In the Name of Allah, Most Gracious, Most Merciful.

To

My Beloved Parents and Sisters

for their

Innumerable prayers, encouragement and patience.

"O Lord, bestow on them thy Mercy even as they cherished me in childhood." (The Holy Quran 17: 24)

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All praise and thanks are due to Almighty Allah, Most Gracious; Most Merciful, for the immense mercy which have resulted in accomplishing this research. May peace and blessings be upon prophet Muhammad (PBUH), his family and his companions.

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THESIS ABSTRACT

FULL NAME OF STUDENT	: MOHAMMED KASHIF UL ASAD
TITLE OF THE STUDY	: EVALUATION OF PERFORMANCE MEASURES FOR MATERIALS MANAGEMENT PROCESS IN INDUSTRIAL CONSTRUCTION PROJECTS
MAJOR	: CONSTRUCTION ENGINEERING AND MANAGEMENT
DATE OF DEGREE	:DECEMBER, 2005

The Kingdom of Saudi Arabia has experienced a massive construction boom since the early seventies. Among other problems, Materials management has continued to cause a major obstacle to the success and profitability of many construction projects. Studies have indicated that materials constitute about 60% of the total project cost, and control 80% of the project schedule. Effective management of materials represents an area with great potential for improving productivity of work and also controlling cost. Determining the key effectiveness measures will benefit the construction industry. This research revealed the Usability, Importance and Practicality of 35 Performance Measures for Materials management process in industrial construction projects in Saudi Arabia. From this study it was found that the Performance Measures that were found to be extremely important were Material availability, Procurement lead-time, Construction time lost and the Measures that were found to extremely practical were Material availability and Construction time lost.

MASTER OF SCIENCE DEGREE

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS

Dhahran, Saudi Arabia

خلاصــة الـرســالــة

الاسم الكامل للطالب : محمد كاشـف الأسـد

عنــوان الدراســة : تقييم المقاييس الرئيسه لإدارة المواد في المشاريع الصناعية

التخـصـص : إدارة وهندسـة التشــييد

تاريخ الشهادة : ديســـمبر 2005

تشهد المملكة ومنذ السبعينات برنامج تشييد ضخم، والذي لم يخلو من الصعوبات ومن ضمنها إدارة المواد. ما تزال إدارة المواد تشكل عائقاً رئيسياً لنجاح وربحية الكثير من المشاريع، ولقد بينت الدراسات أن المواد تشكل 60% من التكاليف الإجمالية للمشاريع وتتحكم في 80% من جدول المشروع. تمثل الإدارة الفعالة للمواد أرضية خصبة لتحسين الإنتاجية وتوفير الكاليف ، وبلا شك فإن قطاع صناعة التشييد سيستفيد من تحديد المقاييس الرئيسية للإدارة الفعالة للمواد . يهدف هذا البحث توضيح 35 مقياسا رئيسيا متبعا في المشاريع الصناعية من خلال قياس أهميتها ومدى عمليتها ومقدار استخدامها. اتضح أن المقاييس الرئيسية ذات الأهمية القصوى تتمركز حول : توفر المواد ، الزمن اللازم لوصول المشتريات ، و الوقت الضائع في عمليات التشييد . كما أن المقاييس الرئيسية الأكثر عملية هي: توفر المواد، والوقت الضائع في عمليات التشييد.

درجة الماجستير في العلوم

جامعة الملك فهد للبترول والمعادن

الظهران ، المملكة العربية السعودية

CHAPTER 1

INTRODUCTION

1.1 Materials Management

Materials management is a process for planning, executing and controlling field and office activities in construction. The goal of materials management is to insure that construction materials are available at their point of use when needed. The materials management system attempts to insure that the right quality and quantity of materials are appropriately selected, purchased, delivered, and handled onsite in a timely manner and at a reasonable cost. Materials management is the system for planning and controlling all of the efforts necessary to ensure that the correct quality and quantity of materials and equipment are properly specified in a timely manner, are obtained at a reasonable cost, and, most importantly, are available at the point of use when required.(BRT 1982).

Materials management is an important element in project management. Materials represent a major expense in construction, so minimizing procurement costs improves opportunities for reducing the overall project costs. Poor materials management can result in increased costs during construction. Efficient management of materials can result in substantial savings in project costs. If materials are purchased too early, capital may be held up and interest charges incurred on the excess inventory of materials. Materials may deteriorate during storage or get stolen unless special care is taken. Delays and extra expenses may be incurred if materials required for particular activities are unavailable. Ensuring a timely flow of materials is an important concern of material management.

For effectively managing and controlling materials, the performance of materials management should be measured. A performance measure calculates the effective working of a function. These performance measures may differ from system to system. The measures divide the materials management system in parts and make the working of the system more efficient. When joined, the measures make the complete materials management system. Research has been done in the past by Plemmons (1995) and Al-Darweesh (1999) about the effectiveness measures in materials management. Plemmons developed a list of effectiveness measures for industrial construction and proposed a model for benchmarking the materials management process in industrial construction. Al-Darweesh developed a list of measures from literature review and applied those measures to 17 ongoing projects in Saudi Arabia to gain an understanding of the effectiveness of these measures.

This study is about the performance measures affecting the materials management system in industrial construction industry in Saudi Arabia. A list of performance measures applicable in Saudi Arabia can be developed and their importance and practicality can be studied to understand the working efficiency of the materials management system in industrial construction in Saudi Arabia. This study looks at the effectiveness, the performance measures of materials management have on industrial construction, from contractors' point of view.

1.2 Research Objectives

The objectives of this research are to:

1. Determine the performance measures used in the past and currently in use for Materials management in industrial construction projects in the Eastern Province of Saudi Arabia.
2. Determine the importance of the performance measures in assessing the effectiveness of the materials management process.
3. Determine the practicality of implementation of performance measures in industrial construction projects in Eastern Province of Saudi Arabia.

1.3 Research Methodology:

An extensive literature review was done to find the past and currently used performance measures. The next step was to develop the questionnaire based on the literature review. The third step was to conduct interviews with the contractors working in materials management in SABIC and Saudi ARAMCO to determine the performance measures that have been used or currently being used in Saudi Arabia. Also the importance and practicality of these measures were calculated from the responses received through interviews. Spearman rank correlation was done as part of the analysis to find the correlation between the ranks under importance and practicality category. T-test was conducted between the responses of Saudi ARAMCO and SABIC to find the difference between their opinions in ranking the measures.

1.4 Scope and Limitations:

Industrial construction involves huge scope and hence large amount of materials involvement, and complexities managing it. This is the reason that industrial construction was preferred over other forms of construction for this research. Due to time and accessibility constraints, the study was limited to the Eastern Province of Saudi Arabia. Materials management is a field that has problems from owners' as well as contractors' point of view. This research is focused from contractors' point of view, because it is the contractor who is mainly responsible for the materials supply and management throughout the duration of any project. The functions and measures for materials management process are obtained by interviews with materials management personnel.

This study is to find the impact of performance measures of materials management in industrial construction. The research was to evaluate the importance and practicality of performance measures of materials management in industrial construction from contractors' point of view.

CHAPTER 2

LITERATURE REVIEW

2.1 Background to Materials Management

The basic goal of any industrial activity is the development and manufacture of products that can be marketed and sold at a profit. This goal is accomplished by the appropriate blending of what management authorities historically have called the five M's: machines, manpower, materials, money, and management. Materials are the life and blood of construction industry. Materials of the appropriate quality must be available at the right time, in the proper quantity, at the needed location, and at an acceptable total cost.

Failure to fulfill any of the responsibilities concerning materials adds to project costs and decreases project profit. In this chapter an extensive review of literature was done to gain an insight in the research done in the field of materials management and its improvement. Articles from journals and books were reviewed. The areas in which the articles were reviewed include industrial construction materials management processes, materials management functions, performance categories, effectiveness measure, supply chain management in construction, project management, and re-engineering materials management system.

According to Popescu (1982), the Planning Engineer is responsible for development and implementation of the materials execution plan tailored to fit specific project requirements. Several areas that should be covered by a materials management system as follows:

1. Materials identification and control
2. Materials procurement phases: purchasing, traffic, expediting, inspection and vendor coordination
3. Materials tracking
4. Client approval procedures
5. Contractor procedures: purchasing, damage replacement
6. Contractor, designer, client reporting and communications.

In the BRT (1982) it was shown that the lack of effectively managing materials to carry out the concept of materials management is evident when:

1. Management of project work is complicated by inconsistent and/or illogical assignment of responsibility for materials management activities among project support groups.
2. Personnel are not appropriately trained to perform their assigned tasks, and lack full understanding of the interdependency of their own work and that of related work performed by other organizations.
3. Integration of materials management into project planning is noticeably lacking.

4. Systems used to support materials management are generally not effectively meshed with the overall project management system.

5. Existing control information is poorly used to monitor performance against plans, to forecast all the impacts of design changes and to adjust the total project plan in response to change.

2.2 Problems in Materials Management:

Materials management is concerned with the flow of materials from suppliers to production and the subsequent flow of products through distribution centers to the customer. This includes the planning, acquisition, storage, movement, and control of materials and final products. For construction projects today, materials costs usually are the largest single expenditure. (Clough et al, 2005)

Although owners and contractors may have different perceptions on project management for construction, they have a common interest in creating an environment leading to successful projects in which project quality, completion time and final costs are within prescribed limits and tolerances.

Problems related to Owners

1. Outdated management systems can prove to be inefficient and costly.

2. Inefficient planning for materials management may rise serious problems to the construction projects.

3. Selection of incapable design-construct and construction contractor whose procedures and capabilities do not meet the prescribed standards for control of materials management.

Owners should consider

1. The need for modern, cost effective, management systems to plan, execute, and control their projects.
2. Their responsibilities and prerogatives as related to the use of management systems. In this regard, they should formally establish their specific scheduling, cost control, quality assurance and materials management objectives prior to requesting bids for a construction project.
3. The selection of design-construct and construction contractors who can demonstrate that their procedures, systems, and personnel capabilities meet prescribed standards for control of schedule, cost, quality assurance, and materials management.
4. The possible use of incentives to contractors to achieve project objectives, whether they be schedule, cost, or quality assurance.(BRT 1982)

Problems related to Owners and Contractors

1. If there are no standards of performance for materials management activities.

2. Untrained personnel in materials management can create problems.

3. Absence of automatic data processing, especially for large projects can increase cost and waste time.

4. Inefficient job site inventory control can prove to be costly and time consuming.

Owners and Contractors should

1. Develop standards of performance for materials management activities.

2. Select materials management personnel carefully, provide adequate training and career progression plans. Increased attention should be given to providing training for any local hire personnel performing materials management activities at the job site.

3. Use automatic data processing more extensively for materials management, especially for large projects and for job site activities where it can be most effective at eliminating waste of time and money.

4. Expedite placement of purchase orders by techniques, varied to suit the dollar amount and conditions of orders, such as a form of proposal to encourage technical uniformity in bids, price agreements, requirements orders, small dollar value orders, and petty cash fund purchases for small items.

5. Improve job site inventory control by broader use of coding systems and of re-order points for commonly stocked materials. Satellite warehouses close to work areas should be established for large projects.(BRT 1982)

2.3 Materials Management in Construction Industry

Effective materials management requires a high degree of cooperation among many people involved in a construction project. For construction to progress smoothly all the various materials management functions and activities should be established and the assignment to carry out each specific responsibility clearly outlined.

The materials management problems that may arise in every form of construction unless special care is taken in the following areas:

1. planning materials deliveries
2. ordering the materials
3. checking deliveries on site
4. placing materials onsite
5. processing delivery tickets and invoices
6. controlling the use of materials
7. producing a costing analysis
8. paying for materials
9. Feedback on performance during construction.

The CII report in its materials management primer (1988) explains materials management as "*a process that enables the organization to become the low cost/high quality provider of services in the marketplace and maintaining that position in this environment of constant change*".

1. Strategic Organization--organizing effectively for the work that must be done.
2. Organizational Development--providing the skills and communications to make the changes.
3. Operational Improvement--making the necessary changes and improvements.
4. Benefits Realization--reaping the rewards of all of the hard work.
5. Continuous Improvement preparing for the inevitable outside changes which will occur.

Stukhart and Bell (1986) recommend the following for material management:

1. Obtain the best value from the perspective of the customer (not necessarily the best price) for purchased materials,
2. Assure materials are in place when and where required,
3. Reduce inventory and surplus,
4. Assure quality requirements are met, and
5. Provide efficient low cost movement of materials to site and within site storage areas.

The orders for the supply of building materials services are typically placed by the main contractor. The contactor should check the order details and make sure it fits into his program. Improper warehousing can result in decrease in space utilization, inaccurate retrievable data, increase in manpower, inferior customer services. Improper warehousing increases the waste. Improper Materials takeoff will result in lack of materials when required.

