1.1 INTRODUCTION

Supply chain management may be defined in terms of the managerial decisions that create and regulate the supply chain. Among these decisions are sourcing, forecasting, batch sizing, safety-stock setting, order timing and locating stock. During recent years, supply chain management (SCM) has emerged as a critically important aspect of the business viability of a small scale Industry. Competitive advantage can be achieved through:-

- Reducing or avoiding material shortages that delay projects and degrade the reputation of the industry,
- Reducing or avoiding excess material stock that is costly to store, transport and finance.

Although material management problems highly impact Big Players, they are more critical for specialty small scale industries including electrical industries. Most electrical fabrication & manufacturing Companies are small in size. Therefore, they have to efficiently manage their materials to lower cost in order to remain in business. Because of the risk that electrical contractors undertake in every construction job, they are constantly tracking their resources particularly their material. This tracking is useful to avoid losing material due to theft, misplacement or damage, to improve
productivity, and to compare actual resource and labor usage against planned values. In addition, tracking allows materials for identifying when materials need to be ordered, based on actual usage of materials on site and progress of the work. Other challenges encountered include dealing with suppliers, on site materials handling, storage, and handling of material surplus.

1.2 PROBLEM STATEMENT

Current materials management practices in the small scale industries are performed on a fragmented basis with unstructured communication and no clearly established responsibilities between the parties involved. This fragmentation creates gaps in information flow, which affects the decision making process and lead to delays in material ordering and receiving, among other problems. The material manager needs to realize that decisions taken at one stage in the process will certainly impact other activities and processes in the supply chain, a problem not realized due to this fragmentation.

The initial phase of this research investigated current material management practices in the Small Scale Electrical Contracting & Manufacturing industry. The investigation considered the entire range of activities necessary for procuring the needed material, starting with the estimating process and ending with site delivery, distribution and storage logistics. Research outcomes included documenting the problem bottlenecks in the supply chain as well as identifying and classifying the various criteria that influence the decision process for procuring material. A comprehensive flowchart describing the material supply chain process was developed based on various discussions and interviews with several National Electrical Contracting Association (NECA) members. The flowchart considered many
decision alternatives including material type, supplier availability and relationship, procurement options and incentives, quantities needed, delivery dates, storage alternatives, and project schedules.

Figure 1.1(A & B) depicts a detailed material management flowchart for a typical electrical contractor that specializes in commercial construction. The flowchart was developed through several interviews with office and site personnel of various electrical contracting companies in the Dehradun & Selaqui Industrial area. Flowcharts prepared for the companies, narratives and questionnaires used during the interviews and site visits are available in the Appendix I & II. From the information acquired from these interviews, five distinct phases that comprise the process were identified: 1-Bidding Phase, 2-Sourcing Phase, 3-Materials Procurement, 4-Construction Phase, 5-Post-Construction Phase. The flowchart identifies several decision nodes, in each phase, requiring alternative management actions to be taken.
Decision nodes identified include supplier selection, material procurement (where to buy from, how much to buy, when to buy) and delivery options, and storage alternatives. Actions to be taken at every decision node are complex because of their dependency on many other factors that could represent constraints or alternatives distribution.

Many challenges are encountered during the various phases of material management process including challenges with bid procurement, material procurement, material storage & distribution. Examples of challenges include:-

**Bid procurement challenges** - During budget negotiation, the general contractor may be forced to cut costs to satisfy budget limits of owners while still committing to the same scope of work. The electrical job is usually one of the last trades to be procured in a project and in many times is asked by the General Contractor (GC), prior to finalizing the sub-contract, to absorb some of the cost reductions. This puts even more pressure on the electrical industry to complete the scope of work for a lower cost than what was initially budgeted.

**Supplier selection challenges** - The selection of a reputable supplier is critical for ensuring that materials are delivered in the quantities needed and at the dates specified.

**Material purchasing challenges** - Once a supplier is selected, the contractor has to systematically follow up the status of ordered material in order to assure that the material arrives to the job site in the quantities and dates specified.
Jobsite storage and handling challenges- The majority of the problems faced by electrical contractors with respect to materials management are encountered at the job site and include tracking of material, storage issues, material distribution and re-handling.

The challenges related to the material management practices in the electrical industry are further analyzed and discussed in Chapter 5.

