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**Spreadsheet Optimization of Flow for WIP Goods  
at a Yarn and Tire Cord Manufacturer: A Case Study**

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## Abstract

**We developed a spreadsheet optimization model to find the optimal material handling policy at a leading yarn and tire cord manufacturer's facility. The focus of the study is to optimize the movement of looms of yarn and tire cord between two major manufacturing steps. The considered flow network within the manufacturing facility is a miniature two-stage supply chain, including the middle layer of depots. Movement of material takes place through forklift trucks and cranes, which impose electricity, labor, maintenance, and depreciation costs. After introducing the company, the facility, and the project goals, we present the underlying linear programming (LP) model and our spreadsheet implementation. The results of our model suggest an annual saving of approximately \$22,000 for the facility.**

Submission areas: **Manufacturing Systems Engineering, Decision Support Systems**

## **Introduction**

Material handling is a significant activity that takes place at every manufacturing facility where final product(s) are produced. Significant amount of labor, equipment, and energy (electricity) costs may be incurred for material handling, especially when the materials handled are bulky. The composition of the material handling costs at a facility depends on the product characteristics, and the selection of labor and equipment alternatives.

This paper reports an industrial engineering project carried out to reduce material handling costs at a yarn and tire cord manufacturing facility in Turkey. The equipment used in the facility include forklift trucks and cranes. The technique used to improve the system is linear programming (LP), a fundamental deterministic modeling and optimization technique in operations research, used frequently by industrial engineers. After identifying the material

handling problem at the manufacturing facility, the facility structure is analyzed and the cost parameters related with operating the equipment are calculated. Then a spreadsheet model is built using MS Excel software and is solved to optimality using Excel's Solver. Operations research can have a remarkable impact on improving operational profitability in almost any company, in almost every function. In this project, the operating strategy suggested brought an improvement of approximately \$22,000 annually.

### **The Company and the Manufacturing Facility**

Our project was primarily concerned with the long-run profit maximization of material handling activities within Izmit, Turkey manufacturing facility of Kordsa<sup>1</sup> (Sabanci Dupont Industrial Yarn and Tire Cord Fabric Manufacturing and Trading Inc.) There are approximately 800 people working at the Izmit facility and there are approximately 20 people working at Kordsa Head Office at Sabanci Center in Istanbul, Turkey. The Izmit facility is located within KENTSA (SA City), a large manufacturing complex operated by the Sabanci Group which focuses on tire manufacturing.

Kordsa, founded in 1972 as a manufacturer of yarn and tire cord, now operates in seven countries, with 9 manufacturing facilities. Kordsa International, the majority shareholder of Kordsa is owned by Sabanci Holding with headquarters in Wilmington Delaware, USA. Some of the companies where Kordsa Int. has shares are Nilekords (Egypt, with %51 share of Kordsa Int.), Interkordsa (Germany, with %80 share of Kordsa Int.), Kiankordsa (Iran, with %60 share of Kordsa Int.), Kordsa Argentina and Kordsa Brasil (under 100% ownership of Kordsa Int.) Kordsa has a remarkable market share in Turkey and in Europe with respect to tire cord products. The company also offers a wide range of products to textile industry. Figure 1 illustrates the Nylon 6.6 yarn manufactured by Kordsa, which comprises approximately %75 of total production at the Izmit plant.

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<sup>1</sup> <http://www.kordsa.com.tr>



Figure 1. Nylon 6.6 produced at Kordsa; Source: <http://www.kordsa.com.tr>

There are 3 factories located in Kordsa's Izmit facility: Kordsa 1, 2, and 3. Kordsa 1 was founded in 1973 and now produces only yarn fabric. In 1980's Kordsa 2 started its operations to produce industrial fabrics such as liner and chafer. Finally, Kordsa 3 was founded in 1993 as a part of the growth strategy of expanding into global markets and integrating into yarn and cord fabric. Kordsa 1 survived and succeeded in the long-term due to developing competitive strategies in its industry. After assessing the condition of the market, the managers of Kordsa made the strategic decision of having a dominant role in industrial fabrics as a part of their growth strategy. As a result, Kordsa 2 was built to fill the gap in the sector. Finally, Kordsa 3 was built to expand a company's capacity.