Kini (1999) in his study describes materials management as "*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 and can be integrated with engineering to provide an end product that meets the client's needs and is cost effective. A typical engineer/procure/construct (EPC) project can be divided into seven distinct stages, during which the project manager must ensure a materials management focus among the project management team. The seven stages are planning, preliminary design, final design, procurement, vendor control, construction and closeout.

2.3.1 Materials Management in Industrial construction

Industrial construction usually involves very large scale projects with a high degree of technological complexity, such as oil refineries, steel mills, chemical processing plants and power plants. Industrial construction differs from other types of construction in scope, amount and complexity of work. The owners are usually deeply involved in the development of a project, and prefer to work with designers-builders such that the total time for the completion of the project can be shortened. They also want to pick a team of designers and builders with whom the owner has developed good working relations over the years. For projects involving the large scale use of critical resources, the owner may initiate the procurement procedure even before the selection of a contractor in order to avoid shortages and delays. Under ordinary circumstances, the contractor handles the procurement to shop for materials with the best price/performance characteristics specified by the designer.

2.3.2 Materials Management Organization and Personnel

The CII report (1988) gives considerable importance to integrated materials management organization in determining the ultimate cost of a construction project. The organization must be structured to provide for the timely performance of the work, with materials personnel located at appropriate levels of project management to contribute to and influence the decision making process.

Dey and Banwet (1999) were of the view that the conventional materials management was not effective and an overall organizational approach is required for successful material management. They came up with a list of problem issues for materials management functions. The list is as follows:

1. Receiving materials before they are required;
2. Not receiving materials when they are needed;
3. Incorrect material takeoff form drawing and design document;
4. Subsequent design changes;
5. Damage/loss of items;
6. Failure on installation;

7. Selection of type of contract for specific materials procurement to prevent loss;

8. Vendor evaluation criteria to select the best available vendor;

9. Pilling up of inventory and controlling of the same to prevent shortage and excess of materials;

10. Management of surplus materials.

In some cases, particularly on larger projects, the entire scope of materials functions may be consolidated into one unit. On smaller jobs, various materials functions sometimes are assigned to individuals who have other responsibilities and assignments. This poses significant challenges to the individual responsible for managing all materials functions. A single focus for the management of these functions is essential, even though the assigned individual may have other project duties.

CII (1988) states that "*the organizational structure of materials management must take into consideration the size, scope, contracting strategy, and location of the project. A primary requirement is the coordination between the home office and the field, which is achieved by individuals and computer systems complimenting each other throughout the materials cycle. Large projects, regardless of location, will require a full staff of skilled professionals with a direct reporting line to project management. These materials organizations continue to rely on home office guidance in procedure and policy development and the selection and supply of key field materials management personnel*".

The CII (1988) continues to explain the staff requirement in materials management organizations as "*It is essential that the organization be staffed with professionals* *possessing skills consistent with the scope of work. The requirements are changing to fewer semi-skilled and more professional personnel. The required key personnel must have a thorough understanding of the project materials plan and its function within the total project. Prior experience in requirements definition, procurement, quality assurance/quality control, transportation, and site materials management is highly desirable. Computer conversancy is increasingly important as the benefits of materials management automation become practical for ever smaller jobs".*

CII (1988) identifies the advantages of proper staff selection and training and states that "*Although proper selection of personnel will minimize the necessary training, some training for the particular requirements of each project will be required. Much of this training can be on-the-job, but formal training in management, business, and computers is increasingly required. Lack of training, especially of site personnel, has been a frequently cited factor on "problem" projects".*

CII (1988) finally describes the benefit of integrated systems approach as "*A proactive integrated systems approach is the only successful way to ensure that materials are considered in project planning, controlling, and directing activities. Materials management personnel must be able to operate in the project environment, to anticipate the requirements of other organizations, to administer their program within a complex set of organizational arrangements, and to communicate the importance of materials management*".

A construction industry cost effectiveness project report BRT (1982) point out the following as organizational responsibilities:

1. Organizational responsibilities for all materials management activities, including those at job sites, must be fully defined, logically and consistently assigned, and understood by all personnel involved.
2. Detailed written procedures should be published covering the performance of all materials management activities and the monitoring of that performance against plans. The procedures must be consistent with the assignment of organizational responsibility.
3. Standards should be used to establish staffing levels for each activity. There should be procedures to keep track of staff levels and make adjustments to suit changed requirements.

Stukhart and Marsh (1986) discussed about achieving a proactive integrated materials management through the involvement of the materials personnel in different phases of project management. They state the treating materials as a system does not necessarily imply a materials organization, generally thought of as one of the functional organizations in the company, comprising most of the materials-related activities. In some few cases the entire scope of materials activities may be consolidated into one single functional unit. In most situations, however, materials responsibilities are divided among project control, engineering, construction, and other entities of the project team. The authors stated the roles and responsibilities of the proactive materials management as:

1. Every member of the materials management group recognizes his or her role.
2. Materials management be involved in the requirements and planning process.
3. Materials management takes the initiative in making things happen.

Marsh (1985) discuss the role of material coordinator as the link in project team planning and coordination of material requirements. Marsh considers this as a difficult role, because of the conflicting functional interests in most companies and projects. It requires considerable interpersonal and technical skills to relate material objectives to those of other functional areas, knowing the points of interaction, and ultimately getting other people in the team to realize the role of materials in project success. If the materials coordinator is successful, other functional managers and coordinators will routinely coordinate planning, engineering, changes, and field requirements with the materials coordinator.

2.3.3 Improvement in Materials Management System

Researchers and practitioners have studied the materials management functions and the system and tried to improve it with time. Many studies have been done in the past to improve the traditional materials management system. Studies have been done on problems existing in materials management to increase its efficiency.

Jortberg and Haggard (1993) prepared a technical report on the progress of the Construction Industry Institute in its first ten years of working. The evolution of construction education and research was an issue addressed in the report. The report also highlights materials management as one of the main topics for research, as stated in the CII research program. The publications which received the greatest demand and highest level of interest include materials management. Materials management has been addressed in a series of CII publications, the most notable being the "*Project Materials Management Handbook*". This publication has generated an increased awareness among owners and contractors of the significance of materials management. Not only does this publication recognize that savings in the order of six percent of total project cost can be achieved through an effective materials management program, but it emphasizes to project teams the ultimate exposure to loss that will result from ineffective materials management.

Muehlhausen (1987) in the study briefly reviews some materials management basics, the impact of existing practice as well as the definition, goal and framework of the materials management function. Muehlhausen states that "*the role of site materials handling is examined within the total material flow including its impact on productivity and cost*". The following practices should be considered for the achievement of the overall goal of materials management:

1. Obtain the best value on purchased materials
2. Reduce the inventory to the lowest amount required
3. Assure quality requirements are met
4. Minimize the amount and cost of handling and storing the material on site.

Stukhart and Marsh (1986) expressed that the key to achieving proactive integration is not the computer, even though this is a valuable tool. Materials planning and control are similar to other functional areas in that success is due to deliberate, detailed work by a core of individuals who are knowledgeable and able to get things accomplished. They pointed that project must ensure materials as part of the overall plan; and that individuals know their responsibilities so that there is continuity of effort in the execution phase. Other participants must be made aware of the impact of their actions on the materials process, especially in the early stages where frequent changes are possible.

Stukhart (1983) described the existing practices in materials management for major construction projects and provided recommendations for improvement in the problem areas and offered criteria for effective materials management systems.

The survey conducted by Stukhart (1983) uncovered three major deficiencies in the effective management of materials in the construction industry.

1. The senior management of the firms in the construction industry has not always recognized the significant contribution that materials management has on the cost effectiveness of their project operations. Too little attention has been given to materials which is the largest single element of project cost.

2. When top executives lack an appreciation of the importance of materials management systems, the personnel performing the related functions are not properly selected and trained.

3. Even the sophisticated and computerized systems for materials and equipment were often not properly selected, designed, or are being misused. As a result, they do not provide the information to let management control the system.

Barba et al, (1986) made a study on improving the plant life cycle through materials management and computer aided engineering. The study was based on a company named Lummus. The materials management system developed was the combination of bill of materials, procurement and inventory control with Lummus additions and enhancements. The objective of the Lummus materials management system was to control materials through the life of the project. Materials management system (MMS) had been designed as an integrated, on-line real time system. The system makes use of data base technology and a telecommunication protocol permitting terminals situated in diverse areas, e.g., engineering design, purchasing, expediting and construction, access to common and up-to-date information. It is even possible to provide an inspector with a portable terminal for data input and inquiry into MMS from a vendor's plant site. The data within the system is logically tied to a project number, thereby allowing the material control process to reflect the methodology used by Lummus, project oriented design, procurement and utilization. The system has been designed so that the user may tailor it to suit the particular requirements of a given project/client. The implementation of MMS resulted in:

1. Reduce material lost at jobsite by improved inventory control and receiving information and procedures.

2. Reduce subcontractor charges for idle manpower while they "wait" for material delivery.
3. Material control personnel on jobsite will be able to identify potential material shortfalls by reviewing the bills of material requirements against requisitioned and purchased status reports.
4. Planners can establish construction areas in MMS and identify material availability for these areas.

2.3.4 Models Developed in Materials Management

A numbers of models have been developed to improve the materials management from organization, finance, scheduling, and time point of view.

Walters (1979) developed a materials management system for supporting materials related activities, beginning with the identification and requisitioning of the materials and ending with the accounting function. Other major functions included intermediate steps in the procurement process, the receipt of materials, and the management of the inventories of the storerooms and the plant sites. The main advantages of this system were:

1. Reducing the costs of holding the inventory through the consolidation and elimination of duplicate items that may be held under different part numbers.

2. Improving the reliability of operating units, such as power plants, by providing quick access to an integrated pool of materials resources.

3. Increasing the efficiency of materials management by streamlining and standardizing the various existing systems and by developing new ones whenever appropriate.

Muehlhausen (1987) presented a model of materials management activities for developing a construction program. The model, depicted in a flow chart form, identified three elements:

1. Management activities required to manage material flow to and through the job-site.

2. Cognitive activities (thought processes) required to perform the management activities.

3. Key information required to complete the management or cognitive activity.

2.3.5 Cost Effectiveness through Materials Management

The costs and benefits of materials management systems vary depending on the type and magnitude of the project, the type of system, and other factors. The importance of proper management of materials is highlighted by the fact that they account for substantial portions of project cost and time. Major projects are characterized by cost items of different nature, overlapped design and construction, and increased rate and degree of changes. These features have exposed the shortcomings of the traditional clerically-oriented price-focused approach to managing project materials. (Ibn-Homaid 2002)

Marquardt (1994) states that "*controlling the cost of a given capital project can be accomplished when the owner of a facility insists that the engineering and construction teams have and utilize a proactive materials management program and strategy in the execution of project*".

The Business Round Table Construction Industry Cost Effectiveness (CICE) Project in 1982 and CII in 1985 and 1986 emphasized the proper materials management. The studies have shown that real savings exist in improved labor productivity, reduced surplus, and improved cash flow. Materials and equipment comprise more than half of the project cost and that the lack of materials is the major cause of project delays.

Silvestrini (1982) identified cost control as the function relating to material that falls within the responsibility of materials management in some organizations, but is treated as a separate entity in others, is that of material cost control. Tasks under this function include development of cost centers and cost factors for purchasing, inventory control, transportation and material handling operations, as well as planning, implementing and controlling cost reduction projects. He concluded his discussion with the following conclusions:

1. The Cost Engineer has an obligation to understand the full costs involved in dealing with materials.

2. The Professional Planning Engineer and/or a Cost Engineer should be part of the staff of the Materials Manager.

3. The Cost Engineer should participate in cost benefit analysis of a firm changing over to or assessing the value of a materials management system concept.

4. Cost and Planning Engineers could participate in a materials management audit which would examine the organization, the material flow, the existing planning, etc.

5. Cost and Planning Engineers involved in manufacturing should promote the involvement of materials personnel while a new product is still on the drawing board.

6. Cost and Planning Engineers, who are often involved in the development or implementation of management systems, should not overlook the opportunity to factor a materials management subdivision into a total integrated management system.

7. The outage (retrofit) Management Committee of the AACE should acquaint itself with management information systems available for utilities which address the functional and possible problem areas of material planning, purchasing, and stores operation.(Silvestrini 1987).

2.3.6 Productivity and Materials Management

Productivity is one of the critical elements contributing to a project success. Studies have been done to find the impact of materials management on productivity.

Thomas et al, (1989) made a study on the impact of materials management on productivity. Their objective was to quantify the adverse impacts of ineffective materials management practices. Data collected as part of a construction productivity study was used to analyze and compare the effects of material management practices on two steel erection projects. Adverse conditions caused by the lack of an effective materials management program were identified. The cost impact was compared to the cost of effective material management. The results showed a benefit/cost ratio of 5.7, favoring greater attention to material management. The research provided a quantitative estimate of the work-hour losses resulting from ineffective material management practices.