The material procurement (ordering and delivery) phase is very critical to the successful execution and completion of any project. The person in charge of procuring materials or the purchasing department, in the case of a large company, needs to ensure that the correct materials in the correct quantities are ordered. They also need to verify the release dates at which the material is needed and clearly specify those delivery dates as well as the location of delivery to the supplier.

The focus of the procurement decision node includes how much material to buy, when to buy this material, which supplier to choose and where to deliver this material. The decision of how much to buy is very important to assure that material quantities needed are available and that there are no material shortages. From the interviews, it was found that most of the electrical contractors buy large amounts of their material early based on field personnel purchase requests without planning which quantity is needed. This result in additional costs associated with storage fees, damage during storage, and re-handling due to space limitations. Electrical contractors believe that these costs are minor when compared to delays and labor costs if the material is not available when needed.

The decision of when to buy is important to ensure that material is available when needed. In many companies, this process starts with the generation of a
material requisition schedule (e.g. release forms) specifying material types, quantities needed and dates of when the material should be delivered. In large jobs, the schedule is usually prepared by the site staff then sent to the purchasing department to request the material from the suppliers/distributors under contract. In smaller companies or smaller size jobs, material may be procured directly by the field personnel’s. To avoid surplus, many contractors request about 75% of planned material needed. Additional quantities are purchased when the job is near completion and a better estimate is realized.

The selection of suppliers is primarily based on lowest price. However, contractors may consider suppliers with higher prices that will provide better service or that have a record to supply the right material in the quantities needed at the times specified. If there are no qualified suppliers from the proposals received, the contractor should request bids from other suppliers. In some situations the contractor might enter into a blanket or yearly contract. This is a common practice used in purchasing miscellaneous material. Yearly contracts guarantee the price, availability and delivery of the specified materials and equipment. This approach also reduces the company's risk of stock-outs and procurement costs because time and paperwork’s are reduced.

The decision of where to deliver the material requires space planning and consideration of site limitations, pre-fabrication strategies, and subcontractors to be engaged. Material is generally requested for delivery to the job site. From the site visits to some projects, it was observed that in many instances the material was stored in "sea cans" located far away from the jobsite. This increases the potential of material loss due to theft. Regarding material stored in the work area, this was done without proper planning, and material needs to be moved to free space so that other trades can work in the area. The costs associated with re-handling, loss and/or theft are not realized when ordering
the material. The electrical contractor could use better procurement policies to avoid having over-stocking of inventory on the jobsite, and to decrease inventory costs. However, the effort of changing ordering policies will require a commitment of delivery when needed by the supplier. Another approach that could be used to decrease inventory is called vendor managed inventory (VMI). When this approach is used, the distributor places a trailer on site with the needed materials and equipment and takes the responsibility of maintaining the inventory throughout the project. The distributor charges the contractor for materials and equipment used at predetermined prices. At the end of the project, the distributor removes the trailer along with the unused inventory. The company can outsource their warehouse operation to the distributor.

In some instances delivering material directly to the jobsite may not be feasible due to storage or access limitations. In this case, the material is delivered to other locations such as the contractor's warehouse or another subcontractor storage area. Material is delivered to a warehouse in cases such as when critical specialty items are ordered early and are not going to be installed immediately, when storage area at the job-site is unavailable, or if the material will be used for pre-fabrication. Storage of the material at the warehouse prior to moving it to the jobsite increases indirect costs due to re-handling. Some companies utilize a pre-fabrication shop facility to assemble components in a controlled environment. In some instances, the material is sent to a subcontractor for temporary storage at his facility prior to delivery and installation. There are additional costs associated using the subcontractor's storage yard, but since he is already contracted for installation these fees are smaller compared to using an independent storage facility. The current material management practices in the electrical contracting industry will be discussed further in Chapter 4.
Material procurement problems greatly affect the construction stage and failure to manage this phase effectively could result in project disruption and possible delays due to late deliveries, stock outs due to small quantities bought, material delivered to the wrong locations, material backordered and overall costs. The owner has to systematically follow up the status of ordered material to assure that the material arrives to the job site in the quantities and dates specified. Expediting is one control system necessary to assure a timely equipment and materials arrival to achieve a project completion on schedule. Expediting involves monitoring all steps in the procurement cycle, with special focus on those involving the vendor or subcontractor, to assure reliable, economical, on-schedule delivery.

