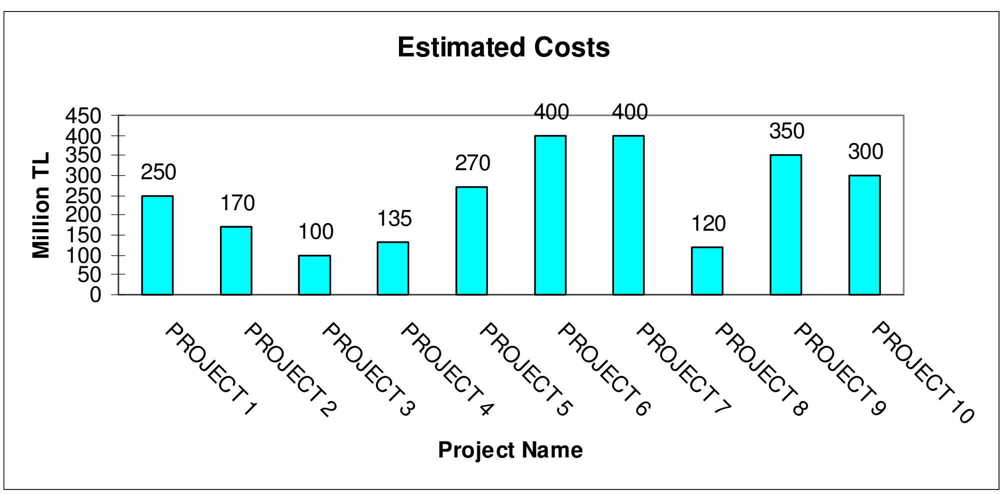


Figure 4.1 Projects Estimated Costs

Estimated cost of the smallest project among the selected is nearly 100 million TL. Organizations of this project and larger projects would be inevitably comprehensive. Therefore, studying the material management in such high budget projects would be more sensible.

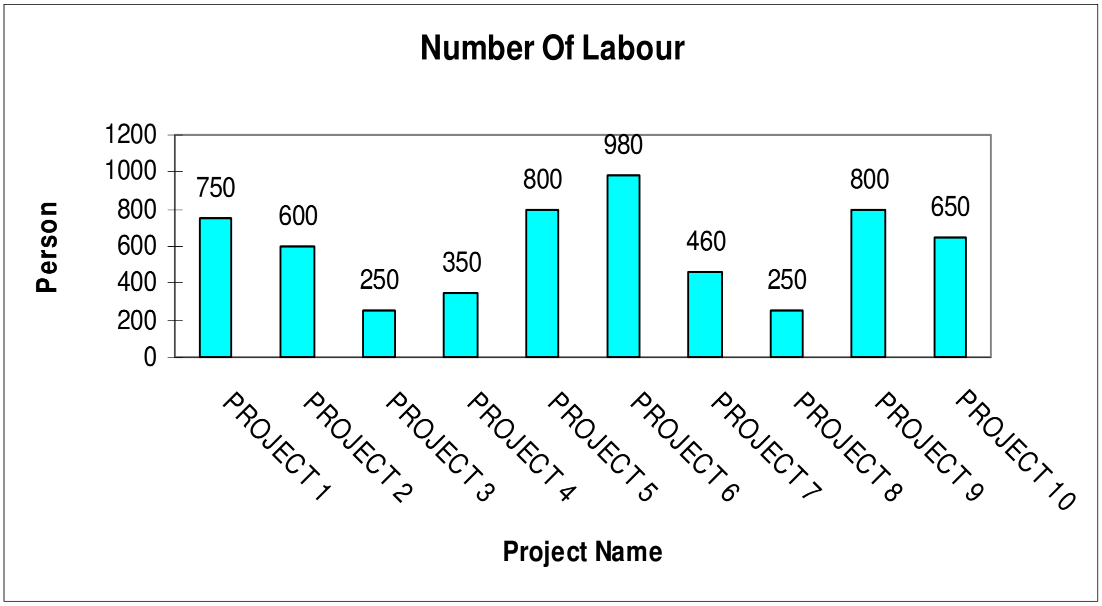


Figure 4.2 Number of Labour

Besides, presence of consulting companies in projects, are another factor effective on the selection. Projects with consulting companies are implemented more systematically. Connections between departments and inspection procedures are strictly controlled by the consulting companies. This is one of the important factors that we want to see in material management.

Another selection criterion is the background and business career of the company. Construction companies are implementing a lot of projects in Istanbul. Some of them work more professionally. Project management carried out by a good organization is common in these companies. Analyzing the material management systems of such companies will provide much more reliable and suitable knowledge as far as materials management concerned.

A small survey with 25 questions was conducted on the managers of the selected projects (See appendix B). The purpose of this survey was to see if a real material management is carried out. The questions were prepared in accordance with the material management theory mentioned in this thesis. The questions were asked to project managers, assistant project managers, and site chiefs. In others words, the most authorized figures were asked to give information.

4.1 Results of The Questionnaire

As it was mentioned before, the purpose of this study is to see if contractor companies have any material management systems. Following the above mentioned questions, some conclusions about the material management approaches and practices of the companies were reached. The companies answers to the questionnaire are presented in Table 4.1.

Table 4.1 Answers of the questionnaire

	PROJECT 1	PROJECT 2	PROJECT 3	PROJECT 4	PROJECT 5	PROJECT 6	PROJECT 7	PROJECT 8	PROJECT 9	PROJECT 10	Ref. Answer according to MM theory
question 1	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
question 2	4	3	2	2	1	3	3	4	3	3	min 4
question 3	no	no	yes	no	yes	no	no	no	no	no	yes
question 4	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
question 5	no	yes	yes	no	no	yes	no	yes	yes	yes	no
question 6	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
question 7	see fig.4.3	see fig.4.3	see fig.4.3	see fig.4.3	see fig.4.3	see fig.4.3	see fig.4.3	see fig.4.3	see fig.4.3	see fig.4.3	
question 8	see fig.4.4	see fig.4.4	see fig.4.4	see fig.4.4	see fig.4.4	see fig.4.4	see fig.4.4	see fig.4.4	see fig.4.4	see fig.4.4	max %5 of const. Area
question 9	see fig.4.5	see fig.4.5	see fig.4.5	see fig.4.5	see fig.4.5	see fig.4.5	see fig.4.5	see fig.4.5	see fig.4.5	see fig.4.5	max 100 m
question 10	sometimes	yes	sometimes	yes	sometimes	yes	yes	yes	yes	sometimes	no
question 11	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
question 12	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
question 13	no	no	no	no	no	no	no	no	no	no	yes
question 14	N\A	N\A	N\A	N\A	N\A	N\A	N\A	10000$	N\A	N\A	
question 15	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A	N\A	