Beringer (1986) discussed increasing productivity through inventory and production control. Beringer was of the view that management tools coupled with statistical modeling can translate quantitative facts about the past into a program forecast of the future, and a knowledge of the past performance of a program coupled with the right modeling techniques for interpretation and extrapolation should yield an accurate program model. Beringer stresses on managing costs in any project, and the integration of cost/schedule in a model, so that optimizing cost does not result in sacrificing important schedule objectives and vice versa. The objective of automating the cost and schedule function is to tear down the barriers which exist between planners and cost engineers. Only then project plans can be created that optimize cost, schedule, and technical goals all at the same time. The system program plan should be a living document which is updated frequently and coordinated with those involved in order to provide support to the program. The plan should contain: corporate objectives, system objectives, system requirements, the work plan, program schedules and budgets,

Effective program management requires the integration of many functional systems in concert with the program planning and control system. These functional systems include but are not limited to: Corporate Finance, Engineering Systems, Quality Assurance, Procurement, Materials Management, Work Definition and Authorization, Estimating, Scheduling, Budgeting, Program Cost, Manpower Planning/Control, Reporting, Forecasting, Change Control.

2.3.7 Computerized Materials Management

Materials management has improved with time, and now in the age of computers it is improving well with the technology. Computerized materials management has proved to be more efficient and reliable compared to the traditional materials management system. A number of computerized materials management modules were developed to assist the materials management system.

Cook (1984) presented a computerized approach to Materials Management on engineering/construction projects. The system tracks material through its three key elements:

1. Identification

2. Acquisition

3. Disposition

The author states that many of the difficulties in attempting to handle materials management with a conventional system arise because these systems are activity oriented. All data entry and selective reporting are based on activity attributes. The Computerized Materials Management System (CMMS), on the other hand, focuses on the item to be tracked or statused. Scheduling activities or events are merely attributes of this item. The key elements of the CMMS are as follows:

1. The ability to track every item on every drawing.

2. The ability to report "expected" delivery dates for materials.

3. The ability to prioritize materials based upon their impact upon the overall project completion.

The author states that a Computerized Materials Management System is a significant undertaking which requires detailed tracking of l00,000 - 200,000 material items on a drawing by drawing basis and an organization must commit substantial resources to successfully implement CMMS. The benefits of CMMS are projects which are completed at a lower overall cost and in a shorter span of time than projects which do not have Materials Management.

Harper (1982) worked on combining the operational responsibilities with the maintenance of a materials information system. A material control coordinator was assigned to each project to establish and maintain the database. The increasing size and complexity of projects dictate the use of the computer to manage this information system and provide support to the operational facets of the programs. The author describes the goals of a data base management system as data integrity, data security and data independence. Harper stresses on the software development that can assist the materials management department according to its needs. Once materials items are entered into the data base, activities performed by the purchasing and warehousing groups will be monitored by the computer. The warehouse is equipped with a minicomputer which is in contact with the engineering office main frame. As purchase orders are issued, transmission of the information to the field computer is automatic. As activities are added to the work schedule, the materials required are allocated to the tasks. The database reflects this allocation and the warehouse cannot disburse allocated materials, except for the planned activity. The use of an on line database manager in conjunction with materials management functions provides a gold mine of information resources. A status report can be generated by selecting any combination of commodities and fields. Harper concludes the study with the opinion that by placing the responsibility for materials with a single organization, the efficiency of material flow and craft productivity can be maximized. The generation and status of information associated with materials management provides a powerful partner in increasing our project control capabilities. Using the computer to control that information, the construction industry will benefit from a more precise and effective handling of material resources.

In a computer-based system, the same records that are maintained in a manual system, the same records that are accessible to the computer's central processing unit. The records readily available to the computer for display or processing typically are:

1. Open-order file
2. Order/parts behind schedule file
3. Supplier record file
4. Material record file
5. Inventory record file

The data inputs vary from firm to firm, as do the desired data outputs. The form and timing of various reports depend to a great extent on the operating needs of each particular firm. The basic materials activities which can be performed well by a computer based system are the same in all cases. They are:

1. Maintenance of inventory records
2. Computation of order quantities
3. Preparation of purpose requisitions for inventory items
4. Preparation of requests for quotation
5. Preparation of purchase orders

6. Maintenance of order status records

7. Distribution of accounting charges

8. Automation preparation of follow up memos

9. Posting of delivery and quality records, by part and by supplier

10. Preparation of numerous operating reports for management

11. Provision of decision support system information

12. Auditing of invoices and preparation of checks for payment

13. Electronic data interchange communications.

Three types of hardware were used in computer based purchasing operations.

1. The large mainframe system that purchasing shares with most other operating units in the organization.

2. The second type of system found in purchasing departments was built around the use of a minicomputer.

3. Finally, purchasing and supply operating systems in some firms, particularly smaller companies, are often handled adequately by a network of microcomputers that constitute purchasing own freestanding system (Dobler and Burt 1996).

According to Elzarka and Bell (1995) materials management systems should be integrated with computer systems that are used for design and scheduling. In addition, many materials management systems would benefit from integration efforts that would facilitate rule-based reasoning. They developed attributes incorporated into a materials management system that was evaluated by industry professionals. The attribute included automatic commodity code generation, automatic takeoff execution, intelligent purchase order generation, and components of design and schedule integration. The result was that computers not only facilitate the development of more versatile systems, but also results in a computer code that is far easier to generate and less expensive to maintain.

2.3.8 Implementation of Materials Management

In the past, materials management was not seen as a separate field and was not given much importance. Case studies have been done to study the improvement of the project performance based on the implementation of the materials management system.

Berka and Conn (1994) studied the development and implementation of materials management system in Coors Brewing Company's Engineering and Construction Division. The division created a central scheduling group that reviewed requisitions and assembled materials in a central staging area by discipline. The engineer was developing an accompanying bill of material to the design drawings for use in determining total installation packages. It became readily apparent that many of the bulk construction items were being bought in small quantities on a repetitive basis, which was compounded by the many projects that were being executed concurrently. The main reason to develop a computerized bill of material system stemmed primarily as a labor-saving device for purchase of bulk construction items. The overall goal of the computerized system was to standardize commodity descriptions and the material procurement process, to provide an audit trail, and improve efficiencies in all groups that depended on information contained on the bill of material. A materials status module was developed by the committee that contained required project and material information from the bill of material, as well as key status information supplied by purchasing, staging and receiving, and construction.

Although the comprehensive materials management system was not the most efficient system developed, the efforts toward streamlining the system contributed significantly to efficient materials management at Coors.

Danko and Owen (1985) in their article discuss the materials management function at Tennessee Gas Transmission. More specifically, their study elaborates on Tennessee Gas Transmission's fully integrated materials management system, IMPACS. The authors detailed the need for a new system, the implementation of the system, the benefits derived from the system, and the operation of the system. The materials management system in Tennessee Gas Transmission was small within the engineering department that was responsible for the procurement of materials for construction projects. They had few mechanized tools to aid them in their effort, and there were a number of difficult problems. Timely arrival of material at construction jobs was hindered by lack of any mechanized tracking system. Changes in the requirements for material could not be easily tracked and no record of the changes existed on any system. Large volumes of paper, crossing many desks, made manual tracking a tedious job. The implementation of the new materials management system consisted of four phases, requirement definition, software search, system design, and installation. The consequence of implementing IMPACS, in Tennessee Gas Transmission was a combination of manual procedures, mechanization and people in such a way as to produce the most effective and efficient materials management system possible. The changes in the organization and the detailed business functions were made toward this end and not just to mesh with the computer.

After the establishment of IMPACS, the materials management department was formed to act as the focal point of all departments associated with the materials management process. Its specific functions are to:

1. Manage materials for construction projects and for company-wide, operating maintenance.

2. Prove the necessary interface among other materials management related departments.

3. Administer inventory levels and other user-defined variables for IMPACS.

Cato and Murthy (1983) focused on the lack of integration between cost, scheduling, and materials management. Their study includes a brief description of the system component being used in their company and a list of areas in which such integration has been accomplished and planned. The component systems were conceived, developed, and implemented within their company. They were used at the industrial projects. The systems were based on the utilization of computers at the field level for maximum efficiency and flexibility. The different component systems like Cost, Scheduling, and Materials Management are used in many industrial construction projects. The authors expressed that the integration of information from different systems can yield beneficial results to accomplish increased savings in time and cost. In addition, it can eliminate communication barriers among the clients, design engineers, and contractors. It encourages concentrated efforts to achieve the common goals by making the information available from one system to another thus avoiding duplication of efforts.

2.4 Techniques in Materials Management

There are different industrial engineering techniques (methods) used in materials management. They are used to facilitate in managing materials in all industries including construction industry. Some of these techniques are:

2.4.1 Economic Order Quantity

The economic order quantity determines the amount of orders that minimizes total variable costs required to order and hold inventory. EOQ is a formula that determines the point at which the combination of order costs and inventory carrying costs are the least. This concept holds that the appropriate quantity to order may be the one that tends to minimize all the costs associated with the order, carrying costs, acquisition costs, and the cost of the material itself (Dobler and Burt, 1996). The economic order quantity simply says that the sum of all the indirect costs associated with inventory will be minimized on an annual basis if the material, for which the graph is drawn, is ordered (or delivered) consistently in the quantity that corresponds with the low point on the total cost curve. The result is the most cost effective quantity to order. In purchasing, this is known as the order quantity, and in manufacturing it is known as the production lot size.

Economic order quantity has been used in construction as well as in the manufacturing industry to effectively manage the flow of materials.

2.4.2 Materials Requirement Planning

Materials requirements planning (MRP) is a technique used to determine the quantity and timing requirements of materials used in the manufacturing operation. The materials requirement planning is the responsibility of the production planning and control group. Materials requirement planning is a computer-based production planning and inventory control system. It is also known as "time-phased requirements planning". MRP is concerned with both production scheduling and inventory control. It provides a precise scheduling system, an efficient material control system, and a rescheduling mechanism for revising plans as changes occur. It keeps the inventory at a minimum while assuring that required materials are available when needed. The MRP takes the master production schedule output for a given product and calculates precisely the specific part and component requirements for that product during the given period of operation. This is done by "exploding" the product bill of material and extending these requirements for the number of units to be produced. Since a given parts is often used in more than one finished product, the process is repeated for all products. Then all products requirements for a given part can be summed to obtain the total requirement for the part during the given period of operation.

The output of the MRP system can be following items:

1. Current order releases to purchasing with due date requirements.

2. Planned order releases to purchasing for ensuing periods.

3. Current and planned order releases for in-house production, with completion date requirements.

4. Feedback to the master production scheduler, in case operating changes or supplier performance has produced material availability problems.

5. With revised output from the master production schedule, the MRP system will re-plan and schedule the material requirements (Dobler and Burt 1996).

Integration of Materials Requirement Planning for Improvement

Graves et al, (1996) developed a model for studying requirements planning in multistage production-inventory systems. The first step involved characterizing the working of industrial planning systems, and then developing a mathematical model to capture some of the key dynamics in the planning process. The approach was to use a model for a single production stage as a building block for modeling a network of stages. Graves et al, illustrated how to analyze the single-stage model to determine the production smoothness and stability for a production stage and the inventory requirements, and also showed how to optimize the tradeoff between production capacity and inventory for a single stage. Then modeled the multistage supply chain using the single stage as a building block. Finally illustrating the multistage model with an industrial application. Materials requirement planning was integrated with a product data management module to improve the overall process.

Ou-Yang and Liu (2001) carried out research on linking design procedures and material requirement planning (MRP). Ou-Yang and Liu stated that, an engineering change (EC) might have an influence on the material requirements as well as on the inventory, and hence might affect the manufacturing process. Therefore, it is necessary to consider the material status during the EC stage. This concept has formed a new area for concurrent engineering that is design for MRP (DFMRP). In this research, a computer-aided environment that integrates a product data management (PDM) module and an MRP module, to support DFMRP had been proposed. The major function of this environment was to investigate the influence of EC schedule changes on MRP. This environment provides the information about the influence on MRP when the starting time or finishing time of certain EC tasks have been altered. A process model was developed to describe the relations between EC and production management tasks. An integration module was developed to extract the related information from PDM and MRP, and to analyze the possible influence on MRP based on the process model. The analyzed results can be used as reference information for project management in PDM.

Materials requirement planning was also used to improve the estimation process, where huge amount of information is involved.

Barriga et al, (2003) proposed a material requirement planning (MRP) system that uses a database approach to manage the large amount of information involved in the material requirement estimation process. In order to design an efficient and effective material supply chain management system for the manufactured housing industry, it is necessary to accelerate the flow of information and products across the supply chain. To achieve this goal, the system needs three ingredients: generators of quick information flow, generators of quick material flow, and facilitators of both quick information flow and material flow. The Database has been created using information provided by a manufactured housing facility to demonstrate the benefits that the application of these systems can bring to the manufactured housing industry. The MRP database has to be supported by a visual basic interface to demonstrate its functionality. The main advantage of a MRP system is its ability to relate demand for material directly to the master production schedule. This process provides better planning reducing the amount of items in stock thus reducing holding cost and increasing the inventory turnover of the facilities. Reduced stock levels improve the utilization of facilities as materials are always available when needed.