Figure 2 illustrates the manufacturing steps at Kordsa. First, twisting is carried out to increase the strength of the yarn. Then, the twisted yarn is woven together on looms at dedicated Kordsa 1, 2 and 3 factories. Finally, dipping and hot-stretching are carried out as fundamental steps in tire cord fabric manufacturing.

## **The Project**

The scope of our project was the flow of material between Kordsa 1 and 3 factories and the dipping facilities. The output of the factories is looms of yarn, which are transported to one of the three depots (Depots 1, 2, and 3) to be stored for some time, and then transported to one of the two dipping facilities (Dipping Facilities 1 and 2).

Figure 3 gives an illustration of the system considered. The illustration suggests that the system considered is a network of nodes and arcs, where flow takes place on arcs to move work-in-process looms between nodes (factories, depots, and dipping facilities). The figure is illustrative and does not reflect the real distances (due to confidentiality). In reality distances play a crucial role in the costs of using each of the arcs in the network. For example, there is considerable distance between Kordsa 1 and Kordsa 3, which has implications for arc costs. Kordsa 2 factory is not considered in the project since the flow out of that factory is already determined. Instead, products coming from contractors are considered in the project by representing contractors as a factory.

The goal of the project was to decide on how the flow should be distributed to the arcs in the network. The flows of the work-in-process (WIP) looms are currently distributed to arcs in an ad-hoc manner. The goal is to minimize the total cost of transportation on all arcs.

Transportation is carried out with forklifts (Figure 4a) and cranes (Figures 4b and 4c shown empty crane and crane loaded with a loom). These equipment impose a great deal of costs, especially when the associated depreciation, maintenance and labor costs in operating the forklift trucks are taken into consideration.

The distances in the network are accurately calculated by using the CAD drawings provided by the Kordsa management. Afterwards, costs of the equipment are calculated in terms of data given such as cost of energy (electricity) spent for crane and forklifts (in kW per hour).