	PROJECT 1	*PROJECT 2*	*PROJECT 3*	*PROJECT 4*	*PROJECT 5*	*PROJECT 6*	*PROJECT 7*	*PROJECT 8*	*PROJECT 9*	*PROJECT 10*	*Ref. Answer according to MM theory*
question 16	yes	sometimes	sometimes	yes	sometimes	yes	yes	yes	sometimes	yes	yes
question 17	sometimes	yes	sometimes	sometimes	yes	sometimes	sometimes	sometimes	sometimes	sometimes	yes/ sometimes
question 18	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
question 19	no	no	yes	no	no	no	no	no	no	no	yes
question 20	3	2	3	2	2	3	3	5	2	3	min3
question 21	2	2	3	2	2	3	2	4			min 4
question 22	see fig.4.6	see fig.4.6	see fig.4.6	see fig.4.6	see fig.4.6	see fig.4.6	see fig.4.6	see fig.4.6	see fig.4.6	see fig.4.6	max %2-3
question 23	sometimes	sometimes	sometimes	sometimes	sometimes	sometimes	sometimes	sometimes	sometimes	sometimes	no
question 24	see fig.4.7	see fig.4.7	see fig.4.7	see fig.4.7	see fig.4.7	see fig.4.7	see fig.4.7	see fig.4.7	see fig.4.7	see fig.4.7	
question 25	see fig.4.2	see fig.4.2	see fig.4.2	see fig.4.2	see fig.4.2	see fig.4.2	see fig.4.2	see fig.4.2	see fig.4.2	see fig.4.2	

All project authorities subjected to the questionnaire answered Questions 1 and 3 “yes”(see table 4.1). In Question 1, we asked if there is a general organization, and in Question 3 we asked if the leader of the organization reports directly to Project Manager. These questions were based on the basic factors identified in the theory of material management in Section 2 and 3. Although the answers are quantitatively positive by means of material management, in fact, the department in question being an Accounting or Purchasing Department, is a significant detail pointing out that the concept of material management is not known well. Besides, it was understood that in none of the projects an engineer or an architect or anybody fit to this position with the responsibility of material management is assigned.

Answers given to Question 9 showed that the distance between the material and Staging Area, which prevents the job prescribed by Model 3 examined in the Part 3 being completed in a short time, is outside the acceptable limits. Although an it is discussed in Model 3 of section 3, the reasonable distance is 150 m the average distance between the material and the Production Area is 300 m in 10 projects examined (see Fig.4.3). Such distance leads to a significant labor loss. An employee has to travel 600 m (including return) with the material, spending nearly 10 minutes. However, if the material is stored 100 m away from a predetermined yard the distance to be traveled would be max. 200 m. including return.

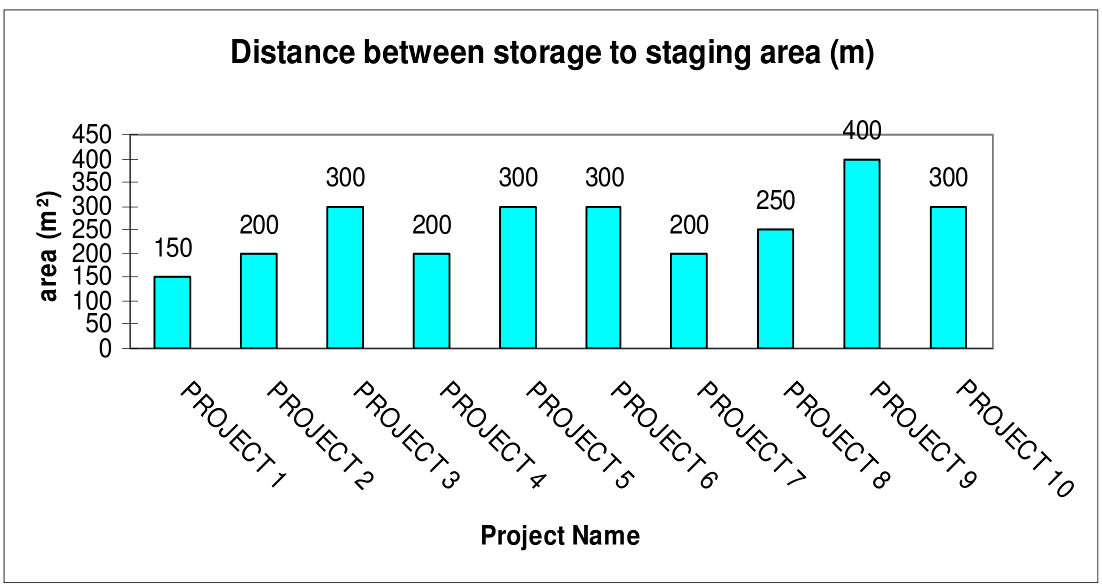


Figure 4.3 Distance Between Storage To Staging Area

According to the answers given to Questions 7 and 8 (see Fig. 4.4 & 4.5), storage yards are not adequate in most of the sites. Availability of more storage yards would be contractors' benefit in material supply. They would be able to purchase materials anytime they like, thus the storing expenses are eliminated. They would not need to hire warehouses. They would be able to buy materials when prices are low, even long before the job completion date as per the work schedule. Besides, separating materials which should not be stored together, and piling up materials neatly can only be possible with an adequate storage capacity.