2.4.3 Just-In-Time

Just-In-Time (JIT) is an operating management philosophy of continuous improvement in which non-value-adding activities (or wastes) are identified and removed for the purposes of reducing cost, improving quality, improving performance, improving delivery, adding flexibility, increase innovativeness. Based on JIT, a number of specific operating techniques have been developed, techniques for manufacturing operations, for production, planning, and for inventory management. Those dealing with inventory management are the products of the JIT decisions made in the manufacturing and the planning areas. The operating concept of the system is to gear factory output tightly to distribution demand for finished goods, to gear individual feeder production units tightly together, and to gear the supply of production inventories tightly to the manufacturing demand schedule. This means that all inventories in the system, including production inventories, are maintained at absolutely minimal levels. Most firms utilizing the JIT concept do so for no more than 5 to 10 percent of the materials handled by the purchasing and supply activity, regardless of the extent of the commitment in the manufacturing operation. This means that the production inventory items handled in the JIT inventory system are primarily high-value items. All these items are purchased on a long-term contractual basis, with small-volume deliveries scheduled as frequently as once or twice a day up to once or twice a week (Dobler and Burt, 1996). JIT eliminates waste by providing the environment to perfect and simplify the processes. JIT is a collection of techniques used to improve operations.

Popescu and Anglin (1995) researched the applicability of Just-In-Time in construction, with the objective of determining the impressions and reactions towards the applicability of the just-in-time approach in construction. A survey was conducted by developing a questionnaire and distributing it to 100 members of American construction organizations and academic institutions. Most of the respondents were employees of high-level construction organizations or had a strong academic background. From the results of the survey, it was evident that the majority of the respondents (82%) have been exposed to the concept of just-in-time in some way. However, when they were asked to identify the principles associated with the approach, 94% of them related it with the literal definition of "materials arrive when needed in the exact quantity," while only 22% recognized that waste reduction is one of the approach's principal objectives. The survey also showed that there is a general impression that the applicability of just-in-time is not determined by the type of project, since 93% of the respondents who considered that the approach is applicable in construction also considered that it could be implemented in all the major types of construction projects (power plants, environmental projects, transportation, water related projects, industrial facilities, and buildings).

Based on their study they concluded that just-in-time managerial approach, may well represent a new way of managing construction organizations, which challenges more traditional approaches. However, the long-lasting benefits perceived in more aggressive types of industries in which the approach has been implemented, and its simplicity and flexibility, are strong incentives for introducing it to the construction industry.

2.5 Materials Management Process

Materials management is a process that encompasses activities crossing the organizational boundaries of a construction project. Beginning with the early communication of materials related information and continuing through to the reconciliation of installed, consumed, or surplus materials and equipment. Materials management is the planning, executing, and controlling of all activities influencing the flow of materials to and through the jobsite. These activities include material requirements and project planning, requisitioning of materials, purchasing materials, expediting shop drawing approval and material fabrication and delivery, shipping the materials, receiving the material at site or other storage location, and storing and handling the material (Frederick 1991).

Considering the impact of cost and schedule, it will be easy to see the positive influence that effective materials management can have on the cost of construction. Materials management is a clearly defined task under proper planning and execution. It provides project management with a valuable tool to optimize schedules and improve productivity (Bell and Stukhart 1985). CII handbook (1987) stated that the materials represent more than half of the construction cost and lack of materials at the site when needed is the most frequent cause of construction delay.

2.6 Materials Management Functions

Materials management consists of seven integrated functions as applicable to a typical industrial construction project. Theses functions are project planning, materials take-off, vendor enquiry and evaluation, purchasing, expediting, transportation, field material control, and warehousing (Clough and Sears 1994).

There is a loss of productivity due to inefficient materials management. The common problems or pitfalls that are associated with materials management functions are: receiving materials before they are required, not receiving materials at the time of requirement, incorrect materials take-off, subsequent design changes, damage/loss of items, failure on installation, type of materials procurement, contract type, vendor evaluation criteria, control of inventory, and management of surplus materials (Dey 2001).

2.6.1 Project Planning

For successful execution of any project, planning had to be done beforehand. Planning is arrangement of the activities involved in the project to assist smooth flow of the project. Materials management represents a field with a lot of potential for savings in cost from effective planning of materials management system. Materials management can assist in effective managing of the project if integrated in the initial stages of the project. Materials management should be planned simultaneously with the project plan to have an effective integration with the project. If materials management planning is not integrated properly with the project, it can create problems during the execution of the project.

2.6.2 Materials Take-off

A forecast of the scope and magnitude of key operating activities is the starting point for the development of the plan. Materials take-off is identifying what materials are needed and how much. It can be executed initially from conceptual drawings indicating the materials quantity, and then it gets updated, as more definitive design information becomes available. This function depends on the attribute timeliness, as it affects the procurement lead time, purchase order to material receipt duration, materials withdrawal request lead time, and average man hour per material take-off. The quality of materials takeoff can affect the time and cost associated with the project. Improper materials takeoff can cause wastage of or lack of materials when needed.

2.6.3 Vendor enquiry

In any construction project, materials are to be purchased from reliable organizations and vendors that can deliver the materials when and where required. A vendor selection criterion is also an important phenomenon in any project planning. In the selection of a vendor, the cost of the material is not the only criteria but quality and service of the vendor and the previous history should be taken into account. If materials are not delivered by the vendor on time, it will result in loss of time and additional labor costs.

2.6.4 Purchasing

The terms "*purchasing*" and "*procurement*" are used interchangeably in many organizations. Purchasing has long been considered one of the basic functions common to all organizations. Dobler and Burt (1996), reports that during the 1960s and 1970s, purchasing and materials management frequently used manual "*Kardex*" systems to manage inventory. By the end of 1970s, computers began to help in the management of inventory. During the 1980s, many organizations became profitable largely through the careful management of the inventories. The inventories using manual "kardex" systems calculated that inventories cost 25 to 35 percent of the values carried, depending on capital. Computer generated material requirements planning (MRP) and improved supplier discipline, including just-in-time inventory allowed customers to reduce their inventories significantly. The influence of purchasing on electronic data interchange purchases affects quantity and hence sole source purchasing of materials. It is also influenced by cost in payment discounts on materials, and electronic funds transfer payments. The purchasing function is usually performed most effectively and efficiently by a centralized unit made up of buying specialists, who at times work in conjunction with a more comprehensive cross-functional team of specialists.

2.6.5 Material Control

Material control is one of the important elements in materials management. Materials management control is the process through which the various materials management attributes, such as cost, quality, quantity, timeliness and availability are monitored and compared to established benchmarks with the objective of taking timely corrective actions when undesired deviations were detected. In most cases, a manager needs feedback on at least a monthly basis, and frequently more often, to do a good job of controlling buying effectiveness. According to Dobler and Burt (1996) to control prices and costs of materials the number of partnering arrangements and the estimated annual cost savings from them should be tracked over time, and also a track of percentage of purchasing expenditures covered by long term contracts. Another way of controlling is to establish target prices for most major materials. Prices actually paid can then be charted against the target figures to display any significant differences. Periodic cost savings figures can be charted individually for savings arising from such activities as negotiation, value analysis design changes, value analysis materials changes, cost analysis, supplier suggestions, changing suppliers and transportation cost reduction projects. Field material control has influence on almost all the activities stated above. The point where it affects accuracy is materials receipt problems, both internal and external. Material control can be related to timeliness under materials receiving processing time, and under availability as materials availability. Another important aspect in controlling is the controlling of quality project. Once materials specifications have been established, the most direct measure of quality performance is the percentage or number of delivered materials that are rejected by the inspection and operating departments. Another measure to control quality is to keep check on the number of suppliers that have achieved and maintained a certified supplier status with the buying firm.

2.6.6 Warehousing

Warehousing is one of the important functions of materials management. Dobler and Burt (1996) states that a good layout for storage methods yield the following benefits:

1. Ready accessibility of major materials, permitting efficient service to users.

2. Efficient space utilization and flexibility of arrangement.

3. A reduced need for materials handling equipment.

4. Minimization of material deterioration and pilferage.

5. Ease of physical counting.

Most firms emphasize the need to minimize inventories and non-value-added support activities. Attainment of these objectives often called for smaller warehouses and more efficient layout and stores operations. Consequently, stores management is being pressed for continuing improvements in the warehousing and physical supply operation. The automated warehousing had found its place in the market. Automated storage/retrieval system (AS/RS) is a combination of the random-access storage concept, highly sophisticated storage/retrieval machines, and a computerized control system. An important objective of all stores operations is to minimize deterioration and spoilage. It is common practice, particularly when dealing with materials that tend to deteriorate or become obsolete, to issue old material ahead of new material. Numerous schemes can be devised for accomplishing this.

According to Dobler and Burt (1996) an efficient warehousing system aims at achieving the following objectives:

1. A straight-line flow of activity through the storage areas with minimum backtracking.

2. Minimum handling and transportation of materials.

3. Minimum travel and waste motion for personnel.

4. Efficient use of space.

5. Provision for flexibility and expansion of layout.

2.6.7 Expediting and Shipping

Expediting and shipping affects the lead time and cost in different ways. It influences the attribute timeliness as in materials withdrawal request processing time, and commodity vendor timeliness. Formation of a separate expediting department permits a high degree of specialization; additionally, it facilitates an even distribution of the workload and efficient utilization of expediting personnel. It also affects the cost depending on freight cost percent, and construction time lost. Lastly, the project planning depends on the quality and cost as in jobsite rejections of tagged equipment, and total surplus.

2.7 Material Management Performance Attributes

Plemmons (1995) identified six performance attributes of the materials management process. These attributes are accuracy, quality, quantity, timeliness, cost, and availability. Five of these evolved from the Business Roundtable definition of materials management (BRT 1982). The sixth attribute, accuracy, evolved from discussions with the *Construction Industry Action Group* (CIAG) members. These discussions identified the need for accurate information associated with material management. The following is a description of the six attributes.

2.7.1 Accuracy

Accuracy is an attribute of the information that adds to relevant knowledge, reduces uncertainty and supports the decision-making process in an organization (Senn 1990). It is the degree to which an item of information is true or false. Without verification of each item of information, inaccurate information may be treated by a user as if it were accurate.

2.7.2 Quality

Dobler and Burt (1996) defined quality as “fitness; merit; excellence”. In industrial and institutional purchasing, quality has an entirely different meaning. Here quality is related to suitability and cost, rather than to intrinsic excellence. The best quality is that which can be purchased at the lowest cost to fulfill the need or satisfy the intended function for which the material is being purchased. Purchase descriptions directly affect the quality and performance of the item purchased and the price paid. Performance specifications that describe the function to be performed without specifying the materials and procedures to be used allow potential suppliers to propose alternative approaches to satisfy the requirement. When purchasing with performance specifications, the buyer benefits through a competition of concepts,” frequently with significant savings. Many firms pay a “fair and reasonable” price for materials; however, they do not always pay the “right” price. The right price is paid only when the “right” material is specified and after all reasonable efforts to improve the purchase description have been exhausted. Quality is the degree to which a system conforms to requirements, specifications, or expectations and is considered an outcome of an organizational system (Sink 1985).

2.7.3 Quantity

The purpose of quantity measures is to quantify the volume of transactions of the materials management process (Plemmons 1995). A discount is major issue related to quantity. Quantity discounts are reductions given to a buyer for purchasing increasingly large quantities of materials. Dobler and Burt (1996) divides discount under three purchasing arrangements:

1. For purchasing a specific quantity of items at one time.

2. For purchasing a specified number of different items at one time.

3. For purchasing a specified number of items over an agreed-upon time period.

Controlling quantity is another issue that requires close check on the following measures:

1. Percentage of stock-outs caused by poor management of materials.

2. Number of production stoppage caused by poor performance.

3. Actual stock supply "service level" compared with a target service-level figure.

Other measurements useful in controlling the quantity factor are:

1. A chart showing target and actual inventory levels in the aggregate and by major material classification.

2. A report of "dead stock" materials in stores, resulting from overbuying or requirements changes.

3. A list of supplier stocking arrangements that have been negotiated and an estimate of resulting inventory savings.

2.7.4 Timeliness

Timeliness is defined as the measurable interval between two events or the period during which some activity occurs (Swanson 1994). Measures of this characteristic represent duration aspects of the materials management process. Timing of purchase is a factor that must be given due consideration. When considering the timing of purchases, buyers are interested first in assuring their firms an adequate supply of material and second in acquiring the material at an optimal price, considering quality and service requirements. Timing is a much more important matter when a purchase is made in a market that tends to be unstable.