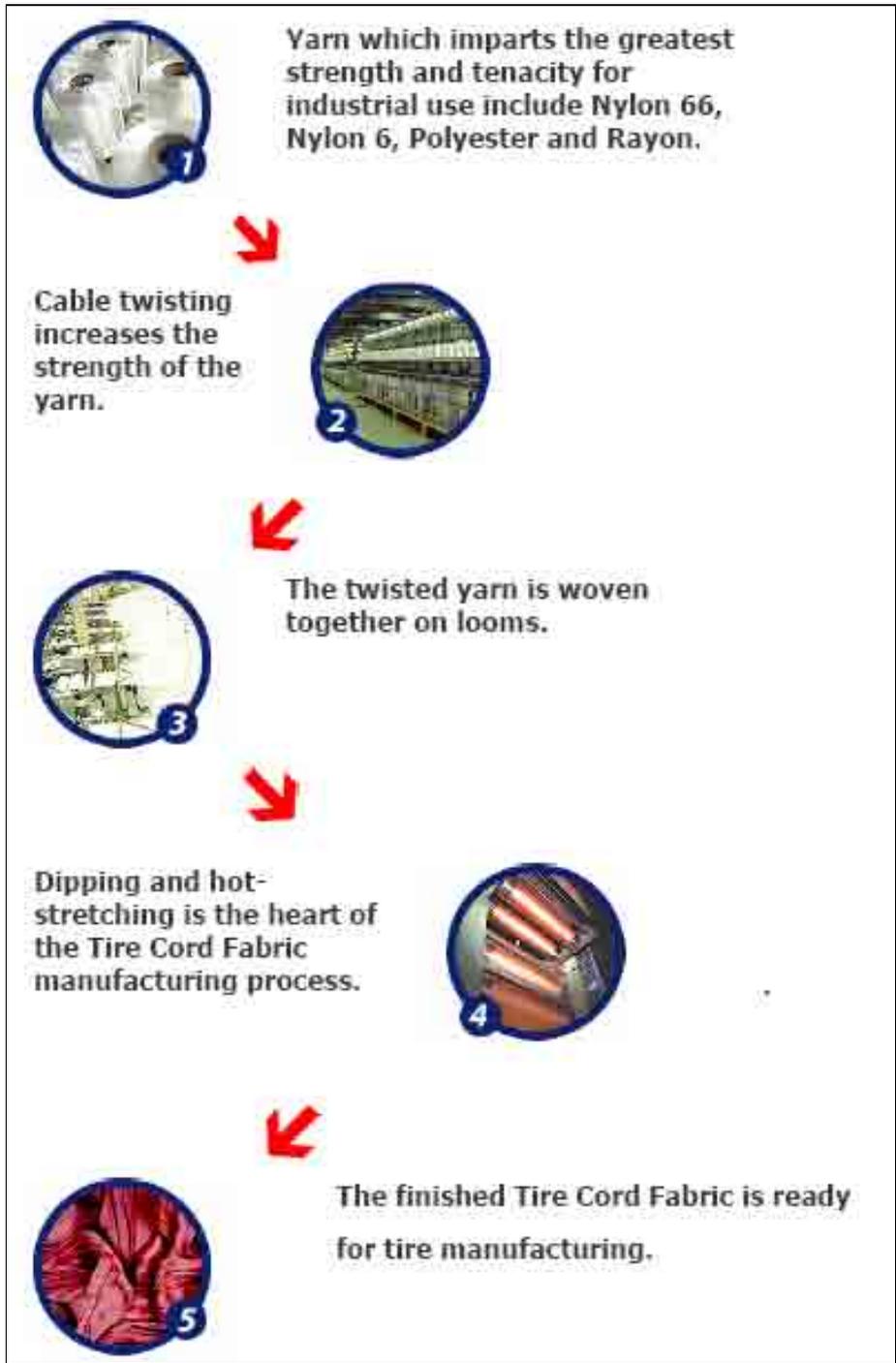


Figure 2. Manufacturing steps at Kordsa

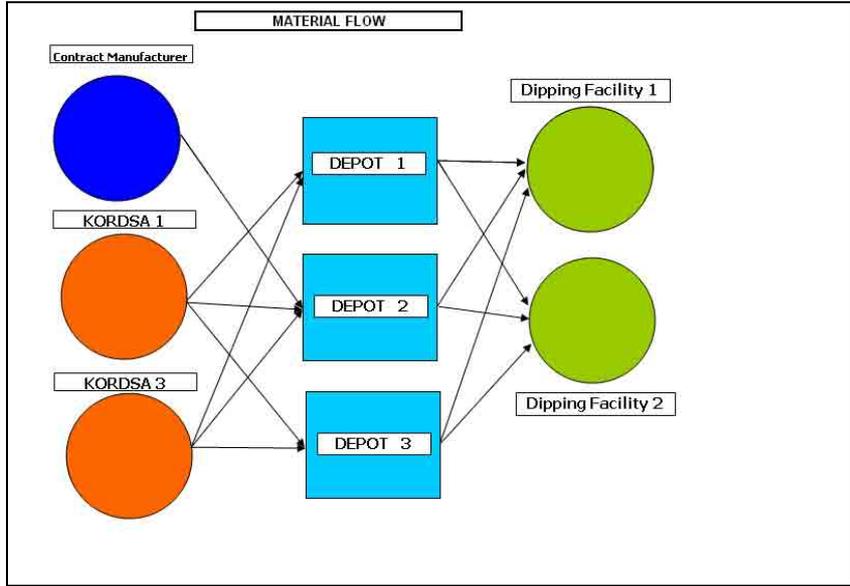


Figure 3. The network to be optimized

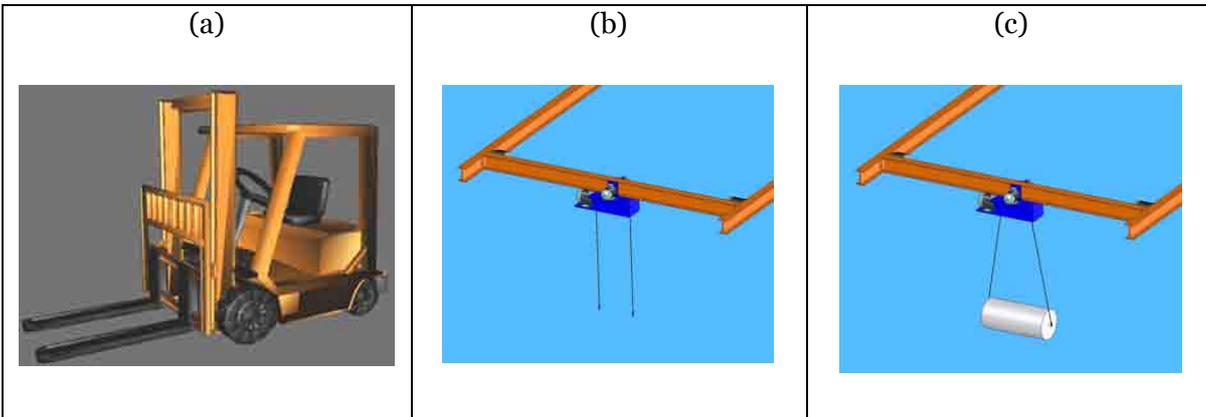


Figure 4. Pictures for forklift (a) and empty (b) and full crane (c)