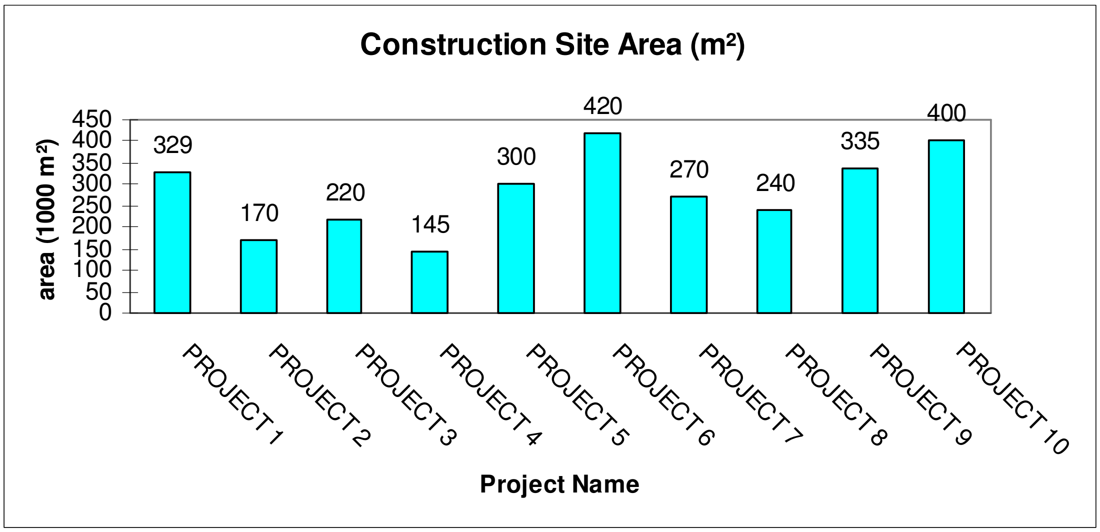


Figure 4.4 Construction Site Area

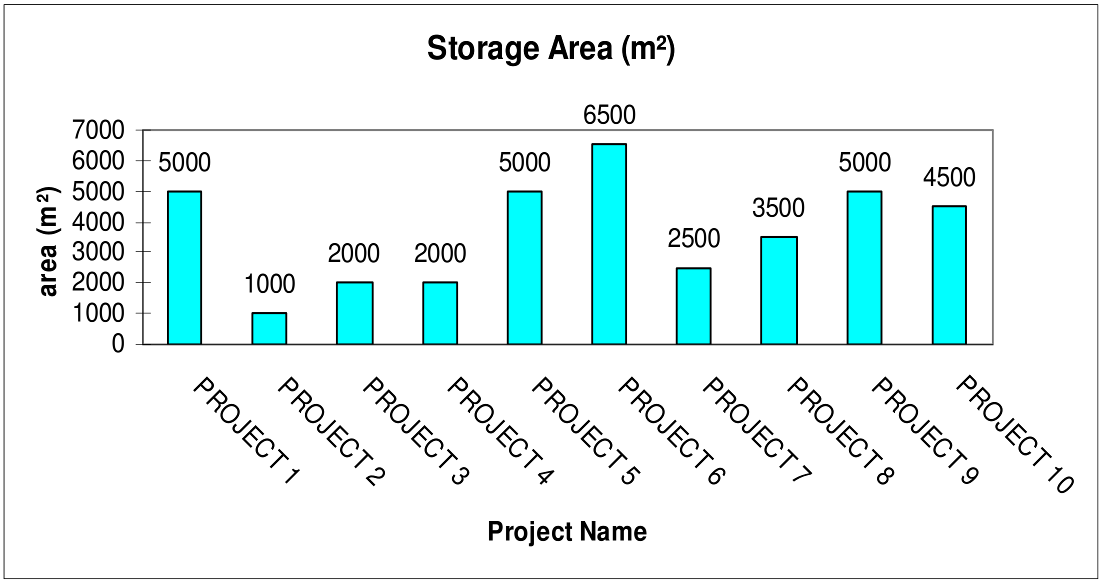


Figure 4.5 Storage Area

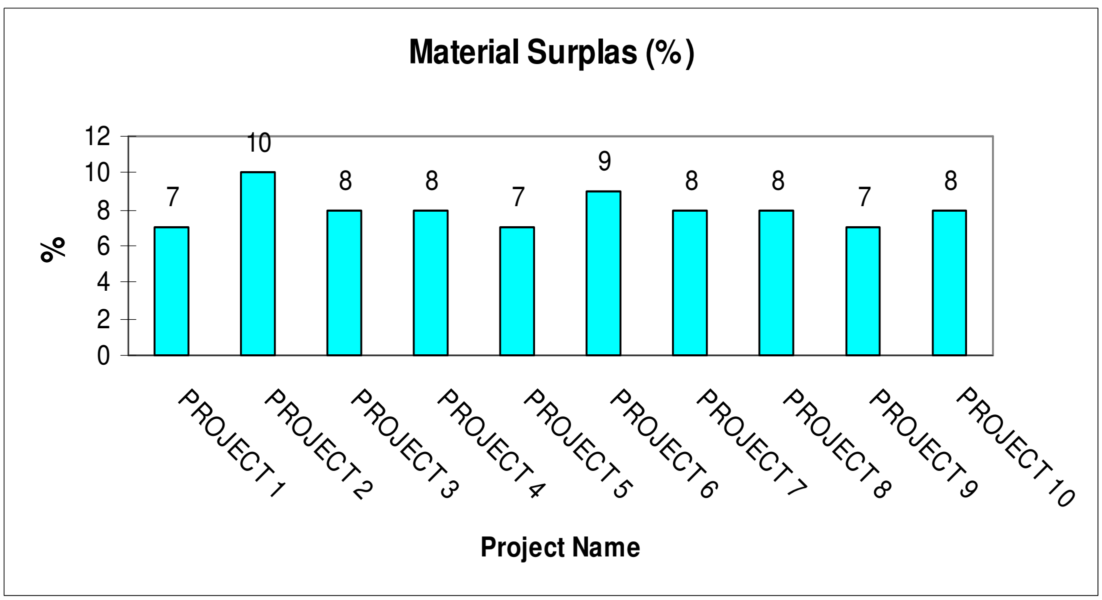


Figure 4.6 Percentage Of Material Surplus

According to the answers given to Question 22 average waste material percentage at sites is found to be around 8 to 9% (see Fig.4.6). This ratio is 4 times higher than the ratio at a site where a good material management is carried out. This ratio is a factor directly effective on cost. Decreasing this ratio down to 2% is among the basic objectives of material management. Therefore, the result of this survey shows that none of the projects incorporates any effective material management disciplines. Besides, material purchase prior to the firm project is another important factor, which increases waste material quantity. Some companies answered Question 5, which points out this issue, “yes”.

Quality checks and inspections, carried out for the materials delivered at sites, is another important issue by means of material management. Answers given to Questions 18 and 19 about this issue are partially in compliance with the theory of material management (see Table 4.1). On the other hand, only one inspection is carried out in some projects. However, according to the theories mentioned in Part 2, inspections should be carried out before and after purchasing materials.

Questions 13 and 14 are about material management software use. As mentioned in Part 2 use of software is essential for a seamless material management in today’s conditions. Barcode systems, synchronization with business program, distribution program and coordination with general budget can only be established by using good material management software. Focusing on the results, as seen in Table 4.1 material management programs are not used in any of the projects.

