# Sizing of Raw Materials in a Corrugated Cardboard Box Manufacturing Company via Simulated Annealing Incorporating Integer Linear Programming

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## Abstract

In order to survive and to be competitive in today's highly turbulent business environments manufacturing companies should manage their operations efficiently and effectively. Optimizing costs, including purchasing and raw material waste costs is an important step in reaching these targets. Wasting raw materials due to non-optimal utilization is one of the reasons for considerable financial losses in many industries including corrugated box manufacturers. Based on this motivation, it is aimed to optimize purchasing and raw material waste costs of a corrugated box manufacturing company in this work. The company, where the case study is performed manufactures boxes of different sizes by cutting them from two-dimensional cardboard raw materials of certain sizes. The manufacturing company sizes its raw materials heuristically that is based on the experience gained over the years. However, the company is aware of non-optimal product-raw material matchings and aims to reduce resulting costs. In this study, an integer nonlinear programming (INP) model is developed in order to determine optimal sizes of raw materials to be purchased and their matching with the products to be manufactured. In order to be able to solve the developed model effectively the stated INP problem is decomposed into two interrelated problems (parts). In the first part, a simulated annealing (SA) algorithm is devised for sizing of the raw materials, as soon as the SA algorithm determines alternative raw material sizes it calls the second part, where an integer linear programming (ILP) model is solved to assign products to raw materials and compute costs under several constraints. The proposed optimization system is coded in Python where Gurobi solver is called for solving ILP. Application of the proposed optimization system to company's data has revealed considerable cost reductions.

## Keywords
Corrugated Box Manufacturing, Raw Material Sizing, Waste Reduction, Metaheuristics, Integer Programming

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## Biographies

**Ilkim Sipahi** received her B.Sc. degree in Industrial Engineering from Dokuz Eylul University; and continues her M.Sc. degree in the same field and institution. She currently works as material planning engineer at TEI – TUSAS Engine Industries, Inc.

**Adil Baykasoğlu** received his B.Sc., M.Sc. and Ph.D. degrees from Mechanical and Industrial Engineering areas in Turkey (Gaziantep) and England (Nottingham). He is presently a full Professor and chair at the Industrial Engineering Department at the Dokuz Eylul University. He has published numerous academic papers, books and edited several conference books on operational research, computational intelligence, engineering management, and manufacturing systems design.

**Kemal Subulan** received his B.Sc. degree in Industrial Engineering from Dokuz Eylul University, as the highest ranked student of the Industrial Engineering Department and Engineering Faculity. After completing his M.Sc. degree in 2012, he started doctorate program in the same department. During his graduate education, he was entitled to receive TUBITAK domestic master's and PhD scholarships. His articles have been published in many international scientific journals and peer-reviewed congresses. He served as a referee in many international journals. He received publication incentive awards from TUBITAK and Dokuz Eylul University for his international scientific studies. His researches focus on operations research, logistics and supply chain management, fuzzy logic, meta-heuristic algorithms and artificial intelligence. He has been working as an Associate Professor in the Industrial Engineering Department of Dokuz Eylul University since 2020, and he is also responsible for the intelligent optimization and decision-making laboratory and the CANIAS Enterprise Resource Planning laboratory.