2.7.5 Cost

Cost characteristics define the process in terms of meeting planned cost and labor targets. The focus is on the efficient use of labor, the introduction of labor-saving technology, and the avoidance of "unreasonable" or unnecessary expenses (Plemmons 1995). Some of the most important elements affecting costs are given by Dobler and Burt (1996):

1. The capabilities of management
2. The efficiency of labor
3. The amount and quality of subcontracting
4. The plant capacity and the continuity of output

Although maintaining a large inventory is one way to achieve uninterrupted flow of materials, it is also costly. It costs most firms between 25 and 35 percent of the average inventory value per year for the convenience of having the inventory available (Dobler and Burt, 1996). Hence the supply management job is to achieve a reasonable balance between the level of inventory required to support operations and the cost of carrying the inventory. Some of the costs associated with the inventory are:

1. Opportunity cost of invested funds

2. Insurance costs

3. Property taxes

4. Storage costs

5. Obsolescence and deterioration

Acquisition costs comprise different set of indirect costs related to materials management. These costs contribute to the cost of generating, processing, and handling and order, along with its related paperwork. Examples of these costs are listed below and can be thought of as inventory acquisition costs.

1. A certain portion of wages and operating expenses of such departments as purchasing and supply, production control, receiving, inspection, stores, and accounts payable to the departments concerned.

2. The cost of supplies such as engineering drawings, envelopes, stationary, and forms for purchasing, production control, receiving, accounting, and so forth.

3. The cost of services such as computer time, telephone, fax machines, and postage expended in procuring material.

Costs can be computed on either a short-term or a long-term basis. Short term calculations tend to focus on direct measurable costs. As such, they frequently understate tooling costs and overlook such indirect materials costs as those incurred in storage, purchasing, inspection, and similar activities. A short term analysis fails to consider the probable future changes in the relative cost of labor, materials, transportation, and so on. Cost figures must include all relevant costs, direct and indirect, and they must reflect the effect of anticipated cost changes.

2.7.6 Availability

Availability is a major element of customer service (Firth et al, 1988) and characterizes the ability of the materials management process to fill requests for materials at the agreed time and place. It reflects the degree to which the process made the materials available when construction operations planned to withdraw or receive them (Plemmons 1995). If materials required on site are not available, it may cost additional labor charges and loss of productivity.

CHAPTER 3

PERFORMANCE MEASURES

3.1 Background

A performance measure is a measure that calculates the effective working of a function. These performance measures may differ from system to system. The measures divide the materials management system in parts and make the working of the system more efficient. When joined, the measures make the complete materials management system.

Plemmons (1995) research identifies the key effectiveness measures for the materials management process and proposes a mechanism for benchmarking these measures. A total of 35 measures were developed from the construction industry to measure the effectiveness of the materials management process. He developed the measures from site visits and surveys. Survey results were analyzed to identify the key-effectiveness measures for usage, importance in communicating effectiveness, practicality to implement, barriers to implementation, and potential for benchmarking. To facilitate the implementation of the effectiveness measures within the construction industry, a benchmarking mechanism is proposed to support a construction company's benchmarking activities.

Al-Khalil et al, (2004) measured the effectiveness of materials management process. They conducted research to apply a set of key effectiveness measures on 17 ongoing industrial projects. Their research showed that most of the measures were easily obtainable, but some were difficult to obtain. They also showed that it was possible to obtain the highest score on all measures, indicating that best practice in industry is achieving highly successful results. In their research most of the projects appeared to have a highly effective materials management process, as indicated by the fact that median values of these measures were much closer to the best values than those of the mean values.

Based on the literature review, a list of performance measures was developed that were used by Plemmons (1995). It was found form the literature review that the measures used in the past or currently being used in the construction industry were all covered by Plemmons's study, and thus they were adopted in this research. The measures used by Plemmons, (1995), have been described in the next section.

3.2 Measures adopted from Plemmons (1995)

The measures adopted from Plemmons (1995) are presented below with a definition of the measure followed by its place of existence in the materials management system and the category of the attribute as defined by Plemmons (1995).

3.2.1 Materials receipt problems:

Materials receipt problems reports the data or information discrepancies associated with a material delivery that, if not detected and corrected, would cause inaccuracies in the project materials management database.

Location: interface between vendor and warehouse function

Attribute: Accuracy

3.2.2 Material receipt problems-internal:

Materials receipt problems-internal reports the accuracy of internally generated materials related data as determined at the point of receipt.

Location: interface of vendor with warehouse function.

Attribute: Accuracy

3.2.3 Warehouse inventory accuracy:

Warehouse inventory accuracy measures the accuracy of the information associated with the warehouse function.

Location: within the warehouse function

Attribute: Accuracy

3.2.4 Piping spool rework:

Piping spool rework reports the total number of piping spools identified as requiring rework (field modification) divided by the total number of piping spools, multiplied by 100 to provide a percentage or ratio. This measure may be reported as a cumulative and/or periodic measure.

Location: interface of construction with field control function.

Attribute: Quality

3.2.5 Jobsite rejections of tagged equipment:

Jobsite rejections of tagged (unused items) equipment represent the percentage of all rejections of tagged equipment. A rejection occurs when construction notifies the field control function of return of the item.

Location: interface between the construction operations and the field control function.

Attribute: Quality

3.2.6 Home office requisition ratio:

Home office requisition ratio reports the percentage of requisition for quotations (RFQ) performed by the home office compared to the total number of request for quotations (RFQs) during a period of time.

Location: interface of the purchasing function with the vendor

Attribute: Quantity

3.2.7 Home office Purchase Order ratio:

Home office purchase order ratio reports the percentage of purchase orders (PO) performed by the home office compared to the total number of PO transactions during a period of time.

Location: interface of the purchase function with the vendor.

Attribute: Quantity

3.2.8 Average number of line items per release:

Average number of line items per release is the ratio of the average number of line items issued at a particular time and the planned number of line items to be issued for that same time. Measure might be reported in a ration format (13.5/16) to communicate average and planned values.

Location: interface of the purchasing function with the vendor.

Attribute: Quantity

3.2.9 Commitment-home office:

Commitment-home office reports the percentage of the value of material and tagged equipment committed by the home office compared to the total commitment value during a specified time period.

Location: interface of the purchasing function with the vendor.

Attribute: Quantity

3.2.10 Commitment-Field:

Commitment-field is the percentage of the value of material and tagged equipment committed by the field compared to the total commitment value during a specified time period.

Location: interface of the purchasing function with the vendor.

Attribute: Quantity

3.2.11 Electronic Data Interchange purchases:

Electronic Data Interchange (EDI) is the transfer of data between different companies using networks, such as the Internet. As more and more companies get connected to the Internet, EDI is becoming increasingly important as an easy mechanism for companies to buy, sell, and trade information. Electronic data interchange purchases is the percentage of value of purchase made using electronic data interchange applications to the total value of purchases.

Location: interface of the purchasing function with the vendor.

Attribute: Quantity

3.2.12 Sole source purchases:

Sole source purchases is the ratio of materials purchased via sole source to the total amount of purchases for a specified period of time.

Location: interface of the purchasing function with the vendor.

Attribute: Quantity

3.2.13 Minority suppliers:

Minority suppliers is the percentage of total commitments for materials purchased via minority suppliers.

Location: interface of the purchasing function with the vendor.

Attribute: Quantity

3.2.14 Procurement lead time:

Procurement lead time is the ratio of the average actual procurement lead time and the planned procurement lead time.

Location: interface between the vendor and the purchasing function.

Attribute: Timeliness

3.2.15 Bid-Evaluate-Commit lead time:

Bid-Evaluate-Commit lead time is the average duration reported in days to bid, evaluate, and commit (BEC) to the purchase of materials. It uses a ratio format to communicate the average actual BEC duration and the average planned BEC duration.

Location: interface between the vendor and the purchasing function.

Attribute: Timeliness

3.2.16 Purchase Order to material receipt duration:

Purchase order to material receipt duration is the average duration from the issuance of the Purchase Order until the receipt date of the materials. It uses a ratio format to communicate the average actual duration and the average planned duration.

Location: interface of the purchasing function with the vendors.

Attribute: Timeliness

3.2.17 Material receiving processing time:

Material receiving processing time reports the percentage of quantity of material received by the warehouse that is processed within two time periods, same day, and by next day.

Location: within the warehouse and field control functions.

Attribute: Timeliness

3.2.18 Commodity vendor timeliness:

Commodity vendor timeliness is the percentage of number of vendor deliveries that were delivered on time according to the promised delivery date and the total number of deliveries during a specific period of time.

Location: at the interface of the vendors with the warehouse functions

Attribute: Timeliness

3.2.19 Commodity timeliness:

Commodity timeliness is the percentage of number of deliveries made on or before the required delivery date when compared to the required delivery date.

Location: at the interface of the vendors with the warehouse functions.

Attribute: Timeliness

3.2.20 Materials withdrawal request:

Materials withdrawal request (MWR) measures the lead time allowed for the issuance or delivery of materials by reporting time is the difference between the MWR date and the need or requested delivery date. The measure is reported as a ratio of the average MWR lead time and the planned MWR lead time.

Location: at the interface of the construction with warehouse functions.

Attribute: Timeliness

3.2.21 Materials withdrawal request (MWR) processing time:

Materials withdrawal request (MWR) processing time measures the percentage of the number of MRWs processed on or before the material required date.

Location: within the field control and the warehouse functions.

Attribute: Timeliness

3.2.22 Average manhour per Material Take-Off:

Average manhour per material take-off is the average number of work hours required to generate a material takeoff (MTO) for a single drawing sheet. The measure is reported as a ratio of the average actual number of workhours and the planned number of work hours.

Location: within the material takeoff and design interface function.

Attribute: Cost

3.2.23 Average man-hour per Purchase Order:

Average man-hour per purchase order is the average number of man-hours required to generate a purchase order (PO). The measure is reported as a ratio of the average actual number of work hours and the average planned number of work hours to generate a PO.

Location: within the purchasing function.

Attribute: Cost

3.2.24 Freight cost percent:

Freight cost percent is the percentage of freight costs to the materials total cost.

Location: within the expediting and transportation function.

Attribute: Cost

3.2.25 Express deliveries percent:

Express deliveries percent is the percentage of express deliveries made to the project warehouse by dividing the number of express deliveries and the total number of deliveries.

Location: between the vendor and warehouse function.

Attribute: Cost

3.2.26 Construction time lost:

Construction time lost is the percentage of the total construction time lost due to materials delivery to the total project duration as estimated by construction supervisors.

Location: between construction operations and the field control function.

Attribute: Cost

3.2.27 Payment discounts:

Payment discounts is the percentage of payment discounts actually taken within the discount period, from the discounts being offered.

Location: within the purchasing function.

Attribute: Cost

3.2.28 Electronic funds transfer payments:

Electronic funds transfer payments is a financial measure reporting the percentage of funds paid for materials payable in U.S. dollars transferred via electronic funds transfer (EFT) methods to the total funds available for materials.

Location: within the purchasing functions.

Attribute: Cost

3.2.29 Release value breakdown:

Release value breakdown reports a percentage breakdown of six ranges of purchase order release values. The six ranges are based on the approximate standard deviations from the average purchase order release value or three standard deviations on each side of the average. The approximate value of the standard deviation is calculated as equal to the range of releases divided by four. The range value is the largest release minus the smallest release. The releases are divided by the total number of releases for the time period.

Location: within the purchasing function.

Attribute: Cost

3.2.30 Min/Max release activity:

The release activity describes the issuing of the materials from the warehouse and is associated with a specified dollar amount and is used to report the relative volume of Min/Max activity within the warehouse. Min/Max release activity reports percentage of total dollars spent during a monthly period for the contracted minimum and maximum levels of bulk items. The total dollar amount represents the value of bulk materials under warehouse control.

Location: within the warehouse function.

Attribute: Cost

3.2.31 Warehouse safety incident rate:

Warehouse safety incident rate reports the percentage of warehouse lost time incidents compared to the total number of incidents for the project.

Location: within the warehouse function.

Attribute: Cost

3.2.32 Total surplus:

Total surplus is the percentage cost of unused materials in relation to the total purchase cost of all the materials purchased.

Location: within the warehouse and field control functions.

Attribute: Cost

3.2.33 Material availability:

Material availability is calculated by dividing the total number of material line items issued by the total number of material line items requested.

Location: at the interface of the warehouse function with construction operations.

Attribute: Availability

3.2.34 Stock out analysis:

Stock out analysis reflects the shortage of the materials when required. It calculates the ratio of the total number of line items that a warehouse is unable to issue to the craft worker divided by the total number of line items requested.

Location: within the warehouse function.

Attribute: Availability

3.2.35 Backorders:

Backorders is the percentage of materials backordered compared to the total materials required.

Location: within the purchasing function.

Attribute: Availability

CHAPTER 4

DATA COLLECTION

4.1 Background

In determining the performance measures used for materials management process in the construction industry, the research involved interviews with the individuals representing fifteen industrial construction organizations. In many instances, these were managers with the capacity, authority and resources to assist in this endeavor.

