Engineering Management
Field Project

Sporting Good Manufacturing Company Optimal Manufacturing and Shipping Cost Through Linear Programming Models

By

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An EMGT Field Project report submitted to the Engineering Management Program and the Faculty of the Graduate School of The University of Kansas in partial fulfillment of the requirements for the degree of Master's of Science

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Executive Summary

Sporting Good Manufacturing Company (SGMC) needs assistance in defining a linear programming model to find out the minimal cost to manufacture and ship their products to their nationwide distributors. These specialty products are cricket bats, cricket stumps and cricket bails, all products manufactured with the finest quality of wood. SGMC currently has distributors located in Punjab, Sindh, Baluchistan, Northern and Azad Kashmir. The company currently has two factories located in Karachi and Lahore in Pakistan. Warehouses located in Quetta, Lahore, Peshawar and Karachi are utilized to store manufactured products.

From initial engagement with the company, multiple meetings with company officers were conducted for information gathering. The information provided by these officers mainly focused on the price of manufacturing and shipping of the company's products. The end goal for the company was to meet their distributor's demands at a minimal cost. A key understanding was that products could be shipped either from factories to warehouses to distributors or directly from factories to distributors. Currently the company does not have any defined way to find the optimal cost of manufacturing and shipping products. However, the ability to meet distributor's demands is critical. Other relevant information SGMC provided was the company warehouse storage capacity, product manufacturing cost, shipping cost (factories to warehouses, warehouses to distributors & factories to distributors), and factories total manufacturing capacity. Data regarding the factory workers, machines, warehouse staff, and scheduling were not relevant and, therefore, were not considered in the creation of the linear programming model.

All of the basic steps of generating a linear programming model were followed and information was well documented during each step to ensure that the model functioned properly and that enhancements could be easily made for all future requirements. As this project is international, it was difficult and expensive to communicate back and forth. Hurdles due to lack of manufacturing expertise, limited knowledge of supply chain networking, time zone differences from subject matter experts, and geographically dispersed information were all overcome to successfully develop and execute the models.

The products analyzed in developing the linear programming model represent 65 percent of SGMC's annual production volume. The model that was developed indicated that the company did not need to use any of its warehouses and instead needed a simple transportation model from the factories to the distributors. With the initial manufacturing and shipping cost, the total optimal cost indicated by our model for the company was PKR 29,607,400. As the company changed their requirements by adding an additional constraint of manufacturing limit per factory with no change to the shipping cost, the total cost went up to PKR 31,222,500. This change still mimicked our first model outcome indicating the company did not need its warehouses for storage and it is optimal to ship products directly from the factories to distributors.

After SGMC negotiated a new fixed-price shipping cost schedule with the new shipping vendor, the new cost structure was used to successfully execute a new model. This model considered the revised shipping cost and included the factories manufacturing capacity

constraint. The total optimal cost with this new model came out to be PKR 30,525,600. This model showed that the company needed to use both transportation and transshipment models to meet their distributors demand at the optimal cost. During the process of developing these models, important information was revealed, namely that the company ships products 15 days in advance to their warehouses. This piece of information significantly changed the model. This model appeared to be a simple transshipment model due to the fact that all products were shipped to the warehouses before they were shipped to the distributors, but when the model was executed, a feasible solution could not be found and the investigation through manual verification indicated that the company's warehouses capacities are less than their distributor's demands.

One option that the company researched was to expand their Karachi and Lahore warehouses to double their capacity. If the company expands these warehouses and includes the revised shipping price in the model, the optimal cost was found to be PKR 30,606,250 and it will be still a transshipment model.

From the report it's clear this project took some time to lock the requirements for the model, but the end result in the form of the model developed will be a very useful and powerful tool for the company. Even with weekly information changes and situation, this project was an excellent opportunity to exercise and polish linear programming modeling skills. It provided the author with the opportunity to apply skills developed in coursework to practical, real world scenarios.

Table of Contents

List of Figures

List of Principal Symbols and Nomenclature

SGMC	Sporting Good Manufacturing Company
LP	Linear Programming
CEO	Chief Executive Officer
COO	Chief Operation Officer
PKR	Pakistani Rupees
EMGT	Engineering Management
O.F.	Objective Function
A_i	No. of bats manufactured in factory i; where i = k, l
B_i	No. of Stumps manufactured in factory i; where i = k, l
C_i	No. of bails manufactured in factory i; where i = k, l
D_{ij}	No. of bats shipped from factory i to warehouse j; where i = k, l; j = q , k,l, p
E_{ij}	No. of Stumps shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
F_{ij}	No. of bails shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
G_{ij}	No. of bats shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
H_{ij}	No. of Stumps shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
I_{ij}	No. of bails shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
K_{ij}	No. of bats shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
L_{ij}	No. of Stumps shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
M_{ij}	No. of bails shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
N_{ij}	No. of bats received from factory i to warehouse j; where i = k, l; j = q, k, l, p
O_{ij}	No. of Stumps received from factory i to warehouse j; where i = k, l; j = q, k, l, p
P_{ij}	No. of bails received from factory i to warehouse j; where i = k, l; j = q, k, l, p

Chapter 1 -- Introduction

Purpose

The purpose of this project is to build and provide a linear programming model for the Sporting Good Manufacturing Company (SGMC) of Pakistan. It provides the minimal manufacturing and shipping costs incurred by the company based on the input data provided by the company's officers. Currently, SGMC is in contract with a shipping company to deliver its products to its warehouses as well as to distributors. The data used in this modeling was provided by the company and can change at any time due to changes in contracts, cost of materials and labor. This model will support any change to the data to find the minimal shipping and manufacturing costs in the future.

Realizing SGMC has three tiers of products by quality level, the research done in this project only addressed those products in the mid-quality tier, but these products represented approximately 65 percent of SGMC's annual production volume. Development of a linear programming model for this proportion of SGMC's production is expected to provide good guidance to the company, though ultimately it would be appropriate to develop a model which included all quality tiers.

Background

During the last quarter of 2008, a discussion took place with the CEO of SGMC regarding the need for a tool to configure and determine the lowest shipping cost of sending merchandise to distributors. SGMC is an international company who manufactures fine quality wooden equipment for the game of cricket. The company was particularly interested in examining domestic shipping cost minimization which had few constraints. The discussion centered on a main purpose of decreasing costs and indirectly contributing to profit margins.

With that avenue opened, conversations started to take place with the CEO about the concept and benefits of using a linear programming model. After many long conversations and lengthy meetings, the CEO agreed to explore the benefits of linear programming. The selling point was low risk for the company since the model would be provided at no cost and the company would have the choice to implement the model. From the author's perspective, this was a great opportunity to implement concepts learned from classes taken for graduate studies. An additional advantage was the flexibility from the client regarding deadlines. Finally, this project allows for the application of concepts learned in classes to a real world problem in order to improve the chance that these skills can be utilized later as a profession.

This project seemed very interesting from its beginning as it dealt with an international client, foreign exchange, the company's culture and its normal practices. It will be interesting to see this new change introduced in the company instead of allowing the business to run without any change. The toughest part of the project will be the collection of data, knowing that there is no automation or electronic data available in the company.

This report shows how data was collected and processed to get the optimal solution for the company.

Information Gathered

During multiple meetings with the company's officers, information was gathered for enhancing the current business practices and building the requested linear programming model. Some of the information was not valid for the requested model and therefore such information was discarded. Here is the list of the information that was valid and was used to build the model:

Company's Products

The company specializes in the manufacturing of cricket sporting equipment namely bats, bails and stumps (see Figure 1). All products are made from the finest wood and are in high demand nationwide. These products are essential for the game of cricket, as shown in Figure 2.

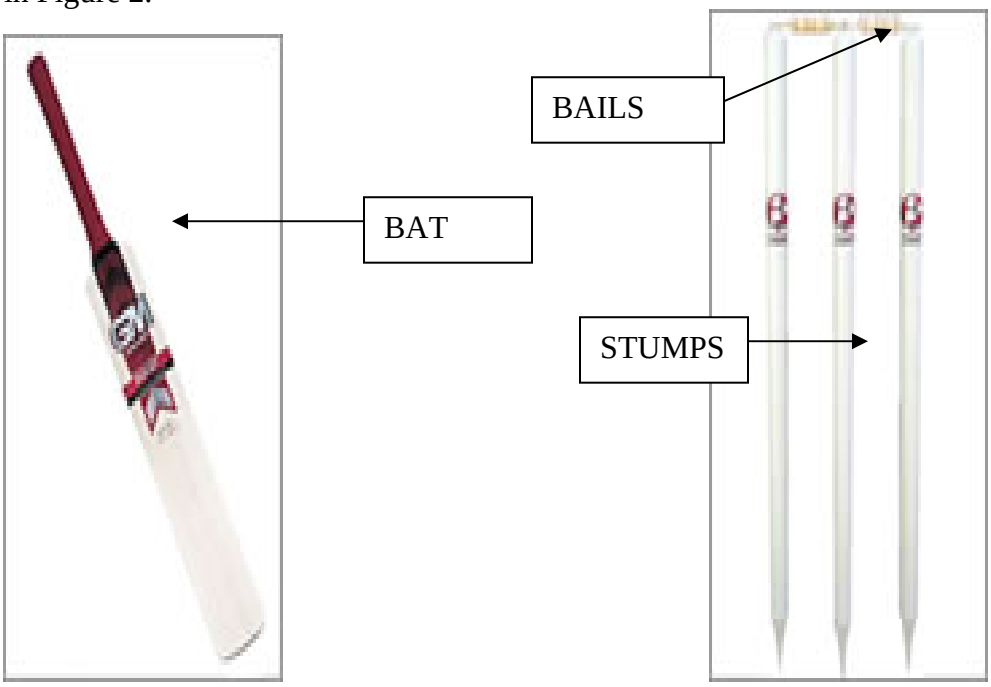

Figure 1: Company's manufactured equipment

Figure 2: Game of cricket

Distribution Shipment Flow

The information received from the company's officers indicated that the process was an integrated flow of transportation and transshipment but later discussion revealed that the flow is solely a transshipment flow. Both flows are attached with this report in Appendix A.

Manufacturing Cost for each Factory per Product

The following data was collected by visiting the factories and analyzing the company's books to get manufacturing costs. As negotiations took place between the client and the shipping company, manufacturing costs for each factory per product did not change. Therefore the manufacturing cost for each factory per product remained the same but the total manufacturing cost changed as the number of equipment pieces varied for different models based on cost and need of the product.

		Products	
	Bats	Stumps	Bails
Karachi Factory	PKR 150	PKR 95	PKR 45
Lahore Factory	PKR 130	PKR 99	PKR 41

Figure 3: Manufacturing cost for each factory per product

Shipping Cost From Factory to Warehouses (PKR per product)

During the process of development of the models, data was changed from its initial state when better shipping cost was negotiated with the shipping company. Negotiated cost was considered with a possibility of a long term contact with the trucking company. This is the transportation cost from each factory to each warehouse per product per piece. Figure 4 shows the initial shipping cost for the company whereas Figure 5 is the revised shipping cost.

		Warehouse Destinations			
		Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse
Karachi Factory	Bats	PKR 5.50	PKR 5.50	PKR 6.00	PKR 5.20
	Stumps	PKR 4.00	PKR 3.75	PKR 4.25	PKR 4.25
	Bails	PKR 2.25	PKR 2.75	PKR 2.50	PKR 2.30
Lahore Factory	Bats	PKR 6.50	PKR 5.30	PKR 5.50	PKR 5.20
	Stumps	PKR 4.25	PKR 3.80	PKR 4.00	PKR 3.75
	Bails	PKR 2.90	PKR 1.90	PKR 1.95	PKR 2.60

Figure 4: Initial shipping cost from factories to warehouses

		Warehouse Destinations			
		Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse
Karachi Factory	Bats	PKR 3.50	PKR 3.50	PKR 4.00	PKR 3.20
	Stumps	PKR 2.00	PKR 1.75	PKR 2.45	PKR 2.25
	Bails	PKR 0.25	PKR 0.75	PKR 0.50	PKR 0.30
Lahore Factory	Bats	PKR 4.50	PKR 3.30	PKR 3.50	PKR 3.20
	Stumps	PKR 2.25	PKR 1.80	PKR 2.00	PKR 1.75
	Bails	PKR 0.90	PKR 0.90	PKR 0.95	PKR 0.60

Figure 5: Revised shipping cost from factories to warehouses

Shipping Cost From Warehouses to Distributors (PKR per product)

As a part of the newly negotiated shipping cost, this data was also changed from its initial state during the process of developing this solution for the client. The same shipping company had the contract to ship products in a situation of transshipment. This data reflected the transportation cost from each warehouse to each distributor per product per piece. Figure 6 shows the initial shipping cost whereas Figure 7 reflects the revised shipping cost for the company.

				Distributor Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Quetta Warehouse	Bats	PKR 6.50	PKR 5.80	PKR 5.50	PKR 6.50	PKR 8.00
	Stumps	PKR 4.00	PKR 3.90	PKR 4.20	PKR 4.30	PKR 5.10
	Bails	PKR 2.75	PKR 2.20	PKR 2.60	PKR 2.30	PKR 2.90
Lahore Warehouse	Bats	PKR 6.00	PKR 5.50	PKR 5.50	PKR 6.00	PKR 5.50
	Stumps	PKR 4.25	PKR 4.00	PKR 4.00	PKR 3.90	PKR 4.50
	Bails	PKR 2.60	PKR 2.60	PKR 2.40	PKR 2.90	PKR 3.25
Peshawar Warehouse	Bats	PKR 6.00	PKR 6.50	PKR 7.00	PKR 7.00	PKR 5.50
	Stumps	PKR 3.90	PKR 4.35	PKR 4.45	PKR 4.80	PKR 4.00
	Bails	PKR 2.75	PKR 2.70	PKR 3.25	PKR 3.20	PKR 2.35
Karachi Warehouse	Bats	PKR 7.50	PKR 6.50	PKR 5.60	PKR 6.50	PKR 5.50
	Stumps	PKR 4.75	PKR 3.30	PKR 3.70	PKR 4.25	PKR 4.10
	Bails	PKR 3.00	PKR 2.60	PKR 3.00	PKR 2.60	PKR 2.40

Figure 6: Initial shipping cost from warehouses to distributors

				Distributor Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Quetta Warehouse	Bats	PKR 2.50	PKR 1.80	PKR 1.50	PKR 2.50	PKR 4.00
	Stumps	PKR 2.00	PKR 1.90	PKR 2.20	PKR 2.30	PKR 3.10
	Bails	PKR 1.25	PKR 1.70	PKR 2.10	PKR 1.80	PKR 2.60
Lahore Warehouse	Bats	PKR 2.00	PKR 1.50	PKR 1.50	PKR 2.00	PKR 1.50
	Stumps	PKR 2.25	PKR 2.00	PKR 2.00	PKR 1.90	PKR 2.50
	Bails	PKR 1.10	PKR 1.20	PKR 1.90	PKR 2.40	PKR 2.75
Peshawar Warehouse	Bats	PKR 2.00	PKR 2.50	PKR 3.00	PKR 3.00	PKR 1.50
	Stumps	PKR 1.90	PKR 2.35	PKR 2.45	PKR 2.80	PKR 2.00
	Bails	PKR 1.25	PKR 1.20	PKR 2.75	PKR 2.70	PKR 1.85
Karachi Warehouse	Bats	PKR 3.50	PKR 2.50	PKR 1.60	PKR 2.50	PKR 1.50
	Stumps	PKR 2.75	PKR 2.30	PKR 1.70	PKR 2.25	PKR 2.10
	Bails	PKR 1.50	PKR 1.10	PKR 2.50	PKR 2.10	PKR 1.90

Figure 7: Revised shipping cost from warehouses to distributors

Shipping Cost From Factory to Distributors (PKR per product)

Like other costs, this shipping cost data was also changed from its initial state due to the successful negotiation between the client company and the shipping company. Figure 8 indicates the initial shipping cost and Figure 9 indicates the revised shipping cost. This is the transportation cost from each factory to each distributor per product per piece.

				Distributors Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Karachi Factory	Bats	PKR 7.75	PKR 8.50	PKR 7.50	PKR 8.00	PKR 7.50
	Stumps	PKR 5.50	PKR 6.00	PKR 5.00	PKR 5.75	PKR 5.60
	Bails	PKR 4.40	PKR 4.50	PKR 3.75	PKR 3.30	PKR 3.85
Lahore Factory	Bats	PKR 8.00	PKR 8.50	PKR 8.50	PKR 7.50	PKR 7.00
	Stumps	PKR 5.25	PKR 5.95	PKR 5.20	PKR 5.50	PKR 5.10
	Bails	PKR 3.95	PKR 4.25	PKR 3.85	PKR 4.35	PKR 3.95

Figure 8: Initial shipping cost from warehouses to distributors

				Distributors Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Karachi Factory	Bats	PKR 5.75	PKR 6.50	PKR 5.50	PKR 6.00	PKR 5.50
	Stumps	PKR 3.50	PKR 4.00	PKR 3.00	PKR 3.75	PKR 3.60
	Bails	PKR 2.40	PKR 2.50	PKR 1.75	PKR 1.30	PKR 1.85
Lahore Factory	Bats	PKR 6.00	PKR 6.50	PKR 6.50	PKR 5.50	PKR 5.00
	Stumps	PKR 3.25	PKR 3.95	PKR 3.20	PKR 3.50	PKR 3.10
	Bails	PKR 1.95	PKR 2.25	PKR 1.85	PKR 2.35	PKR 1.95

Figure 9: Revised shipping cost from warehouses to distributors

Distributor Demand

Distributor's demand represents the requirements needed to keep the business running. The company receives this demand 45 days in advance from its distributors. It is also important to mention that the company can ship the distributor's demand 15 days in advance to ensure meeting this deadline and fulfilling their request. This was the requirement that caused the transshipment model to initially not find any feasible solution.

	Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Bats	30000	23000	15000	32000	16000
Stumps	20000	15000	22000	12000	18000
Bails	25000	22000	16000	20000	25000

Figure 10: Distributor demand

Warehouse Capacity

The company's warehouse capacity requirement was defined by the storage capacity of each warehouse and this constraint was included as an important part of the models that were used to find the optimal solution. This was the constraint that restricted the solely transshipment model from finding a feasible solution because warehouse capacity was less than distributors demand. Based on this information, it was proposed that an in-depth analysis be conducted to study the impact of increasing warehouse capacity at the Karachi and Lahore warehouses with the better negotiated shipping cost.

	Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse
Bats	35000	20000	30000	15000
Stumps	30000	25000	15000	24000
Bails	20000	20000	25000	20000

Figure 11: Warehouse capacity for the company

Factory Manufacturing Capacity

As was stated earlier, each factory's manufacturing capacity was introduced as a constraint after the initial model was developed. Since its introduction, this requirement has remained the same through out the model development life cycle. The following data shows the each factories manufacturing capacity per product.

	Karachi Factory	Lahore Factory
Bats	70000	50000
Stumps	47000	68000
Bails	49000	59000

Figure 12: Each factory manufacturing capacity

Chapter 2 -- Literature Review

The literature review for this field project was divided into two main components. The first component related to project management, whereas the second component is linear programming, which is the core essence of this project.

Project Management provides the tools that are essential for the success of any project in general and specially for a project of such magnitude. A project, as defined in the field of project management, consists of a temporary endeavor undertaken to create a unique product, service or result[1]. Whereas project management is comprised of a set of activities, that include planning, executing, and delivering successful results on a project.

The following topics present the literature surrounding project management and its implementation. These topics will cover how to structure a project, what it will take to control the project and what is needed for successful project management. The following literature is the result of in-depth reviews of books, journals, and websites which encompass the body of knowledge of project management.

Project Management

Since late 1960's, project management has been considered a discipline. Different societies in the different parts of the world were critical to the adoption of project management disciplines. The popularity of the discipline is now deeply rooted within different organizations and does fit well within the framework of business, government and the military. However, project management is still viewed by most organizations as a set of planning controls and techniques, rather than true management.

Project Management Definition

> "A project is a unique, finite undertaking with clearly-defined objectives, involving many inter-related tasks or activities and the contribution of a number of people working co-operatively under centralized control to produce a specified outcome or product within clearly-defined parameters of time, cost, and quality" [2].

The above definition of project management captures the essence of project management. The most important component of project management is the presence of a project manager, without which project management will not be successful in any organization. A project manager is the leader of all aspects of project execution and is responsible for each step and action related to the project. The tools of project management were utilized in this project to ensure that the project was successful.

Project management can also be defined by a hierarchal breakdown of finite steps that must be carried out for the project to be implemented successfully. This is commonly referred to as the work breakdown structure (WBS). "The WBS organizes and defines the

total scope of the project. The WBS subdivides the project work into smaller, more manageable pieces of work, with each descending level of the WBS representing an increasingly detailed definition of the project work" [1]. The lowest levels of tasks in the work breakdown structure are called work packages. These work packages can be scheduled, monitored, and controlled by the project manager.

Project Organization

There are three main types of project organization that are derived mainly from the organizations that initiate the projects. There is a client focused organization, where the project is integrated into the organizational structure that already exists. Another is the matrix organization, where the project manager pulls resources from the existing functional departments of the organization[3]. Third type of project organization is called project focused organization. In this type of organization the project team exists as a self-contained group with its own resources. For this field project, the project focused organization is the closest fit. The author can lend help to other company in order to meet their objective of finding the optimal shipping cost by utilizing linear programming models.

It is widely accepted around the world that the use of project teams increases the level of commitment of the team members, especially when dealing with projects that are leading change within an organization. But there is a debate among the experts as which type of team structure produces the best results. One researcher found that in studying the success of 546 projects that projects relying on the functional organization were less successful than those which used a balanced matrix, project matrix, or project team[4]. Over the years organizations have found that the above statement holds true that having a dedicated project team does increase the level of commitment from team members since they are stakeholders in the project. Each member has a component of the project that they own and for which they are responsible. The author will be a team member of this project team (unfortunately, a single member team), will be committed 100% to the project, and will be independently responsible since this project could bring change to the whole organization.

Project Goals and Objectives

Project goals and objectives are two faces of a coin and can not be separated from each other. The main objectives of any project require meeting the three constraints of cost, time, and quality which are referred to as the triple constraint in project management terms. According to the standards in different organizations, a project cannot be considered successful without meeting all three of these constraints. As shown in Figure 13 below; the triple constraint is represented by a triangle with one of the constraints at each corner,

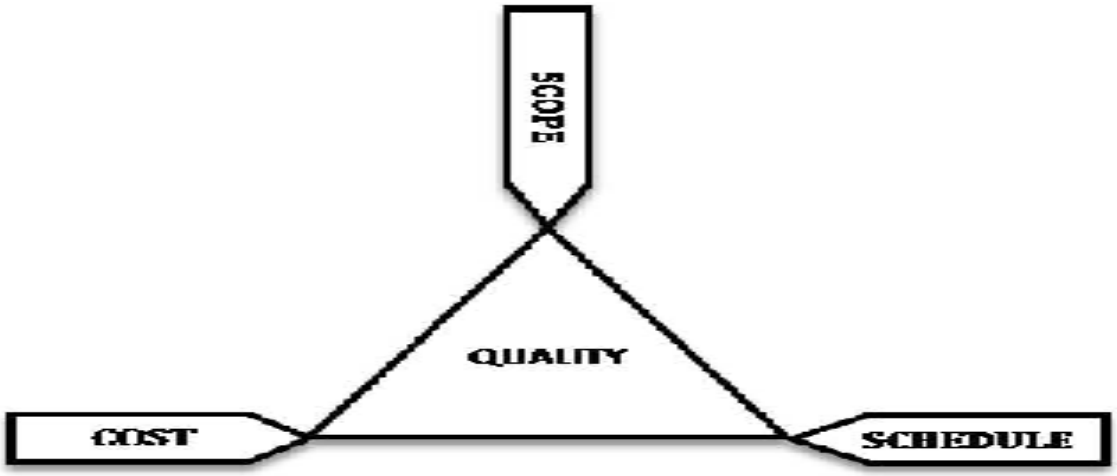

Figure 13: Triple constraints

Some researchers argue that the people involved in the project should be considered as a part of the triangle. According to that argument, people involved in the project (project team and other stakeholders) influence the completion of each of the constraints and the overall success of the project. However, in its simplest form this is representative of the ultimate goal of a project. If one of the legs of the triangle does not meet the goal it will invariably impact one of the other constraints.

The outcome of triple constraints is to gain quality by defining a feasible and scalable scope within the limits of cost (budget) and scheduling (time). As a field project course requirement, these triple constraints are of high importance where success or failure of a project is based on these constraints with the focus on the quality of the work done.

All projects are performed and delivered under some constraints and some of the very common and agreed upon constraints that we deal for every project are these triple constraints. If we compare and contrast the interaction of these triple constraints we will know that one side of the triple constraints triangle cannot be changed without affecting the others. All three constraints are often competing constraints: if the scope of the project increases it typically means increased time and increased cost. If the time constraint is tightened, it could result in reduced scope and an increase cost/budget. If we try to reduce the cost/budget, it could mean an increase in the time schedule (meaning less resources allocated and lengthened time to complete the project) and reduced scope.

Among these constraints, cost/budget tends to take priority over others in the real world due to the current financial situation. For this project (as a field project), the highest priority is the time factor, followed by scope. The third constraint “Cost/Budget” is defined as “Efforts” to complete the triple constraints concept for this project. Therefore we experienced the impact of reducing time/schedule directly to the scope of the project,

which results in increased efforts on a project. We derive quality from the scope of the project based on how much time is spent, plus the perceived level of effort in order to determine the rest of the constraints.

Project Management Factors for Success and Failure

During the long history of project management, there has been much research performed in the area of analyzing why projects succeed or fail. The simple answer for success or failure is that all projects have some risk [6]. This uncertainty involved in projects is the usual place of blame by team members and project manager for project failure. If the project is a success the project team considers the uncertainties to have been non-factors in the completion of the project.

In his writing, David Cleland[4] did agree that a project can be successful in meeting the constraints, while possibly not satisfying the customer's needs. In this field project the customer needs are what is driving the project and therefore, meeting customer's requirement is a high priority. Cleland also defined a successful project as meeting the triple constraint and integrating the objectives into the customer's organization to contribute to the customer's mission. If this is true, all projects connect to the mission or vision of an organization to ensure that ultimately the project is contributing to the organization's goals.

Common success factors for projects can be found in many of the writings of different authors and experts even though they may not agree on the order of factors. Common factors for project success and impact on this project include:

- Upper management support – This project had the full support of upper management, who accepted the proposal and agreed upon working independently to accomplish the task on time, within scope and budget (efforts).
- Customer involvement - It wouldn't be possible to succeed without customer involvement. Involvement included receiving timely feedback and information needed to complete this project.
- Experienced project manager – The author has experience managing different projects. These project management skills were polished which allowed effective interaction with the customer and others.
- Clearly defined goals –Even though the customer might not be able to clearly define goals at the start, by working together as a team, goals refined clearly and simply. Clear goal definition worked as a roadmap for this project.
- Defined scope – Requirements or expectations can vary over the life of any project. It is a responsibility of project manager to keep the scope of the project clearly defined and attainable to work successfully on the project.
- Standardized procedures –All standard processes and procedures in this project were followed whether they were specific to project management or linear programming modeling. A project plan was developed and was strictly followed

to clear all obstacles and push the project towards success. On the other hand, algebraic formulation had to be completed prior to creating the models and required manual verification in addition to using all seven fundamental steps of linear programming.

- Technical expertise – Technical expertise in linear programming and project management was acquired thru engineering management classes at University of Kansas. Technical expertise in the area of project management was polished through work experience and was used in this project.
- Great communication – It is important to have good communication between all the stakeholders of the project. In this project, the communication lines were open and easy to access by all stakeholders. That helped in handling tough situations that were faced during the course of the project. Communication proved to be the life line for this project and helped in launching a successful project.
- Careful team selection – For this project, work was undertaken solely. However, direction and guidance outsiders such as the project committee, was utilized. For larger projects it is essential to select good team members to ensure success of a project.

Looking at the major causes of the failure, according to the data collected over a three-year period from over 400 project leaders leads to the following list of failure causes[7]:

- Insufficient upper management support
- Customer and management changes
- Technical complexities
- Staffing problems
- Unrealistic project plans
- Trouble detecting problems early
- Poor front-end planning
- Underestimated project scope
- Weak project leadership
- Communication issues

All stakeholders of the projects and experts in project management field are well aware of the above mentioned failures, and are echoed by many different renowned authors around the world. The above mentioned lists of failure causes may vary slightly but all have the same undertones. One common failure that all agree on is that upper management support is critical for any project leading change. To validate the above statement the only reasoning that came across in the literature review is that everything boils down to budget and the payoff the company will get from that particular project with the fact that nothing can be approved without upper management support.

Linear Programming

It's important to understand some basic concepts that are used in linear programming before proceeding to the project research. This requires an understanding of these terminologies in mathematics terms and therefore, many references to mathematical equations and notations were exposed in the process of exploring the linear programming literature.

Problem Solving

Since this project is about solving the problem faced by client, it was important to understand the definition of problem solving first, so that proper roles can be assigned for this project. By reviewing different definitions through different sources it is clear that problem solving is a process in which we have to identify the problem and then take measures to resolve the situation or gap or problem.

To solve a problem, one must identify the problem and one way is to understand the difference incurred between reality (where we stand today) and the goal (what we want to accomplish). As the scope of this project mentioned, currently the client didn't have a predictable approach to identify or minimize manufacturing and shipping costs. They only had a desire to have a systemic way to identify such optimal solutions. Therefore the problem in this project is clear and to solve that problem linear programming models were utilized as a problem solving technique.

Decision Making

Based on collection of literature reviews, decision making is also a process (collection of steps) that leads to a point of making a decision. During this project different steps were taken in making sound decisions related to this project. The client has to be involved in this process of decision making due to the fact that the end decision relies heavily on them.

Optimization

Optimization refers to a field of applied mathematics whose principles and methods are used to solve quantitative problems in disciplines including physics, biology, engineering, and economics. Questions of maximizing or minimizing functions arising in the various disciplines can be solved using the same mathematical tools. In a typical optimization problem, the goal is to find the values of controllable factors determining the behavior of a system that maximize profit or minimize cost. Linear programming was developed to solve optimization problems involving two or more input variables. The simplest problems involve functions of a single variable and may be solved with differential calculus.

Linear Equation

A linear equation is an algebraic equation in which each term is either a constant or the product of a constant and (the first power of) a single variable. Linear equations can have one or more variables. Linear equations occur with great regularity in applied mathematics. While they arise quite naturally when modeling many phenomena, they are particularly useful since many non-linear equations may be reduced to linear equations by assuming that quantities of interest vary to only a small extent from some "background" state[5].

Constant

A constant in mathematics means fixed value (a number) that does not change, over time. In many discussions the term “constant” is a simple opposite of "variable", but in mathematical dialect a mathematical variable may sometimes also be called a constant.

