

# Chapter 20

## A Production Planning Optimization Model for Maximizing Battery Manufacturing Profitability

Hesham K. Alfares

King Fahd University of Petroleum & Minerals, Saudi Arabia

### ABSTRACT

*This paper presents an integer programming (IP) model for production planning, which is used to maximize the profitability of battery manufacturing in a mid-size company. Battery production is a complicated multi-stage process. The formation stage, during which the batteries are filled with acid and charged with electricity, is considered to be the bottleneck of this process. The IP model maximizes the total profit of batteries produced in the formation stage, subject to limited manufacturing resources as well as time limitations and demand restrictions. The IP model is able to accommodate a large variety of battery models and sizes, and also different charging circuit capacities and speeds. The model is formulated and optimally solved using Microsoft Excel Solver. Compared to the current manual production planning approach, the optimum IP-generated production plans lead to an average increase of 12% in daily profits.*

### INTRODUCTION

Battery production requires a special manufacturing process that involves several distinctive steps such as chemical curing, acid filling, and electrical charging. Due to the unique characteristics of the

battery manufacturing process, battery production planning has its own distinguishing features. In this paper, an integer programming model is presented for maximizing the profitability of battery production at the formation stage of manufacturing for the Middle East Battery Company (MEBCO) in Saudi Arabia. The model is formulated and applied to real production data, showing significant

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advantages over the current manual production planning approach.

The Middle East Battery Company (MEBCO) is a joint venture between a group of Saudi industrialists and Johnson Control International (JCI). MEBCO produces AC Delco, JCI and Toyota branded maintenance-free batteries. As an equity partner in MEBCO, JCI has management responsibility for the plant operation. MEBCO plant, which is located in Dammam, Saudi Arabia, started commercial production in 1998. The production has been steadily growing and it has exceeded 2.5 million batteries since 2006. The plant produces batteries for all vehicle types, as well as marine, commercial and industrial applications. MEBCO's primary market is the Middle East, but it also has growing markets in Asia, Europe, and North America.

MEBCO's battery manufacturing plant is divided into 4 main areas; X-Met, Green Group, Formation, and Final Assembly. The Formation area's main function is the electrical charging of batteries for periods that range from 14.5 hours to 24 hours, depending on the type of battery. Because of the limited time per day, and also because of space limitations that restrict the number of charging circuits, the Formation area is considered to be the bottleneck of the battery production capacity.

According to the theory of constraints, the throughput rate of any multi-component system is controlled by the slowest component (called the constraint or the bottleneck). In order to maximize the productivity (profitability) of the battery production line, the company needs to optimize the production planning output in the formation stage. As shown in the following section, a variety of optimization and heuristic techniques have been used to solve battery production planning problems. In this paper, an integer programming (IP) model is used to maximize the profitability of the formation area. This IP model has been practically applied to optimally schedule the daily production of 74 battery models. The model considers different

battery sizes, charging times, and daily demands, as well as limitations on times, capacities, and numbers of different types of charging circuits. Compared to manually generated production plans, the IP-optimized production plans increase daily profits by 12% on average.

The remaining sections of this paper are arranged as follows. First, previous literature on battery production planning is reviewed. Next, the manufacturing process, especially in the formation step, is described in more detail. Subsequently, the integer programming model for battery production planning is presented, and then the model's performance is compared to the current manual approach. Finally, results are analyzed, and conclusions are drawn.

## **LITERATURE REVIEW**

Previous approaches to battery production planning include simulation, network flow models, EOQ-type techniques, mathematical programming, and various heuristics. Turnquist (1991) described a software system for battery production planning developed by Cornell University for the Battery Strategic Business Unit of Delco Remy. The PC-based system includes three main components: (1) a forecasting module, (2) a multi-plant product allocations module, and (3) a scheduling module. The production scheduling module employs a network flow model to dynamically balance inventory and overtime costs given limited capacities and fluctuating demands for each plant.

Yenradeea (1994) combines simulation, the optimized production technology (OPT), and simple scheduling rules to schedule a four-stage battery production line. The OPT production plans successfully minimize inventory while maximizing the throughput rate. Using simulation experiments, these plans are shown to outperform both the push and the pull policies. Khadem and Ali (2008) develop a simulation model to optimize the cost effectiveness of a car battery manufacturer.

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