Importance of the MM can be explained from the results of the 24th question, which is about the ratio of (material cost to total cost) (see fig.4.7). The average of the answers is approximately 50 percent. It means that materials cost to be consisted 50 percent of the total cost. Thus, materials should be directed in a system. MM is not being considered sufficiently in spite of its significant effect on the project cost. Turkish construction firms should revise their materials management policy. For an effective cost control MM principles must be adapted on the project management process. MM mission should be defined and all stuff should be informed.

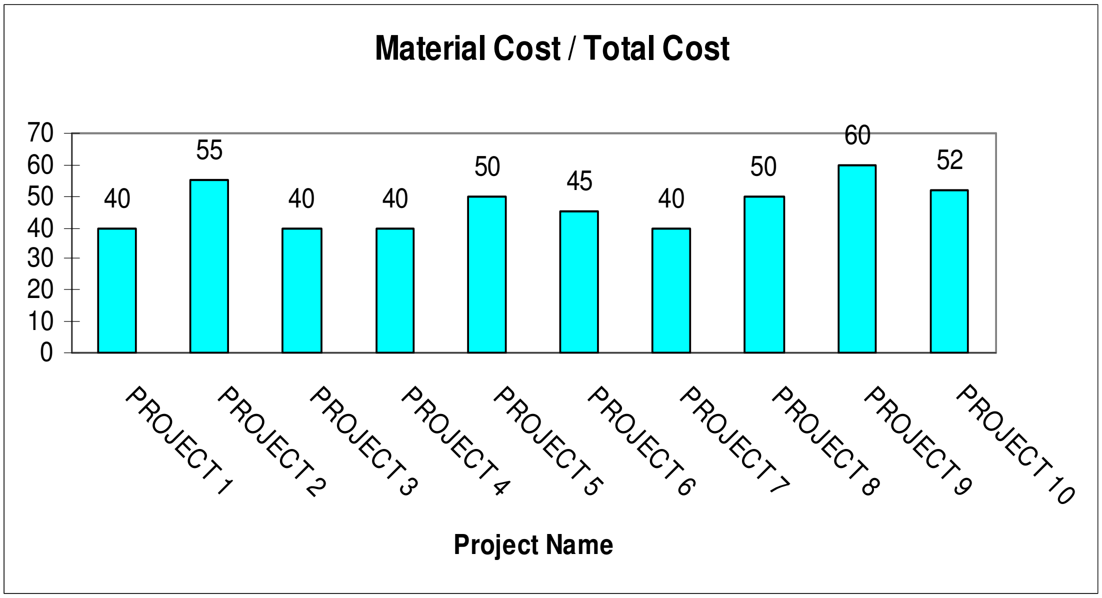


Figure 4.7 Material Cost \ Total Cost Ratio

5 A MODEL PROPOSAL FOR MATERIALS MANAGEMENT SYSTEM

Analyzing of the models discussed in Section 3 and the result of the questionnaire in Section 4 show that a material management system in compliance with the theory specified in this thesis does not exist. Survey results shows that this issue is a need to be filled, and there are not any material management procedures practiced especially in Turkey. From this point of view, believing that developing a material management program would help; developing a model in compliance with the material management theories taken from the literature in the beginning of this thesis was worked on. Considering the characteristics of the Turkish contractors sector, a comprehensive, effective, and simple material management system model is proposed in this study. General management concepts of Turkish contractors are also taken into account.

The proposed model is given in Figure 5.1. There are 3 sub-departments that constitute the material management, and are established by Material Manager. The material management is in constant communication and collaboration with other departments in the project. Material Planning Work Program and Directing is controlled by a separate department, while purchasing and procedures at site are controlled and carried out by two other departments. The aim of the proposed model is operating 3 different and important procedures synchronously prescribed in material management.