Variable

A variable is usually used as an opposite of a constant. A variable is a symbol that stands for a value that may vary and need not be numeric. In a spreadsheet, the variable *last name* might stand for a customer's last name. These concepts of constants and variables are basic to all modern mathematics, science, engineering, and computer programming fields.

Non-Linear Systems

A nonlinear system is a system which is not linear (as the name mentioned), that is, a system which does not satisfy the superposition principle, or whose output is not proportional to its input. Less technically, a nonlinear system is any problem where the variable(s) to be solved for cannot be written as a linear combination of independent components. A non-homogeneous system, which is linear apart from the presence of a function of the independent variables, is nonlinear according to a strict definition, but such systems are usually studied alongside linear systems, because they can be transformed to a linear system of multiple variables[5].

Nonlinear problems are of interest to physicists and mathematicians because most physical systems are inherently nonlinear in nature. Nonlinear equations are difficult to solve and give rise to interesting phenomena such as chaos. The weather is famously nonlinear, where simple changes in one part of the system produce complex effects throughout.

Model

Models in real life can be presented in different forms; it can be an object or a situation. When we talk about models, authors[13] distinguish models in three main classifications:

- Iconic Model: As the name predict, its physical look-alike representation of some specific entity. For example; a house.
- Analog Model: The representation of entities of a system by analogue entities pertaining to the model (e.g. through diagrams).

- Mathematical Model: This class of modeling is the representation of entities of a system through symbols. Symbols can be mathematical or logical or ad-hoc.

Linear Programming Definition

In mathematics, linear programming (LP) is a technique useful for guiding quantitative decisions in business, industrial engineering, and to a lesser extent the social and physical sciences. Informally, linear programming determines the way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model and given some list of requirements represented as linear equations.

- Constraints -- The first step in model formulation is the recognition of the constraints. In this project, we first identified the constraints that will be used to restrict the decision variable. From the project point of view some of the constraints are; Warehouses Storing Capacity Limits, Distributors Demand Limits, Factories Manufacturing Limits, Warehouses Distribution Limits and Factories Shipment limits.
- Objective Functions – The second feature of the linear programming is a single performance measure to be maximized or minimized. In our case the objective function is to MIN the manufacturing and shipping cost for the company by finding the optimal cost solution to their transportation/transshipment model.

Transportation Model

In simple words, the term transportation model is a linear programming model, which finds the least expensive way (minimal cost) of fulfilling the demands at X destination, which are the distributors in our situation with supplies from the Y origins locations. In our project we define a two layer transportation model, meaning the origins can be the factories or the warehouse and the destinations are the distributors. It all depends on how a model is developed with the provided data. In this transportation model, it is easy to see that this model goes directly from origin(s) to destination with no intermediate layer.

If all of the supplies and demand in a transportation model have integer values, the optimal values of the decision variables will also have integer values[9].

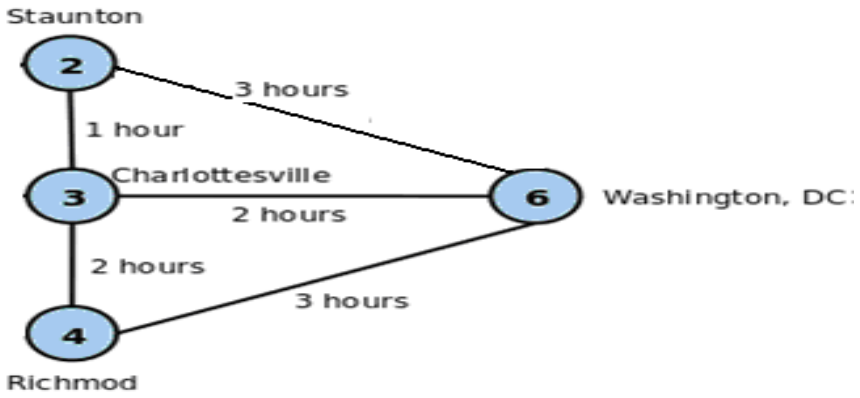

Figure 14: Example transportation model

Transshipment Model

This is another type of linear programming model, which also finds the least expensive way of fulfilling demand at X destination with supplies from the Y or Z origins. In this project, there is a possibility that the supplies can be shipped from the factories and/or from warehouses. A transshipment model is a transportation model with intermediate destinations between sources and destinations.

Example: Goods are often transported from manufacturing plants to distribution centers or warehouses, then finally to stores. But for our project, the scope is defined to have manufacturing at the factories and the goal is to reach the distributors. So, delivering goods to shops is not considered during the analysis of our project.

Constraints involving sources and destinations are similar:

- Everything leaving sources must not exceed supplies.
- Everything entering destinations must not exceed demand.

New constraint: everything entering an intermediate point must equal everything leaving the intermediate point. Review Figure 15[10], below, as an example of a transshipment model.

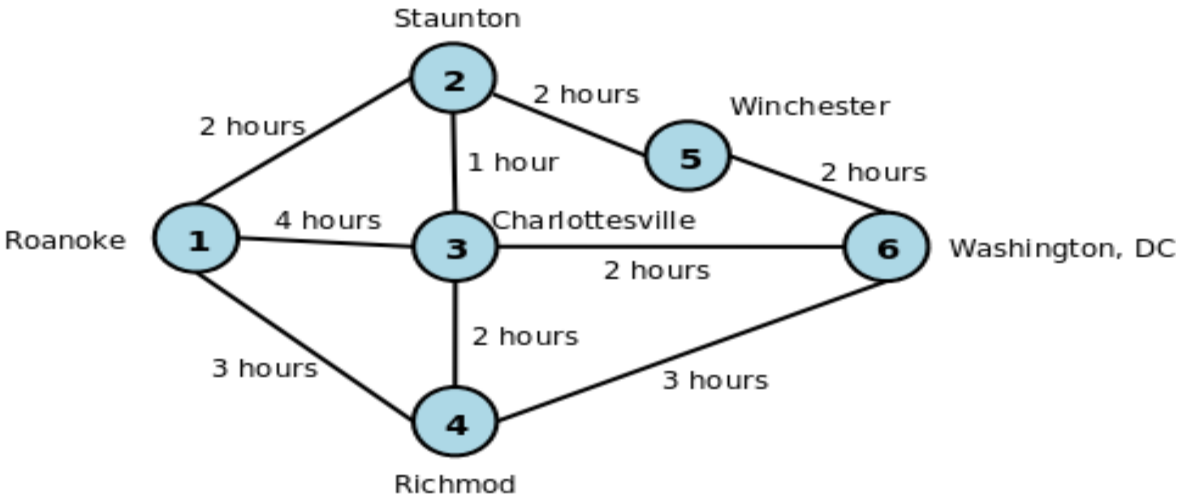

Figure 15: Example transshipment model

Chapter 3 -- Research Procedures

Project Planning:

Work Breakdown Structure

Each project plan has to have a work breakdown structure (WBS) to show what tasks are performed in this project and also indicate the time line for each task. This project's work breakdown structure was divided into four main tasks:

1) Initiate Project – This task basically focused on the development and publishing of scope. An important sub-task was to get approval for the defined scope. This task was the foundation for the whole project.
2) Plan a Project – This task was actually to plan the staffing, scheduling and budgeting in alignment of the defined scope. Another important sub-task was to collect data and validate it through different resources.
3) Develop and Control a Project – This task was for the actual development and testing of the models and was broken into different sub-tasks to handle this project.
4) Close a Project – This task will not be completed for this paper, but will be important and proper documentation is required by the client.

The complete WBS for this project is attached as Appendix A with this report.

Risks and Assumptions

The following risks and assumptions were discussed and were not considered in building this solution for the SGMC client:

- The biggest risk our client faces is domestic instability. The assumption is that this is a normal situation and that the workforce is available to get the job done to meet the distributor demand.
- In today's world, everyone including SGMC is also under an economical crunch but from our modeling point of view the assumption is that there is economical stability. We assume that the client was able to get the proper rates from the shipping company as well as for the material and labor use in the manufacturing process.
- Another risk that our client faces is the labor union issue. From our modeling point of view we have normal working environment of the company, to meet the demand of the distributors.
- Transportation risks, as all routes are safe and sound for the supplies to reach the distributors. Insurance for shipping goods is provided as a cost per item and it is not a separate cost.
- Good will of the company is good with the shipping company and the distributors.

Building Linear Programming Models

The seven basic steps of building a linear programming model as learned during EMGT coursework were utilized. These steps are:

1. Identify Purpose/Functionality Needed
2. Collect Necessary Information
3. Formulate Model
4. Validate Model
5. Exercise Model
6. Report Results
7. Implement Model for Ongoing Use

Identify Purpose/Functionality Needed

The main purpose of this model was to find the minimal cost of manufacturing and shipping the company's products to its nationwide customers. It was also identified what different functionalities were needed to accomplish building this model, which included functionality to make sure that the required demand of distributors was met, warehouse capacity is not overrun and manufacturing capacity of factories equals need. It was also realized that manufacturing and shipping charges will significantly impact this model. These charges were identified by company officers early on and were revisited and changed later due to the long term contract possibility with the transportation company.

Collect Necessary Information

This step was difficult due to the fact the company is located overseas. For every piece of information collected, project costs increased or time was extended. The linear programming concept was not well understood among the work force or management and was therefore it was difficult to collect data. Data that was collected was subject to continuous change which proportionally caused the modeling requirements to change. After many meetings and updates, all necessary data was successfully collected. Necessary data included shipping charges, manufacturing changes, distributor's demand, warehouse capacity and factory manufacturing capacities.

Formulate Model

During the formulation of this linear programming model, the algebraic formulations were completed first and then translated into linear programming models using Microsoft Excel Solver (standard version). All algebraic formulations are attached with this report, in Appendix C. The major reason to complete the algebraic formulations prior to each model was to understand how to create the model and fulfill all requirements, which is also first step in the process of building models.

Validate Model

Since there was no historical data available in the company, model validation was completed against manual validation for all manufacturing and shipping cost. Models developed after the revised shipping cost were validated against the earlier developed model developed based on the initial information provided.

Exercise Model

Models were exercised successfully with the data provided by company officers. As the data was changing, newly developed models indicated change in the cost as well. As new constraints were added, models did not show the same optimal solutions indicated by earlier models. This also proves what was learned from our linear programming studies. If there was no change in distributors demand, numbers of product manufactured remained the same in our earlier models, but after we added the constraints of factories total manufacturing capacity which relates with factories output, manufacturing cost changed for that model. In the later models where no new constraint was added for factories the manufacturing cost remain unchanged. All the models were built and executed successfully resulting in an optimal solution satisfying all constraints that were defined for these linear programming models.

Report Results

All models that were built provided the optimal solutions, like the initial model which shows its shipment transportation model flow. Based on the information provided in the early period of this project, the model recommended that the company did not need to have warehouses and it would be cheaper to transport products directly from the factories to the distributors. Even with the added constraint of factories manufacturing capacity, the fact remains the same that the company does not need the warehouses. But the incurred cost of manufacturing and shipping the products to the company changed with this model by adding the new constraint.

The company revealed that the new shipping cost resulting from negotiation with the shipping company. When the new shipping charges were run through the model, it indicated the use of warehouses and also indicated a change in the shipping cost for the company. Later, a company officer mentioned that the company was actually using a transshipment model flow instead of an integrated model. But when the new model was built based on new flow it was not able to find any feasible solution. Investigation through manual verification indicated that, that the capacity of the warehouses was less than the demand from the distributors.

Implement Model for Ongoing Use (if needed)

For ongoing use, the following steps were taken when building linear programming models for the company:

- For the purpose of the future use, a separate sheet is provided to update any input data, instead of changing the actual model spreadsheet. This gives flexibility to the company officers to change input data as it best fits the situation.
- All agree that algebraic formulations are very important in the creation of linear programming models; therefore an algebraic formulation for each model was created to understand how the variables and constraints will be related to build a successful model.
- Defined warehouse capacity constraints to figure out how much shipped to a particular warehouse for the transshipment models.
- Defined distributor's demand constraints to make sure that company is producing enough product types to fulfill the demand. This way the company will be manufacturing only what it needs in order to minimize manufacturing and shipping costs.

Chapter 4 -- Results

The models were built and exercised with the initial information provided by the company officers. Relevant information was the company's warehouses storing capacity, distributor's demands, manufacturing cost, shipping cost from factories to warehouses, factories to distributors and from warehouses to distributors. The first constraint for this model was that all products that are manufactured in the factories have to be shipped. Another constraint was that all shipments to each warehouse had to be shipped to distributors, meaning warehouses can not be used to hold products for backlog. Based on this information the situation most fit with transportation linear modeling. According to the model:

- Total manufacturing cost = PKR 27,773,000
- Total shipment cost = PKR 01,834,400
- Total cost incur to the company = PKR 29,607,400

The model also revealed that the company will manufacture the following quantity of each product based on factory:

- Lahore Factory --- Bats = 116000
- Lahore Factory --- Bails (in pair) = 108000
- Karachi Factory --- Stumps (in pair) = 87000

But the most interesting fact from this model was that the company in reality does not need any warehouses. Due to higher shipping costs that the company will incur, the model showed that it is cheaper to ship directly from factories to distributors and have a simple transportation model. It seems like a just-in-time manufacturing and shipping process from the outcome of the model. The model was successfully exercised and validated with all the constraints satisfied.

After reviewing the initial model with the company's officer, a new piece of information was provided that each factory also has a manufacturing capacity limit. Therefore this new piece of information was added to the earlier model with initial shipping cost. Now the cost for the company for manufacture and ship change and the new costs were shown as follows by the new model.

- Total manufacturing cost = PKR 29,449,000
- Total shipment cost = PKR 01,773,500
- Total cost incur to the company = PKR 31,222,500

This model also reiterates the first recommendation from the initial model that the company did not need any warehouses and it is cheaper to directly ship products from factories to warehouses.

The new results and models were reviewed with the company officials and after a couple of weeks, the company's manager came back with new and improved shipment charges. The manager mentioned that the company negotiated new prices and the possibility is that these transportation charges will be locked for next few years. The new shipping charges were inserted in the model with the factories manufacturing capacity and according to the new model:

- Total manufacturing cost = PKR 29,449,000
- Total shipment cost = PKR 01,076,600
- Total cost incur to the company = PKR 30,525,600

According to this model the manufacturing cost incurred by the company will be unchanged although the company's warehouses will be used to ship its products directly to the distributors from its factories. This was a true integrated transportation and transshipment model. This model was successfully exercised and validated with all the constraints satisfied.

During a conversation with the company's Chief Planning Officer (CPO), it was mentioned that all the products were manufactured in the company's factories fifteen days in advance of the distributor's demand date. As an explanation given, the orders are received 45 days in advance and the company shipped the products 15 days in advance to its warehouses in order to get orders to distributors on time. This new situation (piece of information) changed the whole prospect of earlier models. Now it seems like a simply transshipment model where products are shipped to company's warehouse and then distributed from warehouse to the distributors. The new information was integrated into the model and constraints where removed that where not necessarily related to shipment from factories to distributor. This new model could not find a feasible solution. Upon investigation it was found out (by manual verification) that the demand of distributors is higher than the warehouses capacity.

Currently company is reviewing this new situation and wants to have some further analysis to determine whether they should buy another warehouse or should extend the existing ones. One option that company wants to explore is extension of its current warehouses capacity. The company officer came back and stated that they have an opportunity to double the capacity of their Karachi and Lahore warehouses. As a new enhancement, new Karachi and Lahore warehouse capacity was plugged in to the model for validation. According to the model total shipping cost incurred by the company will be PKR 1,157,250. Whereas the manufacturing cost to the company will remain the same.

- Total manufacturing cost = PKR 29,449,000
- Total shipment cost = PKR 01,157,250
- Total cost incur to the company = PKR 30,606,250

Extension to Karachi and Lahore warehouses seems like a good option since these warehouses are closer to the company's factories, but further analysis have to be done at the later stage as it is out of scope for this field project.

Chapter 5 -- Conclusion

Based on our Excel model creating both transportation and transshipment modeling structures, it seems like the company does not need to have warehouses from the original shipping prices. But later models based on transshipment modeling revealed that the company will not only need the warehouse but will also have to increase their warehouses capacity or have to add a new warehouse. Currently the company is looking into this option, but it appears that the company might be more interested in boosting their Karachi and Lahore warehouse capacity. From all the models based on the shipment prices, the company's shipping cost varies. Therefore the company requires clear information of what it will cost per product per piece to get a better picture of what it will cost the company to ship its products to the distributors.

This project produced a model that can be a very useful and powerful tool to the company, provided it is used in determining the optimal solution for the manufacturing and shipping cost. The company is currently reviewing and understanding this linear model and has showed interest in having other models for their product production line, marketing and scheduling to determine the best optimal solution.

Chapter 6 -- Recommendations

The following are the highly recommended steps or future enhancements that will benefit the company based on the information and experience gained from this project.

- It is highly recommended that a model be developed which includes products of all three quality tiers for the purpose of making final decisions regarding product manufacturing and distribution.
- A high priority recommendation for the company is to consider transforming into a transportation model. Initial models recommended this option, but as more constraints were added, the model changed to a transshipment model. Future analysis and efforts are required to explore this opportunity.
- It is highly recommended to negotiate a better shipping cost and lock that for a period because as the models predict that this variance (shipping cost), can change not only the model but it can impact the optimal solution.
- As a proposal, based on the data provided, extensions of Karachi and Lahore warehouses to increase storing capacity can benefit the company. But before the company implements this proposed solution, a complete in-depth analysis of the sensitivity reports of the proposed model will be required to understand the different variances and their impact to the model and to determine the feasibility.
- The company might also look into owning the shipping process by buying and maintaining the fleet. A whole new study needs to be conducted to make use of the available information regarding shipping cost. If owning and maintaining this shipping process costs less than the negotiated shipping cost in a mid term period, then it might be an option. But there are few other related items to consider:
    - Time value in maintaining the fleet
    - Insurance plus the maintenance cost
    - Employee cost
- It will also be beneficial to the company to look into a scheduling optimization for their workforce. This can help in reducing the manufacturing cost that will directly contribute to optimal solutions of these models. The only precaution is that this scheduling model will require data which is not easy to extract based on the current processes of the company. New technologies can straighten these processes and will help in effectively utilizing the company's workforce.
- These models are just a way to predict the optimal solutions; the company should review all data and inputs plus other information that were not shared before making any decision.
- Due to the requirement and nature of the project plus the timeline available, Microsoft Excel Solver (standard version) was used to build the requested linear programming model. Therefore some limitations were experienced on how the model was built. For example the number of constraints used can be a constraint of using Microsoft Excel Solver (standard version). Therefore it is recommended that the model should be transferred to a premium version of Microsoft Excel Solver or some other tool that can handle this in a more efficient way in the future.

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Appendix A

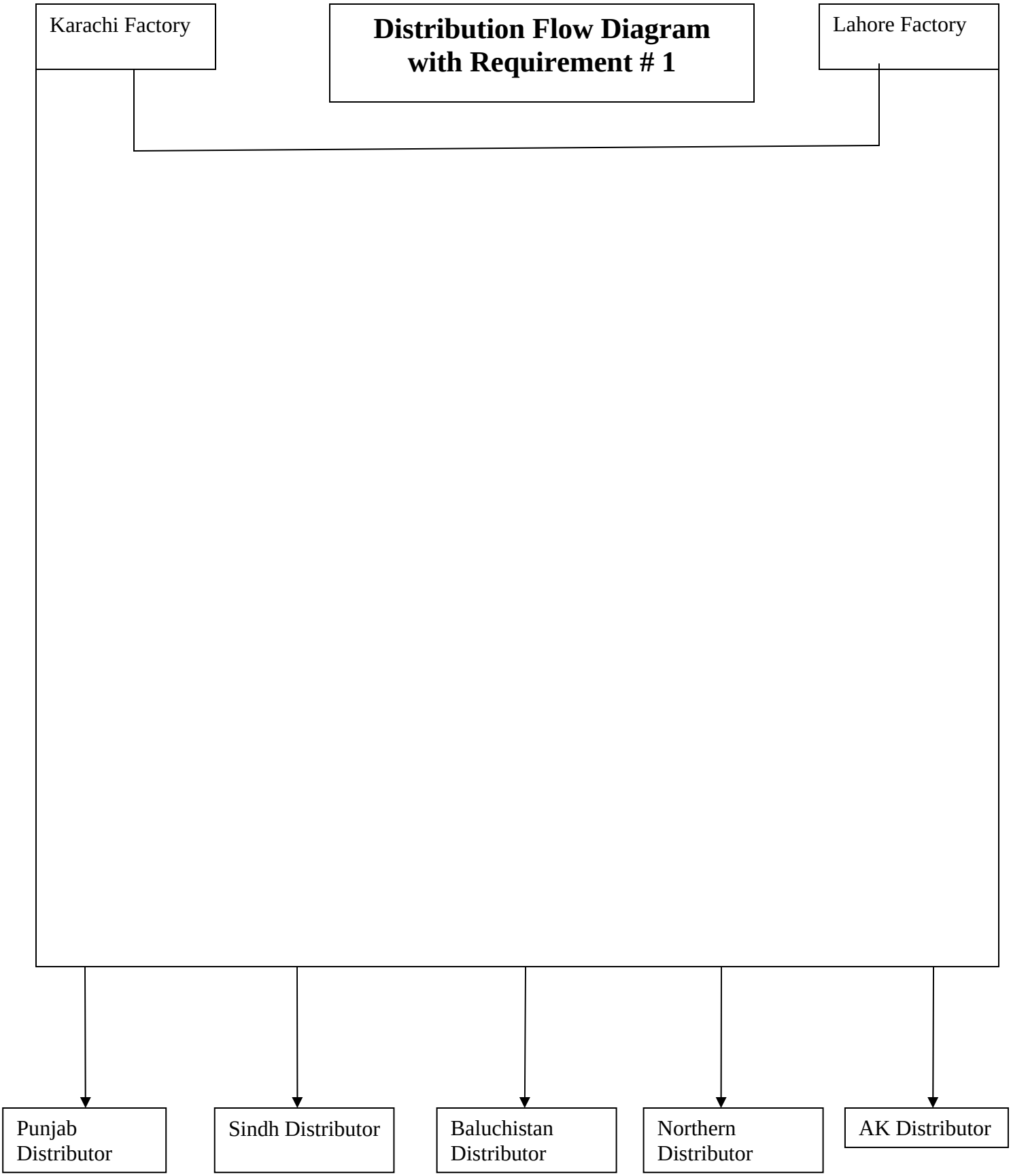
Work Breakdown Structure:

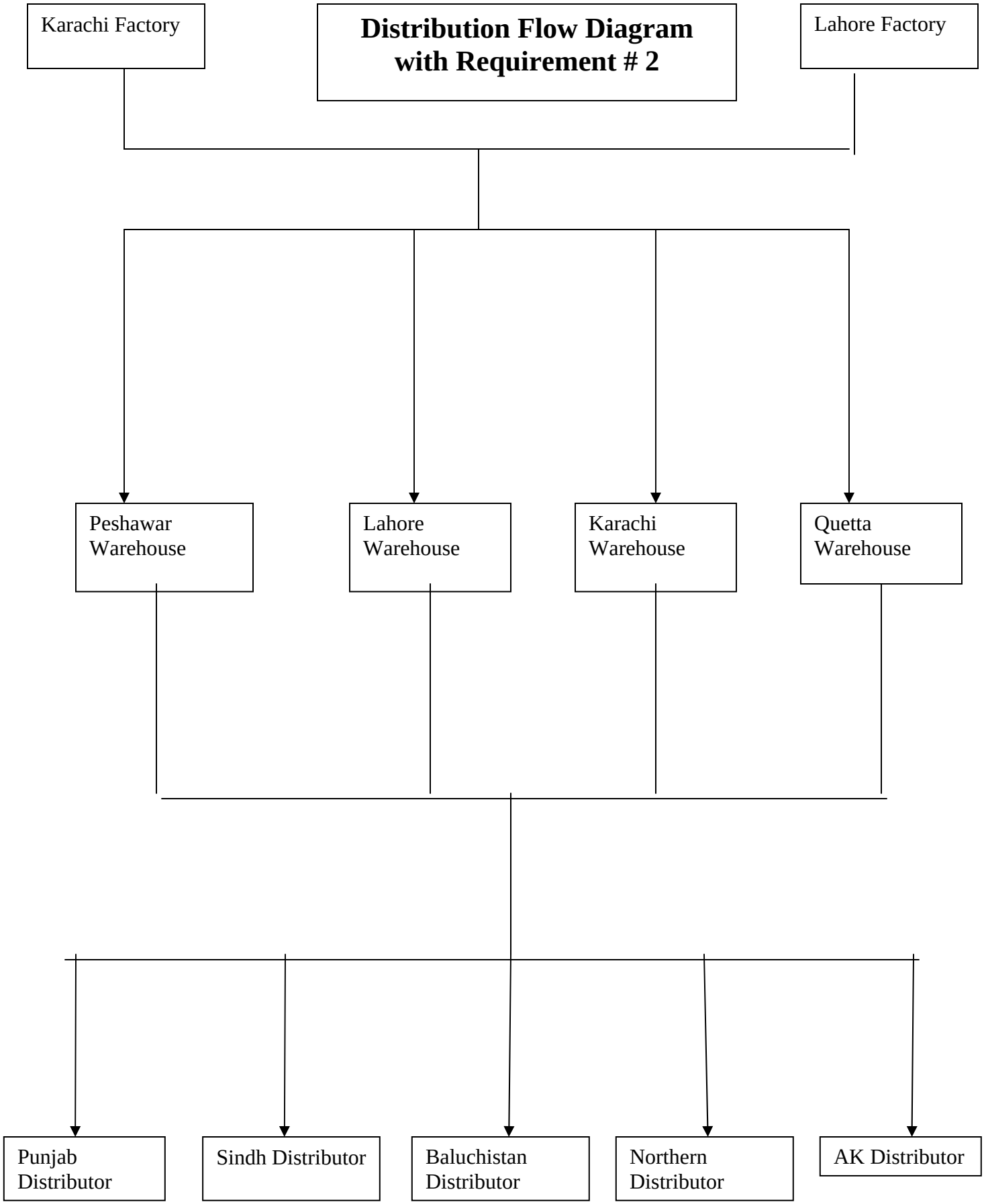
		Name	Duration	Start	Finish	Complete	Predecessors	Resource Names
1		EMGT 835 Field Project	118 days?	11/3/08 8:00 AM	4/15/09 5:00 PM			
2	✓	Initiate Project	49 days?	11/3/08 8:00 AM	1/8/09 5:00 PM	☑		
3	✓	Develop Project Proposal	49 days?	11/3/08 8:00 AM	1/8/09 5:00 PM	☑		
4	✓	Define Scope	4 days?	11/3/08 8:00 AM	11/6/08 5:00 PM	☑		
5	✓	Define Requirements	10 days?	11/3/08 8:00 AM	11/14/08 5:00 PM	☑		
6	✓	Identify High-Level Roles	5 days?	11/3/08 8:00 AM	11/7/08 5:00 PM	☑		
7	✓	Identify High-Level Control Strategies	20 days?	11/3/08 8:00 AM	11/28/08 5:00 PM	☑		
8	✓	Finalize Proposal and Gain Approvals	9 days?	12/1/08 8:00 AM	12/11/08 5:00 PM	☑		
9	✓	Consolidate and Publish Project Proposal	11 days?	12/15/08 8:00 AM	12/29/08 5:00 PM	☑		
10	✓	Hold Review Meeting	2 days?	1/1/09 8:00 AM	1/2/09 5:00 PM	☑		
11	✓	Revise Project Proposal	4 days?	1/5/09 8:00 AM	1/8/09 5:00 PM	☑		
12	✓	Gain Approvals	1 day?	1/8/09 8:00 AM	1/8/09 5:00 PM	☑		
13	✓	Plan Project	50 days?	11/3/08 8:00 AM	1/9/09 5:00 PM	☑		
14	✓	Develop Work Plan	50 days?	11/3/08 8:00 AM	1/9/09 5:00 PM	☑		
15	✓	Develop Work Breakdown Structure	50 days?	11/3/08 8:00 AM	1/9/09 5:00 PM	☑		
16	✓	Develop Project Staffing Plan	1 day?	11/3/08 8:00 AM	11/3/08 5:00 PM	☑		
17	✓	Develop Project Schedule	50 days?	11/3/08 8:00 AM	1/9/09 5:00 PM	☑		
18	✓	Develop Project Budget	50 days?	11/3/08 8:00 AM	1/9/09 5:00 PM	☑		
19	✓	Finalize Project Plan and Gain Approvals	50 days?	11/3/08 8:00 AM	1/9/09 5:00 PM	☑		
20		Execute and Control Project	68 days?	1/12/09 8:00 AM	4/15/09 5:00 PM			
21	✓	Design Framework	35 days?	1/12/09 8:00 AM	2/27/09 5:00 PM	☑		
22	✓	Define Models and activities	5 days?	1/12/09 8:00 AM	1/16/09 5:00 PM	☑		
23	✓	Design Models	31 days?	1/12/09 8:00 AM	2/23/09 5:00 PM	☑		
24	✓	Design Solution tool	35 days?	1/12/09 8:00 AM	2/27/09 5:00 PM	☑		
25	✓	Build the Framework	15 days?	3/3/09 8:00 AM	3/23/09 5:00 PM	☑		
26	✓	Write the framework data	9 days?	3/3/09 8:00 AM	3/13/09 5:00 PM	☑		
27	✓	Review framework data for quality	4 days?	3/10/09 8:00 AM	3/13/09 5:00 PM	☑		
28	✓	Build Models Prototype	6 days?	3/16/09 8:00 AM	3/23/09 5:00 PM	☑		
29		Test the Framework	16 days?	3/23/09 8:00 AM	4/13/09 5:00 PM			
30	✓	Test usability of Models	7 days?	3/23/09 8:00 AM	3/31/09 5:00 PM	☑		
31	✓	Test usability of solution	7 days?	3/23/09 8:00 AM	3/31/09 5:00 PM	☑		
32		Adjust framework based on user feedback	2 days?	4/10/09 7:00 AM	4/13/09 5:00 PM			
33		Implement Framework	3 days?	4/13/09 7:00 AM	4/15/09 5:00 PM			
34		Move framework to production environment	3 days?	4/13/09 7:00 AM	4/15/09 5:00 PM			
35		Announce availability of framework	1 day?	4/15/09 7:00 AM	4/15/09 5:00 PM			
36		Close the Project	1 day?	4/15/09 7:00 AM	4/15/09 5:00 PM			
37		Conduct Post-Project Review	1 day?	4/15/09 7:00 AM	4/15/09 5:00 PM			
38		Celebrate	1 day?	4/15/09 7:00 AM	4/15/09 5:00 PM			