The organizations that contributed to the research are ranked as some of the top organizations in Saudi Arabia. The companies involved were basically petrochemicals and petroleum industries. As evidenced from their size, each of these companies maintained a construction engineering staff. It was with this staff that the researcher conducted the interviews.

A preliminary search was made to find out the contractor firms involved in industrial construction, in Jubail Industrial City. The contractors that were selected were those working for SABIC and Saudi ARAMCO. The Saudi ARAMCO took a lengthy approval process to obtain permission to conduct interviews with their contractors. With the use of the 35 measures selected from the literature review, the research focused on identifying the measures best communicating the effectiveness of the industrial construction materials management process. A survey questionnaire was used to solicit the opinions from 15 materials management professionals selected from construction related organizations. The functional experts selected were considered by their peers, supervisors, or themselves to possess the knowledge and expertise to provide the needed information. Their ability to answer the questionnaire was judged form their qualification and experience they had in materials management and by their involvement in materials management system.

From each of the two selected owners, the author developed a list of 42 potential respondents working in materials management. Then this was short listed to 15 respondents that were suitable for the interview. The selection of the respondents was done based on their experience in industrial construction and more particularly in materials management. Only those respondents were selected that had experience in industrial construction. The data obtained for this research was primarily obtained through interviews. The research data constituted the opinions of materials management professionals selected by the researcher to complete the questionnaire. Table 4.1 shows the list of positions prepared by Plemmons 1995, reflecting the materials management personnel that can be interviewed, for acquiring data relating to the performance measures. Initially all the respondents were selected from the positions listed in table 4.1.

Access to the respondents in the contractors' organizations was possible through managers in SABIC and Saudi ARAMCO organizations. The opinions of the respondents constituted the research data used to evaluate the selected performance measures of the materials management process.

Table 4.1 Position Titles of the Questionnaire Respondents (Plemmons 1995)

S.No.	Position Title or Equivalent
1	Materials Manager
2	Project Purchasing Agent
3	Project Manager
4	Chief, Materials Manager
5	Project Director
6	Senior Manager, Procurement
7	Project Procurement Manager
8	Company president
9	V.P. Industrial sales
10	Resident Engineer
11	General Project Manager
12	V.P. Construction Operations
13	Project Controls Manager
14	Senior Project Engineer
15	Quality Systems Manager
16	Senior, Materials Control
17	Materials Specialists
18	General Manager, Procurement
19	Manager, Construction Support
20	Director, Purchasing
21	Senior Manager, Field Materials Operations
22	Financial Services Supervisor
23	Warehouse Manager
24	Manager, Purchasing Materials management Services
25	Director, Procurement
26	Manager, Procurement and Materials Management

4.2 Research approach

The first objective of the study was to develop a list of performance measures for materials management process in industrial construction in Saudi Arabia. The first question of the questionnaire was used to collect the information regarding this. No distinction was made whether the measure reported efficiency, productivity, effectiveness, or other performance measure. Each of the visits was made to large industries, SABIC and Saudi ARAMCO, defined as industrial projects by the ministry of housing and public works, Saudi Arabia. Visits were made to the companies of SABIC and Saudi ARAMCO to interview the materials management professionals selected based on their experience and years of contribution of their service in the materials management field. The respondents selected were contractors' representatives for materials management in industrial construction for these companies.

The most appropriate application of a survey questionnaire is where conditions indicate that the respondents are uniquely qualified to provide the desired information. (Emory and Cooper, 1991). For this reason, a survey questionnaire was selected as the research instrument and considerable effort was expended to gain access to the respondents.

The questionnaire format underwent changes and improvements in an effort to achieve a questionnaire that could be answered easily. Initially the questionnaire format made the questionnaire very lengthy, which caused a concern that it may discourage respondents to participate in the interview. Then this same questionnaire was reformatted to a single page. This questionnaire format looked less time consuming compared to the previous.

The process of interview started with the approval of a willingness letter authorized by the Chairman of the CEM department. The researcher solicited SABIC approval by first faxing this letter of willingness to take part in the research. A total of 42 materials management Contractors personnel working for SABIC and Saudi ARAMCO were contacted initially. Nineteen of the 42 contacted expressed their willingness to participate. A point of contact (mediator) was also used to reach the required personnel in materials management. This point of contact was an employee in SABIC Company. A copy of the questionnaire explaining the performance measures in detail as in section 3.2, was then faxed to the respondents prior to making an appointment date. Each materials management professional was then contacted and an appointment was fixed for an interview. Visits to the SABIC companies in Jubail Industrial City, were made to interview the materials management contractor personnel.

For respondents from ARAMCO contractors, a point of contact was made. This point of contact was an employee in ARAMCO. Through this point of contact it was made possible to contact the contractor representatives in Saudi ARAMCO. Initially it was not easy to get the access to the required materials management personnel, but with the help of point of contact it was made possible. The questionnaire along with the explanations of the questions was faxed to the potential respondents. This facilitated the respondents in getting acquainted with the measures. Then an appointment date for the interview was fixed. Then on the selected schedule the interview was conducted. The respondents were asked to answer the questions in the questionnaire, and if they had any doubts about the measures, they were explained in detail to help them fill the questionnaire. The interviews were on an individual basis with an average time of 30 minutes for each of the interview conducted. The entire process involved several follow ups with the respondents for obtaining an interview date from them.

4.3 Content of Questionnaire

The questionnaire was designed to obtain data concerning the functional expert profile sheet, the measures, their importance and practicality. The questionnaire started with a willingness letter faxed to the functional experts prior to the interview, introductory section covering explanations of the measures in the questionnaire, a profile sheet for the respondent, and one section for questions. The objective of faxing the questionnaire prior to the interview was to help the respondent to develop a general understanding about each of the 35 measures.

The willingness letter stated the purpose of the interview and the title of the research being conducted. It included the name of the interviewer and the contact details, with request to the participants to take part in the study. In this letter the respondents were asked to contact the interviewer if they are willing to participate in the study.

The data contained in the profile sheet, were considered to be ancillary or supplemental data. This data represented the respondents' level of experience. Data on each of the proposed measures was considered to be beneficial to understanding the past, present, and the future usage of the measure, the importance of the measure in communicating effectiveness, and the practicality of implementing the measure. Before starting with the questionnaire the interviewees were requested to fill in the profile sheet. This profile sheet had questions on respondents' experience. The profile sheet started with space provided for personal details, company name and address followed by the grade of the company. It also requested the participants to fill in their years of experience in construction industry and in materials management. The other information requested was the primary areas of experience in materials management, the classification of the project as government or private and lastly the type of construction involved. This profile sheet was used to develop the experience level of the interviewees. The profile sheet is attached in the appendix.

The materials management performance measures were arranged in a questionnaire format with 3 questions to be answered for each of the 35 measures used in the questionnaire. The questionnaire consisted of 5 columns with the first column depicting the serial no. of the measure. The second column consisted of the measure name, followed by three columns to be answered by the respondents about the usability of the measure, its importance, and its practicality respectively, in the materials management process for industrial construction in Saudi Arabia. The interviewees were first asked verbally to answer the question about the usability of a measure in past or currently in industrial construction, and were given an option of "yes" or "no". If the response for the first question was "yes" then the interviewees were further questioned about the importance and practicality of that measure. The importance and practicality of the measures were measured on a 5-point scale ranging from 5 for "extremely important" and

1 for “not important”. The practicality criteria also had the similar division of scale with the value of 5 representing the “extremely practical” while the lowest value, i.e., 1 representing “not practical”. If the interviewees had some problems in understanding any question, they were helped by the author. A sample of the questionnaire is attached in the appendix.

4.4 Interviews

Due to the size of the industrial projects, a full time staff supporting the field construction operations of materials management like procurement, warehousing and field control was available for interviews. The industrial visits lasted for about 1 month. The whole process of contacting the materials management professionals and getting the appointment dates and actually taking the interviews took 6 months.

Out of 42 materials personnel contacted only 19 showed willingness for participation in the study. The materials manager or engineer from the owner organizations arranged the meetings, identified key individuals to attend the initial briefing, and obtained the necessary approvals for sharing company information. The communicated purpose of each visit was to receive a briefing of the materials-related people, processes, and measures being employed on the construction project. As a result of the effort, the meetings included the individuals who were considered materials management professionals.

As a result of the interviews, a general understanding of the materials management control procedures was obtained and a discussion on the measures associated with materials related performance was approved. The interviews reflected a good level of understanding of the measures by the materials management professionals interviewed.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Overview

The data collected from the 15 respondents formed the basis for the analysis of the study. The three objectives of the study i.e. determining the performance measures used, the importance and practicality of the measures in Saudi Arabia were to be analyzed based on the data collected form the interviews.

In the preliminary analysis of the questionnaire data, it was found that some of the respondents did not have the full knowledge of all the 35 measures questioned. This can be attributed to the non-usability of those measures in Saudi Arabia. Thus some of the questions were left unanswered in the interview. For example, some respondents did not answer the questions concerning the proposed measure, Average Man-hours per MTO, and Release Value Breakdown. Whereas, some of the measures that were found to be least rated due to their insignificance in the Eastern Province of Saudi Arabia are Piping Spool Rework, Minority Suppliers, and Home Office PO Ratio. Therefore, the analysis and findings for each measure were based on the number of responses for that particular question.

5.2 Profiles of Materials Management Professionals

The first section in the questionnaire contained the respondent profile. The information to be provided by the respondents consisted of their current position, the grade of the firm, length of experience in industrial construction, length of experience in materials management, areas of experience in materials management, and the type of projects they worked on. The data is summarized in Table 5.1.

Table 5.1 Profile of the Respondents

Respondent #	Position	Grade of Firm	Exp. In industrial construction	Exp. In Materials management
1	Materials Planner	1	10-15 yrs	10-15 yrs
2	Materials Specialist	1	15-20 yrs	10-15 yrs
3	Materials Inspection and Monitoring	1	10-15 yrs	<10 yrs
4	Materials Purchaser	1	10-15 yrs	<10 yrs
5	Warehouse manager	1	15-20 yrs	10-15 yrs
6	Senior Materials Control	1	15-20 yrs	10-15 yrs
7	Procurement Manager	1	10-15 yrs	<10 yrs
8	Materials Engineer	1	<10 yrs	<10 yrs
9	Procurement Engineer	2	<10 yrs	<10 yrs
10	Materials Handling Engineer	1	<10 yrs	<10 yrs
11	Senior Materials Buyer	2	10-15 yrs	<10 yrs
12	Project Engineer	1	10-15 yrs	10-15 yrs
13	Procurement Engineer	1	<10 yrs	<10 yrs
14	Project Manager	1	10-15 yrs	<10 yrs
15	Senior Materials Planner	1	10-15 yrs	10-15 yrs

The profile of the respondents showed that 6 out of the 15 respondents had an experience in the range of 10-15 years, with the rest having an experience of less than 10 years in industrial construction materials management system. This represents a wide range of experience of the participants. Before the interview the measures in the questionnaire were discussed with the participants. In the questionnaire the participants were asked to answer the questions based on their experience in different fields of materials management. Their responses showing their experience in different fields of materials management are shown in table 5.2. Having been allowed to identify the perspective with one or more materials management functions, the respondents showed a relatively uniform representation of the functions in materials management, with planning and administration and purchase as the second most common area of expertise among the participants.

Table 5.2 Respondents Areas of Expertise

S.No.	Area of Expertise	Total Responses
1	Planning and Administration	9
2	Material Takeoff and Material Control	6
3	Vendor Inquiry and Evaluation	6
4	Purchasing (Home office)	6
5	Purchasing (Field)	8
6	Transportation and Expediting	3
7	Warehousing	9
8	Field Control	4

5.3 Performance measures

Table 5.3 shows the response received for each of the measure included in the questionnaire. Some of the measures were not responded due to lack of their use in part or current. Moreover the lack of response for some of the performance measures can be attributed to lack of knowledge about the performance measures. The table ranks the measures according to the maximum number of responses achieved. The first column shows the serial no of the measure, followed by the measure name in the second column. The third column displays the percentage of response achieved for that measure under consideration. The discussions that follow highlight some of the relationships and rankings that may be drawn from this research. The purpose of the assessment is to present auxiliary information regarding the identification of the key performance measures for the industrial construction materials management process. The auxiliary information deals with three areas: utilization of the measure in past or present, importance, and practicality to implement.

Table 5.3 Response to the performance measures

Rank	Measure	Percent
1	Materials Receipt Problems	100%
2	EDI purchase	100%
3	Procurement lead time	100%
4	Material receiving processing time	100%
5	Commodity vendor timeliness	100%
6	Freight cost percent	100%
7	Express deliveries percent	100%
8	Warehouse safety incident rate	100%
9	Total surplus	100%
10	Material availability	100%
11	Stock out analysis	100%
12	Backorders	100%
13	Warehouse inventory accuracy	93%
14	Jobsite rejection of tagged equipment	93%
15	Average line items per release	93%
16	BEC lead time	93%
17	PO to materials receipt duration	93%

Table 5.3 Contd...