Ensuring that material deliveries occur on a timely basis is a very difficult task. As revisions come through from material takeoff, it is all too easy for this to impact on material deliveries, resulting in them arriving late or in insufficient quantities. The impact of schedule changes can have a similar effect. While material may originally have been ordered in good time, this may no longer be the case. Design changes may result in a reduction in requirements for some material and an increase for others, which will also affect the delivery schedule. These changes can have a considerable impact on cost and evaluating the full impact of the changes is extremely important. Material may not arrive on time, work may have to begin out of sequence, or the fabrication process may be delayed.

Effective planning and communication is required to keep costs to a minimum, to minimize errors in ordering and to increase the probability that the material is on site when needed. Constant communication and clearly specifying, without ambiguities, the material needed could help to minimize errors in ordering.
1.3 RESEARCH OBJECTIVE

The objective of this research is to improve the decision making process for supply chain management in the Small scale Manufacturing & contracting Electrical industry. This objective can be broken down into the following components:

- Identify bottlenecks in the current decision making process for material management for the electrical industry
- Develop responses to the bottlenecks in current practices. This will require identifying in greater detail the decision nodes in the material supply chain for the electrical firm.
- Apply knowledge-management and decision-modeling concepts to design an integrated, effective system of decision-support tools for the material supply chain of the electrical industry.
- Identify all of the knowledge elements that constitute the alternatives, factors or parameters and performance measures for each decision node.
- Develop decision making flowcharts that describe the material management decision making process for the decision nodes considered in the study. These flowcharts will also describe the relationships between the knowledge elements.

1.4 RESEARCH CONTRIBUTION

The main contribution of this research is the identification of bottlenecks in the supply chain management process and the development of a new decision model for the EC industry. This contribution is comprised by:
1. The design of an industry-specific framework for the development of structured systems design of distributed, integrated computerized decision support systems for the supply chains of the small scale electrical contracting industry.

The framework developed is valuable in two fundamental ways. First, the framework identifies and describes all phases of materials management for an integrated, holistic view of all factors that affect the total cost of materials and material shortages. The research created detailed mappings of the essential decisions, decision models and data that are required to support supply-chain activities of construction contractors throughout a project life cycle.

Second, the framework differentiates those steps in the materials management process that are straightforward applications of methods from those steps that are decisions. For these decisions, that are critical to the performance of the materials management process, the research introduces the concept of a decision model and describes how such models can be incorporated into an advanced materials management system. This phase of the research developed a structured systems design of distributed, integrated decision support systems for materials management of the electrical contractor. The research derives the most favorable integration of people, decision processes, decision support systems and data that are required to support efficient and effective systems for acquisition, procurement, transport, storage and allocation of material in the construction industry.

2. The identification of the current material management practices for the electrical contracting industry and the representation of these by the development of the flowcharts presented in Chapter Four. By doing the
representation of the current process, the framework addresses a fundamental and critical aspect, which is that in order to improve a process it is very important to know how it works.

3. The identification of decision nodes in the current material management practices for the electrical contractor. More specifically, identifying which are the important questions and aspects related to decision making for material supply chain in the electrical contracting industry.

4. The development of SPARCS, Supply Chain Parameter Classification System, is a major contribution of this study. SPARCS is a hierarchical structure for classifying parameters for material supply chain, specifically for the electrical Manufacturing & contracting industry. Up to the development of SPARCS, there was no structured approach to categorize the parameters that need to be considered on the supply chain decision making process for the small scale electrical Industry.

The development of SPARCS provides the following contributions:-

a. SPARCS defines the database that would be extracted from ERP databases or other company data sources in order to support specific decisions.

b. SPARCS defines data that may have to be extracted from different corporate entities and different corporate databases (general contractor, sub contractor, suppliers, and owner).

c. SPARCS assists in the development of small-scale decision support that a sub- contractor may utilize in the absence of an ERP system.

5. The definition of the data, models, decision makers and procedures that make up the knowledge and a mapping of their relationships is another
The contribution of this study. The identification and collection of all the knowledge elements, through interviews with electrical contractors, suppliers and manufacturers, that constitute the alternatives, factors or parameters and performance measures, allowed using practical data in the development of the framework. The framework not only identified knowledge elements required for the overall material management system, but, in addition, knowledge elements that are related to each decision independently were also identified.