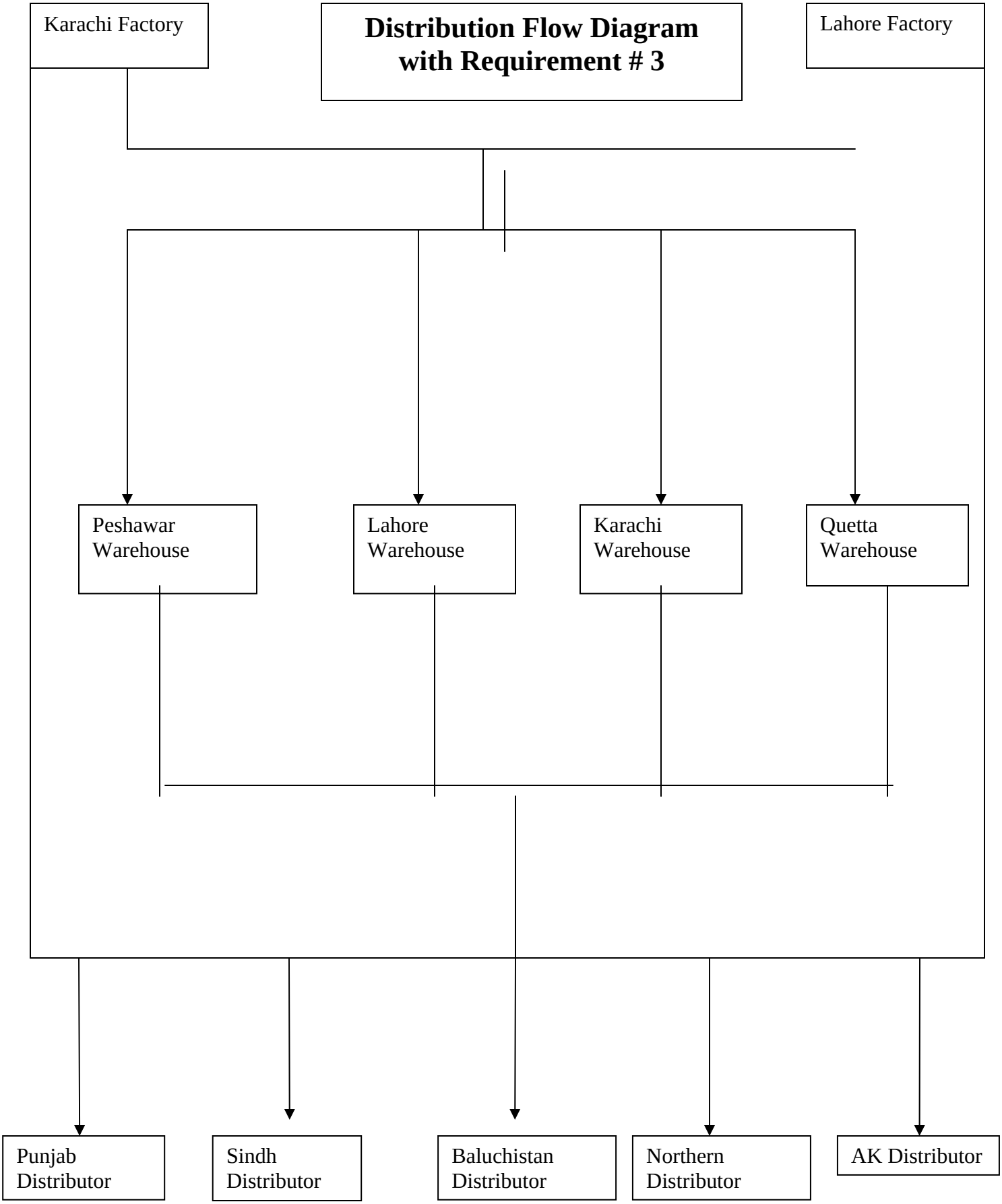
Appendix B

Transportation and Transshipment Models Flow Charts:

Distribution Flow Diagram with Requirement # 1




Distribution Flow Diagram with Requirement # 2
Karachi Factory
Lahore Factory
Peshawar Warehouse
Lahore Warehouse
Karachi Warehouse
Quetta Warehouse
Punjab Distributor
Sindh Distributor
Baluchistan Distributor
Northern Distributor
AK Distributor


Distribution Flow Diagram with Requirement # 3
Karachi Factory
Lahore Factory
Peshawar Warehouse
Lahore Warehouse
Karachi Warehouse
Quetta Warehouse
Punjab Distributor
Sindh Distributor
Baluchistan Distributor
Northern Distributor
AK Distributor

Appendix C

Algebraic Formulation for Models with Original Shipping Charges

Algebraic Formulation with Initial Shipping Cost

LET:

A_i $\equiv$ # of bats manufactured in factory i; where i = k, l
B_i $\equiv$ # of Stumps manufactured in factory i; where i = k, l
C_i $\equiv$ # of bails manufactured in factory i; where i = k, l
D_{ij} $\equiv$ # of bats shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
E_{ij} $\equiv$ # of Stumps shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
F_{ij} $\equiv$ # of bails shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
G_{ij} $\equiv$ # of bats shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
H_{ij} $\equiv$ # of Stumps shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
I_{ij} $\equiv$ # of bails shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
K_{ij} $\equiv$ # of bats shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
L_{ij} $\equiv$ # of Stumps shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
M_{ij} $\equiv$ # of bails shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
N_{ij} $\equiv$ # of bats received from factory i to warehouse j; where i = k, l; j = q, k, l, p
O_{ij} $\equiv$ # of Stumps received from factory i to warehouse j; where i = k, l; j = q, k, l, p
P_{ij} $\equiv$ # of bails received from factory i to warehouse j; where i = k, l; j = q, k, l, p

O.F.

MIN

$$(150A_k+95B_k+45C_k+130D_l+99E_l+41F_l)+(5.5D_{kq}+4E_{kq}+2.25F_{kq}+6.5D_{lq}+4.25E_{lq}+2.90F_{lq})+(5.5D_{kl}+3.75E_{kl}+2.75F_{kl}+5.3D_{ll}+3.8E_{ll}+1.9F_{ll})+(6D_{kp}+4.25E_{kp}+2.5F_{kp}+5.5D_{lp}+4E_{lp}+1.95F_{lp})+(5.2D_{kk}+4.25E_{kk}+2.3F_{kk}+5.2D_{lk}+3.75E_{lk}+2.6F_{lk})+(7.75G_{kp}+5.5H_{kp}+4.4I_{kp}+8G_{lp}+5.25H_{lp}+3.95I_{lp})+(8.5G_{ks}+6H_{ks}+4.5I_{ks}+8.5G_{ls}+5.95H_{ls}+4.25I_{ls})+(7.5G_{kb}+5H_{kb}+3.75I_{kb}+8.5G_{lb}+5.2H_{lb}+3.85I_{lb})+(8G_{kn}+5.75H_{kn}+3.3I_{kn}+7.5G_{ln}+5.5H_{ln}+4.35I_{ln})+(7.5G_{ka}+5.6H_{ka}+3.85I_{ka}+7G_{la}+5.1H_{la}+3.95I_{la})+(6.5K_{qp}+4L_{qp}+2.75M_{qp}+6K_{lp}+4.25L_{lp}+2.6M_{lp}+6K_{pp}+3.9L_{pp}+2.75M_{pp}+7.5K_{kp}+4.75L_{kp}+3M_{kp})+(5.8K_{qs}+3.9L_{qs}+2.2M_{qs}+5.5K_{ls}+4L_{ls}+2.6M_{ls}+6.5K_{ps}+4.35L_{ps}+2.7M_{ps}+6.5K_{ks}+3.3L_{ks}+2.6M_{ks})+(5.5K_{qb}+4.2L_{qb}+2.6M_{qb}+5.5K_{lb}+4L_{lb}+2.4M_{lb}+7K_{pb}+4.45L_{pb}+3.25M_{pb}+5.6K_{kb}+3.7L_{kb}+3M_{kb})+(6.5K_{qn}+4.3L_{qn}+2.3M_{qn}+6K_{ln}+3.9L_{ln}+2.9M_{ln}+7K_{pn}+4.8L_{pn}+3.2M_{pn}+6.5K_{kn}+4.25L_{kn}+2.6M_{kn})+(8K_{qa}+5.1L_{qa}+2.9M_{qa}+5.5K_{la}+4.5L_{la}+3.25M_{la}+5.5K_{pa}+4L_{pa}+2.35M_{pa}+5.5K_{ka}+4.1L_{ka}+2.4M_{ka})$$

(Minimize Manufacturing and Shipping cost PKR)

S.T:

Warehouses Storing Capacity Limits:

$D_{kq} + D_{lq} \leq 35000$ (Bat storing capacity limit at Quetta Warehouse)
$E_{kq} + E_{lq} \leq 30000$ (Stumps storing capacity limit at Quetta Warehouse)
$F_{kq} + F_{lq} \leq 20000$ (Bails storing capacity limit at Quetta Warehouse)

$D_{kl} + D_{ll} \leq 20000$ (Bat storing capacity limit at Lahore Warehouse)
$E_{kl} + E_{ll} \leq 25000$ (Stumps storing capacity limit at Lahore Warehouse)
$F_{kl} + F_{ll} \leq 20000$ (Bails storing capacity limit at Lahore Warehouse)

$D_{kp} + D_{lp} \leq 30000$ (Bat storing capacity limit at Peshawar Warehouse)
$E_{kp} + E_{lp} \leq 15000$ (Stumps storing capacity limit at Peshawar Warehouse)
$F_{kp} + F_{lp} \leq 25000$ (Bails storing capacity limit at Peshawar Warehouse)

$D_{kk} + D_{lk} \leq 15000$ (Bat storing capacity limit at Karachi Warehouse)
$E_{kk} + E_{lk} \leq 24000$ (Stumps storing capacity limit at Karachi Warehouse)
$F_{kk} + F_{lk} \leq 20000$ (Bails storing capacity limit at Karachi Warehouse)

Distributors Demand Limits:

$G_{kp}+G_{lp}+K_{qp}+K_{lp}+K_{pp}+K_{kp} \geq 30000$ (Bat's Demand limit for Punjab Distributor)
$H_{kp}+H_{lp}+L_{qp}+L_{lp}+L_{pp}+L_{kp} \geq 20000$ (Wicket's Demand limit for Punjab Distributor)
$I_{kp}+I_{lp}+M_{qp}+M_{lp}+M_{pp}+M_{kp} \geq 25000$ (Bail's Demand limit for Punjab Distributor)

$G_{ks}+G_{ls}+K_{qs}+K_{ls}+K_{ps}+K_{ks} \geq 23000$ (Bat's Demand limit for Sindh Distributor)
$H_{ks}+H_{ls}+L_{qs}+L_{ls}+L_{ps}+L_{ks} \geq 15000$ (Wicket's Demand limit for Sindh Distributor)
$I_{ks}+I_{ls}+M_{qs}+M_{ls}+M_{ps}+M_{ks} \geq 22000$ (Bail's Demand limit for Sindh Distributor)

$G_{kb}+G_{lb}+K_{qb}+K_{lb}+K_{pb}+K_{kb} \geq 15000$ (Bat's Demand limit for Baluchistan Distributor)
$H_{kb}+H_{lb}+L_{qb}+L_{lb}+L_{pb}+L_{kb} \geq 22000$ (Wicket's Demand limit for Baluchistan Distributor)
$I_{kb}+I_{lb}+M_{qb}+M_{lb}+M_{pb}+M_{kb} \geq 16000$ (Bail's Demand limit for Baluchistan Distributor)

$G_{kn}+G_{ln}+K_{qn}+K_{ln}+K_{pn}+K_{kn} \geq 32000$ (Bat's Demand limit for Northern Distributor)
$H_{kn}+H_{ln}+L_{qn}+L_{ln}+L_{pn}+L_{kn} \geq 12000$ (Wicket's Demand limit for Northern Distributor)
$I_{kn}+I_{ln}+M_{qn}+M_{ln}+M_{pn}+M_{kn} \geq 20000$ (Bail's Demand limit for Northern Distributor)

$G_{ka}+G_{la}+K_{qa}+K_{la}+K_{pa}+K_{ka} \geq 16000$ (Bat's Demand limit for AK Distributor)
$H_{ka}+H_{la}+L_{qa}+L_{la}+L_{pa}+L_{ka} \geq 18000$ (Wicket's Demand limit for AK Distributor)
$I_{ka}+I_{la}+M_{qa}+M_{la}+M_{pa}+M_{ka} \geq 25000$ (Bail's Demand limit for AK Distributor)

Factories Shipment limits:

$D_{kq}+D_{kl}+D_{kp}+D_{kk}+G_{kp}+G_{ks}+G_{kb}+G_{kn}+G_{ka} \leq A_k$ (Bats shipment limit from Karachi factory to warehouse and distributors)
$E_{kq}+E_{kl}+E_{kp}+E_{kk}+H_{kp}+H_{ks}+H_{kb}+H_{kn}+H_{ka} \leq B_k$ (Stumps shipment limit from Karachi factory to warehouse and distributors)
$F_{kq}+F_{kl}+F_{kp}+F_{kk}+I_{kp}+I_{ks}+I_{kb}+I_{kn}+I_{ka} \leq C_k$ (Bails shipment limit from Karachi factory to warehouse and distributors)

$D_{lq}+D_{ll}+D_{lp}+D_{lk}+G_{lp}+G_{ls}+G_{lb}+G_{ln}+G_{la} \leq A_l$ (Bats shipment limit from Lahore factory to warehouse and distributors)
$E_{lq}+E_{ll}+E_{lp}+E_{lk}+H_{lp}+H_{ls}+H_{lb}+H_{ln}+H_{la} \leq B_l$ (Stumps shipment limit from Lahore factory to warehouse and distributors)
$F_{lq}+F_{ll}+F_{lp}+F_{lk}+I_{lp}+I_{ls}+I_{lb}+I_{ln}+I_{la} \leq C_l$ (Bails shipment limit from Lahore factory to warehouse and distributors)

Warehouses Distribution Limits:

$K_{qp}+ K_{qs}+ K_{qb}+ K_{qn}+ K_{qa} = N_{kq}+ N_{lq}$ (Bats distribution limit from Quetta warehouse to distributors)
$L_{qp}+ L_{qs}+ L_{qb}+ L_{qn}+ L_{qa} = O_{kq}+ O_{lq}$ (Stumps distribution limit from Quetta warehouse to distributors)

$M_{qp} + M_{qs} + M_{qb} + M_{qn} + M_{qa} = P_{kq} + P_{lq}$ (Bails distribution limit from Quetta warehouse to distributors)

$K_{lp} + K_{ls} + K_{lb} + K_{ln} + K_{la} = N_{kl} + N_{ll}$ (Bats distribution limit from Lahore warehouse to distributors)
$L_{lp} + L_{ls} + L_{lb} + L_{ln} + L_{la} = O_{kl} + O_{ll}$ (Stumps distribution limit from Lahore warehouse to distributors)
$M_{lp} + M_{ls} + M_{lb} + M_{ln} + M_{la} = P_{kl} + P_{ll}$ (Bails distribution limit from Lahore warehouse to distributors)

$K_{pp} + K_{ps} + K_{pb} + K_{pn} + K_{pa} = N_{kp} + N_{lp}$ (Bats distribution limit from Peshawar warehouse to distributors)
$L_{pp} + L_{ps} + L_{pb} + L_{pn} + L_{pa} = O_{kp} + O_{lp}$ (Stumps distribution limit from Peshawar a warehouse to distributors)
$M_{pp} + M_{ps} + M_{pb} + M_{pn} + M_{pa} = P_{kp} + P_{lp}$ (Bails distribution limit from Peshawar warehouse to distributors)

$K_{kp} + K_{ks} + K_{kb} + K_{kn} + K_{ka} = N_{kk} + N_{lk}$ (Bats distribution limit from Karachi warehouse to distributors)
$L_{kp} + L_{ks} + L_{kb} + L_{kn} + L_{ka} = O_{kk} + O_{lk}$ (Stumps distribution limit from Karachi warehouse to distributors)
$M_{kp} + M_{ks} + M_{kb} + M_{kn} + M_{ka} = P_{kk} + P_{lk}$ (Bails distribution limit from Karachi warehouse to distributors)

Non-Negativity Constraints:

$A_i \geq 0$ where $i = k, l$ (non-negativity)
$B_i \geq 0$ where $i = k, l$ (non-negativity)
$C_i \geq 0$ where $i = k, l$ (non-negativity)
$D_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$E_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$F_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$G_{ij} \geq 0$ where $i = k, l$; $j = p, s, b, n, a$ (non-negativity)
$H_{ij} \geq 0$ where $i = k, l$; $j = p, s, b, n, a$ (non-negativity)
$I_{ij} \geq 0$ where $i = k, l$; $j = p, s, b, n, a$ (non-negativity)
$K_{ij} \geq 0$ where $i = q, k, l, p$; $j = p, s, b, n, a$ (non-negativity)
$L_{ij} \geq 0$ where $i = q, k, l, p$; $j = p, s, b, n, a$ (non-negativity)
$M_{ij} \geq 0$ where $i = q, k, l, p$; $j = p, s, b, n, a$ (non-negativity)
$N_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$O_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$P_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)

Algebraic Formulation with Initial Shipping Cost and Factories Manufacturing Capacity Limits

LET:

A_i $\equiv$ # of bats manufactured in factory i; where i = k, l
B_i $\equiv$ # of Stumps manufactured in factory i; where i = k, l
C_i $\equiv$ # of bails manufactured in factory i; where i = k, l
D_{ij} $\equiv$ # of bats shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
E_{ij} $\equiv$ # of Stumps shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
F_{ij} $\equiv$ # of bails shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
G_{ij} $\equiv$ # of bats shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
H_{ij} $\equiv$ # of Stumps shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
I_{ij} $\equiv$ # of bails shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
K_{ij} $\equiv$ # of bats shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
L_{ij} $\equiv$ # of Stumps shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
M_{ij} $\equiv$ # of bails shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
N_{ij} $\equiv$ # of bats received from factory i to warehouse j; where i = k, l; j = q, k, l, p
O_{ij} $\equiv$ # of Stumps received from factory i to warehouse j; where i = k, l; j = q, k, l, p
P_{ij} $\equiv$ # of bails received from factory i to warehouse j; where i = k, l; j = q, k, l, p

O.F.

MIN

$$(150A_k+95B_k+45C_k+130D_l+99E_l+41F_l)+(5.5D_{kq}+4E_{kq}+2.25F_{kq}+6.5D_{lq}+4.25E_{lq}+2.90F_{lq})+(5.5D_{kl}+3.75E_{kl}+2.75F_{kl}+5.3D_{ll}+3.8E_{ll}+1.9F_{ll})+(6D_{kp}+4.25E_{kp}+2.5F_{kp}+5.5D_{lp}+4E_{lp}+1.95F_{lp})+(5.2D_{kk}+4.25E_{kk}+2.3F_{kk}+5.2D_{lk}+3.75E_{lk}+2.6F_{lk})+(7.75G_{kp}+5.5H_{kp}+4.4I_{kp}+8G_{lp}+5.25H_{lp}+3.95I_{lp})+(8.5G_{ks}+6H_{ks}+4.5I_{ks}+8.5G_{ls}+5.95H_{ls}+4.25I_{ls})+(7.5G_{kb}+5H_{kb}+3.75I_{kb}+8.5G_{lb}+5.2H_{lb}+3.85I_{lb})+(8G_{kn}+5.75H_{kn}+3.3I_{kn}+7.5G_{ln}+5.5H_{ln}+4.35I_{ln})+(7.5G_{ka}+5.6H_{ka}+3.85I_{ka}+7G_{la}+5.1H_{la}+3.95I_{la})+(6.5K_{qp}+4L_{qp}+2.75M_{qp}+6K_{lp}+4.25L_{lp}+2.6M_{lp}+6K_{pp}+3.9L_{pp}+2.75M_{pp}+7.5K_{kp}+4.75L_{kp}+3M_{kp})+(5.8K_{qs}+3.9L_{qs}+2.2M_{qs}+5.5K_{ls}+4L_{ls}+2.6M_{ls}+6.5K_{ps}+4.35L_{ps}+2.7M_{ps}+6.5K_{ks}+3.3L_{ks}+2.6M_{ks})+(5.5K_{qb}+4.2L_{qb}+2.6M_{qb}+5.5K_{lb}+4L_{lb}+2.4M_{lb}+7K_{pb}+4.45L_{pb}+3.25M_{pb}+5.6K_{kb}+3.7L_{kb}+3M_{kb})+(6.5K_{qn}+4.3L_{qn}+2.3M_{qn}+6K_{ln}+3.9L_{ln}+2.9M_{ln}+7K_{pn}+4.8L_{pn}+3.2M_{pn}+6.5K_{kn}+4.25L_{kn}+2.6M_{kn})+(8K_{qa}+5.1L_{qa}+2.9M_{qa}+5.5K_{la}+4.5L_{la}+3.25M_{la}+5.5K_{pa}+4L_{pa}+2.35M_{pa}+5.5K_{ka}+4.1L_{ka}+2.4M_{ka})$$

(Minimize Manufacturing and Shipping cost PKR)

S.T:

Factory Manufacturing Capacity Limits:

$A_k \leq 70000$	(Bat manufacturing capacity limit at Karachi Factory)
$B_k \leq 47000$	(Stumps manufacturing capacity limit at Karachi Factory)
$C_k \leq 49000$	(Bails manufacturing capacity limit at Karachi Factory)
$A_l \leq 50000$	(Bat manufacturing capacity limit at Lahore Factory)
$B_l \leq 68000$	(Stumps manufacturing capacity limit at Lahore Factory)
$C_l \leq 59000$	(Bails manufacturing capacity limit at Lahore Factory)

Warehouses Storing Capacity Limits:

$D_{kq} + D_{lq} \leq 35000$	(Bat storing capacity limit at Quetta Warehouse)
$E_{kq} + E_{lq} \leq 30000$	(Stumps storing capacity limit at Quetta Warehouse)
$F_{kq} + F_{lq} \leq 20000$	(Bails storing capacity limit at Quetta Warehouse)
$D_{kl} + D_{ll} \leq 20000$	(Bat storing capacity limit at Lahore Warehouse)
$E_{kl} + E_{ll} \leq 25000$	(Stumps storing capacity limit at Lahore Warehouse)
$F_{kl} + F_{ll} \leq 20000$	(Bails storing capacity limit at Lahore Warehouse)
$D_{kp} + D_{lp} \leq 30000$	(Bat storing capacity limit at Peshawar Warehouse)
$E_{kp} + E_{lp} \leq 15000$	(Stumps storing capacity limit at Peshawar Warehouse)
$F_{kp} + F_{lp} \leq 25000$	(Bails storing capacity limit at Peshawar Warehouse)
$D_{kk} + D_{lk} \leq 15000$	(Bat storing capacity limit at Karachi Warehouse)
$E_{kk} + E_{lk} \leq 24000$	(Stumps storing capacity limit at Karachi Warehouse)
$F_{kk} + F_{lk} \leq 20000$	(Bails storing capacity limit at Karachi Warehouse)

Distributors Demand Limits:

$G_{kp}+G_{lp}+K_{qp}+K_{lp}+K_{pp}+K_{kp} \geq 30000$ (Bat's Demand limit for Punjab Distributor)
$H_{kp}+H_{lp}+L_{qp}+L_{lp}+L_{pp}+L_{kp} \geq 20000$ (Wicket's Demand limit for Punjab Distributor)
$I_{kp}+I_{lp}+M_{qp}+M_{lp}+M_{pp}+M_{kp} \geq 25000$ (Bail's Demand limit for Punjab Distributor)

$G_{ks}+G_{ls}+K_{qs}+K_{ls}+K_{ps}+K_{ks} \geq 23000$ (Bat's Demand limit for Sindh Distributor)
$H_{ks}+H_{ls}+L_{qs}+L_{ls}+L_{ps}+L_{ks} \geq 15000$ (Wicket's Demand limit for Sindh Distributor)
$I_{ks}+I_{ls}+M_{qs}+M_{ls}+M_{ps}+M_{ks} \geq 22000$ (Bail's Demand limit for Sindh Distributor)

$G_{kb}+G_{lb}+K_{qb}+K_{lb}+K_{pb}+K_{kb} \geq 15000$ (Bat's Demand limit for Baluchistan Distributor)
$H_{kb}+H_{lb}+L_{qb}+L_{lb}+L_{pb}+L_{kb} \geq 22000$ (Wicket's Demand limit for Baluchistan Distributor)
$I_{kb}+I_{lb}+M_{qb}+M_{lb}+M_{pb}+M_{kb} \geq 16000$ (Bail's Demand limit for Baluchistan Distributor)

$G_{kn}+G_{ln}+K_{qn}+K_{ln}+K_{pn}+K_{kn} \geq 32000$ (Bat's Demand limit for Northern Distributor)
$H_{kn}+H_{ln}+L_{qn}+L_{ln}+L_{pn}+L_{kn} \geq 12000$ (Wicket's Demand limit for Northern Distributor)
$I_{kn}+I_{ln}+M_{qn}+M_{ln}+M_{pn}+M_{kn} \geq 20000$ (Bail's Demand limit for Northern Distributor)

$G_{ka}+G_{la}+K_{qa}+K_{la}+K_{pa}+K_{ka} \geq 16000$ (Bat's Demand limit for AK Distributor)
$H_{ka}+H_{la}+L_{qa}+L_{la}+L_{pa}+L_{ka} \geq 18000$ (Wicket's Demand limit for AK Distributor)
$I_{ka}+I_{la}+M_{qa}+M_{la}+M_{pa}+M_{ka} \geq 25000$ (Bail's Demand limit for AK Distributor)

Factories Shipment limits:

$D_{kq}+D_{kl}+D_{kp}+D_{kk}+G_{kp}+G_{ks}+G_{kb}+G_{kn}+G_{ka} \leq A_k$ (Bats shipment limit from Karachi factory to warehouse and distributors)
$E_{kq}+E_{kl}+E_{kp}+E_{kk}+H_{kp}+H_{ks}+H_{kb}+H_{kn}+H_{ka} \leq B_k$ (Stumps shipment limit from Karachi factory to warehouse and distributors)
$F_{kq}+F_{kl}+F_{kp}+F_{kk}+I_{kp}+I_{ks}+I_{kb}+I_{kn}+I_{ka} \leq C_k$ (Bails shipment limit from Karachi factory to warehouse and distributors)

$D_{lq}+D_{ll}+D_{lp}+D_{lk}+G_{lp}+G_{ls}+G_{lb}+G_{ln}+G_{la} \leq A_l$ (Bats shipment limit from Lahore factory to warehouse and distributors)
$E_{lq}+E_{ll}+E_{lp}+E_{lk}+H_{lp}+H_{ls}+H_{lb}+H_{ln}+H_{la} \leq B_l$ (Stumps shipment limit from Lahore factory to warehouse and distributors)
$F_{lq}+F_{ll}+F_{lp}+F_{lk}+I_{lp}+I_{ls}+I_{lb}+I_{ln}+I_{la} \leq C_l$ (Bails shipment limit from Lahore factory to warehouse and distributors)

Warehouses Distribution Limits:

$K_{qp}+ K_{qs}+ K_{qb}+ K_{qn}+ K_{qa} = N_{kq}+ N_{lq}$ (Bats distribution limit from Quetta warehouse to distributors)
$L_{qp}+ L_{qs}+ L_{qb}+ L_{qn}+ L_{qa} = O_{kq}+ O_{lq}$ (Stumps distribution limit from Quetta warehouse to distributors)
$M_{qp}+ M_{qs}+ M_{qb}+ M_{qn}+ M_{qa} = P_{kq}+ P_{lq}$ (Bails distribution limit from Quetta warehouse to distributors)

$K_{lp}+ K_{ls}+ K_{lb}+ K_{ln}+ K_{la} = N_{kl}+ N_{ll}$ (Bats distribution limit from Lahore warehouse to distributors)
$L_{lp}+ L_{ls}+ L_{lb}+ L_{ln}+ L_{la} = O_{kl}+ O_{ll}$ (Stumps distribution limit from Lahore warehouse to distributors)
$M_{lp}+ M_{ls}+ M_{lb}+ M_{ln}+ M_{la} = P_{kl}+ P_{ll}$ (Bails distribution limit from Lahore warehouse to distributors)

$K_{pp}+ K_{ps}+ K_{pb}+ K_{pn}+ K_{pa} = N_{kp}+ N_{lp}$ (Bats distribution limit from Peshawar warehouse to distributors)
$L_{pp}+ L_{ps}+ L_{pb}+ L_{pn}+ L_{pa} = O_{kp}+ O_{lp}$ (Stumps distribution limit from Peshawar a warehouse to distributors)
$M_{pp}+ M_{ps}+ M_{pb}+ M_{pn}+ M_{pa} = P_{kp}+ P_{lp}$ (Bails distribution limit from Peshawar warehouse to distributors)

$K_{kp}+ K_{ks}+ K_{kb}+ K_{kn}+ K_{ka} = N_{kk}+ N_{lk}$ (Bats distribution limit from Karachi warehouse to distributors)
$L_{kp}+ L_{ks}+ L_{kb}+ L_{kn}+ L_{ka} = O_{kk}+ O_{lk}$ (Stumps distribution limit from Karachi warehouse to distributors)
$M_{kp}+ M_{ks}+ M_{kb}+ M_{kn}+ M_{ka} = P_{kk}+ P_{lk}$ (Bails distribution limit from Karachi warehouse to distributors)

Non-Negativity Constraints:

$A_i \geq 0$ where i = k, l (non-negativity)

$B_i \geq 0$ where i = k, l (non-negativity)

$C_i \geq 0$ where i = k, l (non-negativity)

$D_{ij} \geq 0$ where i = k, l; j = q , k, l, p (non-negativity)

$E_{ij} \geq 0$ where i = k, l; j = q , k, l, p (non-negativity)

$F_{ij} \geq 0$ where i = k, l; j = q , k, l, p (non-negativity)

$G_{ij} \geq 0$ where i = k, l; j = p, s, b, n, a (non-negativity)

$H_{ij} \geq 0$ where i = k, l; j = p, s, b, n, a (non-negativity)

$I_{ij} \geq 0$ where i = k, l; j = p, s, b, n, a (non-negativity)

$K_{ij} \geq 0$ where i = q, k, l, p; j = p, s, b, n, a (non-negativity)

$L_{ij} \geq 0$ where i = q, k, l, p; j = p, s, b, n, a (non-negativity)

$M_{ij} \geq 0$ where i = q, k, l, p; j = p, s, b, n, a (non-negativity)

$N_{ij} \geq 0$ where i = k, l; j = q, k, l, p (non-negativity)

$O_{ij} \geq 0$ where i = k, l; j = q, k, l, p (non-negativity)

$P_{ij} \geq 0$ where i = k, l; j = q, k, l, p (non-negativity)

Algebraic Formulation For Models with Revised Shipping Charges

Algebraic Formulation with Revised Shipping Charges

LET:

A_i $\equiv$ # of bats manufactured in factory i; where i = k, l

B_i $\equiv$ # of Stumps manufactured in factory i; where i = k, l

C_i $\equiv$ # of bails manufactured in factory i; where i = k, l

D_{ij} $\equiv$ # of bats shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p

E_{ij} $\equiv$ # of Stumps shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p

F_{ij} $\equiv$ # of bails shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p

G_{ij} $\equiv$ # of bats shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a

H_{ij} $\equiv$ # of Stumps shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a

I_{ij} $\equiv$ # of bails shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a

K_{ij} $\equiv$ # of bats shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a

L_{ij} $\equiv$ # of Stumps shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a

M_{ij} $\equiv$ # of bails shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a

N_{ij} $\equiv$ # of bats received from factory i to warehouse j; where i = k, l; j = q, k, l, p

O_{ij} $\equiv$ # of Stumps received from factory i to warehouse j; where i = k, l; j = q, k, l, p

P_{ij} $\equiv$ # of bails received from factory i to warehouse j; where i = k, l; j = q, k, l, p

O.F.