Rank	Measure	Response Percent
18	Materials withdrawal request	93%
19	Materials withdrawal request (MWR) processing time	93%
20	Electronic funds transfer payments	93%
21	Min/Max release activity	93%
22	Materials Receipt Problems-internal	87%
23	Commitment home office	87%
24	Commitment field	87%
25	Commodity timeliness	87%
26	Construction time lost	87%
27	Payment discounts	87%
28	Home office requisition ratio	80%
29	Sole source purchase	80%
30	Average man hour per MTO	80%
31	Average man hour per PO	80%
32	Home office PO ratio	73%
33	Release value breakdown	73%
34	Minority suppliers	67%
35	Piping spool rework	53%

5.4 Past and Presently used Measures

The first objective of the study was to determine the performance measures used in the past or currently being used in Saudi Arabia. The question asks "Is measure 'X' used by your organization in industrial construction in Saudi Arabian environment". Table 5.4 shows percent response for the past or present use of the measure.

Table 5.4 Performance Measures for Saudi Arabia

S.No.	Measure	Number of Responses	Past or Current use (%) response
1	Materials Receipt Problems	15	80
2	Materials Receipt Problems-internal	13	80
3	Warehouse inventory accuracy	14	76
4	Piping Spool Rework	8	36
5	Jobsite rejection of tagged equipment	14	72
6	Home office requisition ratio	12	52
7	Home office PO ratio	11	50
8	Average line items per release	14	58
9	Commitment home office	13	60
10	Commitment field	13	58
11	EDI purchase	15	68
12	Sole source purchase	12	60
13	Minority Suppliers	10	37
14	Procurement lead-time	15	88

Table 5.4 Contd...

S.No.	Measure	Number of Responses	Past or Current use (%) response
15	BEC lead-time	14	74
16	PO to materials receipt duration	14	78
17	Material receiving processing time	15	72
18	Commodity vendor timeliness	15	76
19	Commodity timeliness	13	66
20	Materials withdrawal request	14	64
21	Materials withdrawal request (MWR) processing time	14	62
22	Average man hour per MTO	12	52
23	Average man hour per PO	12	54
24	Freight cost percent	15	78
25	Express deliveries percent	15	80
26	Construction time lost	13	86
27	Payment discounts	13	64
28	Electronic funds transfer payments	14	56
29	Release Value Breakdown	11	48
30	Min/Max release activity	14	54
31	Warehouse safety incident rate	15	62
32	Total surplus	15	70
33	Material availability	15	92
34	Stock out analysis	15	80
35	Backorders	15	68

The first question in the questionnaire enquired about the use of the measure in the past or currently being used. Based on the responses, the table 5.4 shows that all the 35 measures were used or are currently in use in Saudi Arabia. The first column shows the serial number of the measure among the 35 performance measures. The second column gives the name of the measure followed by the percentage of positive responses for that measure for its usability in Saudi Arabia.

Based on the response score for each of the measures, the measures were categorized in 4 different groups with a range of 25% for each category. The ranges were divided as follows:

1. Rare use: 0 – 25%

2. Low use: 26 – 50%

3. Moderate use: 51 – 75%

4. High use: 76 – 100 %

According to the respondents none of the measures was rated in rare use category. The measures under low use were Piping Spool rework, Minority suppliers, and Release value breakdown.

The measures in the moderate use category were Jobsite rejection of tagged equipment, Home office PO ratio, Home office requisition ratio, Average line items per release, Commitment home office, Commitment field, EDI purchase, Sole source purchase, BEC lead-time, Material receiving processing time, Commodity timeliness, Materials withdrawal request, Materials withdrawal request (MWR) processing time, Average man hour per MTO, Average man hour per PO, Payment discounts, Electronic funds transfer payments, Min/Max release activity, Warehouse safety incident rate, Total surplus and Backorders.

The measures that were calculated in the high use category were Materials Receipt Problems, Materials Receipt Problems-internal, Warehouse inventory accuracy, Procurement lead-time, PO to materials receipt duration, Commodity vendor timeliness, Freight cost percent, Express deliveries percent, Construction time lost, Material availability and Stock out analysis.

None of the measures fell under the category of rare use. This signifies the usage of the performance measures. Only 3 of the 35 measures came under the category of low use. This is reflected from the non existence of a clear definition for minority suppliers. Majority of the performance measures fall under the category of moderate use. Out of 20 performance measures in the moderate category 8 can be linked with the attribute quantity, 5 with timeliness, 6 with cost and only 1 with availability. It can be seen that a majority of the performance measures are related to the attribute quantity indicating the use of the measures related to the quantities of materials. It can also be seen that only 1 measure is under the attribute availability indicating the low use of the performance measure. This reflects that the availability of materials has not been an issue in the past or current. From this it can be seen that majority of the performance measures can be linked with quantity followed by cost and timeliness. Eleven of the 35 measures fell under high use category. Of the 11 measures 3 measures can be linked with the attribute accuracy, 3 with timeliness, 3 with cost and 2 with availability. The measures falling under this category can be equally distributed among the attributes accuracy, cost, timeliness, and availability. This shows that performance measures are equally distributed among the different attributes.

5.5 Importance of the Performance Measures

The data for the importance measures was calculated using an importance index. This importance index shows the importance of each measure.

The response was taken from the materials management personnel in direct response to the questionnaire. The importance levels of the performance measures were distributed in five categories, assigning 5 to the extremely important and the not important was given the weight of 1. The values assigned to the importance levels were as follows:

Extremely important : the assigned weight of 5

Very important : the assigned weight of 4

Important : the assigned weight of 3

Somewhat important : the assigned weight of 2

Not important : the assigned weight of 1

The following is the calculation of the index values obtained for the importance of the performance measures:

Importance index of a measure = (X1 * 5 + X2 * 4 + X3 * 3 + X4 * 2 + X5 * 1) / N

Where X1, X2 ….represents the frequency of responses in a particular rating and 5,4,3,2,1....represents the numerical score of the respective rating. N is the number of responses. For example, the index for materials availability was developed as:

$$(10 * 5 + 4 * 4 + 1 * 3 + 0 * 2 + 0 * 1) / 15 = 4.60$$

Table 5.5 shows the results of the importance indices of all performance measures in a descending order of importance.

Table 5.5 Importance of Proposed Performance measures

Questionnaire Response			
Rank	**Measure**	**Number of Responses**	**Importance (1 - 5)**
1	Material availability	15	4.60
2	Procurement lead time	15	4.47
3	Construction time lost	13	4.38
4	Express deliveries percent	15	4.07
5	Materials Receipt Problems-internal	13	4.00
6	Materials Receipt Problems	15	4.00
7	Stock out analysis	15	4.00
8	PO to materials receipt duration	14	3.93
9	Freight cost percent	15	3.93
10	Warehouse inventory accuracy	14	3.87
11	Commodity vendor timeliness	15	3.87
12	BEC lead time	14	3.71
13	Jobsite rejection of tagged equipment	14	3.60
14	Material receiving processing time	15	3.60
15	Total surplus	15	3.57
16	EDI purchase	15	3.47
17	Backorders	15	3.40

Table 5.5 Contd...

Rank	Measure	Number of Responses	Importance (1 - 5)
18	Commodity timeliness	13	3.36
19	Materials withdrawal request	14	3.20
20	Payment discounts	13	3.20
21	Warehouse safety incident rate	15	3.14
22	Materials withdrawal request (MWR) processing time	14	3.13
23	Sole source purchase	12	3.08
24	Commitment home office	13	3.07
25	Average line items per release	14	2.94
26	Commitment field	13	2.93
27	Electronic funds transfer payments	14	2.87
28	Average man hour per PO	12	2.77
29	Min/Max release activity	14	2.71
30	Average man hour per MTO	12	2.64
31	Home office requisition ratio	12	2.60
32	Home office PO ratio	11	2.50
33	Release Value Breakdown	11	2.42
34	Minority Suppliers	10	1.86
35	Piping Spool Rework	53	1.82

Seven of the 35 measures were found to be in a range of very important to extremely important. This was calculated on the scale developed for rating the importance and practicality of the performance measures during the questionnaire. On the scale developed 5 represents the highest importance level representing "extremely important" with 1 standing for not important. Therefore the measures with means above 4 were considered as very important to extremely important. The measures ***Materials Availability, Procurement lead time, Construction time lost, Express deliveries percent, Materials Receipt problems, Receipt problems – internal, and stock out analysis***. This indicates the importance these measures hold in materials management process in the industrial construction industry in Saudi Arabia.

The measures that received the least importance in the proposed measures were Home ***Office PO ratio, Release Value Breakdown, Minority Suppliers, Piping Spool Rework***.

Based on the index score for each of the measures, the measures were categorized in 4 different groups with a range of 1. The range was as follows:

1. Extremely important: 4.25 – 5.00

2. Important: 3.25 – 4.24

3. Moderately important: 2.25 – 3.24

4. Somewhat Important: 1.25 – 2.24

The measures that were categorized as extremely important were Material availability, Procurement lead-time, Construction time lost.

The measures in the important category were Express deliveries percent, Materials Receipt Problems, Materials Receipt Problems-internal, and Stock out analysis, PO to materials receipt duration, Freight cost percent, Warehouse inventory accuracy, Commodity vendor timeliness, BEC lead-time, jobsite rejection of tagged equipment, Material receiving processing time, Total surplus, EDI purchase, Backorders, Commodity timeliness.

The measures categorized as moderately important are Materials withdrawal request, Materials withdrawal request (MWR) processing time, Payment discounts, Warehouse safety incident rate, Sole source purchase and commitment home office, Average line items per release, Commitment field, Electronic funds transfer payments, Average man hour per PO, Min/Max release activity, Average man hour per MTO, Home office requisition ratio, home office PO ratio and release value breakdown.

The measures under the somewhat important category were Minority suppliers and Piping spool rework.

It can be seen that only 3 measures came under the category of extremely important. Each of the 3 measures are from availability, timeliness and cost respectively. Fifteen of the performance measures fell under the category of important, out of which 5 can be associated with the attribute timeliness, 3 each with accuracy and cost, 2 with availability and 1 each with quality and quantity respectively. The performance measures that came under the moderately important category also summed up to 15, out of which 7 can be linked with the attribute cost, 6 with quantity and 2 with timeliness respectively. None of the measures in the importance category can be linked with accuracy, quality and availability. The measures that fell under the category of somewhat important were minority suppliers and piping spool rework. These measures can be linked with quantity and quality attributes.

5.6 Practicality of the Performance Measures

The data for the practicality measures was calculated using a practicality index. This practicality index shows the practicality of each measure.

The same type of analysis was used in determining the practicality index as shown in the importance index discussed earlier.

The data for practicality was obtained as a result of the response received from the participants during interview. It was evident from the calculated means, that the measures had some variation in the ranks when compared in the two categories of importance and practicality. Table 5.6 shows the results of the practicality indices of all performance measures in descending order of practicality.

Table 5.6 Practicality of Proposed Performance measures

Questionnaire Response			
Rank	Measure	Number of Responses	Practicality (1 – 5)
1	Material availability	15	4.33
2	Construction time lost	13	4.31
3	Procurement lead time	15	4.20
4	Materials Receipt Problems	15	4.14
5	Materials Receipt Problems-internal	13	4.08
6	Stock out analysis	15	4.00
7	Freight cost percent	15	3.80
8	PO to materials receipt duration	14	3.73
9	Warehouse inventory accuracy	14	3.60
10	Express deliveries percent	15	3.60
11	BEC lead time	14	3.57
12	Jobsite rejection of tagged equipment	14	3.53
13	Total surplus	15	3.50
14	Commodity vendor timeliness	15	3.47
15	Material receiving processing time	15	3.40
16	Backorders	15	3.33
17	Sole source purchase	12	3.31
18	Commodity timeliness	13	3.14

Table 5.6 Contd...

Rank	Measure	Number of Responses	Practicality (1 – 5)
19	Warehouse safety incident rate	15	3.07
20	EDI purchase	15	3.07
21	Materials withdrawal request (MWR) processing time	14	3.07
22	Payment discounts	13	3.00
23	Average line items per release	14	2.93
24	Materials withdrawal request	14	2.93
25	Commitment home office	13	2.67
26	Min/Max release activity	14	2.64
27	Average man hour per PO	12	2.62
28	Home office requisition ratio	12	2.60
29	Commitment field	13	2.60
30	Electronic funds transfer payments	14	2.60
31	Home office PO ratio	11	2.50
32	Average man hour per MTO	12	2.46
33	Release Value Breakdown	11	2.08
34	Minority Suppliers	10	1.86
35	Piping Spool Rework	8	1.82

The top five measures under the practicality criteria were ***Materials availability, Construction time lost, Procurement lead time, Materials receipt problems, and Stock out analysis***. Meanwhile the measures that were measured to be the least practical were Materials availability, Construction time lost, Procurement lead time, Materials receipt problems, and Stock out analysis.