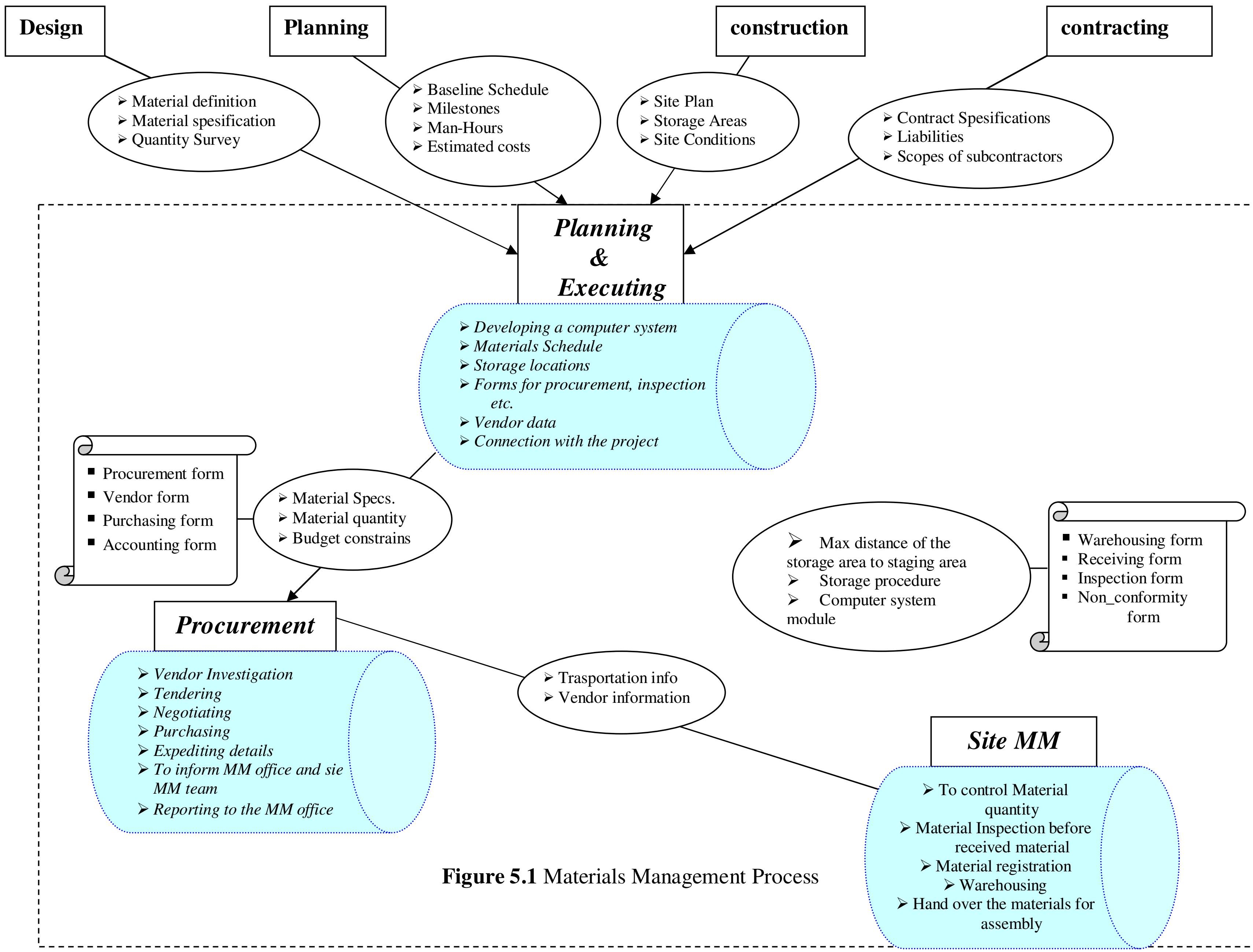
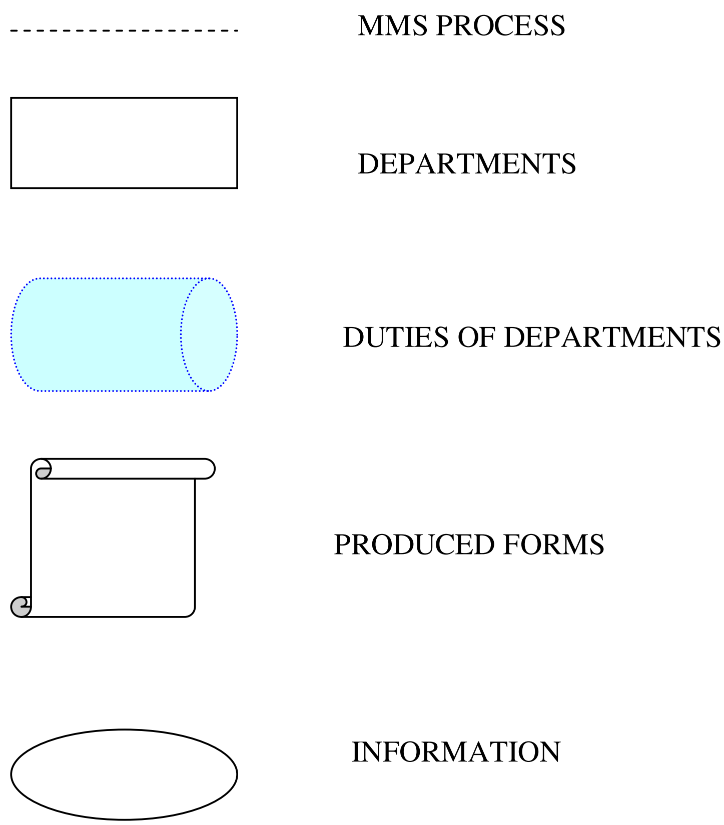


Figure 5.1 Materials Management Process

Legend :



5.1 Organisation of the Proposed Model

The first part of the proposed model will be the organization of the Material Management. As mentioned above, the model has 3 legs; as, Material Management Planning and Controlling, Purchasing, and Site Material Management.

Material Management Planning and Controlling department completes material manager organization prior to starting the job and makes the necessary assignments, and with the authorization conferred by project manager, selects prescribed number of personnel for certain tasks as shown Fig. 5.2. The selected personnel are expected to be specialized and experienced in material management. The model has no limitations on the number of personnel. However, financial issues should not be neglected, and unnecessary employment should be avoided. Depending on the project, personnel quantity and quality may vary. For instance, it would be logical employing personnel proportional to the amount of pipes and machines purchased in an industrial project. For another project, in which architectural issues are important, personnel should be hired according to the requirements of that project. A good organization is the foundation of a successful material management. Operating with right and correct number of people enhances the effectiveness of material management, and thus the project efficiency is enhanced as the domino effect.