MIN

$$(150A_k+95B_k+45C_k+130D_l+99E_l+41F_l)+(3.5D_{kq}+2E_{kq}+0.25F_{kq}+4.5D_{lq}+2.25E_{lq}+0.90F_{lq})+(3.5D_{kl}+1.75E_{kl}+0.75F_{kl}+3.3D_{ll}+1.8E_{ll}+0.9F_{ll})+(4D_{kp}+2.45E_{kp}+0.5F_{kp}+3.5D_{lp}+2E_{lp}+0.95F_{lp})+(3.2D_{kk}+2.25E_{kk}+0.3F_{kk}+3.2D_{lk}+1.75E_{lk}+0.6F_{lk})+(5.75G_{kp}+3.5H_{kp}+2.4I_{kp}+6G_{lp}+3.25H_{lp}+1.95I_{lp})+(6.5G_{ks}+4H_{ks}+2.5I_{ks}+6.5G_{ls}+3.95H_{ls}+2.25I_{ls})+(5.5G_{kb}+3H_{kb}+1.75I_{kb}+6.5G_{lb}+3.2H_{lb}+1.85I_{lb})+(6G_{kn}+3.75H_{kn}+1.3I_{kn}+5.5G_{ln}+3.5H_{ln}+2.35I_{ln})+(5.5G_{ka}+3.6H_{ka}+1.85I_{ka}+5G_{la}+3.1H_{la}+1.95I_{la})+(2.5K_{qp}+2L_{qp}+1.25M_{qp}+2K_{lp}+2.25L_{lp}+1.1M_{lp}+2K_{pp}+1.9L_{pp}+1.25M_{pp}+3.5K_{kp}+2.75L_{kp}+1.5M_{kp})+(1.8K_{qs}+1.9L_{qs}+1.7M_{qs}+1.5K_{ls}+2L_{ls}+1.2M_{ls}+2.5K_{ps}+2.35L_{ps}+1.2M_{ps}+2.5K_{ks}+2.3L_{ks}+1.2M_{ks})+(1.5K_{qb}+2.2L_{qb}+2.1M_{qb}+1.5K_{lb}+2L_{lb}+1.9M_{lb}+3K_{pb}+2.45L_{pb}+2.75M_{pb}+1.6K_{kb}+1.7L_{kb}+2.5M_{kb})+(2.5K_{qn}+2.3L_{qn}+1.8M_{qn}+2K_{ln}+1.9L_{ln}+2.4M_{ln}+3K_{pn}+2.8L_{pn}+2.7M_{pn}+2.5K_{kn}+2.25L_{kn}+2.1M_{kn})+(4K_{qa}+3.1L_{qa}+2.6M_{qa}+1.5K_{la}+2.5L_{la}+2.75M_{la}+1.5K_{pa}+2L_{pa}+1.85M_{pa}+1.5K_{ka}+2.1L_{ka}+1.9M_{ka})$$

(Minimize Manufacturing and Shipping cost PKR)

S.T:

Warehouses Storing Capacity Limits:

$D_{kq} + D_{lq} \leq 35000$ (Bat storing capacity limit at Quetta Warehouse)
$E_{kq} + E_{lq} \leq 30000$ (Stumps storing capacity limit at Quetta Warehouse)
$F_{kq} + F_{lq} \leq 20000$ (Bails storing capacity limit at Quetta Warehouse)

$D_{kl} + D_{ll} \leq 20000$ (Bat storing capacity limit at Lahore Warehouse)
$E_{kl} + E_{ll} \leq 25000$ (Stumps storing capacity limit at Lahore Warehouse)
$F_{kl} + F_{ll} \leq 20000$ (Bails storing capacity limit at Lahore Warehouse)

$D_{kp} + D_{lp} \leq 30000$ (Bat storing capacity limit at Peshawar Warehouse)
$E_{kp} + E_{lp} \leq 15000$ (Stumps storing capacity limit at Peshawar Warehouse)
$F_{kp} + F_{lp} \leq 25000$ (Bails storing capacity limit at Peshawar Warehouse)

$D_{kk} + D_{lk} \leq 15000$ (Bat storing capacity limit at Karachi Warehouse)
$E_{kk} + E_{lk} \leq 24000$ (Stumps storing capacity limit at Karachi Warehouse)
$F_{kk} + F_{lk} \leq 20000$ (Bails storing capacity limit at Karachi Warehouse)

Distributors Demand Limits:

$G_{kp}+G_{lp}+K_{qp}+K_{lp}+K_{pp}+K_{kp} \geq 30000$ (Bat's Demand limit for Punjab Distributor)
$H_{kp}+H_{lp}+L_{qp}+L_{lp}+L_{pp}+L_{kp} \geq 20000$ (Wicket's Demand limit for Punjab Distributor)
$I_{kp}+I_{lp}+M_{qp}+M_{lp}+M_{pp}+M_{kp} \geq 25000$ (Bail's Demand limit for Punjab Distributor)

$G_{ks}+G_{ls}+K_{qs}+K_{ls}+K_{ps}+K_{ks} \geq 23000$ (Bat's Demand limit for Sindh Distributor)
$H_{ks}+H_{ls}+L_{qs}+L_{ls}+L_{ps}+L_{ks} \geq 15000$ (Wicket's Demand limit for Sindh Distributor)
$I_{ks}+I_{ls}+M_{qs}+M_{ls}+M_{ps}+M_{ks} \geq 22000$ (Bail's Demand limit for Sindh Distributor)

$G_{kb}+G_{lb}+K_{qb}+K_{lb}+K_{pb}+K_{kb} \geq 15000$ (Bat's Demand limit for Baluchistan Distributor)
$H_{kb}+H_{lb}+L_{qb}+L_{lb}+L_{pb}+L_{kb} \geq 22000$ (Wicket's Demand limit for Baluchistan Distributor)
$I_{kb}+I_{lb}+M_{qb}+M_{lb}+M_{pb}+M_{kb} \geq 16000$ (Bail's Demand limit for Baluchistan Distributor)

$G_{kn}+G_{ln}+K_{qn}+K_{ln}+K_{pn}+K_{kn} \geq 32000$ (Bat's Demand limit for Northern Distributor)
$H_{kn}+H_{ln}+L_{qn}+L_{ln}+L_{pn}+L_{kn} \geq 12000$ (Wicket's Demand limit for Northern Distributor)
$I_{kn}+I_{ln}+M_{qn}+M_{ln}+M_{pn}+M_{kn} \geq 20000$ (Bail's Demand limit for Northern Distributor)

$G_{ka}+G_{la}+K_{qa}+K_{la}+K_{pa}+K_{ka} \geq 16000$ (Bat's Demand limit for AK Distributor)
$H_{ka}+H_{la}+L_{qa}+L_{la}+L_{pa}+L_{ka} \geq 18000$ (Wicket's Demand limit for AK Distributor)
$I_{ka}+I_{la}+M_{qa}+M_{la}+M_{pa}+M_{ka} \geq 25000$ (Bail's Demand limit for AK Distributor)

Factories Shipment limits:

$D_{kq}+D_{kl}+D_{kp}+D_{kk}+G_{kp}+G_{ks}+G_{kb}+G_{kn}+G_{ka} \leq A_k$ (Bats shipment limit from Karachi factory to warehouse and distributors)
$E_{kq}+E_{kl}+E_{kp}+E_{kk}+H_{kp}+H_{ks}+H_{kb}+H_{kn}+H_{ka} \leq B_k$ (Stumps shipment limit from Karachi factory to warehouse and distributors)
$F_{kq}+F_{kl}+F_{kp}+F_{kk}+I_{kp}+I_{ks}+I_{kb}+I_{kn}+I_{ka} \leq C_k$ (Bails shipment limit from Karachi factory to warehouse and distributors)

$D_{lq}+D_{ll}+D_{lp}+D_{lk}+G_{lp}+G_{ls}+G_{lb}+G_{ln}+G_{la} \leq A_l$ (Bats shipment limit from Lahore factory to warehouse and distributors)
$E_{lq}+E_{ll}+E_{lp}+E_{lk}+H_{lp}+H_{ls}+H_{lb}+H_{ln}+H_{la} \leq B_l$ (Stumps shipment limit from Lahore factory to warehouse and distributors)
$F_{lq}+F_{ll}+F_{lp}+F_{lk}+I_{lp}+I_{ls}+I_{lb}+I_{ln}+I_{la} \leq C_l$ (Bails shipment limit from Lahore factory to warehouse and distributors)

Warehouses Distribution Limits:

$K_{qp}+ K_{qs}+ K_{qb}+ K_{qn}+ K_{qa} = N_{kq}+ N_{lq}$ (Bats distribution limit from Quetta warehouse to distributors)
$L_{qp}+ L_{qs}+ L_{qb}+ L_{qn}+ L_{qa} = O_{kq}+ O_{lq}$ (Stumps distribution limit from Quetta warehouse to distributors)

$M_{qp} + M_{qs} + M_{qb} + M_{qn} + M_{qa} = P_{kq} + P_{lq}$ (Bails distribution limit from Quetta warehouse to distributors)

$K_{lp} + K_{ls} + K_{lb} + K_{ln} + K_{la} = N_{kl} + N_{ll}$ (Bats distribution limit from Lahore warehouse to distributors)
$L_{lp} + L_{ls} + L_{lb} + L_{ln} + L_{la} = O_{kl} + O_{ll}$ (Stumps distribution limit from Lahore warehouse to distributors)
$M_{lp} + M_{ls} + M_{lb} + M_{ln} + M_{la} = P_{kl} + P_{ll}$ (Bails distribution limit from Lahore warehouse to distributors)

$K_{pp} + K_{ps} + K_{pb} + K_{pn} + K_{pa} = N_{kp} + N_{lp}$ (Bats distribution limit from Peshawar warehouse to distributors)
$L_{pp} + L_{ps} + L_{pb} + L_{pn} + L_{pa} = O_{kp} + O_{lp}$ (Stumps distribution limit from Peshawar a warehouse to distributors)
$M_{pp} + M_{ps} + M_{pb} + M_{pn} + M_{pa} = P_{kp} + P_{lp}$ (Bails distribution limit from Peshawar warehouse to distributors)

$K_{kp} + K_{ks} + K_{kb} + K_{kn} + K_{ka} = N_{kk} + N_{lk}$ (Bats distribution limit from Karachi warehouse to distributors)
$L_{kp} + L_{ks} + L_{kb} + L_{kn} + L_{ka} = O_{kk} + O_{lk}$ (Stumps distribution limit from Karachi warehouse to distributors)
$M_{kp} + M_{ks} + M_{kb} + M_{kn} + M_{ka} = P_{kk} + P_{lk}$ (Bails distribution limit from Karachi warehouse to distributors)

Non-Negativity Constraints:

$A_i \geq 0$ where $i = k, l$ (non-negativity)
$B_i \geq 0$ where $i = k, l$ (non-negativity)
$C_i \geq 0$ where $i = k, l$ (non-negativity)
$D_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$E_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$F_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$G_{ij} \geq 0$ where $i = k, l$; $j = p, s, b, n, a$ (non-negativity)
$H_{ij} \geq 0$ where $i = k, l$; $j = p, s, b, n, a$ (non-negativity)
$I_{ij} \geq 0$ where $i = k, l$; $j = p, s, b, n, a$ (non-negativity)
$K_{ij} \geq 0$ where $i = q, k, l, p$; $j = p, s, b, n, a$ (non-negativity)
$L_{ij} \geq 0$ where $i = q, k, l, p$; $j = p, s, b, n, a$ (non-negativity)
$M_{ij} \geq 0$ where $i = q, k, l, p$; $j = p, s, b, n, a$ (non-negativity)
$N_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$O_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)
$P_{ij} \geq 0$ where $i = k, l$; $j = q, k, l, p$ (non-negativity)

Algebraic Formulation with Revised Shipping Charges and Factories Manufacturing Capacity Limits

LET:

A_i $\equiv$ # of bats manufactured in factory i; where i = k, l
B_i $\equiv$ # of Stumps manufactured in factory i; where i = k, l
C_i $\equiv$ # of bails manufactured in factory i; where i = k, l
D_{ij} $\equiv$ # of bats shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
E_{ij} $\equiv$ # of Stumps shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
F_{ij} $\equiv$ # of bails shipped from factory i to warehouse j; where i = k, l; j = q , k, l, p
G_{ij} $\equiv$ # of bats shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
H_{ij} $\equiv$ # of Stumps shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
I_{ij} $\equiv$ # of bails shipped from factory i to distributor j; where i = k, l; j = p, s, b, n, a
K_{ij} $\equiv$ # of bats shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
L_{ij} $\equiv$ # of Stumps shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
M_{ij} $\equiv$ # of bails shipped from warehouse i to distributor j; where i = q, k, l, p; j = p, s, b, n, a
N_{ij} $\equiv$ # of bats received from factory i to warehouse j; where i = k, l; j = q, k, l, p
O_{ij} $\equiv$ # of Stumps received from factory i to warehouse j; where i = k, l; j = q, k, l, p
P_{ij} $\equiv$ # of bails received from factory i to warehouse j; where i = k, l; j = q, k, l, p

O.F.

MIN

$$(150A_k+95B_k+45C_k+130D_l+99E_l+41F_l)+(3.5D_{kq}+2E_{kq}+0.25F_{kq}+4.5D_{lq}+2.25E_{lq}+0.90F_{lq})+(3.5D_{kl}+1.75E_{kl}+0.75F_{kl}+3.3D_{ll}+1.8E_{ll}+0.9F_{ll})+(4D_{kp}+2.45E_{kp}+0.5F_{kp}+3.5D_{lp}+2E_{lp}+0.95F_{lp})+(3.2D_{kk}+2.25E_{kk}+0.3F_{kk}+3.2D_{lk}+1.75E_{lk}+0.6F_{lk})+(5.75G_{kp}+3.5H_{kp}+2.4I_{kp}+6G_{lp}+3.25H_{lp}+1.95I_{lp})+(6.5G_{ks}+4H_{ks}+2.5I_{ks}+6.5G_{ls}+3.95H_{ls}+2.25I_{ls})+(5.5G_{kb}+3H_{kb}+1.75I_{kb}+6.5G_{lb}+3.2H_{lb}+1.85I_{lb})+(6G_{kn}+3.75H_{kn}+1.3I_{kn}+5.5G_{ln}+3.5H_{ln}+2.35I_{ln})+(5.5G_{ka}+3.6H_{ka}+1.85I_{ka}+5G_{la}+3.1H_{la}+1.95I_{la})+(2.5K_{qp}+2L_{qp}+1.25M_{qp}+2K_{lp}+2.25L_{lp}+1.1M_{lp}+2K_{pp}+1.9L_{pp}+1.25M_{pp}+3.5K_{kp}+2.75L_{kp}+1.5M_{kp})+(1.8K_{qs}+1.9L_{qs}+1.7M_{qs}+1.5K_{ls}+2L_{ls}+1.2M_{ls}+2.5K_{ps}+2.35L_{ps}+1.2M_{ps}+2.5K_{ks}+2.3L_{ks}+1.2M_{ks})+(1.5K_{qb}+2.2L_{qb}+2.1M_{qb}+1.5K_{lb}+2L_{lb}+1.9M_{lb}+3K_{pb}+2.45L_{pb}+2.75M_{pb}+1.6K_{kb}+1.7L_{kb}+2.5M_{kb})+(2.5K_{qn}+2.3L_{qn}+1.8M_{qn}+2K_{ln}+1.9L_{ln}+2.4M_{ln}+3K_{pn}+2.8L_{pn}+2.7M_{pn}+2.5K_{kn}+2.25L_{kn}+2.1M_{kn})+(4K_{qa}+3.1L_{qa}+2.6M_{qa}+1.5K_{la}+2.5L_{la}+2.75M_{la}+1.5K_{pa}+2L_{pa}+1.85M_{pa}+1.5K_{ka}+2.1L_{ka}+1.9M_{ka})$$

(Minimize Manufacturing and Shipping cost PKR)

S.T:

Factory Manufacturing Capacity Limits:

$A_k \leq 70000$	(Bat manufacturing capacity limit at Karachi Factory)
$B_k \leq 47000$	(Stumps manufacturing capacity limit at Karachi Factory)
$C_k \leq 49000$	(Bails manufacturing capacity limit at Karachi Factory)
$A_l \leq 50000$	(Bat manufacturing capacity limit at Lahore Factory)
$B_l \leq 68000$	(Stumps manufacturing capacity limit at Lahore Factory)
$C_l \leq 59000$	(Bails manufacturing capacity limit at Lahore Factory)

Warehouses Storing Capacity Limits:

$D_{kq} + D_{lq} \leq 35000$	(Bat storing capacity limit at Quetta Warehouse)
$E_{kq} + E_{lq} \leq 30000$	(Stumps storing capacity limit at Quetta Warehouse)
$F_{kq} + F_{lq} \leq 20000$	(Bails storing capacity limit at Quetta Warehouse)
$D_{kl} + D_{ll} \leq 20000$	(Bat storing capacity limit at Lahore Warehouse)
$E_{kl} + E_{ll} \leq 25000$	(Stumps storing capacity limit at Lahore Warehouse)
$F_{kl} + F_{ll} \leq 20000$	(Bails storing capacity limit at Lahore Warehouse)
$D_{kp} + D_{lp} \leq 30000$	(Bat storing capacity limit at Peshawar Warehouse)
$E_{kp} + E_{lp} \leq 15000$	(Stumps storing capacity limit at Peshawar Warehouse)
$F_{kp} + F_{lp} \leq 25000$	(Bails storing capacity limit at Peshawar Warehouse)
$D_{kk} + D_{lk} \leq 15000$	(Bat storing capacity limit at Karachi Warehouse)
$E_{kk} + E_{lk} \leq 24000$	(Stumps storing capacity limit at Karachi Warehouse)
$F_{kk} + F_{lk} \leq 20000$	(Bails storing capacity limit at Karachi Warehouse)

Distributors Demand Limits:

$G_{kp}+G_{lp}+K_{qp}+K_{lp}+K_{pp}+K_{kp} \geq 30000$ (Bat's Demand limit for Punjab Distributor)
$H_{kp}+H_{lp}+L_{qp}+L_{lp}+L_{pp}+L_{kp} \geq 20000$ (Wicket's Demand limit for Punjab Distributor)
$I_{kp}+I_{lp}+M_{qp}+M_{lp}+M_{pp}+M_{kp} \geq 25000$ (Bail's Demand limit for Punjab Distributor)

$G_{ks}+G_{ls}+K_{qs}+K_{ls}+K_{ps}+K_{ks} \geq 23000$ (Bat's Demand limit for Sindh Distributor)
$H_{ks}+H_{ls}+L_{qs}+L_{ls}+L_{ps}+L_{ks} \geq 15000$ (Wicket's Demand limit for Sindh Distributor)
$I_{ks}+I_{ls}+M_{qs}+M_{ls}+M_{ps}+M_{ks} \geq 22000$ (Bail's Demand limit for Sindh Distributor)

$G_{kb}+G_{lb}+K_{qb}+K_{lb}+K_{pb}+K_{kb} \geq 15000$ (Bat's Demand limit for Baluchistan Distributor)
$H_{kb}+H_{lb}+L_{qb}+L_{lb}+L_{pb}+L_{kb} \geq 22000$ (Wicket's Demand limit for Baluchistan Distributor)
$I_{kb}+I_{lb}+M_{qb}+M_{lb}+M_{pb}+M_{kb} \geq 16000$ (Bail's Demand limit for Baluchistan Distributor)

$G_{kn}+G_{ln}+K_{qn}+K_{ln}+K_{pn}+K_{kn} \geq 32000$ (Bat's Demand limit for Northern Distributor)
$H_{kn}+H_{ln}+L_{qn}+L_{ln}+L_{pn}+L_{kn} \geq 12000$ (Wicket's Demand limit for Northern Distributor)
$I_{kn}+I_{ln}+M_{qn}+M_{ln}+M_{pn}+M_{kn} \geq 20000$ (Bail's Demand limit for Northern Distributor)

$G_{ka}+G_{la}+K_{qa}+K_{la}+K_{pa}+K_{ka} \geq 16000$ (Bat's Demand limit for AK Distributor)
$H_{ka}+H_{la}+L_{qa}+L_{la}+L_{pa}+L_{ka} \geq 18000$ (Wicket's Demand limit for AK Distributor)
$I_{ka}+I_{la}+M_{qa}+M_{la}+M_{pa}+M_{ka} \geq 25000$ (Bail's Demand limit for AK Distributor)

Factories Shipment limits:

$D_{kq}+D_{kl}+D_{kp}+D_{kk}+G_{kp}+G_{ks}+G_{kb}+G_{kn}+G_{ka} \leq A_k$ (Bats shipment limit from Karachi factory to warehouse and distributors)
$E_{kq}+E_{kl}+E_{kp}+E_{kk}+H_{kp}+H_{ks}+H_{kb}+H_{kn}+H_{ka} \leq B_k$ (Stumps shipment limit from Karachi factory to warehouse and distributors)
$F_{kq}+F_{kl}+F_{kp}+F_{kk}+I_{kp}+I_{ks}+I_{kb}+I_{kn}+I_{ka} \leq C_k$ (Bails shipment limit from Karachi factory to warehouse and distributors)

$D_{lq}+D_{ll}+D_{lp}+D_{lk}+G_{lp}+G_{ls}+G_{lb}+G_{ln}+G_{la} \leq A_l$ (Bats shipment limit from Lahore factory to warehouse and distributors)
$E_{lq}+E_{ll}+E_{lp}+E_{lk}+H_{lp}+H_{ls}+H_{lb}+H_{ln}+H_{la} \leq B_l$ (Stumps shipment limit from Lahore factory to warehouse and distributors)
$F_{lq}+F_{ll}+F_{lp}+F_{lk}+I_{lp}+I_{ls}+I_{lb}+I_{ln}+I_{la} \leq C_l$ (Bails shipment limit from Lahore factory to warehouse and distributors)

Warehouses Distribution Limits:

$K_{qp}+ K_{qs}+ K_{qb}+ K_{qn}+ K_{qa} = N_{kq}+ N_{lq}$ (Bats distribution limit from Quetta warehouse to distributors)
$L_{qp}+ L_{qs}+ L_{qb}+ L_{qn}+ L_{qa} = O_{kq}+ O_{lq}$ (Stumps distribution limit from Quetta warehouse to distributors)
$M_{qp}+ M_{qs}+ M_{qb}+ M_{qn}+ M_{qa} = P_{kq}+ P_{lq}$ (Bails distribution limit from Quetta warehouse to distributors)

$K_{lp}+ K_{ls}+ K_{lb}+ K_{ln}+ K_{la} = N_{kl}+ N_{ll}$ (Bats distribution limit from Lahore warehouse to distributors)
$L_{lp}+ L_{ls}+ L_{lb}+ L_{ln}+ L_{la} = O_{kl}+ O_{ll}$ (Stumps distribution limit from Lahore warehouse to distributors)
$M_{lp}+ M_{ls}+ M_{lb}+ M_{ln}+ M_{la} = P_{kl}+ P_{ll}$ (Bails distribution limit from Lahore warehouse to distributors)

$K_{pp}+ K_{ps}+ K_{pb}+ K_{pn}+ K_{pa} = N_{kp}+ N_{lp}$ (Bats distribution limit from Peshawar warehouse to distributors)
$L_{pp}+ L_{ps}+ L_{pb}+ L_{pn}+ L_{pa} = O_{kp}+ O_{lp}$ (Stumps distribution limit from Peshawar a warehouse to distributors)
$M_{pp}+ M_{ps}+ M_{pb}+ M_{pn}+ M_{pa} = P_{kp}+ P_{lp}$ (Bails distribution limit from Peshawar warehouse to distributors)

$K_{kp}+ K_{ks}+ K_{kb}+ K_{kn}+ K_{ka} = N_{kk}+ N_{lk}$ (Bats distribution limit from Karachi warehouse to distributors)
$L_{kp}+ L_{ks}+ L_{kb}+ L_{kn}+ L_{ka} = O_{kk}+ O_{lk}$ (Stumps distribution limit from Karachi warehouse to distributors)
$M_{kp}+ M_{ks}+ M_{kb}+ M_{kn}+ M_{ka} = P_{kk}+ P_{lk}$ (Bails distribution limit from Karachi warehouse to distributors)

Non-Negativity Constraints:

$A_i \geq 0$ where i = k, l (non-negativity)
$B_i \geq 0$ where i = k, l (non-negativity)
$C_i \geq 0$ where i = k, l (non-negativity)
$D_{ij} \geq 0$ where i = k, l; j = q , k, l, p (non-negativity)
$E_{ij} \geq 0$ where i = k, l; j = q , k, l, p (non-negativity)
$F_{ij} \geq 0$ where i = k, l; j = q , k, l, p (non-negativity)
$G_{ij} \geq 0$ where i = k, l; j = p, s, b, n, a (non-negativity)
$H_{ij} \geq 0$ where i = k, l; j = p, s, b, n, a (non-negativity)
$I_{ij} \geq 0$ where i = k, l; j = p, s, b, n, a (non-negativity)
$K_{ij} \geq 0$ where i = q, k, l, p; j = p, s, b, n, a (non-negativity)
$L_{ij} \geq 0$ where i = q, k, l, p; j = p, s, b, n, a (non-negativity)
$M_{ij} \geq 0$ where i = q, k, l, p; j = p, s, b, n, a (non-negativity)
$N_{ij} \geq 0$ where i = k, l; j = q, k, l, p (non-negativity)
$O_{ij} \geq 0$ where i = k, l; j = q, k, l, p (non-negativity)
$P_{ij} \geq 0$ where i = k, l; j = q, k, l, p (non-negativity)

Appendix D

Data, Model and Sensitivity Report Model with Initial Shipping Cost

Manufacturing Cost for each Factory Per Product

	Products		
	Bats	Stumps	Bails
Karachi Factory	PKR 150	PKR 95	PKR 45
Lahore Factory	PKR 130	PKR 99	PKR 41

Shipping Cost From Factory To Warehouses (PKR per product)

		Warehouse Destinations			
		Quetta	Lahore	Peshawar	Karachi
Karachi Factory	Bats	PKR 5.50	PKR 5.50	PKR 6.00	PKR 5.20
	Stumps	PKR 4.00	PKR 3.75	PKR 4.25	PKR 4.25
	Bails	PKR 2.25	PKR 2.75	PKR 2.50	PKR 2.30
Lahore Factory	Bats	PKR 6.50	PKR 5.30	PKR 5.50	PKR 5.20
	Stumps	PKR 4.25	PKR 3.80	PKR 4.00	PKR 3.75
	Bails	PKR 2.90	PKR 1.90	PKR 1.95	PKR 2.60

Shipping Cost From Factory To Distributors (PKR per product)

				Distributors Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Karachi Factory	Bats	PKR 7.75	PKR 8.50	PKR 7.50	PKR 8.00	PKR 7.50
	Stumps	PKR 5.50	PKR 6.00	PKR 5.00	PKR 5.75	PKR 5.60
	Bails	PKR 4.40	PKR 4.50	PKR 3.75	PKR 3.30	PKR 3.85
Lahore Factory	Bats	PKR 8.00	PKR 8.50	PKR 8.50	PKR 7.50	PKR 7.00
	Stumps	PKR 5.25	PKR 5.95	PKR 5.20	PKR 5.50	PKR 5.10
	Bails	PKR 3.95	PKR 4.25	PKR 3.85	PKR 4.35	PKR 3.95

Shipping Cost From Warehouses To Distributors (PKR per product)

				Distributor Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Quetta	Bats	PKR 6.50	PKR 5.80	PKR 5.50	PKR 6.50	PKR 8.00
	Stumps	PKR 4.00	PKR 3.90	PKR 4.20	PKR 4.30	PKR 5.10
	Bails	PKR 2.75	PKR 2.20	PKR 2.60	PKR 2.30	PKR 2.90
Lahore	Bats	PKR 6.00	PKR 5.50	PKR 5.50	PKR 6.00	PKR 5.50
	Stumps	PKR 4.25	PKR 4.00	PKR 4.00	PKR 3.90	PKR 4.50
	Bails	PKR 2.60	PKR 2.60	PKR 2.40	PKR 2.90	PKR 3.25
Peshawar	Bats	PKR 6.00	PKR 6.50	PKR 7.00	PKR 7.00	PKR 5.50
	Stumps	PKR 3.90	PKR 4.35	PKR 4.45	PKR 4.80	PKR 4.00
	Bails	PKR 2.75	PKR 2.70	PKR 3.25	PKR 3.20	PKR 2.35
Karachi	Bats	PKR 7.50	PKR 6.50	PKR 5.60	PKR 6.50	PKR 5.50
	Stumps	PKR 4.75	PKR 3.30	PKR 3.70	PKR 4.25	PKR 4.10
	Bails	PKR 3.00	PKR 2.60	PKR 3.00	PKR 2.60	PKR 2.40

Distributor Demand

	Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Bats	30000	23000	15000	32000	16000
Stumps	20000	15000	22000	12000	18000
Bails	25000	22000	16000	20000	25000

Warehouse Capacity

	Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse
Bats	35000	20000	30000	15000
Stumps	30000	25000	15000	24000
Bails	20000	20000	25000	20000

CONSTRAINTS

Number of products shipped from factories to Warehouses

		Quetta Warehouse			Lahore Warehouse				Peshawar Warehouse			Karachi Warehouse	
		Received		Capacity	Received		Capacity	Received		Capacity	Received		Capacity
Karachi and Lahore Factory	Bats	0	≤	35000	0	≤	20000	0	≤	30000	0	≤	15000
	Stumps	0	≤	30000	0	≤	25000	0	≤	15000	0	≤	24000
	Bails	0	≤	20000	0	≤	20000	0	≤	25000	0	≤	20000

Number of products shipped from Factories and Warehouses to Distributors

		Punjab Distributor			Sindh Distributor			Baluchistan Distributor			Northern Distributor			AK Distributor		
		Received		Demand	Received		Demand	Received		Demand	Received		Demand	Received		Demand
Factory and Warehouse	Bats	30000	≥	30000	23000	≥	23000	15000	≤	15000	32000	≥	32000	16000	≥	16000
	Stumps	20000	≥	20000	15000	≥	15000	22000	≤	22000	12000	≥	12000	18000	≥	18000
	Bails	25000	≥	25000	22000	≥	22000	16000	≤	16000	20000	≥	20000	25000	≥	25000