Based on the index score for each of the measures, the measures were categorized in 4 different groups with a range of 1. The range was as follows:

1. Extremely practical: 4.25 – 5.00

2. Practical: 3.25 – 4.24

3. Moderately practical: 2.25 – 3.24

4. Somewhat practical: 1.25 – 2.24

The measures that were categorized as extremely practical were Material availability, and Construction time lost.

The measures in the practical category were Procurement lead-time, Materials Receipt Problems, Materials Receipt Problems-internal, and Stock out analysis, PO to materials receipt duration, Freight cost percent, Warehouse inventory accuracy, Express deliveries percent, Commodity vendor timeliness, BEC lead-time, Jobsite rejection of tagged equipment, Material receiving processing time, Total surplus, Backorders, and Sole source purchase.

The measures to be categorized as moderately practical are Materials withdrawal request (MWR) processing time, Payment discounts, EDI purchase, Commodity timeliness, Warehouse safety incident rate, Average line items per release, Materials withdrawal request, Commitment home office, Commitment field, Electronic funds transfer payments, Average man hour per PO, Min/Max release activity, Average man hour per MTO, Home office requisition ratio, and home office PO ratio.

The measures under the somewhat practical category were Release value breakdown, Minority suppliers and Piping spool rework.

It can be seen that only 2 measures came under the category of extremely practical. Each of the 2 measures are from availability and cost respectively. Fifteen of the performance measures fell under the category of practical, out of which 5 can be associated with the attribute timeliness, 3 each with accuracy and cost, 2 with availability and 1 each with quality and quantity respectively. The performance measures that came under the moderately practical category also summed up to 15, out of which 6 can be linked with the attribute cost, 6 with quantity and 3 with timeliness respectively. None of the measures in the practical category can be linked with accuracy, quality and availability. The measures that fell under the category of somewhat practical were minority suppliers and piping spool rework. These measures can be linked with quantity and quality attributes.

Relationship between Practicality and Importance Measures

A relationship between practicality and importance was studied. This relationship was assessed by the use of Pearson's correlation coefficient. The coefficient will help in finding the correlation between the two categories of importance and practicality.

Pearson's correlation coefficient was carried out to find the correlation between average responses to the importance and practicality of the 35 measures shown in Table 5.7. SPSS statistical software was used to calculate the correlation coefficient.

Table 5.7 Pearson's Correlation

S.No.	Performance Measure	Average Response to Importance	Average Response to Practicality
1	Material availability	4.60	4.33
2	Procurement lead time	4.47	4.20
3	Construction time lost	4.38	4.31
4	Express deliveries percent	4.07	3.60
5	Materials Receipt Problems-internal	4.00	4.14
6	Materials Receipt Problems	4.00	4.08
7	Stock out analysis	4.00	4.00
8	PO to materials receipt duration	3.93	3.80
9	Freight cost percent	3.93	3.73
10	Warehouse inventory accuracy	3.87	3.60
11	Commodity vendor timeliness	3.87	3.47
12	BEC lead time	3.71	3.57
13	Jobsite rejection of tagged equipment	3.60	3.53
14	Material receiving processing time	3.60	3.40
15	Total surplus	3.57	3.50
16	EDI purchase	3.47	3.07
17	Backorders	3.40	3.33

Table 5.7 contd...

S.No	Performance Measure	Average Response to Importance	Average Response to Practicality
18	Commodity Timeliness	3.36	3.14
19	Materials Withdrawal Request	3.20	3.00
20	Payment Discounts	3.20	2.93
21	Warehouse Safety incident rate	3.14	3.07
22	Materials Withdrawal request processing time	3.13	3.07
23	Sole source purchase	3.08	3.31
24	Commitment Home-Office	3.07	2.67
25	Average line items per release	2.94	2.93
26	Commitment field	2.93	2.60
27	Electronic funds transfer payments	2.87	2.60
28	Average man hour per PO	2.77	2.62
29	Min/Max release activity	2.71	2.64
30	Average man hour per MTO	2.64	2.46
31	Home office requisition ratio	2.60	2.60
32	Home office PO ratio	2.50	2.50
33	Release value breakdown	2.42	2.08
34	Minority suppliers	1.86	1.86
35	Piping spool rework	1.82	1.82

Using the formula of Pearson's correlation coefficient, $r = \frac{\sum (X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum (X - \bar{X})^2 \sum (Y - \bar{Y})^2}}$

Where X and Y are the sample means average (Importance) and average (Practicality),

the resulting correlation coefficient **r = 0.9714**

The above value of the Pearson's correlation coefficient indicates a **strong positive correlation** between the two sets of ranks under importance and practicality criteria. The very strong positive correlation between the importance and practicality of the performance measures suggests that there is a wider use of those performance measures which are considered highly important. It can be observed that the top five performance measures Materials availability, Procurement lead time, Construction time lost, and Materials receipt problems – internal maintained their positions in both the categories. These measures represent the attributes accuracy, timeliness, availability, and cost.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The objective of the research was to identify and assess the usability, importance and practicality of the performance measures in the materials management process in the industrial construction sector in Saudi Arabia. The first or the primary objective was to find the performance measures used in the past or currently being used. This was determined by literature review and by conducting interviews of selected participants in the industrial construction sector in the Eastern Province of Saudi Arabia. The second and third objective of determining the importance and practicality of the performance measures was conducted in the later stage of the research through structured interviews of the materials management professionals in the industry.

6.2 Conclusions

The following can be concluded based on the results of this research:

1. Past and Presently used Measures

It was found from the analysis of the questionnaire that all of the measures were used or are presently in use in Saudi Arabia. The measures were categorized in 4 different groups:

i. ***Rare use:*** none

ii. ***Low use:*** Piping Spool rework, Minority suppliers, and Release value breakdown.

iii. ***Moderate use:*** Jobsite rejection of tagged equipment, Home office PO ratio, Home office requisition ratio, Average line items per release, Commitment home office, Commitment field, EDI purchase, Sole source purchase, BEC lead-time, Material receiving processing time, Commodity timeliness, Materials withdrawal request, Materials withdrawal request (MWR) processing time, Average man hour per MTO, Average man hour per PO, Payment discounts, Electronic funds transfer payments, Min/Max release activity, Warehouse safety incident rate, Total surplus and Backorders.

iv. ***High use:*** Materials Receipt Problems, Materials Receipt Problems-internal, Warehouse inventory accuracy, Procurement lead-time, PO to materials receipt duration, Commodity vendor timeliness, Freight cost percent, Express deliveries percent, Construction time lost, Material availability and Stock out analysis.

2. Importance of the Performance Measures

The second question in the questionnaire enquired about the importance of the measures used in industrial construction industry.

Based on the index score for each of the measures, the measures were categorized in 4 different groups:

i. ***Extremely important:*** Material availability, Procurement lead-time, Construction time lost.

ii. ***Important***: Express deliveries percent, Materials Receipt Problems, Materials Receipt Problems-internal, and Stock out analysis, PO to materials receipt duration, Freight cost percent, Warehouse inventory accuracy, Commodity vendor timeliness, BEC lead-time, jobsite rejection of tagged equipment, Material receiving processing time, Total surplus, EDI purchase, Backorders, Commodity timeliness.

iii. ***Moderately Important:*** Materials withdrawal request, Materials withdrawal request (MWR) processing time, Payment discounts, Warehouse safety incident rate, Sole source purchase and commitment home office, Average line items per release, Commitment field, Electronic funds transfer payments, Average man hour per PO, Min/Max release activity, Average manhour per MTO, Home office requisition ratio, home office PO ratio and release value breakdown.

iv. ***Somewhat Important:*** Minority suppliers and Piping spool rework.

3. Practicality of Performance Measures

Based on the index score for each of the measures, the measures were categorized in 4 different groups:

i. ***Extremely Practical:*** Material availability and Construction time lost.

ii. ***Practical:*** Procurement lead-time, Materials Receipt Problems, Materials Receipt Problems-internal, and Stock out analysis, PO to materials receipt duration, Freight cost percent, Warehouse inventory accuracy, Express deliveries percent, Commodity vendor timeliness, BEC lead-time, Jobsite rejection of tagged equipment, Material receiving processing time, Total surplus, Backorders, and Sole source purchase.

iii. ***Moderately Practical:*** Materials withdrawal request (MWR) processing time, Payment discounts, EDI purchase, Commodity timeliness, Warehouse safety incident rate, Average line items per release, Materials withdrawal request, commitment home office, Commitment field, Electronic funds transfer payments, Average man hour per PO, Min/Max release activity, Average man hour per MTO, Home office requisition ratio, and home office PO ratio.

iv. ***Somewhat Practical:*** Release value breakdown, Minority suppliers and Piping spool rework.

4. Relationship between Importance and Practicality

After analyzing the responses for the importance and practicality of the measures used, the responses were further analyzed for finding any association between importance and practicality rankings. For this, Pearson’s correlation coefficient was used. In this case, importance and practicality were considered as the two variables. The correlation coefficient was found to be **0.9714** indicating a very strong positive correlation between the two sets of ranks under the importance and practicality criteria.

6.3 Recommendations for Further Studies

Based on the research carried out, the author recommends the following:

1. A study can be carried out to determine the barriers in the implementation of materials management performance measures in the other types of construction like building construction.

2. A study of the use of computerized materials management system currently in use in Saudi construction industry.

3. A similar study can be carried out for other types of constructions, like building construction.

4. A study of the application of materials management models, such as EOQ, MRP, JIT in construction can be done.

6.4 Recommendations for Industry

1. To use the materials management performance measures and benchmark their projects with the performance measures.

2. To educate and train on the use Materials management performance measures and their influence on the projects.

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Appendix-1 Questionnaire

Respondents profile sheet

This questionnaire consists of two parts. First part is regarding the respondents' general information, while the second part is a questionnaire for determining effectiveness measures in materials management. The respondents are specifically reminded of the importance of observing consistency in their answers. Their responses should not be biased towards any particular project whether it was highly successful or disastrous. Any information obtained through this questionnaire will stringently be used for educational use.

PART I (General Information)

1) Respondent Information:

Name (Optional)	
Company Name. (Optional)	
Status (Title)	
Telephone no.	
Facsimile.	
E-Mail Address.	
Company Address.	

2) Specify the classification of your company according to Ministry of Public Works.

a) Grade 01.	b) Grade 02.
c) Grade 03 or Below.	

3) How many years of experience you have in industrial projects:

a) Less than 10 years	b) 10-15 years.
c) 15-20 years	d) Over 20 years.

4) Years of management or responsible project experience in the area of materials management:

a) Less than 10 years	b) 10-15 years.
c) 15-20 years	d) Over 20 years.

5) What is your primary area(s) of experience:

a) Planning and administration	b) Material takeoff and material control.
c) Vendor enquiry and evaluation	d) Purchasing (home office)
e) Purchasing (field)	f) Transportation and expediting
g) Warehousing	h) Field control

6) Projects on which you have the most experience were:

a) Government projects.	b) Private Sector projects.
c) Semi-Government Projects.	d) Other, Specify:

7) Projects on which you have the most experience can be categorized as:

a) Residential projects	b) Commercial projects.
c) Industrial projects.	d) Other, Specify:

S.No.	Measure Description	Used past/current (yes/no)	Importance *	Practicality **
1	Materials receipt problems			
2	Materials receipt problems-internal			
3	Warehouse inventory accuracy			
4	Piping spool rework			
5	Jobsite rejection of tagged equipment			
6	Home office requisition ratio			
7	Home office PO ratio			
8	Average line items per release			
9	Commitment-home office			
10	Commitment-field			
11	EDI purchase			
12	Sole source purchases			
13	Minority suppliers			
14	Procurement lead time			
15	BEC lead time			
16	PO to material receipt duration			
17	Material receiving processing time			
18	Commodity vendor timeliness			
19	Commodity timeliness			
20	Materials withdrawal request			
21	Materials withdrawal request(MWR) processing time			
22	Average man hour per MTO			
23	Average man hour per PO			
24	Freight cost percent			
25	Express deliveries percent			
26	Construction time lost			
27	Payment discounts			
28	Electronic funds transfer payments			
29	Release value breakdown			
30	Min/Max release activity			
31	Warehouse safety incident rate			
32	Total surplus			
33	Material availability			
34	Stock out analysis			
35	Backorders			

** Extremely important–5; Very Important–4; Important–3; Somewhat-important–2; Not important-1.*

*** Extremely practical- 5; Very practical-4; Practical-3; Somewhat Practical-2; Not Practical-1.*

VITA

Mohammed Kashif Ul Asad was born in Hyderabad, India. After graduating from secondary school he enrolled for Bachelor of Engineering at **Osmania University**, Hyderabad, India. In June 2001, he graduated with **distinction in Bachelor of Engineering in Civil Engineering.** Then he joined an eminent engineering firm as an Assistant Planning Engineer. In December 2005, he secured **M.S. degree in Construction Engineering & Management**, from King Fahd University of Petroleum & Minerals, Dhahran Saudi Arabia.

The author can be contacted at: mkashasad@yahoo.co.in