6. The perspective held by many people within and outside the construction industry has been that this industry is different from other manufacturing and service industries. This perspective has created barriers to the adaptation of methods and technologies that are emerging in these other industries. This research breached some of these barriers by working with companies from the electrical contracting industry in the design of the framework for implementing supply-chain practices. The methodology used in the research allowed considering and including the perspective and concepts used by the contractors in this sector. The relationship with the industry contractors, allows continuous learning for these contractors of new technologies and methods for supply-chain management as they were exposed, through the interviews conducted as part of the research, to some of the practices used in manufacturing and other industries.

1.5 JUSTIFICATION

The success of a small scale construction based industry resides in the ability to plan effectively how to manage resources and people and on the successful implementation of the plan. This grand plan includes the determination of the
tasks to be performed, their sequence and strategies for allocation of resources among them. The grand plan is subdivided into smaller plans to facilitate managing the entire project. The quality and effectiveness of the grand plan or individual plans can be measured, among other things, by variability of the time and cost required to complete it, compared to the original estimates.

Construction projects are subjected to continuous variability. This variability can be traced to the dependency of the general contractor on other parties such as suppliers and subcontractors. As a result of deviations from the plan, decreases in productivity and subsequent increases in cost and time required to finish the project can be expected. Materials are one of the areas that require special attention while creating the grand plan for the project. Materials account for more than 60% of the total cost of a construction project. In addition, materials are essential for the daily progress of a construction project. The absence of materials when needed is one of the main causes of loss of productivity in a jobsite. As a result, an elaborate plan for materials management becomes mandatory. The formulation of a plan for materials management involves the development of strategies for the integration and monitoring of the entire process and the implementation of those strategies. This plan should consider, among other things, the flow of materials through all the phases of the project starting from the estimating phase, through procurement, purchasing, delivery, installation and disposal of surpluses as shown in Figure 1.2. General activities that should be considered in preparing the plan for materials include the determination of materials needed (i.e. quantity, type, sizes, color, etc.), specific dates when the materials are needed, procurement, expediting, receiving, storage, usage, disposal and provisions for contingencies.
The accuracy of the plan is evaluated by variations from the estimated cost, variations on the delivery date, and effects of the variations in time of material management related activities on the overall project duration (i.e. On time vs. Delayed). Based on the deviations observed, the materials manager may decide to modify certain decisions or strategies and/or formulate a new plan. This comparison of planned strategies vs. actual results is essential to refine and update the materials management plan. In addition, during the material cycle on the construction project, the project team faces decisions about deliveries, suppliers, among others.

Better materials management practices and decision-making models could increase efficiency in operations and reduce overall costs. There is a growing awareness in the electrical contracting industry that materials management needs to be addressed as a comprehensive integrated management activity. Increasing pressures on project costs and completion times are motivating the need to make supply-chain decisions in a coordinated fashion and in consideration of minimizing total supply-chain cost without causing shortages. The performance of these decisions is heavily dependent on the combination of the different alternatives listed in every phase of the materials management process. Currently, there is no structured approach to identifying the optimum combination of decisions that will lead to processing the needed material with the least total costs. Fortunately, model-based, computerized solutions to supply-chain problems are proliferating. However, the typical Electrical Contractor (EC) may be overwhelmed by the technology embodied
by these solutions and the challenges of integrating this knowledge into business practices. A definition of the data, models, decision makers and procedures that make up this knowledge and a mapping of their relationships and uses is a vital first step towards building integrated decision support for the electrical contractor.

It is clear that effective planning is required to keep costs to a minimum and to insure that the material is on site when needed. Poor planning of materials will increase indirect costs associated with delivery and use of materials. In addition, losses in productivity, delays, re-handling, and duplicate orders among other factors can be expected when there is a poor materials management system. The electrical contractors need to realize that by improving their material management systems improvements could be achieved in other areas such as in the labor force. The effects of not having material available when needed are could be difficult to measure, but the impact in labor productivity could be noticed and quantified. Indirect labor cost due to absence of materials could be significant. Increases in idle time and/or unproductive time should be expected. Crew members will pretend to be busy even if there is no material to install, which increases the labor cost.

Stukhart and Bell (1987) conducted a study of twenty heavy construction sites where the following benefits from the introduction of materials management systems were noted:

- In one project, a 6% reduction in craft labor costs occurred due to the availability of materials on site when needed. On some other projects, an 8% savings was estimated by reducing the delay for materials.
- Two projects, with and without a materials management system, were compared and the comparison revealed a change in productivity from
1.92 man-hours per unit without a system to 1.14 man-hours per unit with a new system. Much of the difference can be attributed to the timely availability of materials.