Total products shipped out Factories

		Karachi Factory		
		Shipped		Manufactured
Karachi Factory	Bats	8.07794E-28	≤	0
	Stumps	87000	≤	87000
	Bails	8.07794E-28	≤	0

		Lahore Factory		
		Shipped		Manufactured
Lahore Factory	Bats	116000	≤	116000
	Stumps	0	≤	0
	Bails	108000	≤	108000

Distribution from Warehouses

		Quetta Warehouse		
		Distributed		Received
Quetta Warehouse	Bats	0	=	0
	Stumps	0	=	0
	Bails	0	=	0

		Lahore Warehouse		
		Distributed		Received
Lahore Warehouse	Bats	0	=	0
	Stumps	0	=	0
	Bails	0	=	0

			Peshawar Warehouse	
		Distributed		Received
Peshawar Warehouse	Bats	0	=	0
	Stumps	0	=	0
	Bails	0	=	0

			Karachi Warehouse	
		Distributed		Received
Karachi Warehouse	Bats	0	=	0
	Stumps	0	=	0
	Bails	0	=	0

DECISION VARIABLE

	Bats	Stumps	Bails	COST
Karachi Factory	0	87000	0	8265000
Lahore Factory	116000	0	108000	19508000
			Total Cost	27773000

Number of products shipped

		Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse	TOTAL
Karachi Factory	Bats	0	0	0	0	0
	Stumps	0	0	0	0	0
	Bails	0	0	0	0	0
Lahore Factory	Bats	0	0	0	0	0
	Stumps	0	0	0	0	0
	Bails	0	0	0	0	0

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTALS
Karachi Factory	Bats	0	0	8.07794E-28	0	0	8.078E-28
	Stumps	20000	15000	22000	12000	18000	87000
	Bails	0	0	0	8.0779E-28	0	8.078E-28
Lahore Factory	Bats	30000	23000	15000	32000	16000	116000
	Stumps	0	0	0	0	0	0
	Bails	25000	22000	16000	20000	25000	108000

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTAL
Quetta Warehouse	Bats	0	0	0	0	0	0
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0
Lahore Warehouse	Bats	0	0	0	0	0	0
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0
Peshawar Warehouse	Bats	0	0	0	0	0	0
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0
Karachi Warehouse	Bats	0	0	0	0	0	0
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0

OPTIMAL RESULTS

Total cost of shipping		PKR 1,834,400
Total cost of production		PKR 27,773,000
	Total Cost	PKR 29,607,400

Microsoft Excel 11.0 Sensitivity Report
Worksheet: [EMGT835 Field Project with Initial Shipping Cost - formatted as instructed.xls]Model
Report Created: 3/22/2009 8:54:05 AM

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B103	Karachi Factory Bats	0	19.00006191	149.9999315	1E+30	19.00006191
C103	Karachi Factory Stumps	87000	0	95	3.49988726	95
D103	Karachi Factory Bails	0	2.949879982	45.00001669	1E+30	2.949879982
B104	Lahore Factory Bats	116000	0	130	19.00006239	130
C104	Lahore Factory Stumps	0	3.499887171	98.99996221	1E+30	3.499887171
D104	Lahore Factory Bails	108000	0	41	2.949880056	41
C110	Bats Quetta Warehouse	0	3.499910235	5.500018597	1E+30	3.499910235
D110	Bats Lahore Warehouse	0	3.499910235	5.500018597	1E+30	3.499910235
E110	Bats Peshawar Warehouse	0	4.999712109	5.999952555	1E+30	4.999712109
F110	Bats Karachi Warehouse	0	3.299862146	5.200132728	1E+30	3.299862146
C111	Stumps Quetta Warehouse	0	1.899885319	3.999844193	1E+30	1.899885319
D111	Stumps Lahore Warehouse	0	1.74975612	3.749877214	1E+30	1.74975612
E111	Stumps Peshawar Warehouse	0	2.599867366	4.249811172	1E+30	2.599867366
F111	Stumps Karachi Warehouse	0	1.549708031	4.249811172	1E+30	1.549708031
C112	Bails Quetta Warehouse	0	1.250207424	2.25007534	1E+30	1.250207424
D112	Bails Lahore Warehouse	0	2.150027248	2.750009298	1E+30	2.150027248
E112	Bails Peshawar Warehouse	0	1.950093283	2.500042319	1E+30	1.950093283
F112	Bails Karachi Warehouse	0	1.600012183	2.29999423	1E+30	1.600012183
C113	Bats Quetta Warehouse	0	3.499952618	6.499886513	1E+30	3.499952618
D113	Bats Lahore Warehouse	0	2.300036612	5.299970508	1E+30	2.300036612
E113	Bats Peshawar Warehouse	0	3.499952617	5.500018597	1E+30	3.499952617
F113	Bats Karachi Warehouse	0	2.300036613	5.200132728	1E+30	2.300036613
C114	Stumps Quetta Warehouse	0	2.649895177	4.249811172	1E+30	2.649895177
D114	Stumps Lahore Warehouse	0	2.300090418	3.800168633	1E+30	2.300090418

E114	Stumps Peshawar Warehouse	0	2.849943266	3.999844193	1E+30	2.849943266
F114	Stumps Karachi Warehouse	0	1.549816952	3.749877214	1E+30	1.549816952
C115	Bails Quetta Warehouse	0	0.850147754	2.900138497	1E+30	0.850147754
D115	Bails Lahore Warehouse	0	0.249793174	1.899898052	1E+30	0.249793174
E115	Bails Peshawar Warehouse	0	0.349745078	1.949816942	1E+30	0.349745078
F115	Bails Karachi Warehouse	0	0.849775225	2.599880099	1E+30	0.849775225
C120	Bats Punjab Distributor	0	0.749966966	7.750093937	1E+30	0.749966966
D120	Bats Sindh Distributor	0	0.999867916	8.499994874	1E+30	0.999867916
E120	Bats Baluchistan Distributor	8.07794E-28	0	7.500126958	0.749966966	19.00006191
F120	Bats Northern Distributor	0	1.499933933	8.000060916	1E+30	1.499933933
G120	Bats AK Distributor	0	1.499999962	7.500126958	1E+30	1.499999962
C121	Stumps Punjab Distributor	20000	0	5.5	0.049984921	100.5
D121	Stumps Sindh Distributor	15000	0	6	0.450111267	0.049822704
E121	Stumps Baluchistan Distributor	22000	0	5	0.700210311	100
F121	Stumps Northern Distributor	12000	0	5.749999999	0.150162219	100.75
G121	Stumps AK Distributor	18000	0	5.599999999	0.049822704	0.250096189
C122	Bails Punjab Distributor	0	1.500078215	4.399940372	1E+30	1.500078215
D122	Bails Sindh Distributor	0	1.300288531	4.500150681	1E+30	1.300288531
E122	Bails Baluchistan Distributor	0	0.950015055	3.749877214	1E+30	0.950015055
F122	Bails Northern Distributor	8.07794E-28	0	3.299862146	0.950015055	2.949879982
G122	Bails AK Distributor	0	0.950225367	3.850087523	1E+30	0.950225367
C123	Bats Punjab Distributor	30000	0	8	6.60298E-05	138
D123	Bats Sindh Distributor	23000	0	8.5	0.299885876	0
E123	Bats Baluchistan Distributor	15000	0	8.5	0	0.299885876
F123	Bats Northern Distributor	32000	0	7.5	1.499933971	137.5
G123	Bats AK Distributor	16000	0	7	0.500132059	137
C124	Stumps Punjab Distributor	0	0.250129196	5.250051618	1E+30	0.250129196
D124	Stumps Sindh Distributor	0	0.450111255	5.950033665	1E+30	0.450111255
E124	Stumps Baluchistan Distributor	0	0.700210293	5.200132728	1E+30	0.700210293
F124	Stumps Northern Distributor	0	0.250096183	5.500018597	1E+30	0.250096183
G124	Stumps AK Distributor	0	0	5.099922419	0.250096183	3.499887171
C125	Bails Punjab Distributor	25000	0	3.95	0.300000001	44.95

D125	Bails Sindh Distributor	22000	0	4.250000001	0.000162216	0.199951906
E125	Bails Baluchistan Distributor	16000	0	3.85	0.199951906	44.85
F125	Bails Northern Distributor	20000	0	4.35	0.200258407	0.000162216
G125	Bails AK Distributor	25000	0	3.95	0.199951906	0.050177296
C129	Bats Punjab Distributor	0	1.499867903	6.499886513	1E+30	1.499867903
D129	Bats Sindh Distributor	0	0.299885868	5.799904466	1E+30	0.299885868
E129	Bats Baluchistan Distributor	0	0	5.500018597	0.299885868	3.499910235
F129	Bats Northern Distributor	0	1.999867891	6.499886513	1E+30	1.999867891
G129	Bats AK Distributor	0	4.000042281	8.000060916	1E+30	4.000042281
C130	Stumps Punjab Distributor	0	0.599837767	3.999844193	1E+30	0.599837767
D130	Stumps Sindh Distributor	0	0	3.900006413	0.599837767	1.899885319
E130	Stumps Baluchistan Distributor	0	1.299885844	4.199892282	1E+30	1.299885844
F130	Stumps Northern Distributor	0	0.650096173	4.300102592	1E+30	0.650096173
G130	Stumps AK Distributor	0	1.599915996	5.099922419	1E+30	1.599915996
C131	Bails Punjab Distributor	0	0.850015058	2.750009298	1E+30	0.850015058
D131	Bails Sindh Distributor	0	0.000162216	2.20015645	1E+30	0.000162216
E131	Bails Baluchistan Distributor	0	0.799885856	2.599880099	1E+30	0.799885856
F131	Bails Northern Distributor	0	0	2.29999423	0.000162216	0.850147754
G131	Bails AK Distributor	0	1.000144257	2.900138497	1E+30	1.000144257
C132	Bats Punjab Distributor	0	0.999933946	5.999952555	1E+30	0.999933946
D132	Bats Sindh Distributor	0	0	5.500018597	0	2.300036612
E132	Bats Baluchistan Distributor	0	0	5.500018597	1E+30	0
F132	Bats Northern Distributor	0	1.499933933	5.999952555	1E+30	1.499933933
G132	Bats AK Distributor	0	1.499999963	5.500018597	1E+30	1.499999963
C133	Stumps Punjab Distributor	0	0.749966966	4.249811172	1E+30	0.749966966
D133	Stumps Sindh Distributor	0	0	3.999844193	0.150162215	1.74975612
E133	Stumps Baluchistan Distributor	0	0.999999975	3.999844193	1E+30	0.999999975
F133	Stumps Northern Distributor	0	0.150162215	3.900006413	1E+30	0.150162215
G133	Stumps AK Distributor	0	0.900306478	4.500150681	1E+30	0.900306478
C134	Bails Punjab Distributor	0	0.299999993	2.599880099	1E+30	0.299999993
D134	Bails Sindh Distributor	0	0	2.599880099	0.199951901	0.249793174
E134	Bails Baluchistan Distributor	0	0.199951901	2.39983201	1E+30	0.199951901

F134	Bails Northern Distributor	0	0.200258402	2.900138497	1E+30	0.200258402
G134	Bails AK Distributor	0	0.95006315	3.249943256	1E+30	0.95006315
C135	Bats Punjab Distributor	0	6.60298E-05	5.999952555	1E+30	6.60298E-05
D135	Bats Sindh Distributor	0	0	6.499886513	6.60298E-05	3.499952617
E135	Bats Baluchistan Distributor	0	0.499933959	6.999820471	1E+30	0.499933959
F135	Bats Northern Distributor	0	1.499933933	6.999820471	1E+30	1.499933933
G135	Bats AK Distributor	0	0.500132047	5.500018597	1E+30	0.500132047
C136	Stumps Punjab Distributor	0	0.049984919	3.900006413	1E+30	0.049984919
D136	Stumps Sindh Distributor	0	0	4.350021482	0.049822703	2.599867366
E136	Stumps Baluchistan Distributor	0	1.099837755	4.449859262	1E+30	1.099837755
F136	Stumps Northern Distributor	0	0.700015063	4.80003655	1E+30	0.700015063
G136	Stumps AK Distributor	0	0.049822703	3.999844193	1E+30	0.049822703
C137	Bails Punjab Distributor	0	0.400096178	2.750009298	1E+30	0.400096178
D137	Bails Sindh Distributor	0	0.050177295	2.700090408	1E+30	0.050177295
E137	Bails Baluchistan Distributor	0	1.000030133	3.249943256	1E+30	1.000030133
F137	Bails Northern Distributor	0	0.450111257	3.200024366	1E+30	0.450111257
G137	Bails AK Distributor	0	0	2.34991312	0.050177295	0.349745078
C138	Bats Punjab Distributor	0	2.400270569	7.500126958	1E+30	2.400270569
D138	Bats Sindh Distributor	0	0.900030136	6.499886513	1E+30	0.900030136
E138	Bats Baluchistan Distributor	0	0	5.599856377	0.900030136	2.300036613
F138	Bats Northern Distributor	0	1.900030111	6.499886513	1E+30	1.900030111
G138	Bats AK Distributor	0	1.400162182	5.500018597	1E+30	1.400162182
C139	Stumps Punjab Distributor	0	1.950255501	4.75011766	1E+30	1.950255501
D139	Stumps Sindh Distributor	0	0	3.299862146	1.199949021	1.549708031
E139	Stumps Baluchistan Distributor	0	1.400096153	3.699958324	1E+30	1.400096153
F139	Stumps Northern Distributor	0	1.199949021	4.249811172	1E+30	1.199949021
G139	Stumps AK Distributor	0	1.200192347	4.100054502	1E+30	1.200192347
C140	Bails Punjab Distributor	0	0.800096168	2.999976277	1E+30	0.800096168
D140	Bails Sindh Distributor	0	0.099999996	2.599880099	1E+30	0.099999996
E140	Bails Baluchistan Distributor	0	0.900096165	2.999976277	1E+30	0.900096165
F140	Bails Northern Distributor	0	0	2.599880099	0.099999996	0.849775225
G140	Bails AK Distributor	0	0.1999519	2.39983201	1E+30	0.1999519

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
C48	Bats Received	0	0	35000	1E+30	35000
C49	Stumps Received	0	0	30000	1E+30	30000
C50	Bails Received	0	0	20000	1E+30	20000
F48	< Received	0	0	20000	1E+30	20000
F49	< Received	0	0	25000	1E+30	25000
F50	< Received	0	0	20000	1E+30	20000
I48	< Received	0	0	30000	1E+30	30000
I49	< Received	0	0	15000	1E+30	15000
I50	< Received	0	0	25000	1E+30	25000
L48	< Received	0	0	15000	1E+30	15000
L49	< Received	0	0	24000	1E+30	24000
L50	< Received	0	0	20000	1E+30	20000
C56	Bats Received	30000	138	30000	1E+30	30000
C57	Stumps Received	20000	100.5	20000	1E+30	20000
C58	Bails Received	25000	44.95	25000	1E+30	25000
F56	> Received	23000	138.5	23000	1E+30	23000
F57	> Received	15000	101	15000	1E+30	15000
F58	> Received	22000	45.25	22000	1E+30	22000
I56	> Received	15000	138.5	15000	1E+30	15000
I57	> Received	22000	100	22000	1E+30	22000
I58	> Received	16000	44.85	16000	1E+30	16000
L56	< Received	32000	137.5	32000	1E+30	32000
L57	< Received	12000	100.75	12000	1E+30	12000
L58	< Received	20000	45.35	20000	1E+30	20000
O56	> Received	16000	137	16000	1E+30	16000
O57	> Received	18000	100.6	18000	1E+30	18000
O58	> Received	25000	44.95	25000	1E+30	25000
C64	Bats Shipped	8.07794E-28	-	0	15000.00038	0

			130.9998695			
C65	Stumps Shipped	87000	-95	0	87000	1E+30
C66	Bails Shipped	8.07794E-28	-42.05013671	0	20000.00051	0
C70	Bats Shipped	116000	-130	0	116000	1E+30
C71	Stumps Shipped	0	-95.50007504	0	18000.00045	0
C72	Bails Shipped	108000	-41	0	108000	1E+30
C78	Bats Distributed	0	-132.9999779	0	15000.00038	0
C79	Stumps Distributed	0	-97.09999104	0	15000.00038	0
C80	Bails Distributed	0	-43.05000462	0	20000.00051	0
C84	Bats Distributed	0	-132.9999779	0	23000.00058	0
C85	Stumps Distributed	0	-97.00015326	0	15000.00038	0
C86	Bails Distributed	0	-42.65011876	0	22000.00056	0
C90	Bats Distributed	0	-132.00011	0	23000.00058	0
C91	Stumps Distributed	0	-96.64997597	0	15000.00038	0
C92	Bails Distributed	0	-42.60008574	0	25000.00063	0
C96	Bats Distributed	0	-132.9001401	0	15000.00038	0
C97	Stumps Distributed	0	-97.7001353	0	15000.00038	0
C98	Bails Distributed	0	-42.75011875	0	20000.00051	0

Data, Model and Sensitivity Report with Revised Shipping Cost

Manufacturing Cost for each Factory Per Product

	Products		
	Bats	Stumps	Bails
Karachi Factory	PKR 150	PKR 95	PKR 45
Lahore Factory	PKR 130	PKR 99	PKR 41

Shipping Cost From Factory To Warehouses (PKR per product)

		Warehouse Destinations			
		Quetta	Lahore	Peshawar	Karachi
Karachi Factory	Bats	PKR 3.50	PKR 3.50	PKR 4.00	PKR 3.20
	Stumps	PKR 2.00	PKR 1.75	PKR 2.45	PKR 2.25
	Bails	PKR 0.25	PKR 0.75	PKR 0.50	PKR 0.30
Lahore Factory	Bats	PKR 4.50	PKR 3.30	PKR 3.50	PKR 3.20
	Stumps	PKR 2.25	PKR 1.80	PKR 2.00	PKR 1.75
	Bails	PKR 0.90	PKR 0.90	PKR 0.95	PKR 0.60

Shipping Cost From Factory To Distributors (PKR per product)

				Distributors Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Karachi Factory	Bats	PKR 5.75	PKR 6.50	PKR 5.50	PKR 6.00	PKR 5.50
	Stumps	PKR 3.50	PKR 4.00	PKR 3.00	PKR 3.75	PKR 3.60
	Bails	PKR 2.40	PKR 2.50	PKR 1.75	PKR 1.30	PKR 1.85
Lahore Factory	Bats	PKR 6.00	PKR 6.50	PKR 6.50	PKR 5.50	PKR 5.00
	Stumps	PKR 3.25	PKR 3.95	PKR 3.20	PKR 3.50	PKR 3.10
	Bails	PKR 1.95	PKR 2.25	PKR 1.85	PKR 2.35	PKR 1.95

Shipping Cost From Warehouses To Distributors (PKR per product)

				Distributor Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Quetta	Bats	PKR 2.50	PKR 1.80	PKR 1.50	PKR 2.50	PKR 4.00
	Stumps	PKR 2.00	PKR 1.90	PKR 2.20	PKR 2.30	PKR 3.10
	Bails	PKR 1.25	PKR 1.70	PKR 2.10	PKR 1.80	PKR 2.60
Lahore	Bats	PKR 2.00	PKR 1.50	PKR 1.50	PKR 2.00	PKR 1.50
	Stumps	PKR 2.25	PKR 2.00	PKR 2.00	PKR 1.90	PKR 2.50
	Bails	PKR 1.10	PKR 1.20	PKR 1.90	PKR 2.40	PKR 2.75
Peshawar	Bats	PKR 2.00	PKR 2.50	PKR 3.00	PKR 3.00	PKR 1.50
	Stumps	PKR 1.90	PKR 2.35	PKR 2.45	PKR 2.80	PKR 2.00
	Bails	PKR 1.25	PKR 1.20	PKR 2.75	PKR 2.70	PKR 1.85
Karachi	Bats	PKR 3.50	PKR 2.50	PKR 1.60	PKR 2.50	PKR 1.50
	Stumps	PKR 2.75	PKR 2.30	PKR 1.70	PKR 2.25	PKR 2.10
	Bails	PKR 1.50	PKR 1.10	PKR 2.50	PKR 2.10	PKR 1.90

Distributor Demand

	Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Bats	30000	23000	15000	32000	16000
Stumps	20000	15000	22000	12000	18000
Bails	25000	22000	16000	20000	25000

Warehouse Capacity

	Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse
Bats	35000	20000	30000	15000
Stumps	30000	25000	15000	24000
Bails	20000	20000	25000	20000

CONSTRAINTS

Number of products shipped from factories to Warehouses

		Quetta Warehouse			Lahore Warehouse				Peshawar Warehouse			Karachi Warehouse	
		Received		Capacity	Received		Capacity	Received		Capacity	Received		Capacity
Karachi and Lahore Factory	Bats	3000	≤	35000	20000	≤	20000	30000	≤	30000	15000	≤	15000
	Stumps	0	≤	30000	25000	≤	25000	0	≤	15000	0	≤	24000
	Bails	4.03897E-28	≤	20000	2000	≤	20000	0	≤	25000	20000	≤	20000

Number of products shipped from Factories and Warehouses to Distributors

		Punjab Distributor			Sindh Distributor			Baluchistan Distributor			Northern Distributor			AK Distributor		
		Received		Demand	Received		Demand	Received		Demand	Received		Demand	Received		Demand
Factory and Warehouse	Bats	30000	≥	30000	23000	≥	23000	15000	≤	15000	32000	≥	32000	16000	≥	16000
	Stumps	20000	≥	20000	15000	≥	15000	22000	≤	22000	12000	≥	12000	18000	≥	18000
	Bails	25000	≥	25000	22000	≥	22000	16000	≤	16000	20000	≥	20000	25000	≥	25000

Total products shipped out Factories

		Karachi Factory		
		Shipped		Manufactured
Karachi Factory	Bats	0	≤	0
	Stumps	87000	≤	87000
	Bails	0	≤	8.07794E-28

		Lahore Factory		
		Shipped		Manufactured
Lahore Factory	Bats	116000	≤	116000
	Stumps	0	≤	4.03897E-28
	Bails	108000	≤	108000

Distribution from Warehouses

		Quetta Warehouse		
		Distributed		Received
Quetta Warehouse	Bats	3000	=	3000
	Stumps	0	=	0
	Bails	0	=	4.03897E-28

		Lahore Warehouse		
		Distributed		Received
Lahore Warehouse	Bats	20000	=	20000
	Stumps	25000	=	25000
	Bails	2000	=	2000

			Peshawar Warehouse	
		Distributed		Received
Peshawar Warehouse	Bats	30000	=	30000
	Stumps	0	=	0
	Bails	0	=	0

			Karachi Warehouse	
		Distributed		Received
Karachi Warehouse	Bats	15000	=	15000
	Stumps	6.61744E-24	=	0
	Bails	20000	=	20000

DECISION VARIABLE

	Bats	Stumps	Bails	COST
Karachi Factory	0	87000	8.078E-28	8265000
Lahore Factory	116000	4.03897E-28	108000	19508000
			Total Cost	27773000

Number of products shipped

		Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse	TOTAL
Karachi Factory	Bats	0	0	0	0	0
	Stumps	0	25000	0	0	25000
	Bails	0	0	0	0	0
Lahore Factory	Bats	3000	20000	30000	15000	68000
	Stumps	0	0	0	0	0
	Bails	4.03897E-28	2000	0	20000	22000

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTALS
Karachi Factory	Bats	0	0	0	0	0	0
	Stumps	20000	0	22000	2000	18000	62000
	Bails	0	0	0	0	0	0
Lahore Factory	Bats	0	0	0	32000	16000	48000
	Stumps	0	0	0	0	0	0
	Bails	25000	0	16000	20000	25000	86000

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTAL
Quetta Warehouse	Bats	0	3000	0	0	0	3000
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0
Lahore Warehouse	Bats	0	20000	0	0	0	20000
	Stumps	0	15000	0	10000	0	25000
	Bails	0	2000	0	0	0	2000
Peshawar Warehouse	Bats	30000	0	0	0	0	30000
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0
Karachi Warehouse	Bats	0	0	15000	0	0	15000
	Stumps	0	6.617E-24	0	0	0	6.617E-24
	Bails	0	20000	0	0	0	20000

OPTIMAL RESULTS

Total cost of shipping	PKR 1,121,250
Total cost of production	PKR 27,773,000
Total Cost	PKR 28,894,250

Microsoft Excel 11.0 Sensitivity Report
Worksheet: [EMGT835 Field Project Revised Shipping Cost - formatted as instructed.xls]Model
Report Created: 3/22/2009 9:28:02 AM

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B103	Karachi Factory Bats	0	0	149.9999315	1E+30	18.99983897
C103	Karachi Factory Stumps	87000	0	95	3.499778847	95
D103	Karachi Factory Bails	8.07794E-28	0	45.00001669	1E+30	2.950144099
B104	Lahore Factory Bats	116000	0	130	18.99983858	130
C104	Lahore Factory Stumps	4.03897E-28	0	98.99996221	1E+30	3.499778758
D104	Lahore Factory Bails	108000	0	41	2.950144173	41
C110	Bats Quetta Warehouse	0	18.99983897	3.499910235	1E+30	18.99983897
D110	Bats Lahore Warehouse	0	20.19984506	3.499910235	1E+30	20.19984506
E110	Bats Peshawar Warehouse	0	20.49977902	3.999844193	1E+30	20.49977902
F110	Bats Karachi Warehouse	0	19.99995919	3.200024366	1E+30	19.99995919
C111	Stumps Quetta Warehouse	0	0.050041072	2.000108361	1E+30	0.050041072
D111	Stumps Lahore Warehouse	25000	0	1.75	0.1	1E+30
E111	Stumps Peshawar Warehouse	0	0.849683602	2.4497509	1E+30	0.849683602
F111	Stumps Karachi Warehouse	0	0.700104229	2.25007534	1E+30	0.700104229
C112	Bails Quetta Warehouse	0	3.349939652	0.249966979	1E+30	3.349939652
D112	Bails Lahore Warehouse	0	3.849917743	0.749900937	1E+30	3.849917743
E112	Bails Peshawar Warehouse	0	3.599867758	0.499933958	1E+30	3.599867758
F112	Bails Karachi Warehouse	0	3.699903609	0.299885869	1E+30	3.699903609
C113	Bats Quetta Warehouse	3000	0	4.500000005	0.199933967	0.800108415
D113	Bats Lahore Warehouse	20000	0	3.300000001	1.500000003	1E+30
E113	Bats Peshawar Warehouse	30000	0	3.5	0.5	1E+30
F113	Bats Karachi Warehouse	15000	0	3.2	1.199808035	1E+30
C114	Stumps Quetta Warehouse	0	4.299938101	2.25007534	1E+30	4.299938101
D114	Stumps Lahore Warehouse	0	4.050024927	1.800060272	1E+30	4.050024927

E114	Stumps Peshawar Warehouse	0	4.399971112	2.000108361	1E+30	4.399971112
F114	Stumps Karachi Warehouse	0	4.200100321	1.750141382	1E+30	4.200100321
C115	Bails Quetta Warehouse	4.03897E-28	0	0.900030136	3.349939652	0.199879996
D115	Bails Lahore Warehouse	2000	0	0.899999991	0.049880018	0.050079194
E115	Bails Peshawar Warehouse	0	0.049880017	0.949949026	1E+30	0.049880017
F115	Bails Karachi Warehouse	20000	0	0.6	0.399999984	1E+30
C120	Bats Punjab Distributor	0	19.74992047	5.749985576	1E+30	19.74992047
D120	Bats Sindh Distributor	0	20.19982141	6.499886513	1E+30	20.19982141
E120	Bats Baluchistan Distributor	0	19.50014545	5.500018597	1E+30	19.50014545
F120	Bats Northern Distributor	0	20.49988743	5.999952555	1E+30	20.49988743
G120	Bats AK Distributor	0	20.49995346	5.500018597	1E+30	20.49995346
C121	Stumps Punjab Distributor	20000	0	3.5	0.450210311	0.000210311
D121	Stumps Sindh Distributor	0	0.149878852	3.999844193	1E+30	0.149878852
E121	Stumps Baluchistan Distributor	22000	0	3.000000001	0.249855717	98
F121	Stumps Northern Distributor	2000	0	3.75	0.050041073	0.049951905
G121	Stumps AK Distributor	18000	0	3.6	0.000210311	98.6
C122	Bails Punjab Distributor	0	4.449849784	2.39983201	1E+30	4.449849784
D122	Bails Sindh Distributor	0	4.400060114	2.500042319	1E+30	4.400060114
E122	Bails Baluchistan Distributor	0	3.900159153	1.750141382	1E+30	3.900159153
F122	Bails Northern Distributor	0	2.950144099	1.300126314	1E+30	2.950144099
G122	Bails AK Distributor	0	3.899996936	1.849979162	1E+30	3.899996936
C123	Bats Punjab Distributor	0	0	5.999952555	0.800108395	0.200042374
D123	Bats Sindh Distributor	0	0.199933962	6.499886513	1E+30	0.199933962
E123	Bats Baluchistan Distributor	0	0.500125924	6.499886513	1E+30	0.500125924
F123	Bats Northern Distributor	32000	0	5.5	1.300108415	135.5
G123	Bats AK Distributor	16000	0	5	0.499801912	135
C124	Stumps Punjab Distributor	0	3.749907955	3.249943256	1E+30	3.749907955
D124	Stumps Sindh Distributor	0	4.099890011	3.949925303	1E+30	4.099890011
E124	Stumps Baluchistan Distributor	0	4.199989052	3.200024366	1E+30	4.199989052
F124	Stumps Northern Distributor	0	3.749874942	3.499910235	1E+30	3.749874942
G124	Stumps AK Distributor	0	3.499778758	3.099814057	1E+30	3.499778758
C125	Bails Punjab Distributor	25000	0	1.95	0.050079195	42.95