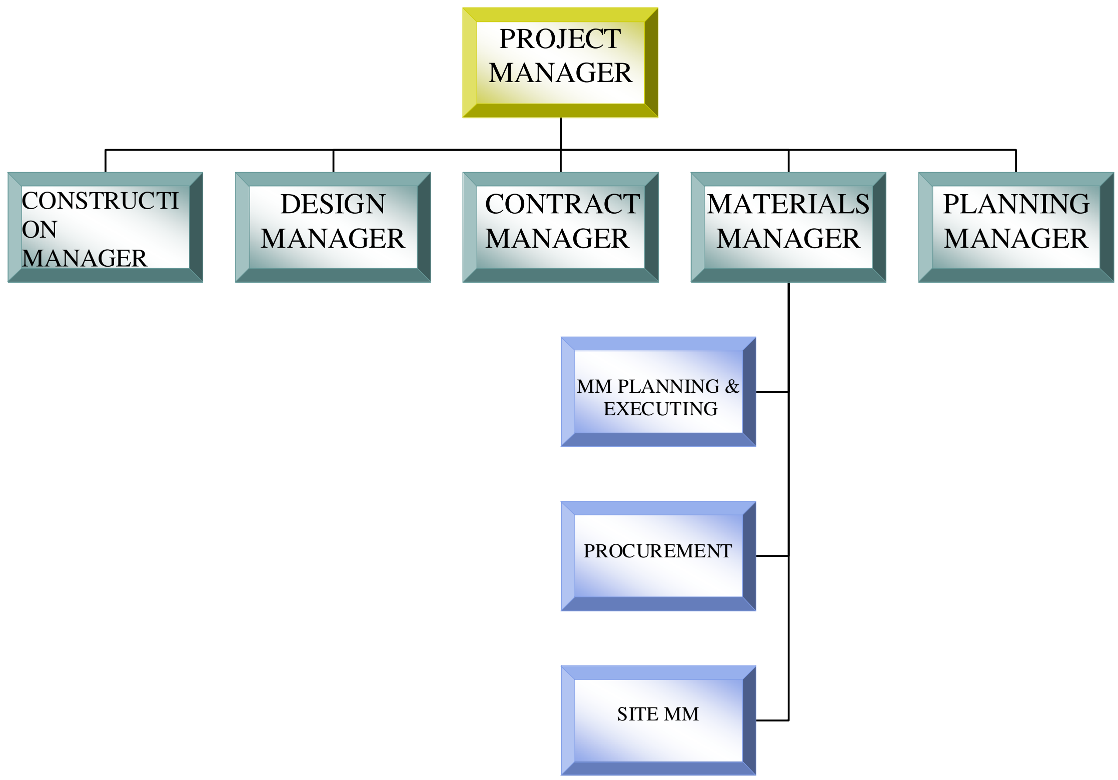


Figure 5.2 Proposal Organisation Chart With MM Duties

5.1.1 Planning & Executing

Planning and Controlling Department is the heart of material management. Having the organization completed, Planning and Controlling Department starts exchanging information between other departments of the project. It gathers all information about materials and related to material management from Designing, Contracts, Site, and Planning Departments. Collected information are filtered and works together with planning department for making a new work program for material management, and material procurement dates are scheduled. Information about characteristics and quality of materials are received from designing department. Information about the contractual inspection and material compliance certificate procedures are taken from the relevant department. Storing and manufacturing information are taken from Site. Consequently, Planning and Controlling Department specifies an overall material management and supply procedure. The concept specified is transferred to the software used. In other words, the entire procedure from specifying to purchasing materials is detailed and saved in computer system. Software use is considered one of the essentials in material management when this model is designed. Seamless operation and organization can only be established with comprehensive software. Material management can not be established without using a paper software in today's world where speed and material variety are quite high. This program will facilitate procedure and work synchronization, storing, bar-coding, communication and manufacturing controls. Features of software used in material management can be listed as follows.

- Separate the types of the materials
- Material flow (material quantity, storage capacity etc.) can be monitored by computer system.
- Material schedule to be under controlled.
- Procurement time to be determined.
- Conformity & non conformity forms to be prepared
- The products which does not provide the requirements of the material specifications to be eliminated.

5.1.2 Procurement

Procurement Department ensuring high quality material procurement and low costs, which are among the main objectives of materials management, is an important department. This department having gathered information such as quantity, material specification, and cost limitation starts and controls material procurement procedures. Purchasing Department should get such information as soon as possible so that it can carry out the necessary supplier research and send materials to the site on time. Purchasing Department's functions can be listed as follows:

- Required materials a definition, specifications, quantity and cost constrains given from MM office to be filed and every materials to be separated.

- Required material manufacturer's to be determined.
- Minimum 3 manufacturers\vendors to be invited for tendering
- Formal offers to be asked from vendors.
- Prices to be determined and negotiations to be achieved
- The exact prices to be notified to the materials manager.
- After materials manager approval purchasing to be carried out.
- Expediting details to be calibrated. Delays to be prevented as possible.
- Accounting documents to be filed.
- Site MM team to be informed. Vendor information, expediting details to be reported to the site.

5.1.3 Site Materials management

Another important department of our material management model is Site Material Management. Material Management's task will not be over as materials are supplied and delivered to Site. First, the personnel in charge carry out the acceptance procedures when materials are delivered to the Site. They perform the necessary inspections and counting. The objective is to verify that the material meets the requirements by means of quality and quantity. Having finished with this procedure, Material Management has to store and transfer the material to Manufacturing Area seamlessly. Materials are stored in predetermined warehouses according to their types. Storing materials under suitable conditions and preventing them from mixing with other materials are important issues that require attention. For instance; materials, which must be kept dry, should not be stored in moist places. Tasks of Material Management at Site can be listed as follows:

- The materials flow synchronization with the schedule should be controlled.
- Defected materials should be sorted and after then reported.
- Assembly of the materials should be supervised on time.
- Storage areas localization should be defined at the beginning of the mobilization.
- Storage areas should be categorized as types of materials.
- Stored materials should be settled as shortest distance as possible to the staging area.
- Required materials should be notified to the main office at the proper time.
- Surplus materials quantity should be kept in acceptable boundaries (max %3-4).
- Shortage material interruption does not occur during construction.

5.2 Hypothetical Test of the Model

In this part, proposed MM model is applied to a residental project. All process of MMS will be integrated into this project. At the end of the implementation, system costs & benefits will be compared and MMS effectiveness can be measured. Measurement of, surplases, shortages, computer system and storage costs will be assumed according to information given by Turkish construction firms. Labour productuvity is also taken into accounted in accordance with MM theory and Turkish construction sector. All these data has collected through interviews with project managers, site managers and etc.

5.2.1 Project Description

A residential project is selected for the hypothetical application of the model Table 5.1 gives the details of the resindential project.

Table 5.1 Residential Project Description

Project Features	Project A
Project Type	Residental
Location	Büyükçekmece
Project cost (TL million)	80
Type of structural frame	Concrete
Number of Blocks	40
Building height per Block	12 m
A Block First floor plan area	250 m²
Site area	30 000 m²
Building-to-site area ratio	~0.50
Responsible entity	General contractor
Number of work days required	400
Crew size	250
Work-hours required	800000
Man-hour cost (TL)	10
Materials cost \ Total cost	%50

An effective MMS must be integrated with the project management concept. According to the proposed MMS model residential project will have an organisation as shown in figure 5.3. Materials manager responsible to the project manager directly. MM planner, computer system executer and quality control specialist to be assigned for planning and executing the MMS in the main office. For the procurement department an account specialist and vendor controller to be assigned. At last for the site a site material manager and junior material controller to be assigned for this project. After these assignments materials manager monitors and supervises to all process. He reports to the project manager once a week about materials management process.