## The Mathematical Model

The problem that we considered is essentially a network flow optimization problem considering the network in Figure 3.

The mathematical model is presented below:

### *SETS:*

$I$  : set of factories,  $i=1,2,3$  to represent Contract Manufacturing, Kordsa 1 and Kordsa 3 factories (Kordsa 2 is excluded since it is not considered in this project)

$J$  : set of depots ( inventory locations),  $j=1,2,3$ .

$K$  :set of dipping facilities,  $k=1,2$ .

### *DECISION VARIABLES:*

$x_{ij}$  : flow of factory  $i$  to depot  $j$ .

$y_{jk}$  : flow from depot  $j$  to dipping facility  $k$ .

$t$  : number of inventory turns

$u_j$  : total flow that passes through depot  $j$ .

**PARAMETERS:**

$c_{ij}$  : cost of flow from factory  $i$  to depot  $j$

$d_{jk}$  : cost flow of one roll from depot  $j$  to dipping facility  $k$

$M_j$  : maximum storage capacity of depot  $j$

$F_i$  : flow out of factory  $i$

$D_k$  : demand at dipping facility  $k$

**THE MODEL**

$$\text{Min } \sum_{(i,j) \in I \times J} c_{ij} x_{ij} + \sum_{(j,k) \in J \times K} d_{jk} y_{jk} \quad (1)$$

$$\text{s.t } \sum_{j \in J} x_{ij} = F_i, \forall i \in I \quad (2) \text{ Flow out of supply nodes (factories)}$$

$$\sum_{j \in J} y_{jk} = D_k, \forall k \in K \quad (3) \text{ Flow into demand nodes (dipping facilities)}$$

$$u_j = \sum_{i \in I} x_{ij}, \forall j \in J \quad (4) \text{ Flow balance constraints (depots)}$$

$$u_j = \sum_{k \in K} y_{jk}, \forall j \in J$$

$$u_j = M_j t, \forall j \in J$$

(5) Inventory turnover  
constraints  
(depots)

$$x_{ij}, y_{jk}, u_j, t \geq 0$$

(6) Non-negativity constraints

The objective of the LP model is to minimize the total cost of transporting the WIP goods from the factories to the depots, and then from the depots to the dipping facilities (1). The flows out of the factories and into the dipping facilities are given as parameters and should be satisfied (2),(3). The inflow and outflow at the depots should be equal (4). The inventory turns at the depots are not known. However, the capacities of each depot are known. Therefore we assume that the inventory turnovers at each of the depots are equal, and we thus include the necessary constraints in the mathematical model and the spreadsheet model (5).

## **The Spreadsheet Model**

### ***The Model***

The spreadsheet implementation of the presented mathematical model is shown in Figures 5 and 6. In Figure 5, the real values are replaced by the parameter/variable symbols due to confidentiality. The cells linked with lines have to be equal to each other. Before running the Solver to solve the model, the options “Assume Linear Model” and “Assume Non-negative” are selected.