D125	Bails Sindh Distributor	0	0.150090326	2.25007534	1E+30	0.150090326
E125	Bails Baluchistan Distributor	16000	0	1.850000001	0.949899041	42.85
F125	Bails Northern Distributor	20000	0	2.35	0.350105393	43.35
G125	Bails AK Distributor	25000	0	1.95	0.800063157	42.95
C129	Bats Punjab Distributor	0	1.00004848	2.500042319	1E+30	1.00004848
D129	Bats Sindh Distributor	3000	0	1.799999997	0.199933967	0.299993881
E129	Bats Baluchistan Distributor	0	0	1.499801874	0.299993874	0.599850399
F129	Bats Northern Distributor	0	1.500048467	2.500042319	1E+30	1.500048467
G129	Bats AK Distributor	0	3.499850328	3.999844193	1E+30	3.499850328
C130	Stumps Punjab Distributor	0	0.4502103	2.000108361	1E+30	0.4502103
D130	Stumps Sindh Distributor	0	0	1.899898052	0.4502103	0.050041072
E130	Stumps Baluchistan Distributor	0	1.149885847	2.199783921	1E+30	1.149885847
F130	Stumps Northern Distributor	0	0.500096177	2.29999423	1E+30	0.500096177
G130	Stumps AK Distributor	0	1.449915998	3.099814057	1E+30	1.449915998
C131	Bails Punjab Distributor	0	0.199879996	1.249834895	1E+30	0.199879996
D131	Bails Sindh Distributor	0	0.499895085	1.699849963	1E+30	0.499895085
E131	Bails Baluchistan Distributor	0	1.149991239	2.099946141	1E+30	1.149991239
F131	Bails Northern Distributor	0	0.350105384	1.800060272	1E+30	0.350105384
G131	Bails AK Distributor	0	1.5499252	2.599880099	1E+30	1.5499252
C132	Bats Punjab Distributor	0	0.800108395	2.000108361	1E+30	0.800108395
D132	Bats Sindh Distributor	20000	0	1.5	0.299993881	1E+30
E132	Bats Baluchistan Distributor	0	0.299993874	1.499801874	1E+30	0.299993874
F132	Bats Northern Distributor	0	1.300108382	2.000108361	1E+30	1.300108382
G132	Bats AK Distributor	0	1.299801882	1.499801874	1E+30	1.299801882
C133	Stumps Punjab Distributor	0	0.600075382	2.25007534	1E+30	0.600075382
D133	Stumps Sindh Distributor	15000	0	2	0.050041073	0.049951905
E133	Stumps Baluchistan Distributor	0	0.85010839	2.000108361	1E+30	0.85010839
F133	Stumps Northern Distributor	10000	0	1.899999999	0.049951905	0.050041073
G133	Stumps AK Distributor	0	0.750042363	2.500042319	1E+30	0.750042363
C134	Bails Punjab Distributor	0	0.050079194	1.100078225	1E+30	0.050079194
D134	Bails Sindh Distributor	2000	0	1.199999994	0.049880018	0.199918875
E134	Bails Baluchistan Distributor	0	0.949899017	1.899898052	1E+30	0.949899017

F134	Bails Northern Distributor	0	0.949832989	2.39983201	1E+30	0.949832989
G134	Bails AK Distributor	0	1.700010267	2.750009298	1E+30	1.700010267
C135	Bats Punjab Distributor	30000	0	2	0.200042379	1E+30
D135	Bats Sindh Distributor	0	0.200042374	2.500042319	1E+30	0.200042374
E135	Bats Baluchistan Distributor	0	1.000168293	2.999976277	1E+30	1.000168293
F135	Bats Northern Distributor	0	1.499976315	2.999976277	1E+30	1.499976315
G135	Bats AK Distributor	0	0.499801899	1.499801874	1E+30	0.499801899
C136	Stumps Punjab Distributor	0	0	1.899898052	0.000210311	0.849683602
D136	Stumps Sindh Distributor	0	0.100015077	2.34991312	1E+30	0.100015077
E136	Stumps Baluchistan Distributor	0	1.049852835	2.4497509	1E+30	1.049852835
F136	Stumps Northern Distributor	0	0.650030144	2.799928188	1E+30	0.650030144
G136	Stumps AK Distributor	0	0.000210311	2.000108361	1E+30	0.000210311
C137	Bails Punjab Distributor	0	0.19991887	1.249834895	1E+30	0.19991887
D137	Bails Sindh Distributor	0	0	1.199916005	0.19991887	0.049880017
E137	Bails Baluchistan Distributor	0	1.80009327	2.750009298	1E+30	1.80009327
F137	Bails Northern Distributor	0	1.250174393	2.700090408	1E+30	1.250174393
G137	Bails AK Distributor	0	0.800063137	1.849979162	1E+30	0.800063137
C138	Bats Punjab Distributor	0	1.899718311	3.499910235	1E+30	1.899718311
D138	Bats Sindh Distributor	0	0.599850399	2.500042319	1E+30	0.599850399
E138	Bats Baluchistan Distributor	15000	0	1.599999999	0.599850414	1E+30
F138	Bats Northern Distributor	0	1.399850382	2.500042319	1E+30	1.399850382
G138	Bats AK Distributor	0	0.899609924	1.499801874	1E+30	0.899609924
C139	Stumps Punjab Distributor	0	0.800015059	2.750009298	1E+30	0.800015059
D139	Stumps Sindh Distributor	6.61744E-24	0	2.29999423	0.049951904	0.700104229
E139	Stumps Baluchistan Distributor	0	0.249855711	1.699849963	1E+30	0.249855711
F139	Stumps Northern Distributor	0	0.050081109	2.25007534	1E+30	0.050081109
G139	Stumps AK Distributor	0	0.049951904	2.099946141	1E+30	0.049951904
C140	Bails Punjab Distributor	0	0.549801882	1.499801874	1E+30	0.549801882
D140	Bails Sindh Distributor	20000	0	1.1	0.399999984	1E+30
E140	Bails Baluchistan Distributor	0	1.650042324	2.500042319	1E+30	1.650042324
F140	Bails Northern Distributor	0	0.74994616	2.099946141	1E+30	0.74994616
G140	Bails AK Distributor	0	0.94989806	1.899898052	1E+30	0.94989806

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
C48	Bats Received	3000	0	35000	1E+30	32000
C49	Stumps Received	0	0	30000	1E+30	30000
C50	Bails Received	4.03897E-28	0	20000	1E+30	20000
F48	< Received	20000	-1.500000003	20000	3000	20000
F49	< Received	25000	-0.1	25000	2000	10000
F50	< Received	2000	0	20000	1E+30	18000
I48	< Received	30000	-0.5	30000	0	30000
I49	< Received	0	0	15000	1E+30	15000
I50	< Received	0	0	25000	1E+30	25000
L48	< Received	15000	-1.199808035	15000	0	15000
L49	< Received	0	0	24000	1E+30	24000
L50	< Received	20000	-0.399999984	20000	2000	18000
C56	Bats Received	30000	136	30000	1E+30	0
C57	Stumps Received	20000	98.5	20000	1E+30	20000
C58	Bails Received	25000	42.95	25000	1E+30	25000
F56	> Received	23000	136.3	23000	32000	3000
F57	> Received	15000	98.85	15000	10000	2000
F58	> Received	22000	43.09999998	22000	18000	2000
I56	> Received	15000	135.999808	15000	31999.99854	0
I57	> Received	22000	98	22000	1E+30	22000
I58	> Received	16000	42.85	16000	1E+30	16000
L56	< Received	32000	135.5	32000	1E+30	32000
L57	< Received	12000	98.75	12000	1E+30	2000
L58	< Received	20000	43.35	20000	1E+30	20000
O56	> Received	16000	135	16000	1E+30	16000
O57	> Received	18000	98.6	18000	1E+30	18000

O58	> Received	25000	42.95	25000	1E+30	25000
C64	Bats Shipped	0	-149.9999315	0	0	1E+30
C65	Stumps Shipped	87000	-95	0	87000	1E+30
C66	Bails Shipped	0	-45.00001669	0	0	1E+30
C70	Bats Shipped	116000	-130	0	116000	1E+30
C71	Stumps Shipped	0	-98.99996221	0	0	1E+30
C72	Bails Shipped	108000	-41	0	108000	1E+30
C78	Bats Distributed	3000	-134.5	0	3000	32000
C79	Stumps Distributed	0	-96.95009945	0	2000.000051	0
C80	Bails Distributed	0	-41.90004402	0	0	20000
C84	Bats Distributed	20000	-134.8	0	3000	20000
C85	Stumps Distributed	25000	-96.85	0	2000	10000
C86	Bails Distributed	2000	-41.89999999	0	2000	18000
C90	Bats Distributed	30000	-134	0	0	30000
C91	Stumps Distributed	0	-96.60009946	0	20000.00051	0
C92	Bails Distributed	0	-41.90008289	0	2000.00005	0
C96	Bats Distributed	15000	-134.399808	0	0	15000
C97	Stumps Distributed	6.61744E-24	-96.55000327	0	2000.000051	0
C98	Bails Distributed	20000	-41.99999998	0	2000	18000

Appendix E

Data, Model and Sensitivity Report with Initial Shipping Cost and Factories Manufacturing Capacity Constraint

Manufacturing Cost for each Factory Per Product

	Products		
	Bats	Stumps	Bails
Karachi Factory	PKR 150	PKR 95	PKR 45
Lahore Factory	PKR 130	PKR 99	PKR 41

Shipping Cost From Factory To Warehouses (PKR per product)

		Warehouse Destinations			
		Quetta	Lahore	Peshawar	Karachi
Karachi Factory	Bats	PKR 5.50	PKR 5.50	PKR 6.00	PKR 5.20
	Stumps	PKR 4.00	PKR 3.75	PKR 4.25	PKR 4.25
	Bails	PKR 2.25	PKR 2.75	PKR 2.50	PKR 2.30
Lahore Factory	Bats	PKR 6.50	PKR 5.30	PKR 5.50	PKR 5.20
	Stumps	PKR 4.25	PKR 3.80	PKR 4.00	PKR 3.75
	Bails	PKR 2.90	PKR 1.90	PKR 1.95	PKR 2.60

Shipping Cost From Factory To Distributors (PKR per product)

				Distributors Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Karachi Factory	Bats	PKR 7.75	PKR 8.50	PKR 7.50	PKR 8.00	PKR 7.50
	Stumps	PKR 5.50	PKR 6.00	PKR 5.00	PKR 5.75	PKR 5.60
	Bails	PKR 4.40	PKR 4.50	PKR 3.75	PKR 3.30	PKR 3.85
Lahore Factory	Bats	PKR 8.00	PKR 8.50	PKR 8.50	PKR 7.50	PKR 7.00
	Stumps	PKR 5.25	PKR 5.95	PKR 5.20	PKR 5.50	PKR 5.10
	Bails	PKR 3.95	PKR 4.25	PKR 3.85	PKR 4.35	PKR 3.95

Shipping Cost From Warehouses To Distributors (PKR per product)

				Distributor Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Quetta	Bats	PKR 6.50	PKR 5.80	PKR 5.50	PKR 6.50	PKR 8.00
	Stumps	PKR 4.00	PKR 3.90	PKR 4.20	PKR 4.30	PKR 5.10
	Bails	PKR 2.75	PKR 2.20	PKR 2.60	PKR 2.30	PKR 2.90
Lahore	Bats	PKR 6.00	PKR 5.50	PKR 5.50	PKR 6.00	PKR 5.50
	Stumps	PKR 4.25	PKR 4.00	PKR 4.00	PKR 3.90	PKR 4.50
	Bails	PKR 2.60	PKR 2.60	PKR 2.40	PKR 2.90	PKR 3.25
Peshawar	Bats	PKR 6.00	PKR 6.50	PKR 7.00	PKR 7.00	PKR 5.50
	Stumps	PKR 3.90	PKR 4.35	PKR 4.45	PKR 4.80	PKR 4.00
	Bails	PKR 2.75	PKR 2.70	PKR 3.25	PKR 3.20	PKR 2.35
Karachi	Bats	PKR 7.50	PKR 6.50	PKR 5.60	PKR 6.50	PKR 5.50
	Stumps	PKR 4.75	PKR 3.30	PKR 3.70	PKR 4.25	PKR 4.10
	Bails	PKR 3.00	PKR 2.60	PKR 3.00	PKR 2.60	PKR 2.40

Distributor Demand

	Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Bats	30000	23000	15000	32000	16000
Stumps	20000	15000	22000	12000	18000
Bails	25000	22000	16000	20000	25000

Warehouse Capacity

	Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse
Bats	35000	20000	30000	15000
Stumps	30000	25000	15000	24000
Bails	20000	20000	25000	20000

Factory Manufacturing Capacity

	Karachi Factory	Lahore Factory
Bats	70000	50000
Stumps	47000	68000
Bails	49000	59000

CONSTRAINTS

Number of products shipped from factories to Warehouses

		Quetta Warehouse			Lahore Warehouse				Peshawar Warehouse			Karachi Warehouse	
		Received		Capacity	Received		Capacity	Received		Capacity	Received		Capacity
Karachi and Lahore Factory	Bats	0	≤	35000	0	≤	20000	0	≤	30000	0	≤	15000
	Stumps	0	≤	30000	0	≤	25000	0	≤	15000	0	≤	24000
	Bails	0	≤	20000	0	≤	20000	0	≤	25000	0	≤	20000

Number of products shipped from Factories and Warehouses to Distributors

		Punjab Distributor			Sindh Distributor			Baluchistan Distributor			Northern Distributor			AK Distributor		
		Received		Demand	Received		Demand	Received		Demand	Received		Demand	Received		Demand
Factory and Warehouse	Bats	30000	≥	30000	23000	≥	23000	15000	≤	15000	32000	≥	32000	16000	≥	16000
	Stumps	20000	≥	20000	15000	≥	15000	22000	≤	22000	12000	≥	12000	18000	≥	18000
	Bails	25000	≥	25000	22000	≥	22000	16000	≤	16000	20000	≥	20000	25000	≥	25000

Total products shipped out Factories

		Karachi Factory		
		Shipped		Manufactured
Karachi	Bats	66000	≤	66000
	Stumps	47000	≤	47000
	Bails	49000	≤	49000

		Lahore Factory		
		Shipped		Manufactured
Lahore	Bats	50000	≤	50000
	Stumps	40000	≤	40000
	Bails	59000	≤	59000

Distribution from Warehouses

		Quetta Warehouse		
		Distributed		Received
Quetta	Bats	0	=	0
	Stumps	0	=	0
	Bails	0	=	0

		Lahore Warehouse		
		Distributed		Received
Lahore	Bats	0	=	0
	Stumps	0	=	0
	Bails	0	=	0

			Peshawar Warehouse	
		Distributed		Received
Peshawar	Bats	0	=	0
	Stumps	0	=	0
	Bails	0	=	0

			Karachi Warehouse	
		Distributed		Received
Karachi	Bats	0	=	0
	Stumps	0	=	0
	Bails	0	=	0

Factories Total products Manufacturing Capacity

		Karachi Factory		
		Manufactured		Capacity
Karachi	Bats	66000	≤	70000
	Stumps	47000	≤	47000
	Bails	49000	≤	49000

		Lahore Factory		
		Manufactured		Capacity
Lahore	Bats	50000	≤	50000
	Stumps	40000	≤	68000
	Bails	59000	≤	59000

DECISION VARIABLE

	Bats	Stumps	Bails	COST
Karachi Factory	66000	47000	49000	16570000
Lahore Factory	50000	40000	59000	12879000
			Total Cost	29449000

Number of products shipped

		Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse	TOTAL
Karachi Factory	Bats	0	0	0	0	0
	Stumps	0	0	0	0	0
	Bails	0	0	0	0	0
Lahore Factory	Bats	0	0	0	0	0
	Stumps	0	0	0	0	0
	Bails	0	0	0	0	0

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTALS
Karachi Factory	Bats	30000	21000	15000	0	0	66000
	Stumps	0	15000	22000	10000	0	47000
	Bails	0	0	16000	20000	13000	49000
Lahore Factory	Bats	0	2000	0	32000	16000	50000
	Stumps	20000	0	0	2000	18000	40000
	Bails	25000	22000	0	0	12000	59000

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTAL
Quetta Warehouse	Bats	0	0	0	0	0	0
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0
Lahore Warehouse	Bats	0	0	0	0	0	0
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0
Peshawar Warehouse	Bats	0	0	0	0	0	0
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0
Karachi Warehouse	Bats	0	0	0	0	0	0
	Stumps	0	0	0	0	0	0
	Bails	0	0	0	0	0	0

OPTIMAL RESULTS

Total cost of shipping		PKR 1,773,500
Total cost of production		PKR 29,449,000
	Total Cost	PKR 31,222,500

Microsoft Excel 11.0 Sensitivity Report
Worksheet: [EMGT835 Field Project with Initial Shipping Cost and Manufacturing Capacity Constraint - formatted as instructed.xls]Model
Report Created: 3/22/2009 9:02:24 AM

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B119	Karachi Factory Bats	66000	0	150	29328052990	20.00000001
C119	Karachi Factory Stumps	47000	0	95	3.750000006	1E+30
D119	Karachi Factory Bails	49000	0	45	36409963818	3.900000001
B120	Lahore Factory Bats	50000	0	130	20.00000001	1E+30
C120	Lahore Factory Stumps	40000	0	99	2747950309	3.750000006
D120	Lahore Factory Bails	59000	0	41	3.900000001	1E+30
C126	Bats Quetta Warehouse	0	2.799977845	5.500018597	1E+30	2.799977845
D126	Bats Lahore Warehouse	0	2.500091976	5.500018597	1E+30	2.500091976
E126	Bats Peshawar Warehouse	0	3.999893851	5.999952555	1E+30	3.999893851
F126	Bats Karachi Warehouse	0	3.200074024	5.200132728	1E+30	3.200074024
C127	Stumps Quetta Warehouse	0	1.899886684	3.999844193	1E+30	1.899886684
D127	Stumps Lahore Warehouse	0	1.749757485	3.749877214	1E+30	1.749757485
E127	Stumps Peshawar Warehouse	0	2.599868731	4.249811172	1E+30	2.599868731
F127	Stumps Karachi Warehouse	0	1.549709395	4.249811172	1E+30	1.549709395
C128	Bails Quetta Warehouse	0	0.300248265	2.25007534	1E+30	0.300248265
D128	Bails Lahore Warehouse	0	1.199905872	2.750009298	1E+30	1.199905872
E128	Bails Peshawar Warehouse	0	0.999971908	2.500042319	1E+30	0.999971908
F128	Bails Karachi Warehouse	0	0.749890804	2.29999423	1E+30	0.749890804
C129	Bats Quetta Warehouse	0	3.799845769	6.499886513	1E+30	3.799845769
D129	Bats Lahore Warehouse	0	2.300043895	5.299970508	1E+30	2.300043895
E129	Bats Peshawar Warehouse	0	3.4999599	5.500018597	1E+30	3.4999599
F129	Bats Karachi Warehouse	0	3.200074031	5.200132728	1E+30	3.200074031
C130	Stumps Quetta Warehouse	0	2.399853742	4.249811172	1E+30	2.399853742

D130	Stumps Lahore Warehouse	0	2.050048983	3.800168633	1E+30	2.050048983
E130	Stumps Peshawar Warehouse	0	2.599901831	3.999844193	1E+30	2.599901831
F130	Stumps Karachi Warehouse	0	1.299775516	3.749877214	1E+30	1.299775516
C131	Bails Quetta Warehouse	0	0.850311389	2.900138497	1E+30	0.850311389
D131	Bails Lahore Warehouse	0	0.249794593	1.899898052	1E+30	0.249794593
E131	Bails Peshawar Warehouse	0	0.349746498	1.949816942	1E+30	0.349746498
F131	Bails Karachi Warehouse	0	0.94977664	2.599880099	1E+30	0.94977664
C136	Bats Punjab Distributor	30000	0	7.75	0.250066031	157.75
D136	Bats Sindh Distributor	21000	0	8.500000001	0.50011568	0.099969842
E136	Bats Baluchistan Distributor	15000	0	7.5	0.099969842	157.5
F136	Bats Northern Distributor	0	0.500115668	8.000060916	1E+30	0.500115668
G136	Bats AK Distributor	0	0.500181697	7.500126958	1E+30	0.500181697
C137	Stumps Punjab Distributor	0	5.46663E-05	5.500018597	1E+30	5.46663E-05
D137	Stumps Sindh Distributor	15000	0	6	0.200069825	0.049984926
E137	Stumps Baluchistan Distributor	22000	0	5	0.45016887	103.75
F137	Stumps Northern Distributor	10000	0	5.75	5.46662E-05	0.200069825
G137	Stumps AK Distributor	0	0.249892442	5.599856377	1E+30	0.249892442
C138	Bails Punjab Distributor	0	0.549956839	4.399940372	1E+30	0.549956839
D138	Bails Sindh Distributor	0	0.350167155	4.500150681	1E+30	0.350167155
E138	Bails Baluchistan Distributor	16000	0	3.75	0.000103956	48.75
F138	Bails Northern Distributor	20000	0	3.300000001	0.850000001	48.3
G138	Bails AK Distributor	13000	0	3.849999999	0.300248272	0.000103956
C139	Bats Punjab Distributor	0	0.250115689	8.000060916	1E+30	0.250115689
D139	Bats Sindh Distributor	2000	0	8.499999996	0.250115604	0.50011568
E139	Bats Baluchistan Distributor	0	1.000049641	8.499994874	1E+30	1.000049641
F139	Bats Northern Distributor	32000	0	7.5	0.50011568	157.5
G139	Bats AK Distributor	16000	0	7	0.500132053	157
C140	Stumps Punjab Distributor	20000	0	5.25	5.46663E-05	104.25
D140	Stumps Sindh Distributor	0	0.20006982	5.950033665	1E+30	0.20006982
E140	Stumps Baluchistan Distributor	0	0.450168858	5.200132728	1E+30	0.450168858
F140	Stumps Northern Distributor	2000	0	5.500000007	0.200069825	5.46662E-05
G140	Stumps AK Distributor	18000	0	5.1	0.249892449	104.1

C141	Bails Punjab Distributor	25000	0	3.95	0.300000001	48.85
D141	Bails Sindh Distributor	22000	0	4.250000001	0.050177295	0.099951908
E141	Bails Baluchistan Distributor	0	0.000103956	3.850087523	1E+30	0.000103956
F141	Bails Northern Distributor	0	0.950037902	4.350021482	1E+30	0.950037902
G141	Bails AK Distributor	12000	0	3.949999999	0.000103956	0.050177295
C145	Bats Punjab Distributor	0	1.449982029	6.499886513	1E+30	1.449982029
D145	Bats Sindh Distributor	0	0	5.799904466	0.700114107	2.799977845
E145	Bats Baluchistan Distributor	0	0.700114107	5.500018597	1E+30	0.700114107
F145	Bats Northern Distributor	0	1.699982016	6.499886513	1E+30	1.699982016
G145	Bats AK Distributor	0	3.700156407	8.000060916	1E+30	3.700156407
C146	Stumps Punjab Distributor	0	0.599837773	3.999844193	1E+30	0.599837773
D146	Stumps Sindh Distributor	0	0	3.900006413	0.599837773	1.899886684
E146	Stumps Baluchistan Distributor	0	1.299885844	4.199892282	1E+30	1.299885844
F146	Stumps Northern Distributor	0	0.650096172	4.300102592	1E+30	0.650096172
G146	Stumps AK Distributor	0	1.849915994	5.099922419	1E+30	1.849915994
C147	Bails Punjab Distributor	0	0.849852841	2.750009298	1E+30	0.849852841
D147	Bails Sindh Distributor	0	0	2.20015645	0.79972364	0.300248265
E147	Bails Baluchistan Distributor	0	0.79972364	2.599880099	1E+30	0.79972364
F147	Bails Northern Distributor	0	0.949837759	2.29999423	1E+30	0.949837759
G147	Bails AK Distributor	0	0.999982042	2.900138497	1E+30	0.999982042
C148	Bats Punjab Distributor	0	1.24993394	5.999952555	1E+30	1.24993394
D148	Bats Sindh Distributor	0	0	5.500018597	0.999999976	2.300043895
E148	Bats Baluchistan Distributor	0	0.999999976	5.500018597	1E+30	0.999999976
F148	Bats Northern Distributor	0	1.499933926	5.999952555	1E+30	1.499933926
G148	Bats AK Distributor	0	1.499999956	5.500018597	1E+30	1.499999956
C149	Stumps Punjab Distributor	0	0.749966972	4.249811172	1E+30	0.749966972
D149	Stumps Sindh Distributor	0	0	3.999844193	0.150162214	1.749757485
E149	Stumps Baluchistan Distributor	0	0.999999975	3.999844193	1E+30	0.999999975
F149	Stumps Northern Distributor	0	0.150162214	3.900006413	1E+30	0.150162214
G149	Stumps AK Distributor	0	1.150306476	4.500150681	1E+30	1.150306476
C150	Bails Punjab Distributor	0	0.299999993	2.599880099	1E+30	0.299999993
D150	Bails Sindh Distributor	0	0	2.599880099	0.199951902	0.249794593

E150	Bails Baluchistan Distributor	0	0.199951902	2.39983201	1E+30	0.199951902
F150	Bails Northern Distributor	0	1.150258377	2.900138497	1E+30	1.150258377
G150	Bails AK Distributor	0	0.950063152	3.249943256	1E+30	0.950063152
C151	Bats Punjab Distributor	0	0.250066024	5.999952555	1E+30	0.250066024
D151	Bats Sindh Distributor	0	0	6.499886513	0.250066024	3.4999599
E151	Bats Baluchistan Distributor	0	1.499933934	6.999820471	1E+30	1.499933934
F151	Bats Northern Distributor	0	1.499933926	6.999820471	1E+30	1.499933926
G151	Bats AK Distributor	0	0.50013204	5.500018597	1E+30	0.50013204
C152	Stumps Punjab Distributor	0	0.049984925	3.900006413	1E+30	0.049984925
D152	Stumps Sindh Distributor	0	0	4.350021482	0.049984925	2.599868731
E152	Stumps Baluchistan Distributor	0	1.099837755	4.449859262	1E+30	1.099837755
F152	Stumps Northern Distributor	0	0.700015062	4.80003655	1E+30	0.700015062
G152	Stumps AK Distributor	0	0.299822701	3.999844193	1E+30	0.299822701
C153	Bails Punjab Distributor	0	0.400096177	2.750009298	1E+30	0.400096177
D153	Bails Sindh Distributor	0	0.050177294	2.700090408	1E+30	0.050177294
E153	Bails Baluchistan Distributor	0	1.000030133	3.249943256	1E+30	1.000030133
F153	Bails Northern Distributor	0	1.400111231	3.200024366	1E+30	1.400111231
G153	Bails AK Distributor	0	0	2.34991312	0.050177294	0.349746498
C154	Bats Punjab Distributor	0	1.750240427	7.500126958	1E+30	1.750240427
D154	Bats Sindh Distributor	0	0	6.499886513	0.09996984	3.200074024
E154	Bats Baluchistan Distributor	0	0.09996984	5.599856377	1E+30	0.09996984
F154	Bats Northern Distributor	0	0.999999968	6.499886513	1E+30	0.999999968
G154	Bats AK Distributor	0	0.50013204	5.500018597	1E+30	0.50013204
C155	Stumps Punjab Distributor	0	1.950255506	4.75011766	1E+30	1.950255506
D155	Stumps Sindh Distributor	0	0	3.299862146	1.19994902	1.299775516
E155	Stumps Baluchistan Distributor	0	1.400096153	3.699958324	1E+30	1.400096153
F155	Stumps Northern Distributor	0	1.19994902	4.249811172	1E+30	1.19994902
G155	Stumps AK Distributor	0	1.450192345	4.100054502	1E+30	1.450192345
C156	Bails Punjab Distributor	0	0.700096171	2.999976277	1E+30	0.700096171
D156	Bails Sindh Distributor	0	0	2.599880099	0.099951906	0.749890804
E156	Bails Baluchistan Distributor	0	0.800096169	2.999976277	1E+30	0.800096169
F156	Bails Northern Distributor	0	0.849999979	2.599880099	1E+30	0.849999979

G156	Bails AK Distributor	0	0.099951906	2.39983201	1E+30	0.099951906

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
C48	Bats Received	0	0	35000	1E+30	35000
C49	Stumps Received	0	0	30000	1E+30	30000
C50	Bails Received	0	0	20000	1E+30	20000
F48	< Received	0	0	20000	1E+30	20000
F49	< Received	0	0	25000	1E+30	25000
F50	< Received	0	0	20000	1E+30	20000
I48	< Received	0	0	30000	1E+30	30000
I49	< Received	0	0	15000	1E+30	15000
I50	< Received	0	0	25000	1E+30	25000
L48	< Received	0	0	15000	1E+30	15000
L49	< Received	0	0	24000	1E+30	24000
L50	< Received	0	0	20000	1E+30	20000
C56	Bats Received	30000	157.75	30000	4000	30000
C57	Stumps Received	20000	104.25	20000	28000	20000
C58	Bails Received	25000	48.85	25000	0	13000
F56	> Received	23000	158.5	23000	4000	21000
F57	> Received	15000	104.75	15000	10000	2000
F58	> Received	22000	49.15	22000	0	13000
I56	> Received	15000	157.5	15000	4000	15000
I57	> Received	22000	103.75	22000	10000	2000
I58	> Received	16000	48.75	16000	0	16000
L56	< Received	32000	157.5	32000	2000	21000
L57	< Received	12000	104.5	12000	28000	2000
L58	< Received	20000	48.3	20000	0	20000
O56	> Received	16000	157	16000	2000	16000
O57	> Received	18000	104.1	18000	28000	18000
O58	> Received	25000	48.85	25000	0	13000

C64	Bats Shipped	66000	-150	0	66000	4000
C65	Stumps Shipped	47000	-98.75000001	0	2000	10000
C66	Bails Shipped	49000	-45	0	49000	0
C70	Bats Shipped	50000	-150	0	21000	2000
C71	Stumps Shipped	40000	-99	0	40000	28000
C72	Bails Shipped	59000	-44.9	0	13000	0
C78	Bats Distributed	0	-152.7000915	0	21000.00053	0
C79	Stumps Distributed	0	-100.8499909	0	2000.000051	0
C80	Bails Distributed	0	-46.94984231	0	13000.00033	0
C84	Bats Distributed	0	-152.9999774	0	21000.00053	0
C85	Stumps Distributed	0	-100.7501532	0	2000.000051	0
C86	Bails Distributed	0	-46.55011866	0	13000.00033	0
C90	Bats Distributed	0	-152.0001095	0	21000.00053	0
C91	Stumps Distributed	0	-100.3999759	0	2000.000051	0
C92	Bails Distributed	0	-46.50008564	0	13000.00033	0
C96	Bats Distributed	0	-152.0001095	0	21000.00053	0
C97	Stumps Distributed	0	-101.4501352	0	2000.000051	0
C98	Bails Distributed	0	-46.55011866	0	13000.00033	0
C105	Bats Manufactured	66000	0	70000	1E+30	4000
C106	Stumps Manufactured	47000	-3.750000006	47000	2000	10000
C107	Bails Manufactured	49000	0	49000	1E+30	0

C112	Bats Manufactured	50000	-20.00000001	50000	21000	2000
C113	Stumps Manufactured	40000	0	68000	1E+30	28000
C114	Bails Manufactured	59000	-3.900000001	59000	13000	0

Data, Model and Sensitivity Report with Revised Shipping Cost and Factories Manufacturing Capacity Constraint

Manufacturing Cost for each Factory Per Product

	Products		
	Bats	Stumps	Bails
Karachi Factory	PKR 150	PKR 95	PKR 45
Lahore Factory	PKR 130	PKR 99	PKR 41

Shipping Cost From Factory To Warehouses (PKR per product)