- Warehouse costs were found to decrease 50% on one project with the introduction of improved inventory management, representing a savings of $92,000. Interest charges for inventory also declined, with one project reporting a cash flow savings of $85,000 from improved materials management.

Other issues that could be a consequence of a bad material management system include disruptions of work flow, time lost due to relocation of the work force, changing set ups to new locations where material is available, even if it is different activity, de-motivation of supervisors and possibly labor force. On the other hand, excess of material due to early deliveries could disrupt the work flow, require re-handling material to free up space for other crews to work, which requires time, the possibility of material being damaged increases and there is a greater probability of having accidents due to extra material on the jobsite.

1.6 METHODOLOGY

A plan of work for the research that identified the tasks that needed to be accomplished to design the proposed decision model for material procurement was prepared. The first task in the development of the framework was to identifying the bottlenecks in the current material management process.

The second task was to identify in greater detail the decision nodes in the material supply chain for the electrical industry. Decision nodes are those junctures in the material management process where a decision has to be made with material such as supplier selection, material procurement (who to
buy from, how much to buy, when to buy), delivery options, and storage alternatives. Figure 1.3 depicts a decision node for material ordering.

![Decision Node Diagram](image)

**Figure 1.3: Decision Nodes for Material Ordering**

Once the decision nodes were identified, supply chain management concepts were applied to design an integrated, effective system of decision-support tools for the material supply chain of the small scale electrical contracting and manufacturing Industry. The design specifies a knowledge database and procedures that allows a contractor to perform what-if scenarios on various procurement decisions to identify better alternatives. Furthermore, this design could serve as a "road map" for the development and integration of decision support tools by a small sale industry. The system design focus mainly on decisions concerned with material procurement, delivery options, and storage alternatives. However, other decision making areas were studied and the effects of these decision making activities in procurement, delivery and
storage options were considered. Therefore, an integrated approach was used to improve communication and minimize information flow gaps between all the parties and departments involved. Furthermore, it was investigated if the procurement, delivery and storage options could be studied in isolation from the other decision making activities.

Decision-modeling concepts were used to develop an integrated system of decision support for material procurement for the electrical contractor. A computer program or algorithm that performs the calculation of performance measures for each alternative is called a descriptive model because it only describes a cause-effect relationship without making any judgment about the desirability of each alternative. This judgment is left to the decision maker. The decision model at any decision node is as depicted in Figure 1.4. The factors (or parameters) and alternatives define the inputs. Performance measures define the output. Alternatives represent the different options available for a particular decision node. Parameters represent “values” that could restrict the decision making process. Performance measures are used to measure the effectiveness of the system with the alternatives and parameters used as inputs.

Figure 1.4 is a schematic representation of the decision model for choosing the order quantity of an item that illustrates how such a computer program would be designed. Some decision models go further than describing the outcomes of each alternative by determining the better choice from among all of the alternatives. These kinds of models are called prescriptive models and embody a search routine that a computer uses to carry out an intelligent, restricted trial-and-error search for the better solution. Prescriptive models leverage the decision maker by evaluating tradeoffs that are too complex or numerous for human judgment to comprehend.
Alternatives
- as estimated
- Less than estimated
- More than estimated

Descriptive Model for Material Purchasing

Performance Measures
- Surplus
- Projected shortage
- Indirect costs

Parameters
- Project schedule
- Uncertainty in project schedule
- Storage capacity
- Installation rate and usage
- Procurement cost rates

**Figure 1.4 Framework for Decision Models**

For example, a descriptive model could be used when a Company orders materials. Decision alternatives might include the time when an order should be placed, resources needed, where to deliver, how much to order, among others. Examples of parameters might include the storage capacity, availability of space, location of the job, among others. Examples of performance measures might include lateness, earliness, surplus of storage capacities, costs, among others. Based on the information input (i.e. alternatives and the parameters), an analysis will be performed to assist the electrical contractor in that decision. In this case, the model will help the decision maker by suggesting where the material should be stored. This is only one example of how the model could be used. Other applications such as batch order size, safety stock inventory and sourcing models could be analyzed with the model. The challenge is to consider all the elements that could have an impact in the specific decision to be made and provide not only the most cost effective solution, but the solution that could better serve the electrical contractor needs at that particular instant.
The next task was to define all of the knowledge elements that constitute the alternatives, factors or parameters and performance measures for each decision node. This required identifying all the data that is needed to make decisions and any other information that might impact the way in which a decision is taken for a particular decision node. The challenge lies in discerning the data that could be used and considered as knowledge from the vast amount of data that could be available.