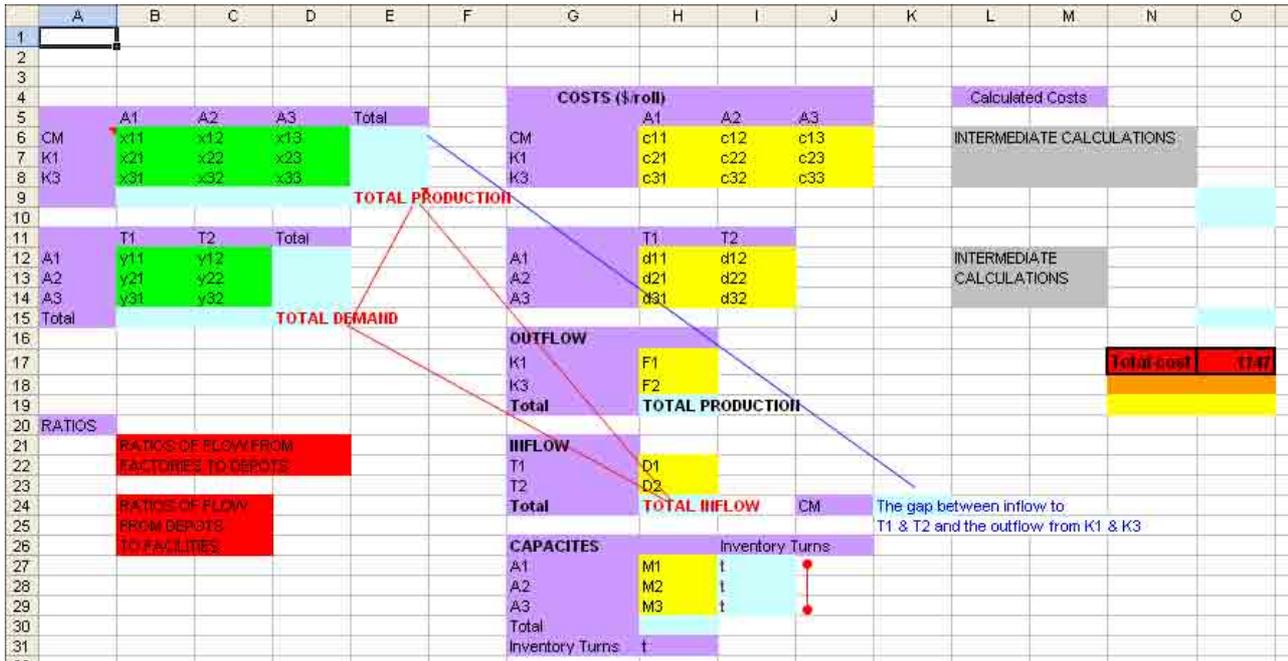


Figure 5. The spreadsheet optimization model: The view of the model worksheet.

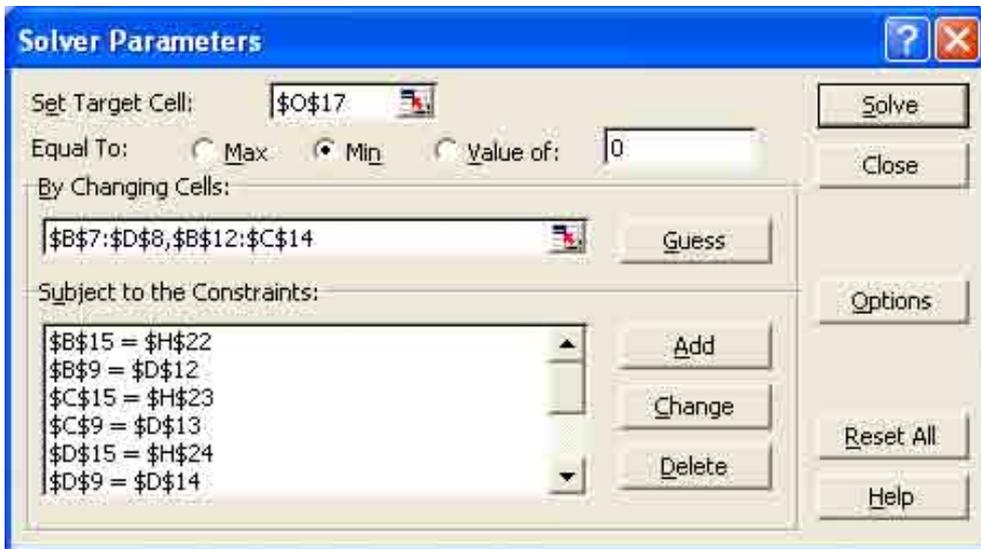


Figure 6. The spreadsheet optimization model: Solver parameters.

## ***Spreadsheet Modeling Guidelines***

Conway and Ragsdale provide some guidelines for good design of spreadsheet models, including the following:

- Numeric constants (the parameters in our case) should not be placed directly into formulas, but should be put into separate cells, so that they can be modified easily.
- The data should be organized and then arranged in the spreadsheet with a reasonable layout.
- Logically related elements should be arranged into cell groups that have close proximity.
- Column and row totals should be placed in cells close to the column and rows that they are summing up.
- Shading and borders should be used to distinguish parameters (which can be changed by the user to create new scenarios) from variables (which will be changed by the solver during the optimization process).
- Text boxes and cell notes should be used to document the model.