		Warehouse Destinations			
		Quetta	Lahore	Peshawar	Karachi
Karachi Factory	Bats	PKR 3.50	PKR 3.50	PKR 4.00	PKR 3.20
	Stumps	PKR 2.00	PKR 1.75	PKR 2.45	PKR 2.25
	Bails	PKR 0.25	PKR 0.75	PKR 0.50	PKR 0.30
Lahore Factory	Bats	PKR 4.50	PKR 3.30	PKR 3.50	PKR 3.20
	Stumps	PKR 2.25	PKR 1.80	PKR 2.00	PKR 1.75
	Bails	PKR 0.90	PKR 0.90	PKR 0.95	PKR 0.60

Shipping Cost From Factory To Distributors (PKR per product)

				Distributors Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Karachi Factory	Bats	PKR 5.75	PKR 6.50	PKR 5.50	PKR 6.00	PKR 5.50
	Stumps	PKR 3.50	PKR 4.00	PKR 3.00	PKR 3.75	PKR 3.60
	Bails	PKR 2.40	PKR 2.50	PKR 1.75	PKR 1.30	PKR 1.85
Lahore Factory	Bats	PKR 6.00	PKR 6.50	PKR 6.50	PKR 5.50	PKR 5.00
	Stumps	PKR 3.25	PKR 3.95	PKR 3.20	PKR 3.50	PKR 3.10
	Bails	PKR 1.95	PKR 2.25	PKR 1.85	PKR 2.35	PKR 1.95

Shipping Cost From Warehouses To Distributors (PKR per product)

				Distributor Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Quetta	Bats	PKR 2.50	PKR 1.80	PKR 1.50	PKR 2.50	PKR 4.00
	Stumps	PKR 2.00	PKR 1.90	PKR 2.20	PKR 2.30	PKR 3.10
	Bails	PKR 1.25	PKR 1.70	PKR 2.10	PKR 1.80	PKR 2.60
Lahore	Bats	PKR 2.00	PKR 1.50	PKR 1.50	PKR 2.00	PKR 1.50
	Stumps	PKR 2.25	PKR 2.00	PKR 2.00	PKR 1.90	PKR 2.50
	Bails	PKR 1.10	PKR 1.20	PKR 1.90	PKR 2.40	PKR 2.75
Peshawar	Bats	PKR 2.00	PKR 2.50	PKR 3.00	PKR 3.00	PKR 1.50
	Stumps	PKR 1.90	PKR 2.35	PKR 2.45	PKR 2.80	PKR 2.00
	Bails	PKR 1.25	PKR 1.20	PKR 2.75	PKR 2.70	PKR 1.85
Karachi	Bats	PKR 3.50	PKR 2.50	PKR 1.60	PKR 2.50	PKR 1.50
	Stumps	PKR 2.75	PKR 2.30	PKR 1.70	PKR 2.25	PKR 2.10
	Bails	PKR 1.50	PKR 1.10	PKR 2.50	PKR 2.10	PKR 1.90

Distributor Demand

	Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Bats	30000	23000	15000	32000	16000
Stumps	20000	15000	22000	12000	18000
Bails	25000	22000	16000	20000	25000

Warehouse Capacity

	Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse
Bats	35000	20000	30000	15000
Stumps	30000	25000	15000	24000
Bails	20000	20000	25000	20000

Factory Manufacturing Capacity

	Karachi Factory	Lahore Factory
Bats	70000	50000
Stumps	47000	68000
Bails	49000	59000

CONSTRAINTS

Number of products shipped from factories to Warehouses

		Quetta Warehouse			Lahore Warehouse				Peshawar Warehouse			Karachi Warehouse	
		Received		Capacity	Received		Capacity	Received		Capacity	Received		Capacity
Karachi and Lahore Factory	Bats	18000	≤	35000	20000	≤	20000	18000	≤	30000	15000	≤	15000
	Stumps	0	≤	30000	25000	≤	25000	0	≤	15000	0	≤	24000
	Bails	20000	≤	20000	0	≤	20000	2000	≤	25000	20000	≤	20000

Number of products shipped from Factories and Warehouses to Distributors

		Punjab Distributor			Sindh Distributor			Baluchistan Distributor			Northern Distributor			AK Distributor		
		Received		Demand	Received		Demand	Received		Demand	Received		Demand	Received		Demand
Factory and Warehouse	Bats	30000	≥	30000	23000	≥	23000	15000	≤	15000	32000	≥	32000	16000	≥	16000
	Stumps	20000	≥	20000	15000	≥	15000	22000	≤	22000	12000	≥	12000	18000	≥	18000
	Bails	25000	≥	25000	22000	≥	22000	16000	≤	16000	20000	≥	20000	25000	≥	25000

Total products shipped out Factories

		Karachi Factory		
		Shipped		Manufactured
Karachi	Bats	66000	≤	66000
	Stumps	47000	≤	47000
	Bails	49000	≤	49000

		Lahore Factory		
		Shipped		Manufactured
Lahore	Bats	50000	≤	50000
	Stumps	40000	≤	40000
	Bails	59000	≤	59000

Distribution from Warehouses

		Quetta Warehouse		
		Distributed		Received
Quetta	Bats	18000	=	18000
	Stumps	0	=	0
	Bails	20000	=	20000

		Lahore Warehouse		
		Distributed		Received
Lahore	Bats	20000	=	20000
	Stumps	25000	=	25000
	Bails	0	=	0

			Peshawar Warehouse	
		Distributed		Received
Peshawar	Bats	18000	=	18000
	Stumps	0	=	0
	Bails	2000	=	2000

			Karachi Warehouse	
		Distributed		Received
Karachi	Bats	15000	=	15000
	Stumps	0	=	0
	Bails	20000	=	20000

Factories Total products Manufacturing Capacity

		Karachi Factory		
		Manufactured		Capacity
Karachi	Bats	66000	≤	70000
	Stumps	47000	≤	47000
	Bails	49000	≤	49000

		Lahore Factory		
		Manufactured		Capacity
Lahore	Bats	50000	≤	50000
	Stumps	40000	≤	68000
	Bails	59000	≤	59000

DECISION VARIABLE

	Bats	Stumps	Bails	COST
Karachi Factory	66000	47000	49000	16570000
Lahore Factory	50000	40000	59000	12879000
			Total Cost	29449000

Number of products shipped

		Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse	TOTAL
Karachi Factory	Bats	18000	20000	0	15000	53000
	Stumps	0	25000	0	0	25000
	Bails	20000	0	2000	7000	29000
Lahore Factory	Bats	0	0	18000	0	18000
	Stumps	0	0	0	0	0
	Bails	0	0	0	13000	13000

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTALS
Karachi Factory	Bats	13000	0	0	0	0	13000
	Stumps	0	0	22000	3.638E-12	0	22000
	Bails	0	0	0	20000	0	20000
Lahore Factory	Bats	0	0	0	32000	0	32000
	Stumps	20000	0	0	2000	18000	40000
	Bails	5000	0	16000	0	25000	46000

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTAL
Quetta Warehouse	Bats	0	3000	15000	0	0	18000
	Stumps	0	0	0	0	0	0
	Bails	20000	0	0	0	0	20000
Lahore Warehouse	Bats	0	20000	0	0	0	20000
	Stumps	0	15000	0	10000	0	25000
	Bails	0	0	0	0	0	0
Peshawar Warehouse	Bats	17000	0	0	0	1000	18000
	Stumps	0	0	0	0	0	0
	Bails	0	2000	0	0	0	2000
Karachi Warehouse	Bats	0	0	0	0	15000	15000
	Stumps	0	0	0	0	0	0
	Bails	0	20000	0	0	0	20000

OPTIMAL RESULTS

Total cost of shipping		PKR 1,076,600
Total cost of production		PKR 29,449,000
	Total Cost	PKR 30,525,600

Worksheet: [EMGT835 Field Project with Revised Shipping Cost and Manufacturing Capacity Constraint - formatted as instructed.xls]Model
Report Created: 3/22/2009 9:32:15 AM

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B119	Karachi Factory Bats	66000	0	150	82.83512173	20.25
C119	Karachi Factory Stumps	47000	0	95	3.75008676	1E+30
D119	Karachi Factory Bails	49000	0	45	40209479707	3.699999999
B120	Lahore Factory Bats	50000	0	130	20.25	1E+30
C120	Lahore Factory Stumps	40000	0	99	961816.7031	3.750088125
D120	Lahore Factory Bails	59000	0	41	3.699999999	1E+30
C126	Bats Quetta Warehouse	18000	0	3.5	0.350012197	0.049735878
D126	Bats Lahore Warehouse	20000	0	3.5	0.049807571	1E+30
E126	Bats Peshawar Warehouse	0	0.249680579	3.999844193	1E+30	0.249680579
F126	Bats Karachi Warehouse	15000	0	3.2	0.249969788	1E+30
C127	Stumps Quetta Warehouse	0	0.049756671	1.999735832	1E+30	0.049756671
D127	Stumps Lahore Warehouse	25000	0	1.75	0.099913235	1E+30
E127	Stumps Peshawar Warehouse	0	0.849771726	2.4497509	1E+30	0.849771726
F127	Stumps Karachi Warehouse	0	0.700192358	2.25007534	1E+30	0.700192358
C128	Bails Quetta Warehouse	20000	0	0.25	0.149999995	1E+30
D128	Bails Lahore Warehouse	0	0.19999558	0.749900937	1E+30	0.19999558
E128	Bails Peshawar Warehouse	2000	0	0.499999993	0.049837778	0.099835959
F128	Bails Karachi Warehouse	7000	0	0.299999999	0.099835961	0.049837778
C129	Bats Quetta Warehouse	0	1.249723575	4.499778152	1E+30	1.249723575
D129	Bats Lahore Warehouse	0	0.049807569	3.299862146	1E+30	0.049807569
E129	Bats Peshawar Warehouse	18000	0	3.499999999	3.01334E-05	0.049735878
F129	Bats Karachi Warehouse	0	0.249969781	3.200024366	1E+30	0.249969781
C130	Stumps Quetta Warehouse	0	0.550009504	2.25007534	1E+30	0.550009504
D130	Stumps Lahore Warehouse	0	0.300009566	1.800060272	1E+30	0.300009566
E130	Stumps Peshawar Warehouse	0	0.649669983	1.999735832	1E+30	0.649669983

F130	Stumps Karachi Warehouse	0	0.449799195	1.749768853	1E+30	0.449799195
C131	Bails Quetta Warehouse	0	0.35004641	0.900030136	1E+30	0.35004641
D131	Bails Lahore Warehouse	0	0.050124676	0.900030136	1E+30	0.050124676
E131	Bails Peshawar Warehouse	0	0.149964278	0.949949026	1E+30	0.149964278
F131	Bails Karachi Warehouse	13000	0	0.600000001	0.049837778	0.099835961
C136	Bats Punjab Distributor	13000	0	5.75	0.049735878	0.049807589
D136	Bats Sindh Distributor	0	1.199722941	6.499886513	1E+30	1.199722941
E136	Bats Baluchistan Distributor	0	0.499855014	5.500018597	1E+30	0.499855014
F136	Bats Northern Distributor	0	0.24978899	5.999952555	1E+30	0.24978899
G136	Bats AK Distributor	0	0.249855048	5.500018597	1E+30	0.249855048
C137	Stumps Punjab Distributor	0	3.30091E-05	3.499910235	1E+30	3.30091E-05
D137	Stumps Sindh Distributor	0	0.14996698	3.999844193	1E+30	0.14996698
E137	Stumps Baluchistan Distributor	22000	0	2.999999999	0.249768954	101.7500868
F137	Stumps Northern Distributor	3.63798E-12	0	3.749877214	3.30091E-05	0.099913269
G137	Stumps AK Distributor	0	0.249870787	3.599748015	1E+30	0.249870787
C138	Bails Punjab Distributor	0	0.749831457	2.39983201	1E+30	0.749831457
D138	Bails Sindh Distributor	0	0.800058734	2.500042319	1E+30	0.800058734
E138	Bails Baluchistan Distributor	0	0.199785264	1.749768853	1E+30	0.199785264
F138	Bails Northern Distributor	20000	0	1.299999999	0.749929441	46.3
G138	Bails AK Distributor	0	0.199995576	1.849979162	1E+30	0.199995576
C139	Bats Punjab Distributor	0	0.499898035	5.999952555	1E+30	0.499898035
D139	Bats Sindh Distributor	0	1.449831985	6.499886513	1E+30	1.449831985
E139	Bats Baluchistan Distributor	0	1.749831974	6.499886513	1E+30	1.749831974
F139	Bats Northern Distributor	32000	0	5.499999999	0.049735878	155.75
G139	Bats AK Distributor	0	3.01334E-05	5.000084639	1E+30	3.01334E-05
C140	Stumps Punjab Distributor	20000	0	3.25	3.30091E-05	0.100015084
D140	Stumps Sindh Distributor	0	0.349889383	3.949925303	1E+30	0.349889383
E140	Stumps Baluchistan Distributor	0	0.449901661	3.200024366	1E+30	0.449901661
F140	Stumps Northern Distributor	2000	0	3.499999996	0.100015084	3.30091E-05
G140	Stumps AK Distributor	18000	0	3.099999999	0.249837784	102.1
C141	Bails Punjab Distributor	5000	0	1.949999996	0.050124677	0.049837778
D141	Bails Sindh Distributor	0	0.250091652	2.25007534	1E+30	0.250091652

E141	Bails Baluchistan Distributor	16000	0	1.850000001	0.199785269	46.55
F141	Bails Northern Distributor	0	0.749929422	2.34991312	1E+30	0.749929422
G141	Bails AK Distributor	25000	0	1.95	0.199995581	46.65
C145	Bats Punjab Distributor	0	0.250042376	2.500042319	1E+30	0.250042376
D145	Bats Sindh Distributor	3000	0	1.799999997	0.950042358	0.049735878
E145	Bats Baluchistan Distributor	15000	0	1.5	0.299801909	155
F145	Bats Northern Distributor	0	0.250042375	2.500042319	1E+30	0.250042375
G145	Bats AK Distributor	0	2.249844265	3.999844193	1E+30	2.249844265
C146	Stumps Punjab Distributor	0	0.449837767	1.999735832	1E+30	0.449837767
D146	Stumps Sindh Distributor	0	0	1.899898052	0.449837767	0.049756671
E146	Stumps Baluchistan Distributor	0	1.149799084	2.199783921	1E+30	1.149799084
F146	Stumps Northern Distributor	0	0.500096177	2.29999423	1E+30	0.500096177
G146	Stumps AK Distributor	0	1.699915989	3.099814057	1E+30	1.699915989
C147	Bails Punjab Distributor	20000	0	1.25	0.149999995	1E+30
D147	Bails Sindh Distributor	0	0.399849992	1.699849963	1E+30	0.399849992
E147	Bails Baluchistan Distributor	0	0.949946166	2.099946141	1E+30	0.949946166
F147	Bails Northern Distributor	0	0.900060291	1.800060272	1E+30	0.900060291
G147	Bails AK Distributor	0	1.349880127	2.599880099	1E+30	1.349880127
C148	Bats Punjab Distributor	0	0.049735879	1.999735832	1E+30	0.049735879
D148	Bats Sindh Distributor	20000	0	1.5	0.049735878	1E+30
E148	Bats Baluchistan Distributor	0	0.299801901	1.499801874	1E+30	0.299801901
F148	Bats Northern Distributor	0	0.049735877	1.999735832	1E+30	0.049735877
G148	Bats AK Distributor	0	0.049801935	1.499801874	1E+30	0.049801935
C149	Stumps Punjab Distributor	0	0.600075377	2.25007534	1E+30	0.600075377
D149	Stumps Sindh Distributor	15000	0	2	0.049756673	0.05008111
E149	Stumps Baluchistan Distributor	0	0.849649098	1.999735832	1E+30	0.849649098
F149	Stumps Northern Distributor	10000	0	1.899999999	0.05008111	0.049756673
G149	Stumps AK Distributor	0	1.000042354	2.500042319	1E+30	1.000042354
C150	Bails Punjab Distributor	0	0	1.100078225	0.049837777	0.050124676
D150	Bails Sindh Distributor	0	0.049837777	1.199916005	1E+30	0.049837777
E150	Bails Baluchistan Distributor	0	0.89981982	1.899898052	1E+30	0.89981982
F150	Bails Northern Distributor	0	1.649753772	2.39983201	1E+30	1.649753772

G150	Bails AK Distributor	0	1.649931069	2.750009298	1E+30	1.649931069
C151	Bats Punjab Distributor	17000	0	1.999999999	0.049807589	0.049735878
D151	Bats Sindh Distributor	0	0.950042362	2.500042319	1E+30	0.950042362
E151	Bats Baluchistan Distributor	0	1.74997631	2.999976277	1E+30	1.74997631
F151	Bats Northern Distributor	0	0.999976328	2.999976277	1E+30	0.999976328
G151	Bats AK Distributor	1000	0	1.499999975	3.01334E-05	0.350012197
C152	Stumps Punjab Distributor	0	0	1.899898052	0.100015081	0.649669983
D152	Stumps Sindh Distributor	0	0.100015081	2.34991312	1E+30	0.100015081
E152	Stumps Baluchistan Distributor	0	1.049766076	2.4497509	1E+30	1.049766076
F152	Stumps Northern Distributor	0	0.650030148	2.799928188	1E+30	0.650030148
G152	Stumps AK Distributor	0	0.249837777	1.999735832	1E+30	0.249837777
C153	Bails Punjab Distributor	0	0.099835958	1.249834895	1E+30	0.099835958
D153	Bails Sindh Distributor	2000	0	1.200000005	0.049837778	0.3
E153	Bails Baluchistan Distributor	0	1.700010354	2.750009298	1E+30	1.700010354
F153	Bails Northern Distributor	0	1.900091458	2.700090408	1E+30	1.900091458
G153	Bails AK Distributor	0	0.699980221	1.849979162	1E+30	0.699980221
C154	Bats Punjab Distributor	0	1.499910259	3.499910235	1E+30	1.499910259
D154	Bats Sindh Distributor	0	0.950042334	2.500042319	1E+30	0.950042334
E154	Bats Baluchistan Distributor	0	0.350012188	1.600012183	1E+30	0.350012188
F154	Bats Northern Distributor	0	0.500042342	2.500042319	1E+30	0.500042342
G154	Bats AK Distributor	15000	0	1.5	0.350012197	1E+30
C155	Stumps Punjab Distributor	0	0.800015055	2.750009298	1E+30	0.800015055
D155	Stumps Sindh Distributor	0	0	2.29999423	0.050081109	0.449799195
E155	Stumps Baluchistan Distributor	0	0.249768948	1.699849963	1E+30	0.249768948
F155	Stumps Northern Distributor	0	0.050081109	2.25007534	1E+30	0.050081109
G155	Stumps AK Distributor	0	0.299951895	2.099946141	1E+30	0.299951895
C156	Bails Punjab Distributor	0	0.449801905	1.499801874	1E+30	0.449801905
D156	Bails Sindh Distributor	20000	0	1.1	0.3	1E+30
E156	Bails Baluchistan Distributor	0	1.550042344	2.500042319	1E+30	1.550042344
F156	Bails Northern Distributor	0	1.399946159	2.099946141	1E+30	1.399946159
G156	Bails AK Distributor	0	0.84989808	1.899898052	1E+30	0.84989808

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
C48	Bats Received	18000	0	35000	1E+30	17000
C49	Stumps Received	0	0	30000	1E+30	30000
C50	Bails Received	20000	-0.149999995	20000	5000	0.522727786
F48	< Received	20000	-0.299999997	20000	3000	17000
F49	< Received	25000	-0.099913235	25000	0	10000
F50	< Received	0	0	20000	1E+30	20000
I48	< Received	18000	0	30000	1E+30	12000
I49	< Received	0	0	15000	1E+30	15000
I50	< Received	2000	0	25000	1E+30	23000
L48	< Received	15000	-0.549999972	15000	1000	15000
L49	< Received	0	0	24000	1E+30	24000
L50	< Received	20000	-0.3	20000	2000	0.681944694
C56	Bats Received	30000	155.75	30000	4000	13000
C57	Stumps Received	20000	102.25	20000	28000	20000
C58	Bails Received	25000	46.65	25000	0	5000
F56	> Received	23000	155.3	23000	4000	3000
F57	> Received	15000	102.6	15000	10000	2000
F58	> Received	22000	46.7	22000	0	2000
I56	> Received	15000	155	15000	4000	15000
I57	> Received	22000	101.7500868	22000	0	2000.000728
I58	> Received	16000	46.55	16000	0	7000
L56	< Received	32000	155.75	32000	4000	12000
L57	< Received	12000	102.5	12000	28000	2000
L58	< Received	20000	46.3	20000	0	20000
O56	> Received	16000	155.25	16000	4000	1000
O57	> Received	18000	102.1	18000	28000	18000
O58	> Received	25000	46.65	25000	0	7000
C64	Bats Shipped	66000	-150	0	66000	4000
C65	Stumps Shipped	47000	-98.75008676	0	2000.000728	0

C66	Bails Shipped	49000	-45	0	49000	0
C70	Bats Shipped	50000	-150.25	0	12000	4000
C71	Stumps Shipped	40000	-99	0	40000	28000
C72	Bails Shipped	59000	-44.7	0	7000	0
C78	Bats Distributed	18000	-153.5	0	18000	4000
C79	Stumps Distributed	0	-100.7000994	0	2000.000051	0
C80	Bails Distributed	20000	-45.4	0	5000	0
C84	Bats Distributed	20000	-153.8	0	3000	4000
C85	Stumps Distributed	25000	-100.6	0	2000	10000
C86	Bails Distributed	0	-45.54992059	0	5000.000126	0
C90	Bats Distributed	18000	-153.75	0	13000	4000
C91	Stumps Distributed	0	-100.3500994	0	20000.00051	0
C92	Bails Distributed	2000	-45.49999999	0	2000	0
C96	Bats Distributed	15000	-153.75	0	1000	4000
C97	Stumps Distributed	0	-100.3000032	0	2000.000051	0
C98	Bails Distributed	20000	-45.6	0	2000	0
C105	Bats Manufactured	66000	0	70000	1E+30	4000
C106	Stumps Manufactured	47000	-3.75008676	47000	2000.000728	0
C107	Bails Manufactured	49000	0	49000	1E+30	0
C112	Bats Manufactured	50000	-20.25	50000	12000	4000
C113	Stumps Manufactured	40000	0	68000	1E+30	28000
C114	Bails Manufactured	59000	-3.699999999	59000	7000	0

Appendix F

Proposed Data, Model and Sensitivity Report by Increasing Warehouses Capacity with Initial Shipping Cost

Manufacturing Cost for each Factory Per Product

	Products		
	Bats	Stumps	Bails
Karachi Factory	PKR 150	PKR 95	PKR 45
Lahore Factory	PKR 130	PKR 99	PKR 41

Shipping Cost From Factory To Warehouses (PKR per product)

		Warehouse Destinations			
		Quetta	Lahore	Peshawar	Karachi
Karachi Factory	Bats	PKR 5.50	PKR 5.50	PKR 6.00	PKR 5.20
	Stumps	PKR 4.00	PKR 3.75	PKR 4.25	PKR 4.25
	Bails	PKR 2.25	PKR 2.75	PKR 2.50	PKR 2.30
Lahore Factory	Bats	PKR 6.50	PKR 5.30	PKR 5.50	PKR 5.20
	Stumps	PKR 4.25	PKR 3.80	PKR 4.00	PKR 3.75
	Bails	PKR 2.90	PKR 1.90	PKR 1.95	PKR 2.60

Shipping Cost From Factory To Distributors (PKR per product)

				Distributors Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Karachi Factory	Bats	PKR 7.75	PKR 8.50	PKR 7.50	PKR 8.00	PKR 7.50
	Stumps	PKR 5.50	PKR 6.00	PKR 5.00	PKR 5.75	PKR 5.60
	Bails	PKR 4.40	PKR 4.50	PKR 3.75	PKR 3.30	PKR 3.85
Lahore Factory	Bats	PKR 8.00	PKR 8.50	PKR 8.50	PKR 7.50	PKR 7.00
	Stumps	PKR 5.25	PKR 5.95	PKR 5.20	PKR 5.50	PKR 5.10
	Bails	PKR 3.95	PKR 4.25	PKR 3.85	PKR 4.35	PKR 3.95

Shipping Cost From Warehouses To Distributors (PKR per product)

				Distributor Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Quetta	Bats	PKR 6.50	PKR 5.80	PKR 5.50	PKR 6.50	PKR 8.00
	Stumps	PKR 4.00	PKR 3.90	PKR 4.20	PKR 4.30	PKR 5.10
	Bails	PKR 2.75	PKR 2.20	PKR 2.60	PKR 2.30	PKR 2.90
Lahore	Bats	PKR 6.00	PKR 5.50	PKR 5.50	PKR 6.00	PKR 5.50
	Stumps	PKR 4.25	PKR 4.00	PKR 4.00	PKR 3.90	PKR 4.50
	Bails	PKR 2.60	PKR 2.60	PKR 2.40	PKR 2.90	PKR 3.25
Peshawar	Bats	PKR 6.00	PKR 6.50	PKR 7.00	PKR 7.00	PKR 5.50
	Stumps	PKR 3.90	PKR 4.35	PKR 4.45	PKR 4.80	PKR 4.00
	Bails	PKR 2.75	PKR 2.70	PKR 3.25	PKR 3.20	PKR 2.35
Karachi	Bats	PKR 7.50	PKR 6.50	PKR 5.60	PKR 6.50	PKR 5.50
	Stumps	PKR 4.75	PKR 3.30	PKR 3.70	PKR 4.25	PKR 4.10
	Bails	PKR 3.00	PKR 2.60	PKR 3.00	PKR 2.60	PKR 2.40

Distributor Demand

	Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Bats	30000	23000	15000	32000	16000
Stumps	20000	15000	22000	12000	18000
Bails	25000	22000	16000	20000	25000

Warehouse Capacity

	Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse
Bats	35000	40000	30000	30000
Stumps	30000	50000	15000	48000
Bails	20000	40000	25000	40000

Factory Manufacturing Capacity

	Karachi Factory	Lahore Factory
Bats	70000	50000
Stumps	47000	68000
Bails	49000	59000

CONSTRAINTS

Number of products shipped from factories to Warehouses

		Quetta Warehouse			Lahore Warehouse				Peshawar Warehouse			Karachi Warehouse	
		Received		Capacity	Received		Capacity	Received		Capacity	Received		Capacity
Karachi and Lahore Factory	Bats	16000	≤	35000	40000	≤	40000	30000	≤	30000	30000	≤	30000
	Stumps	0	≤	30000	47000	≤	50000	0	≤	15000	40000	≤	48000
	Bails	20000	≤	20000	40000	≤	40000	19000	≤	25000	29000	≤	40000

Number of products shipped from Warehouses to Distributors

		Punjab Distributor			Sindh Distributor			Baluchistan Distributor			Northern Distributor			AK Distributor		
		Received		Demand	Received		Demand	Received		Demand	Received		Demand	Received		Demand
Warehouse	Bats	30000	≥	30000	23000	≥	23000	15000	≤	15000	32000	≥	32000	16000	≥	16000
	Stumps	20000	≥	20000	15000	≥	15000	22000	≤	22000	12000	≥	12000	18000	≥	18000
	Bails	25000	≥	25000	22000	≥	22000	16000	≤	16000	20000	≥	20000	25000	≥	25000

Total products shipped out Factories

		Karachi Factory		
		Shipped		Manufactured
Karachi	Bats	66000	≤	66000
	Stumps	47000	≤	47000
	Bails	49000	≤	49000

		Lahore Factory		
		Shipped		Manufactured
Lahore	Bats	50000	≤	50000
	Stumps	40000	≤	40000
	Bails	59000	≤	59000

Total to Warehouse = Total from Warehouse

		Quetta Warehouse		
		Distributed		Received
Quetta	Bats	16000	=	16000
	Stumps	1.00974E-28	=	0
	Bails	20000	=	20000

		Lahore Warehouse		
		Distributed		Received
Lahore	Bats	40000	=	40000
	Stumps	47000	=	47000
	Bails	40000	=	40000

			Peshawar Warehouse	
		Distributed		Received
Peshawar	Bats	30000	=	30000
	Stumps	4.03897E-28	=	0
	Bails	19000	=	19000

			Karachi Warehouse	
		Distributed		Received
Karachi	Bats	30000	=	30000
	Stumps	40000	=	40000
	Bails	29000	=	29000

Factories Total products Manufacturing Capacity

		Karachi Factory		
		Manufactured		Capacity
Karachi	Bats	66000	≤	70000
	Stumps	47000	≤	47000
	Bails	49000	≤	49000

		Lahore Factory		
		Manufactured		Capacity
Lahore	Bats	50000	≤	50000
	Stumps	40000	≤	68000
	Bails	59000	≤	59000

DECISION VARIABLE

	Bats	Stumps	Bails	COST
Karachi Factory	66000	47000	49000	16570000
Lahore Factory	50000	40000	59000	12879000
			Total Cost	29449000

Number of products shipped

		Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse	TOTAL
Karachi Factory	Bats	16000	20000	0	30000	66000
	Stumps	0	47000	0	0	47000
	Bails	20000	0	0	29000	49000
Lahore Factory	Bats	0	20000	30000	0	50000
	Stumps	0	0	0	40000	40000
	Bails	0	40000	19000	0	59000

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTAL
Quetta Warehouse	Bats	0	15000	1000	0	0	16000
	Stumps	1.00974E-28	0	0	0	0	1.01E-28
	Bails	0	20000	0	0	0	20000
Lahore Warehouse	Bats	0	8000	0	32000	0	40000
	Stumps	20000	0	15000	12000	0	47000
	Bails	24000	0	16000	0	0	40000
Peshawar Warehouse	Bats	30000	0	0	0	0	30000
	Stumps	0	0	0	0	4.03897E-28	4.04E-28
	Bails	1000	0	0	0	18000	19000
Karachi Warehouse	Bats	0	0	14000	0	16000	30000
	Stumps	0	15000	7000	0	18000	40000
	Bails	0	2000	0	20000	7000	29000

OPTIMAL RESULTS

Total cost of shipping		PKR 2,455,750
Total cost of production		PKR 29,449,000
	Total Cost	PKR 31,904,750

Microsoft Excel 11.0 Sensitivity Report
Worksheet: [EMGT835 Field Project Proposed by Increase Warehouse Capacity with Initial Shipping Cost- formatted as instructed.xls]Model
Report Created: 3/22/2009 9:17:11 AM