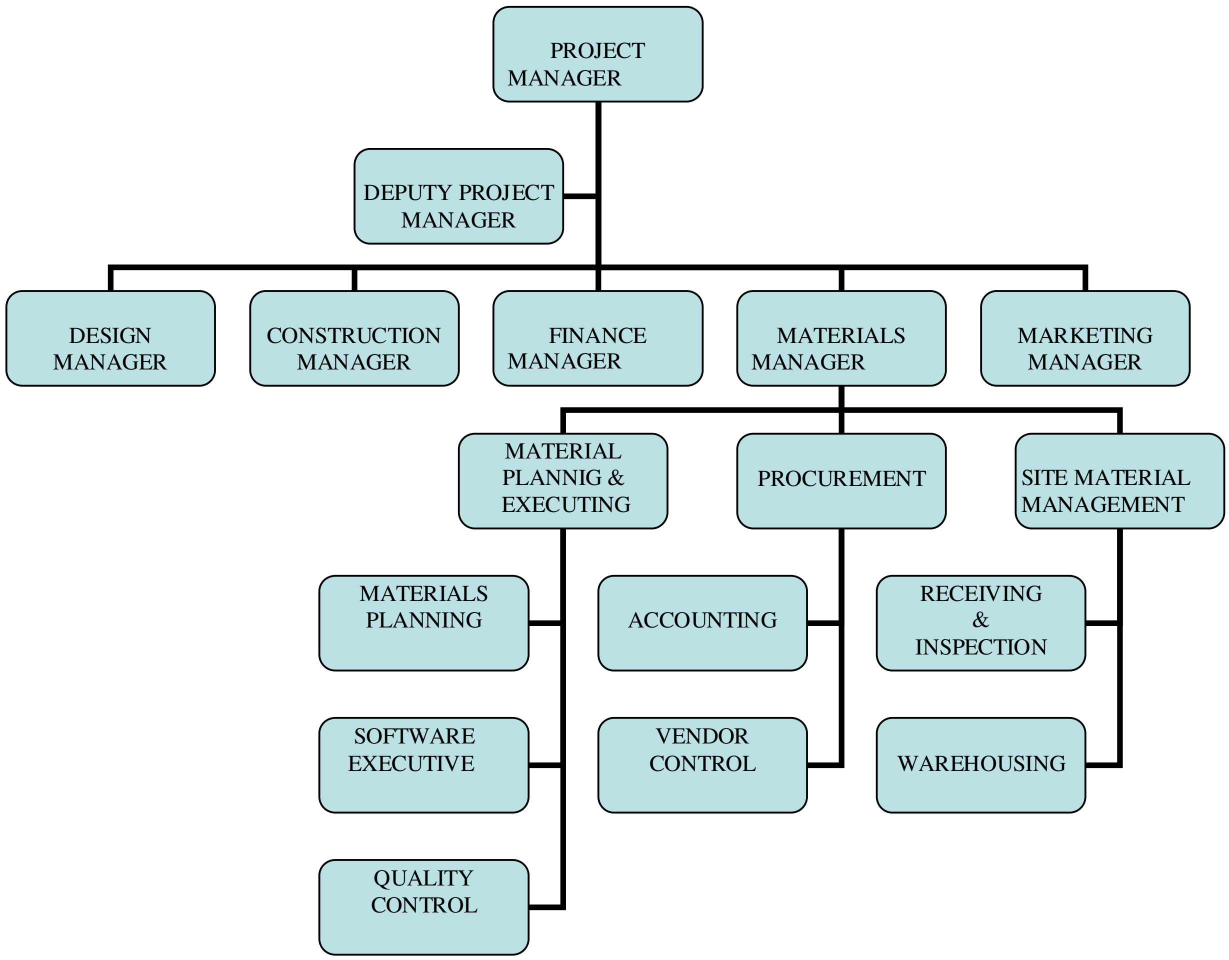


Figure 5.3 Organization Chart of The Residental Project

5.2.2 Test of the Model Implementation

For this project MM team to be assumed as 6 people including materials manager (%2.5 of all personel). Two personel at planning and executing division 1 personel for procurement and at least two personel for site materials management. This organization is sufficient for an effective materials management. All the process can be directed by this team effectively. Estimated personel payroll costs to be accounted according to 'Salary & Wages In Turkey' Poyraz Consultancy (2009) investigation.

A computer system should be established for executing the MM process. The package programs like Primavera, Ms Project, Autodesk Planner prices support the estimated cost of computer system.

Within the MMS, labour productuvity must be improved to 6-8 % according to the research Construction Industry Cost Effectiveness,(1982) around the world. If the labour productivity is assumed to be 7%, then required man hour will be reduced to 750 000 instead of 800 000. Approximately 500 000 TL. cost savings will be provided (see Table 5.2).

Furthermore, surplus material quantity should be between 3-5% according to literature in this subject. If the surplus material quantitiy is aimed to be 4%, then the savings will be 1 600 000 TL. (Stukhart et.al, 1987).

MMS establishement to be prevented from :

- Low quality material usage
- Low labour productivity
- To much wasting-time
- High material surplus quantity

Table 5.2 Proposed System Benefit Calculation

SYSTEM BENEFITS
Required work-hours = 800 000
With MMS labour productivity increasing ratio (approximately) = %6 - %8
Benefit quantity = 800 000 × 0.070(avarage quantity of %6-%8) = 56 000 man-hour
Benefit price = 56 000 ×10tl (man hour cost) = 560 000 TL
Estimated materials cost = 40 000 000 TL
With MMS surplus saving ratio (approximately) = %3 - %5
Surplus savings = 40 000 000 × 0,04 (avarage quantity of %3-%5) = 1 600 000 TL
TOTAL SAVINGS = 1 600 000 + 560 000 = **2 160 000 TL**

On the other hand, for a proper evaluation MMS cost should be determined. Personal payroll costs 'Salary & Wages In Turkey' Poyraz Consultancy investigation (2009) and storage costs are the main factor of the total MMS cost described in Table 5.3. For this project personal payroll costs for 400 days approximately 600 000 TL. Three storages has been formed for an improved labour productivity. Construction, furnishing and maintenance cost of the 3 storages are approximately 200 000 TL.

Table 5.3 Proposed System Cost

SYSTEM COSTS

Personnel cost (included payrolls, SSK, lunch, transportation) for a month = 4 000 TL (for 1 person)

400 day = 14 month

4000×5×14 = 280 000 TL

Materials Manager cost (included payrolls, SSK, lunch, transportation) for a month = 7 000 TL

7000×14 = 98 0000 TL

Computer System Cost : 15 000 TL.

Warehousing cost = 5000 TL \ month \ storage

(3 storages has been constructed at the site)

= 5000×3×14

= 210 000 TL

TOTAL COST = 210 000 +15 000 +280 000 + 98 000

= **603 000 TL**

As a result MMS benefits \ costs ratio has been calculated as 3,52. This ratio has been found as 5.7 by the case study (Impact of material management on productivity-a case study' Thomas et.al.1989) achieved in State Collage Pennsylvania. Therefore, benefit cost ratio can be improved according to implementation.This ratio is acceptable and reasonable for the benefit of the project. However, a model proposed by Thomas et.al.(1989) reaches a ratio of 5.7. This ratio can be improved according to implementation procedures.