All these guidelines were followed in our spreadsheet model.

## ***Advantages of Using Spreadsheet Modeling***

The advantages of using a spreadsheet model -rather than using an IDE (Integrated Development Environment) for LP (such as AMPL<sup>2</sup>, GAMS<sup>3</sup> or LINDO<sup>4</sup>)- are the following:

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<sup>2</sup> <http://www.ampl.com>

<sup>3</sup> <http://www.gams.com>

<sup>4</sup> <http://www.lindo.com>

- Spreadsheets are used by people at all levels of an enterprise, from the foreman to the CEO. Almost everyone knows how to read and use –at least at a basic level- spreadsheet software. This enables accessibility of the model to decision makers at the company. The model that we developed was easily communicated to middle-level managers and foremen at the project’s presentation, drawing their interest and encouraging their participation.
- The spreadsheet model requires no apriori knowledge of or experience with LP at all. Anyone can “hack” the model and rerun the Solver to see the results of new scenarios. If an LP IDE were used, it would be very difficult for the people at Kordsa to use it.
- The coloring of the cells, and other formatting alternatives in the spreadsheet software makes the model even more understandable and usable.
- The MS Excel spreadsheet software is present at almost every company, whereas an LP IDE would require a special purchase and thus additional cost.

One special issue related with our model is that it is extremely simple and easy, even though it suggests significant savings. The authors had experienced earlier that MS Excel Solver may run into computational problems when attempting to solve large nonlinear problems. However, the solution of a small LP problem through MS Excel Solver is typically found with great accuracy in almost no time.

## **The Savings**

When the spreadsheet model is solved the optimal energy (electricity) cost of transportation is found to be \$1,747. However, the existing system requires much more than this cost. Under existing circumstances, the energy costs for transportation amount to \$2,109 per month. The difference between these two cost figures show that the model suggests a monthly saving of \$362 with respect to electricity. This translates in \$4,343 annually. There are also labor savings

due to eliminating a truck operator and due to maintenance and depreciation costs of the lift trucks. The total annual saving proposed by our spreadsheet model is approximately \$22,000.

## **Related Work**

Caine and Parker (1996) report a decade ago that spreadsheet software had enabled LP to become a viable option for solving managerial problems and performing sensitivity analysis of results. They illustrate how a simple LP problem can be modeled using Excel's Solver.

Two of the spreadsheet optimization applications reported in literature are the following:

- Cunha and Mutarelli (forthcoming) have implemented a spreadsheet model to optimize the production and distribution decisions for a Brazilian newsmagazine. Their model is based on a mixed-integer programming (MIP) formulation. Since their problem is fairly large, the authors report using the spreadsheet optimizer What's Best!<sup>5</sup>. They report that they have saved 7.1% in costs, totaling to over \$600,000 annually.
- Buehlmann et al. (2000) describe a decision support system that they have developed to optimize production of wood panels. Their implementation in MS Excel derives data from several worksheets, and provides a user-friendly interface for changing the parameters of the problem and thus solving new instances of the problem.

Other applications that can be found in literature focus on optimally allocating resources to research and development projects (Sonntag and Grossman, 1999), optimally assigning managers to construction projects (LeBlanc et al. 2000), and determining the optimal maintenance schedules for marine machinery (Artana and Ishida, 2002).

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<sup>5</sup> <http://www.lindo.com>

## **Conclusions**

Material handling is an integral part of a manufacturing system. Modeling and analysis of material handling with the aid of spreadsheet software can offer great opportunities for reducing costs, as we have shown in this paper.

In our project, the aggregate flow was optimized through a tactical model, rather than determining the exact flow amounts of individual products. The operational decision of how to dynamically allocate flow of products is still left to the foremen at the facility. Our model simply gives the percentages of aggregate flows that should take place on the average, which serve as guidelines.

Due to unpredictable customer's demands, the solution suggested by this project was not yet implemented at Kordsa, at the time this paper was being written. However, it has definitely provided the Kordsa managers with insights on how to manage the material flow throughout the plant, and how to use spreadsheets to bring operational savings.

## **Acknowledgement**

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