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B119	Karachi Factory Bats	66000	0	150	2.6385E+11	20.2
C119	Karachi Factory Stumps	47000	0	95	3.7	1E+30
D119	Karachi Factory Bails	49000	0	45	1E+30	4.400000001
B120	Lahore Factory Bats	50000	0	130	20.2	1E+30
C120	Lahore Factory Stumps	40000	0	99	1786074.22	3.7
D120	Lahore Factory Bails	59000	0	41	4.400000001	1E+30
C126	Bats Quetta Warehouse	16000	0	5.5	0.300018726	0.100009352
D126	Bats Lahore Warehouse	20000	0	5.5	0.100009388	0.200187427
E126	Bats Peshawar Warehouse	0	0.300007269	5.999952555	1E+30	0.300007269
F126	Bats Karachi Warehouse	30000	0	5.2	0.200000008	1E+30
C127	Stumps Quetta Warehouse	0	0.000469554	4.000216722	1E+30	0.000469554
D127	Stumps Lahore Warehouse	47000	0	3.75	0.000469554	1E+30
E127	Stumps Peshawar Warehouse	0	0.09969148	4.249811172	1E+30	0.09969148
F127	Stumps Karachi Warehouse	0	0.199809802	4.249811172	1E+30	0.199809802
C128	Bails Quetta Warehouse	20000	0	2.25	0.449999999	1E+30
D128	Bails Lahore Warehouse	0	0.450008518	2.750009298	1E+30	0.450008518
E128	Bails Peshawar Warehouse	0	0.15005875	2.500042319	1E+30	0.15005875
F128	Bails Karachi Warehouse	29000	0	2.300000001	0.150058753	0.449999999
C129	Bats Quetta Warehouse	0	1.199941287	6.499886513	1E+30	1.199941287
D129	Bats Lahore Warehouse	20000	0	5.300000001	0.200187427	0.100009388
E129	Bats Peshawar Warehouse	30000	0	5.5	0.100009388	0.300018726
F129	Bats Karachi Warehouse	0	0.200187495	5.200132728	1E+30	0.200187495
C130	Stumps Quetta Warehouse	0	0.550064105	4.249811172	1E+30	0.550064105

D130	Stumps Lahore Warehouse	0	0.349794936	3.799796104	1E+30	0.349794936
E130	Stumps Peshawar Warehouse	0	0.149724602	3.999844193	1E+30	0.149724602
F130	Stumps Karachi Warehouse	40000	0	3.75	0.149724606	3.7
C131	Bails Quetta Warehouse	0	1.050155061	2.900138497	1E+30	1.050155061
D131	Bails Lahore Warehouse	40000	0	1.9	0.199999983	1E+30
E131	Bails Peshawar Warehouse	19000	0	1.949999999	0.699896427	0.199999983
F131	Bails Karachi Warehouse	0	0.699896664	2.599880099	1E+30	0.699896664
C136	Bats Punjab Distributor	0	0.299886671	6.499886513	1E+30	0.299886671
D136	Bats Sindh Distributor	15000	0	5.8	0.099886684	0.100009352
E136	Bats Baluchistan Distributor	1000	0	5.500000007	0.300018726	0.099886684
F136	Bats Northern Distributor	0	0.199886671	6.499886513	1E+30	0.199886671
G136	Bats AK Distributor	0	2.600061045	8.000060916	1E+30	2.600061045
C137	Stumps Punjab Distributor	1.00974E-28	0	4.000216722	0.449675554	0.000469554
D137	Stumps Sindh Distributor	0	0.549789675	3.900006413	1E+30	0.549789675
E137	Stumps Baluchistan Distributor	0	0.449675554	4.199892282	1E+30	0.449675554
F137	Stumps Northern Distributor	0	0.649885861	4.300102592	1E+30	0.649885861
G137	Stumps AK Distributor	0	0.949705701	5.099922419	1E+30	0.949705701
C138	Bails Punjab Distributor	0	0.350009373	2.750009298	1E+30	0.350009373
D138	Bails Sindh Distributor	20000	0	2.199999999	0.099994287	1E+30
E138	Bails Baluchistan Distributor	0	0.39988017	2.599880099	1E+30	0.39988017
F138	Bails Northern Distributor	0	0.099994285	2.29999423	1E+30	0.099994285
G138	Bails AK Distributor	0	0.900138547	2.900138497	1E+30	0.900138547
C139	Bats Punjab Distributor	0	0.100009386	5.999952555	1E+30	0.100009386
D139	Bats Sindh Distributor	8000	0	5.499999998	0.100009352	0.099886684
E139	Bats Baluchistan Distributor	0	0.300075401	5.500018597	1E+30	0.300075401
F139	Bats Northern Distributor	32000	0	6	0.099886684	161.8
G139	Bats AK Distributor	0	0.400075398	5.500018597	1E+30	0.400075398
C140	Stumps Punjab Distributor	20000	0	4.25	0.000469554	0.449675565
D140	Stumps Sindh Distributor	0	0.400254085	4.000216722	1E+30	0.400254085
E140	Stumps Baluchistan Distributor	15000	0	4	0.099691446	0.050162216
F140	Stumps Northern Distributor	12000	0	3.9	0.6497739	106.35
G140	Stumps AK Distributor	0	0.100188064	4.500150681	1E+30	0.100188064

C141	Bails Punjab Distributor	24000	0	2.600000001	0.199897358	0.39988018
D141	Bails Sindh Distributor	0	0.199897426	2.599880099	1E+30	0.199897426
E141	Bails Baluchistan Distributor	16000	0	2.4	0.39988018	49.89999998
F141	Bails Northern Distributor	0	0.500155822	2.900138497	1E+30	0.500155822
G141	Bails AK Distributor	0	1.049960576	3.249943256	1E+30	1.049960576
C142	Bats Punjab Distributor	30000	0	6	0.100009388	161.7
D142	Bats Sindh Distributor	0	0.899886653	6.499886513	1E+30	0.899886653
E142	Bats Baluchistan Distributor	0	1.699820596	6.999820471	1E+30	1.699820596
F142	Bats Northern Distributor	0	0.899820623	6.999820471	1E+30	0.899820623
G142	Bats AK Distributor	0	0.300018719	5.500018597	1E+30	0.300018719
C143	Stumps Punjab Distributor	0	0.050162215	3.900006413	1E+30	0.050162215
D143	Stumps Sindh Distributor	0	1.150177268	4.350021482	1E+30	1.150177268
E143	Stumps Baluchistan Distributor	0	0.850015057	4.449859262	1E+30	0.850015057
F143	Stumps Northern Distributor	0	1.300192343	4.80003655	1E+30	1.300192343
G143	Stumps AK Distributor	4.03897E-28	0	3.999844193	0.050162215	0.09969148
C144	Bails Punjab Distributor	1000	0	2.749999985	0.199976369	0.199897358
D144	Bails Sindh Distributor	0	0.150090474	2.700090408	1E+30	0.150090474
E144	Bails Baluchistan Distributor	0	0.699943337	3.249943256	1E+30	0.699943337
F144	Bails Northern Distributor	0	0.65002443	3.200024366	1E+30	0.65002443
G144	Bails AK Distributor	18000	0	2.35	0.150090478	0.150058753
C145	Bats Punjab Distributor	0	1.200127126	7.500126958	1E+30	1.200127126
D145	Bats Sindh Distributor	0	0.59988667	6.499886513	1E+30	0.59988667
E145	Bats Baluchistan Distributor	14000	0	5.6	0.099886684	0.300018726
F145	Bats Northern Distributor	0	0.099886681	6.499886513	1E+30	0.099886681
G145	Bats AK Distributor	16000	0	5.5	0.300018726	160.9
C146	Stumps Punjab Distributor	0	0.800080379	4.75011766	1E+30	0.800080379
D146	Stumps Sindh Distributor	15000	0	3.3	0.400254095	106.05
E146	Stumps Baluchistan Distributor	7000	0	3.7	0.050162216	0.099691446
F146	Stumps Northern Distributor	0	0.649773883	4.249811172	1E+30	0.649773883
G146	Stumps AK Distributor	18000	0	4.099999999	0.099691482	0.050162216
C147	Bails Punjab Distributor	0	0.199976364	2.999976277	1E+30	0.199976364
D147	Bails Sindh Distributor	2000	0	2.599999998	0.150090478	0.099994287

E147	Bails Baluchistan Distributor	0	0.39997636	2.999976277	1E+30	0.39997636
F147	Bails Northern Distributor	20000	0	2.6	0.099994287	49.9
G147	Bails AK Distributor	7000	0	2.4	0.150058753	0.150090478

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
C48	Bats Received	16000	0	35000	1E+30	19000
C49	Stumps Received	0	0	30000	1E+30	30000
C50	Bails Received	20000	-0.449999999	20000	2000	11000
F48	< Received	40000	-0.300000002	40000	15000	8000
F49	< Received	47000	0	50000	1E+30	3000
F50	< Received	40000	-0.199999983	40000	1000	6000
I48	< Received	30000	0	30000	1E+30	0
I49	< Received	0	0	15000	1E+30	15000
I50	< Received	19000	0	25000	1E+30	6000
L48	< Received	30000	-0.200000008	30000	1000	14000
L49	< Received	40000	0	48000	1E+30	8000
L50	< Received	29000	0	40000	1E+30	11000
C56	Bats Received	30000	161.7	30000	0	20000
C57	Stumps Received	20000	106.7	20000	8000	7000
C58	Bails Received	25000	50.09999999	25000	0	1000
F56	> Received	23000	161.3	23000	4000	15000
F57	> Received	15000	106.05	15000	8000	15000
F58	> Received	22000	49.9	22000	0	2000
I56	> Received	15000	161	15000	4000	1000
I57	> Received	22000	106.45	22000	8000	7000
I58	> Received	16000	49.89999998	16000	0	1000
L56	< Received	32000	161.8	32000	4000	15000
L57	< Received	12000	106.35	12000	8000	7000

L58	< Received	20000	49.9	20000	0	20000
O56	> Received	16000	160.9	16000	4000	1000
O57	> Received	18000	106.85	18000	8000	18000
O58	> Received	25000	49.7	25000	0	7000
C64	Bats Shipped	66000	-150	0	66000	4000
C65	Stumps Shipped	47000	-98.7	0	3000	8000
C66	Bails Shipped	49000	-45	0	49000	0
C70	Bats Shipped	50000	-150.2	0	20000	4000
C71	Stumps Shipped	40000	-99	0	40000	28000
C72	Bails Shipped	59000	-45.4	0	6000	0
C78	Bats Distributed	16000	-155.5	0	16000	4000
C79	Stumps Distributed	1.00974E-28	-102.6997806	0	7000.000177	0
C80	Bails Distributed	20000	-47.7	0	2000	0
C84	Bats Distributed	40000	-155.8	0	15000	4000
C85	Stumps Distributed	47000	-102.45	0	7000	8000
C86	Bails Distributed	40000	-47.49999998	0	1000	0
C90	Bats Distributed	30000	-155.7	0	20000	0
C91	Stumps Distributed	4.03897E-28	-102.8501531	0	18000.00045	0
C92	Bails Distributed	19000	-47.35	0	7000	0
C96	Bats Distributed	30000	-155.4	0	1000	4000
C97	Stumps Distributed	40000	-102.75	0	40000	8000
C98	Bails Distributed	29000	-47.3	0	29000	0
C105	Bats Manufactured	66000	0	70000	1E+30	4000
C106	Stumps Manufactured	47000	-3.7	47000	3000	8000
C107	Bails Manufactured	49000	0	49000	1E+30	0
C112	Bats Manufactured	50000	-20.2	50000	20000	4000
C113	Stumps Manufactured	40000	0	68000	1E+30	28000
C114	Bails Manufactured	59000	-4.400000001	59000	6000	0

Proposed Data, Model and Sensitivity Report by Increasing Warehouses Capacity with Revised Shipping Cost

Manufacturing Cost for each Factory Per Product

	Products		
	Bats	Stumps	Bails
Karachi Factory	PKR 150	PKR 95	PKR 45
Lahore Factory	PKR 130	PKR 99	PKR 41

Shipping Cost From Factory To Warehouses (PKR per product)

		Warehouse Destinations			
		Quetta	Lahore	Peshawar	Karachi
Karachi Factory	Bats	PKR 3.50	PKR 3.50	PKR 4.00	PKR 3.20
	Stumps	PKR 2.00	PKR 1.75	PKR 2.45	PKR 2.25
	Bails	PKR 0.25	PKR 0.75	PKR 0.50	PKR 0.30
Lahore Factory	Bats	PKR 4.50	PKR 3.30	PKR 3.50	PKR 3.20
	Stumps	PKR 2.25	PKR 1.80	PKR 2.00	PKR 1.75
	Bails	PKR 0.90	PKR 0.90	PKR 0.95	PKR 0.60

Shipping Cost From Factory To Distributors (PKR per product)

				Distributors Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Karachi Factory	Bats	PKR 5.75	PKR 6.50	PKR 5.50	PKR 6.00	PKR 5.50
	Stumps	PKR 3.50	PKR 4.00	PKR 3.00	PKR 3.75	PKR 3.60
	Bails	PKR 2.40	PKR 2.50	PKR 1.75	PKR 1.30	PKR 1.85
Lahore Factory	Bats	PKR 6.00	PKR 6.50	PKR 6.50	PKR 5.50	PKR 5.00
	Stumps	PKR 3.25	PKR 3.95	PKR 3.20	PKR 3.50	PKR 3.10
	Bails	PKR 1.95	PKR 2.25	PKR 1.85	PKR 2.35	PKR 1.95

Shipping Cost From Warehouses To Distributors (PKR per product)

				Distributor Destinations		
		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AkDistributor
Quetta	Bats	PKR 2.50	PKR 1.80	PKR 1.50	PKR 2.50	PKR 4.00
	Stumps	PKR 2.00	PKR 1.90	PKR 2.20	PKR 2.30	PKR 3.10
	Bails	PKR 1.25	PKR 1.70	PKR 2.10	PKR 1.80	PKR 2.60
Lahore	Bats	PKR 2.00	PKR 1.50	PKR 1.50	PKR 2.00	PKR 1.50
	Stumps	PKR 2.25	PKR 2.00	PKR 2.00	PKR 1.90	PKR 2.50
	Bails	PKR 1.10	PKR 1.20	PKR 1.90	PKR 2.40	PKR 2.75
Peshawar	Bats	PKR 2.00	PKR 2.50	PKR 3.00	PKR 3.00	PKR 1.50
	Stumps	PKR 1.90	PKR 2.35	PKR 2.45	PKR 2.80	PKR 2.00
	Bails	PKR 1.25	PKR 1.20	PKR 2.75	PKR 2.70	PKR 1.85
Karachi	Bats	PKR 3.50	PKR 2.50	PKR 1.60	PKR 2.50	PKR 1.50
	Stumps	PKR 2.75	PKR 2.30	PKR 1.70	PKR 2.25	PKR 2.10
	Bails	PKR 1.50	PKR 1.10	PKR 2.50	PKR 2.10	PKR 1.90

Distributor Demand

	Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor
Bats	30000	23000	15000	32000	16000
Stumps	20000	15000	22000	12000	18000
Bails	25000	22000	16000	20000	25000

Warehouse Capacity

	Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse
Bats	35000	40000	30000	30000
Stumps	30000	50000	15000	48000
Bails	20000	40000	25000	40000

Factory Manufacturing Capacity

	Karachi Factory	Lahore Factory
Bats	70000	50000
Stumps	47000	68000
Bails	49000	59000

Number of products shipped from factories to Warehouses

		Quetta Warehouse			Lahore Warehouse				Peshawar Warehouse			Karachi Warehouse	
		Received		Capacity	Received		Capacity	Received		Capacity	Received		Capacity
Karachi and Lahore Factory	Bats	16000	≤	35000	40000	≤	40000	30000	≤	30000	30000	≤	30000
	Stumps	20000	≤	30000	27000	≤	50000	0	≤	15000	40000	≤	48000
	Bails	20000	≤	20000	40000	≤	40000	8000	≤	25000	40000	≤	40000

Number of products shipped from Warehouses to Distributors

		Punjab Distributor			Sindh Distributor			Baluchistan Distributor			Northern Distributor			AK Distributor		
		Received		Demand	Received		Demand	Received		Demand	Received		Demand	Received		Demand
Warehouse	Bats	30000	≥	30000	23000	≥	23000	15000	≤	15000	32000	≥	32000	16000	≥	16000
	Stumps	20000	≥	20000	15000	≥	15000	22000	≤	22000	12000	≥	12000	18000	≥	18000
	Bails	25000	≥	25000	22000	≥	22000	16000	≤	16000	20000	≥	20000	25000	≥	25000

Total products shipped out Factories

		Karachi Factory		
		Shipped		Manufactured
Karachi	Bats	66000	≤	66000
	Stumps	47000	≤	47000
	Bails	49000	≤	49000

		Lahore Factory		
		Shipped		Manufactured
Lahore	Bats	50000	≤	50000
	Stumps	40000	≤	40000
	Bails	59000	≤	59000

Total to Warehouse = Total from Warehouse

		Quetta Warehouse		
		Distributed		Received
Quetta	Bats	16000	=	16000
	Stumps	20000	=	20000
	Bails	20000	=	20000

		Lahore Warehouse		
		Distributed		Received
Lahore	Bats	40000	=	40000
	Stumps	27000	=	27000
	Bails	40000	=	40000

			Peshawar Warehouse	
		Distributed		Received
Peshawar	Bats	30000	=	30000
	Stumps	0	=	0
	Bails	8000	=	8000

			Karachi Warehouse	
		Distributed		Received
Karachi	Bats	30000	=	30000
	Stumps	40000	=	40000
	Bails	40000	=	40000

Factories Total products Manufacturing Capacity

		Karachi Factory		
		Manufactured		Capacity
Karachi	Bats	66000	≤	70000
	Stumps	47000	≤	47000
	Bails	49000	≤	49000

		Lahore Factory		
		Manufactured		Capacity
Lahore	Bats	50000	≤	50000
	Stumps	40000	≤	68000
	Bails	59000	≤	59000

DECISION VARIABLE

	Bats	Stumps	Bails	COST
Karachi Factory	66000	47000	49000	16570000
Lahore Factory	50000	40000	59000	12879000

Total Cost	29449000

Number of products shipped

		Quetta Warehouse	Lahore Warehouse	Peshawar Warehouse	Karachi Warehouse	TOTAL
Karachi Factory	Bats	16000	20000	0	30000	66000
	Stumps	20000	27000	0	0	47000
	Bails	20000	0	8000	21000	49000
Lahore Factory	Bats	0	20000	30000	0	50000
	Stumps	0	0	0	40000	40000
	Bails	0	40000	0	19000	59000

		Punjab Distributor	Sindh Distributor	Baluchistan Distributor	Northern Distributor	AK Distributor	TOTAL
Quetta Warehouse	Bats	0	15000	1000	0	0	16000
	Stumps	20000	0	0	0	0	20000
	Bails	0	0	0	20000	0	20000
Lahore Warehouse	Bats	3.63829E-12	8000	0	32000	0	40000
	Stumps	0	15000	1.79456E-10	12000	0	27000
	Bails	24000	0	16000	0	0	40000
Peshawar Warehouse	Bats	30000	0	0	0	0	30000
	Stumps	0	0	0	0	0	0
	Bails	1000	0	0	0	7000	8000
Karachi Warehouse	Bats	0	0	14000	0	16000	30000
	Stumps	0	0	22000	0	18000	40000
	Bails	0	22000	0	0	18000	40000

OPTIMAL RESULTS

Total cost of shipping		PKR 1,157,250
Total cost of production		PKR 29,449,000
	Total Cost	PKR 30,606,250

Microsoft Excel 11.0 Sensitivity Report
Worksheet: [EMGT835 Field Project Proposed by Increase Warehouse Capacity with Revised Shipping Cost - formatted as instructed.xls]Model
Report Created: 3/22/2009 9:38:01 AM

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B119	Karachi Factory Bats	66000	0	150	549427.3744	20.2
C119	Karachi Factory Stumps	47000	0	95	3.699891588	1E+30
D119	Karachi Factory Bails	49000	0	45	206488.9982	3.700000001
B120	Lahore Factory Bats	50000	0	130	20.2	1E+30
C120	Lahore Factory Stumps	40000	0	99	412811.5543	3.699891588
D120	Lahore Factory Bails	59000	0	41	3.700000001	1E+30
C126	Bats Quetta Warehouse	16000	0	3.500000001	1.200205434	0.100164327
D126	Bats Lahore Warehouse	20000	0	3.5	0.100164364	0.200079016
E126	Bats Peshawar Warehouse	0	0.300271386	4.000216722	1E+30	0.300271386
F126	Bats Karachi Warehouse	30000	0	3.2	0.200000022	1E+30
C127	Stumps Quetta Warehouse	20000	0	2.000000001	7.53957E-05	0.15027063
D127	Stumps Lahore Warehouse	27000	0	1.750000001	0.15027063	7.53957E-05
E127	Stumps Peshawar Warehouse	0	0.30015939	2.450123429	1E+30	0.30015939
F127	Stumps Karachi Warehouse	0	0.199966235	2.25007534	1E+30	0.199966235
C128	Bails Quetta Warehouse	20000	0	0.25	0.350046422	1E+30
D128	Bails Lahore Warehouse	0	0.15024052	0.750273466	1E+30	0.15024052
E128	Bails Peshawar Warehouse	8000	0	0.500000003	0.14996531	0.05
F128	Bails Karachi Warehouse	21000	0	0.300000001	0.05	0.149965256
C129	Bats Quetta Warehouse	0	1.200205404	4.500150681	1E+30	1.200205404
D129	Bats Lahore Warehouse	20000	0	3.300000001	0.200079016	0.100164364
E129	Bats Peshawar Warehouse	30000	0	3.5	0.100164364	1E+30
F129	Bats Karachi Warehouse	0	0.200079083	3.200024366	1E+30	0.200079083
C130	Stumps Quetta Warehouse	0	0.550147778	2.25007534	1E+30	0.550147778
D130	Stumps Lahore Warehouse	0	0.350132704	1.800060272	1E+30	0.350132704

E130	Stumps Peshawar Warehouse	0	0.150180803	2.000108361	1E+30	0.150180803
F130	Stumps Karachi Warehouse	40000	0	1.75	0.150180807	3.699891588
C131	Bails Quetta Warehouse	0	0.350046413	0.900030136	1E+30	0.350046413
D131	Bails Lahore Warehouse	40000	0	0.9	0.05	1E+30
E131	Bails Peshawar Warehouse	0	0.149965307	0.949949026	1E+30	0.149965307
F131	Bails Karachi Warehouse	19000	0	0.6	0.149965256	0.05
C136	Bats Punjab Distributor	0	0.199878016	2.500042319	1E+30	0.199878016
D136	Bats Sindh Distributor	15000	0	1.800000002	0.100042405	0.100164327
E136	Bats Baluchistan Distributor	1000	0	1.500000022	0.300230368	0.100042405
F136	Bats Northern Distributor	0	0.200042379	2.500042319	1E+30	0.200042379
G136	Bats AK Distributor	0	2.600216736	4.000216722	1E+30	2.600216736
C137	Stumps Punjab Distributor	20000	0	2.000000001	7.53957E-05	102.6998916
D137	Stumps Sindh Distributor	0	0.150270626	1.900270581	1E+30	0.150270626
E137	Stumps Baluchistan Distributor	0	0.450048083	2.20015645	1E+30	0.450048083
F137	Stumps Northern Distributor	0	0.649994271	2.29999423	1E+30	0.649994271
G137	Stumps AK Distributor	0	0.950078229	3.100186586	1E+30	0.950078229
C138	Bails Punjab Distributor	0	0.250542709	1.250207424	1E+30	0.250542709
D138	Bails Sindh Distributor	0	0.900557769	1.700222492	1E+30	0.900557769
E138	Bails Baluchistan Distributor	0	0.300653974	2.10031867	1E+30	0.300653974
F138	Bails Northern Distributor	20000	0	1.800000001	0.250542715	1E+30
G138	Bails AK Distributor	0	1.000587925	2.600252628	1E+30	1.000587925
C139	Bats Punjab Distributor	3.63829E-12	0	2.000108361	0.199878016	0.100164361
D139	Bats Sindh Distributor	8000	0	1.500000004	0.100164327	0.100042405
E139	Bats Baluchistan Distributor	0	0.300230361	1.500174403	1E+30	0.300230361
F139	Bats Northern Distributor	32000	0	2.000000001	0.100042405	155.8
G139	Bats AK Distributor	0	0.400230359	1.500174403	1E+30	0.400230359
C140	Stumps Punjab Distributor	0	7.53957E-05	2.25007534	1E+30	7.53957E-05
D140	Stumps Sindh Distributor	15000	0	2	0.15027063	102.4498916
E140	Stumps Baluchistan Distributor	1.79456E-10	0	2.000108361	0.099933968	0.050270627
F140	Stumps Northern Distributor	12000	0	1.900000001	0.649994288	102.3498916
G140	Stumps AK Distributor	0	0.099933968	2.500042319	1E+30	0.099933968
C141	Bails Punjab Distributor	24000	0	1.1	0.05	0.300653981

D141	Bails Sindh Distributor	0	0.300305161	1.200288534	1E+30	0.300305161
E141	Bails Baluchistan Distributor	16000	0	1.900000002	0.300653981	47.55
F141	Bails Northern Distributor	0	0.499885934	2.400204539	1E+30	0.499885934
G141	Bails AK Distributor	0	1.050025945	2.750009298	1E+30	1.050025945
C142	Bats Punjab Distributor	30000	0	2	0.100164364	1E+30
D142	Bats Sindh Distributor	0	1.000206717	2.500042319	1E+30	1.000206717
E142	Bats Baluchistan Distributor	0	1.800140647	2.999976277	1E+30	1.800140647
F142	Bats Northern Distributor	0	1.000140691	2.999976277	1E+30	1.000140691
G142	Bats AK Distributor	0	0.400338771	1.500174403	1E+30	0.400338771
C143	Stumps Punjab Distributor	0	0.050270627	1.900270581	1E+30	0.050270627
D143	Stumps Sindh Distributor	0	0.749913161	2.34991312	1E+30	0.749913161
E143	Stumps Baluchistan Distributor	0	0.850015058	2.450123429	1E+30	0.850015058
F143	Stumps Northern Distributor	0	1.299928225	2.799928188	1E+30	1.299928225
G143	Stumps AK Distributor	0	0	2.000108361	0.050270627	0.150180803
C144	Bails Punjab Distributor	1000	0	1.25	0.200190978	0.05
D144	Bails Sindh Distributor	0	0.150292697	1.200288534	1E+30	0.150292697
E144	Bails Baluchistan Distributor	0	0.700013488	2.750009298	1E+30	0.700013488
F144	Bails Northern Distributor	0	0.649759339	2.700090408	1E+30	0.649759339
G144	Bails AK Distributor	7000	0	1.850000003	0.150292701	0.150000003
C145	Bats Punjab Distributor	0	1.100118484	3.500282764	1E+30	1.100118484
D145	Bats Sindh Distributor	0	0.600042386	2.500042319	1E+30	0.600042386
E145	Bats Baluchistan Distributor	14000	0	1.600000001	0.100042405	0.400230369
F145	Bats Northern Distributor	0	0.100042402	2.500042319	1E+30	0.100042402
G145	Bats AK Distributor	16000	0	1.500000001	0.400230369	154.9
C146	Stumps Punjab Distributor	0	0.80015441	2.750009298	1E+30	0.80015441
D146	Stumps Sindh Distributor	0	0.600139337	2.29999423	1E+30	0.600139337
E146	Stumps Baluchistan Distributor	22000	0	1.700000001	0.050270628	0.099933971
F146	Stumps Northern Distributor	0	0.650220443	2.25007534	1E+30	0.650220443
G146	Stumps AK Distributor	18000	0	2.100000001	0.099933971	0.050270628
C147	Bails Punjab Distributor	0	0.200190973	1.500174403	1E+30	0.200190973
D147	Bails Sindh Distributor	22000	0	1.100000001	0.150292701	46.55
E147	Bails Baluchistan Distributor	0	0.400058908	2.500042319	1E+30	0.400058908

F147	Bails Northern Distributor	0	0	2.10031867	0.499885934	0.250542709
G147	Bails AK Distributor	18000	0	1.900000001	0.150000003	0.150292701

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
C48	Bats Received	16000	0	35000	1E+30	19000
C49	Stumps Received	20000	0	30000	1E+30	10000
C50	Bails Received	20000	-0.500335261	20000	0	2.9366E-05
F48	< Received	40000	-0.299999999	40000	15000	8000
F49	< Received	27000	0	50000	1E+30	23000
F50	< Received	40000	-0.05	40000	0.447470467	17000
I48	< Received	30000	-0.100164364	30000	0	7999.99709
I49	< Received	0	0	15000	1E+30	15000
I50	< Received	8000	0	25000	1E+30	17000
L48	< Received	30000	-0.200000022	30000	1000	14000
L49	< Received	40000	0	48000	1E+30	8000
L50	< Received	40000	-0.150000003	40000	1.186369549	17000
C56	Bats Received	30000	155.8001644	30000	3999.998545	0
C57	Stumps Received	20000	102.6998916	20000	0	20000
C58	Bails Received	25000	46.75	25000	0	1000
F56	> Received	23000	155.3	23000	4000	15000
F57	> Received	15000	102.4498916	15000	0	15000
F58	> Received	22000	46.55	22000	0	7000
I56	> Received	15000	155	15000	4000	1000
I57	> Received	22000	102.45	22000	8000	22000
I58	> Received	16000	47.55	16000	0	1000
L56	< Received	32000	155.8	32000	4000	15000

L57	< Received	12000	102.3498916	12000	0	12000
L58	< Received	20000	47.55033526	20000	0	0
O56	> Received	16000	154.9	16000	4000	1000
O57	> Received	18000	102.85	18000	8000	18000
O58	> Received	25000	47.35000001	25000	0	7000
C64	Bats Shipped	66000	-150	0	66000	4000
C65	Stumps Shipped	47000	-98.69989159	0	22000	0
C66	Bails Shipped	49000	-45	0	49000	0
C70	Bats Shipped	50000	-150.2	0	20000	4000
C71	Stumps Shipped	40000	-99	0	40000	28000
C72	Bails Shipped	59000	-44.7	0	21000	0
C78	Bats Distributed	16000	-153.5	0	16000	4000
C79	Stumps Distributed	20000	-100.6998916	0	20000	0
C80	Bails Distributed	20000	-45.75033526	0	0	0
C84	Bats Distributed	40000	-153.8	0	15000	4000
C85	Stumps Distributed	27000	-100.4498916	0	22000	0
C86	Bails Distributed	40000	-45.65	0	1000	0
C90	Bats Distributed	30000	-153.8001644	0	0	3999.998545
C91	Stumps Distributed	0	-100.849889	0	18000.00045	0
C92	Bails Distributed	8000	-45.5	0	8000	0
C96	Bats Distributed	30000	-153.4	0	1000	4000
C97	Stumps Distributed	40000	-100.75	0	40000	8000
C98	Bails Distributed	40000	-45.45	0	7000	0
C105	Bats Manufactured	66000	0	70000	1E+30	4000
C106	Stumps Manufactured	47000	-3.699891588	47000	22000	0
C107	Bails Manufactured	49000	0	49000	1E+30	0
C112	Bats Manufactured	50000	-20.2	50000	20000	4000

C113	Stumps Manufactured	40000	0	68000	1E+30	28000
C114	Bails Manufactured	59000	-3.700000001	59000	21000	0