A database of all the alternatives and parameters needed, for every decision node to be considered, needs to be established. The challenge is to consider all the elements that could have an impact in the specific decision to be made and provide not only the most cost effective solution, but the solution that could better serve the EC needs at that particular instant. A definition of the data, models, decision makers and procedures that make up the knowledge and a mapping of their relationships and uses is a vital first task towards building integrated decision support for the contractor. The term "knowledge management" has become the recognized name for this definition and structuring of all of these "knowledge elements" that an organization uses to make decisions. Understanding the knowledge is the first step to manage it effectively and to document it. For our purpose, the management of the knowledge requires defining the elements and the decision rules associated with every particular decision. In other words, the alternatives and parameters considered to make decisions at every decision node need to be clearly defined. This process needs to be done for every decision node that will be considered in the study.

Table 1.1 presents the procurement decisions to be made, the alternatives and parameters that affect these decisions and the performance measures associated with each decision.
Table 1.1: Procurement Decisions, Alternatives, Parameters and Performance Measures

<table>
<thead>
<tr>
<th>Decision</th>
<th>Alternatives</th>
<th>Parameters</th>
<th>Performance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>What material to buy?</td>
<td>• Major material</td>
<td>• Schedule</td>
<td>• On site availability</td>
</tr>
<tr>
<td></td>
<td>• Commodities</td>
<td>• Foreman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Consumables</td>
<td>• Production and usage</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Needed vs. wanted</td>
<td></td>
</tr>
<tr>
<td>When to buy material?</td>
<td>• 3 months in advance</td>
<td>• Type of material (commodity vs. major)</td>
<td>• Lateness</td>
</tr>
<tr>
<td></td>
<td>• 1 month in advance</td>
<td>• Storage Capacity</td>
<td>• Earliness</td>
</tr>
<tr>
<td></td>
<td>• 1 week in advance</td>
<td>• Location of the project</td>
<td>• Direct costs</td>
</tr>
<tr>
<td></td>
<td>• 1 day in advance</td>
<td>• Location of the supplier</td>
<td>• Indirect costs</td>
</tr>
<tr>
<td></td>
<td>• Same day</td>
<td>• Criticality of the material</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Order to install vs. order to pre-fabrication (Pre-fab)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Supplier's performance and ability to meet schedules</td>
<td></td>
</tr>
<tr>
<td>Where to buy material?</td>
<td>• Local supplier</td>
<td>• Arrangements with suppliers</td>
<td>• Lateness</td>
</tr>
<tr>
<td></td>
<td>• Non-local supplier</td>
<td>• Availability</td>
<td>• Earliness</td>
</tr>
<tr>
<td></td>
<td>• Vendor Managed</td>
<td>• Criticality</td>
<td>• Quality</td>
</tr>
<tr>
<td></td>
<td>• Inventory</td>
<td>• Location of supplier</td>
<td>• Quantities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Location of project</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Supplier's performance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Discounts</td>
<td></td>
</tr>
<tr>
<td>How Much to order?</td>
<td>As estimated</td>
<td>Less than estimated</td>
<td>More than estimated</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------</td>
<td>---------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Where to deliver?</td>
<td>Jobsite</td>
<td>Warehouse/Pre-fab shop</td>
<td>Subcontractor</td>
</tr>
<tr>
<td>Where on site to store?</td>
<td>&quot;Sea cans&quot;</td>
<td>on floor inside the building</td>
<td></td>
</tr>
</tbody>
</table>

The identification of these data required visits and interviews to electrical contractors. These visits allowed identifying the alternatives and parameters considered by these electrical contractors. These knowledge elements not only included what the common literature identifies, but, in addition, parameters that are particularly important for every company individually were identified. Interview sessions allowed for clearly defining the alternatives and parameters that they consider, collect these alternatives and parameters, analyze those ideas and incorporate them into the database of knowledge elements needed as inputs for the development of the model.
The relationships among the alternatives, parameters and performance measures needed to be defined. These relationships are described graphically by developing flowcharts that will illustrate the relationships among the different elements (i.e. alternatives, parameters and performance measures). This representation clearly establishes these relationships to allow users to clearly follow the way in which the decision support system works. These flowcharts are further discussed and explain in Chapter 7.