6. CONCLUSIONS

Considering studies and material management systems in practice, Material Management systems are quite effective on construction projects. Codifying the supply stage of materials to be used and the procedure-oriented handling thereof, are highly important for both the operator and employer by means of budget and quality. Handling material supply, which has a considerable part in construction project budgets, precisely, having an organization for that, and establishing a material management procedure are of great importance for enhancing profitability, productivity, and quality.

In the light of world-wide construction projects, none of those practices incorporates the basic elements of the Material Management Systems. After defining the problem in all respects, a comprehensive literature search was performed to be informed about MMS. From this point of view, suggesting and working on a practical system applicable in Turkey is the conclusion reached.

First of all, analyzing construction projects' approach to the concept of material management in Turkey, and checking if they have any practices thereof were necessary. It was determined that conducting a small survey would be the best possible way of performing the above mentioned analyzes. In this context, 10 big construction projects in Istanbul were visited, and the questions were asked to the authorized persons, and the material management procedures in their projects were analyzed.

This survey revealed that although the estimated cost of the smallest project was 100 million TL with a material cost to total cost ratio of 40%, none of the projects had any material management procedures. Although they all have purchasing units, the absence of material management systems that should run synchronously with the project elements such as Designing, Planning, and Site considerably reduces the profitability of the companies implementing those projects.

In the light of all data and results, developing and suggesting a system was assessed within the scope of this thesis and a theoretical model was developed. The endeavor for creating a system applicable in Turkey is the key element here. The scope of this proposal is providing the high labour productivity and low material surplus. Constituting a practical, simple, effective and comprehensible system is aimed. The application of the model to a residential project was carried out in the end of the study as a hypothetical case study to describe and to illustrate the proposed model by means of all inputs and outputs. The model incorporates three key features :

- Organization and Planning
- Purchasing
- Site Material Management

The remarkable points taken into consideration during the design of the proposed model are :

- MM organisation, consisted qualified staff
- Interfaces with other management departments
- MM Planning & scheduling
- Site MM
- Vendor Control procedures
- Materials receiving procedures

The model is not conform with small scale projects because those kind of projects will not require any detailed MMS. A normal purchasing system is sufficient for them. The benefit of model depends on the variety of project materials. If material variety is less then, the model beneficence would be low. In this situation implementing this MMS model would not be reasonable.

As a result, it was observed that material management has significant effects on construction sector just like on all industrial branches. Therefore, apart from other sectors, a different procedure for each project should be established for construction projects, and the material issue, which makes the 50% of total cost, must be managed well. This would certainly increase the profitability. It is evident that material management systems will be regarded much more seriously and precisely in the future. The model proposed in this study can be assistant of reducing the total project cost.

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APPENDIX A

Features of the selected projects for questionnaire :

Project code	Project Name	Estimated Cost (millon TL)	Location	Contractor
Project 1	European Side Justice Hall	250	istanbul	Varyap
Project 2	Harbiye Cultere Center	170	istanbul	Sembol - Taca
Project 3	Marmaray depots	100	istanbul	Gülermak
Project 4	Kuyumcukent	135	istanbul	Kuzu - Cihan
Project 5	Akbank Gebze	270	istanbul	Koray
Project 6	Halkalı- İstoç Subway	400	istanbul	Gülermak
Project 7	Petro Rabigh	400	UAE	Gama
Project 8	Great Tarabya hotel renovation	120	istanbul	Bayraktar
Project 9	Petro UAE	350	UAE	Gama
Project 10	Bosphorus City	300	istanbul	Dost - İntaya

APPENDIX B

QUESTIONNAIRE : Materials management approaches in Turkish construction firms

	QUESTIONNAIRE UNDER SCOPE OF THE THESIS 'MATERIALS MANAGEMENT APPROACHES' AT MİMARSİNAN FINE ARTS UNIVERSITY INSTITUTE OF SCIENCE AND TECHNOLOGY DIVISION OF STRUCTURAL ENGINEERING PROGRAMME				
	PROJECT NAME				
	COMPANY				
	PROJECT ESTIMATED VALUE				
	NAME&SURNAME				
	OCCUPATION & DUTY				
1	**Is there a department about MM in general organisation**		yes	no	
2	**How many personnel working for only MM**				
3	**Does MM manager primarily responsible to the project manager?**		yes	no	
4	**Is there a plan about MM**		yes	no	
5	**Procurement has been achieved before detailed design**		yes	no	
6	**Is there a procedure about supplier investigation**		yes	no	
7	**The construction site area's magnitude(approximately)**			m^2	

8	**Warehousing area's magnitude (approximately)**	m²		
9	**What is the distance of the warehouse to the manufacturing area (approximately)**	m		
10	**Materials can be stored in the construction building. (basement or etc.)**	yes	no	s.times
11	**Is there a sketch about material storage**	yes	no	
12	**Providing materials protection against external effects**	yes	no	s.times
13	**Using software for MM**	yes	no	
14	**Cost of this software**			
15	**Personnel & equipment cost of MM**	TL\$\euro		
16	**Materials come to the site after mobilization**	yes	no	s.times
17	**Materials bring to the just in time**	yes	no	s.times
18	**Materials quality to be controlled before procurement**	yes	no	s.times
19	**Materials quality to be controlled after procurement**	yes	no	s.times
20	**How many firms to be determined during material selection**	unit		

21	**What is the quantity of the storage variety (external, internal etc.)**		adet	
22	**What is the surplus percentage (approximately)**			
23	**It can be shortage procurement according to detailed design's quantity survey**		yes	no	s.times
24	**What is the range of materials cost to total cost**			
25	**How many personnel has been employed at site**			

Note : Please fill in the blanks with your answers or thick the box according to your answer

BIOGRAPHY

Tahir Akkoyunlu was born in Kayseri on 23th January, 1980. He completed his primary education in Sami Yangın Anatolian High school in 1995 and secondary education in Sümer High School in 1998. Afterwards, he attended Yıldız Technical University (YTU), Faculty of Civil Engineering. He graduated and got his 'Bachelor of Civil Engineering' degree from YTU in 2005.

After graduation, he has completed his military obligation in Kırklareli. He started his businness carrier at Prota under the scope of 'retrofitting buildings against earthquake' as a design & site engineer for 1.5 years. He got acceptence for Construction Project Management Graduate Programme in Mimarsinan Fine Arts University in September 2006 and he took the Master Courses during the academic year of 2006-2007 & 2007-2008. Between years 2007-2009 he worked for Gülermak, contractor of Marmaray CR1 project, as a design engineer. He is still working as an area executive in Dörken Sistem since 2009 January.