Once the descriptive models for the decision making process and the data needed were identified, flowcharts that describe the material management decision making process were developed. These flowcharts describe in detail the decision making process and the parameters that could have an effect in the decision to be taken. These flowcharts are presented and described in Chapter 7. A system for classifying the parameters needed in the decision making process was also developed. The system known as SPARCS is developed & presented in Chapter 8.

It is important to clarify that the research does not aim to develop an information system for decision making. The research will rather look at the decisions to be made and the relationship that might exist among decisions, data and decision makers.

1.7 INDUSTRY RELEVANCE

All sectors of the industry share a common ground for material management and control. Thus, the discussion presented although it is directed towards the small scale electrical manufacturing & contracting industry could be applied to any sector. Material management activities are required throughout a construction project and in every construction project. Moreover, the success of the project is highly dependent on the successful management of the materials required. Hence, managing the materials in an effective way is very
critical to all parties involved not only in the construction industry but also in other industries.

The research work is expected to provide the following benefits to the industry

- Improve the management of materials for the electrical contracting industry
- Provide guidelines to assist in the materials management learning process
- Standardization of the material management practices within a company
- Investigate state of the art tools and technologies that could be helpful in managing and monitoring material and control its quality.
- With the development of a structure for a material management decision support system, facilitated through a knowledge management database, the following benefits are expected:
  - minimization of the repetition of past failures
  - sharing of successful experiences
  - learn from other people's experiences to avoid pitfalls and to minimize the repetitions of errors
  - identify specific design, process, or decision that reduces or eliminates the potential for failures
  - availability of corrective actions for typical problems that might impact the cost of a project
1.8 SCOPE AND LIMITATIONS

The proposed research will be limited to the following assumptions,

- The research only addresses or considers the small electrical manufacturing & contracting industry.
- The research will not study the decision making process for the entire material management process as it will focus in the decision making process for material procurement (purchasing, delivery options and storage alternatives).
- The research will be focused on small size electrical industry that specializes in commercial construction & erection.
- The research will intend to design a blueprint for a knowledge management system for supply chain and not the development of a computer application.

1.9 REPORT STRUCTURE

Chapter 1 presented the research statement. This chapter presented a description of the problem statement, the objective of the research, the justification for the research, the methodology for the research work, relevance of this work to the small scale construction industry and the limitations of this study.

Chapter 2 presents a general introduction to material management in Small scale Industry. This chapter presents literature review on material management system, discuss why is important to have a material management system and the advantages of having it.
Chapter 3 presents the current state of knowledge in material management for industry. This chapter describes other research efforts that have been performed in material management for fabrication. These studies have been classified into materials management and project management, benefits and costs of a materials management system, role of vendor/supplier and fabricator, models developed and studies of effectiveness of materials management, use of technology for materials management, other research related to materials management, materials management for the electrical contracting industry, cultural change in construction, supply chain management for the small scale industry, and knowledge management.

Chapter 4 presents an overview of the electrical contracting industry including services provided by electrical contractors, materials purchasing and typical products used by electrical industry. In addition, this chapter describes the current material management practices in the electrical contracting industry & the different phases. This chapter also describes supplier/contractor arrangements such as partnering, among others.

Chapter 5 describes the many challenges that are encountered during the five phases of the materials management process. These challenges were grouped into three categories: information technology, decision modeling and implementation management.

Chapter 6 presents the decision modeling approach used in the study. The chapter gives an introduction to decision modeling, describes the modeling approach used and explains the decision making processes studied.

Chapter 7 presents the framework for a Decision Support System (DSS) for supply chain management. The chapter provides a description of the decision making process for material supply chain for the decision nodes considered:
what material to buy decision node, how much to order decision node, when to buy material decision node, when to deliver material decision node, where to deliver material decision node, where to store on site decision node. In addition, the chapter provides a description of framework for decision models.

**Chapter 8** provides a description of new concept of SPARCS - Supply-Chain PARameters Classification System. The chapter describes the development of SPARCS, the data definition for SPARCS, and the application of SPARCS to all the decisions considered in the study.

**Chapter 9** presents a summary of the work, the conclusions of this work, Recommendations and directions for future research.

Appendix I present the questionnaires used in the interviews.

Appendix II presents the flowcharts for the material management process for the companies interviewed and the narratives for the flowcharts.