

BAKUP
Team 9

Production Planning Decision Support System (Scheduling and Planning)

Bareks Plastic and Polyethylene AŞ

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Abstract

The problem is to plan the scheduling of products and their machine choices that minimize the setup times of the machines and maximize the production line efficiency. To achieve this, we will design a mathematical model as a decision support system that is capable of generating machine precedence order in every order. The project's expected outcome is determining a precedence order for each product and scheduling machines according to this precedence order. Moreover, the due dates, capacity of the machines and the demands will also be examined in the process of the project and the results will be discussed.

Keywords: Schedule Optimization Models, Parallel Machine Scheduling, Planning, Demand

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1 Description of the System

Bakioğlu Holding is a multi-faceted holding company based in İzmir. They are currently active in industries such as construction, logistics, insurance and packaging. They have 17 companies under the holding company like Bak Ambalaj and Bareks Plastik. Bakioğlu was established in 1973 in İzmir and in 2002 the Bareks Plastik company was founded in the Menemen industrial area. Although the revenue of the holding company is not shared, they are listed as one of the “Second Top 500 Industry Establishments” in the country. In the case of Bareks Plastic, and one of the five companies in the “packaging” field. Like their parent company Bakioğlu Holding, they are listed as one of the top establishments in the company and they are also listed as one of the “Top 1000 Exporters” in the country [Dünya Newspaper \(2024\)](#). In 2023, Bakioğlu Holding’s packaging companies recorded an average of 80 percent export rate over their five companies in the field with Bareks Plastik having a 68 percent overseas sale rate, Bak Ambalaj having a 74 percent overseas sale rate, Polibak having a 46 percent overseas sale rate and Bak Gravür having a 7 percentage

overseas sale rate while there is no data available on the overseas sale rate on Bakcycle. ([Bakioğlu \(2024\)](#))

As mentioned earlier, Bakioğlu Holding has five packaging companies and four of them work on different types of laminations, printing and packaging material based on the type of product they manufacture. Their most recent move was the opening of their recycling company, Bakcycle. Bareks Plastik was founded in 2002, and their main goal was to produce multi-layered polyethylene films designed for printing and lamination that would be suitable for food packaging. Today they operate two companies under the main company in the name of Bareks Plastik and Bareks Polietilen. The company has two factories, in Çiğli and Menemen, they have 16 categories of products in their product portfolio. Some of the categories mentioned in the catalogue are pet food packages, cereal packages and sanitary/hygiene packages. Depending on the category and what type of package the customer wants, the plant that is tasked with producing the product manufactures it based on the requirements. There are two different types of packages: three layered and five layered packages. Again, based on the customer specifications, the coloring of the packaging, the number of layers for the package and the raw material(s) can be changed.

2 Current System Analysis and Problem Definition

2.1 Current System Analysis

The following information is collected from the company site and also from the meeting with the Bakioğlu Holding to make an analysis on the Bareks company's current system and the problem. There are two factories in Menemen and Çiğli in İzmir that work 7/24. The company has a total of 9 production lines where 7 of them were found in the Menemen factory and 2 parallel production lines were found in Çiğli. The company has a production based on orders and not with stocks. In the Menemen factory there are 7 types of machines which have numbers 3, 4, 5, 6, 7, 8 and 9. Whereas in Çiğli there are two machines 1 and 3. Both factories made 7/24 production. Machines 3,4,5,6 and 8 in Menemen and the machine number one in Çiğli have the same capacities. However, machines 3 and 17 have lower capacities than the rest of the machines. The capacities of the machines 3, 4, 5, 6, 7, 9, 9,1 and 2 are 13.9, 13.9, 13.9, 8.8, 13.9, 5.1, 13.9, and 5.2 tons per day respectively. All machines have one layer except machine number 5 which has 5 layers. Company's aim is to make a 7/24 production to produce a variety of products according to ordered tons while satisfying the due dates of the customers. In the case of high order occurrences and the deadlines have critical importance, their aim is to complete the production of orders until their due dates. However, in case of low occurrences of orders, machines may not be produce 7/24 and turned off. When the machines are turned on again, they need to re-enter setup times so the next product's properties such as its length, width, layflat values, raw material and film types which lost them time they didn't want. So they want to minimize machines' setup times and the waste that occurred as in that time

more products can be produced.

Table 1: The Occurred Waste for different Machines' Setup Time

Machines	Occured Waste
Machine 1 for Same Order Code	100 kg
Machine 1 for Different Order Code	200 kg
Machine 2 for Same Order Code	100 kg
Machine 2 for Different Order Code	300 kg
Machine 3 for Same Order Code	100 kg
Machine 3 for Different Order Code	200 kg
Machine 4 for Same Order Code	100 kg
Machine 4 for Different Order Code	200 kg
Machine 5 for Same Order Code	100 kg
Machine 5 for Different Order Code	200 kg
Machine 6 for Same Order Code	100 kg
Machine 6 for Different Order Code	200 kg
Machine 7 for Same Order Code	100 kg
Machine 7 for Different Order Code	200 kg
Machine 8 for Same Order Code	100 kg
Machine 8 for Different Order Code	200 kg
Machine 9 for Same Order Code	100 kg
Machine 9 for Different Order Code	300 kg

In the company there are some flexible machines that are able to produce multiple products. If the order is a frequent order, it is sent to the production line that the same or similar products are produced before. When an order comes, the machine it will be sent to is selected according to efficiency. The efficiency is determined by the experience of the engineers as it is mentioned in the meetings and in teams. Each machine has different flexibility to produce certain products.

Table 2: Machine Production Matrix 1

Machines	Product Z	Product 2	Product 3	Product 4	Product 5
Machine 1	0	1	1	0	1
Machine 2	0	0	0	0	0
Machine 3	0	1	1	0	1
Machine 4	0	1	1	0	1
Machine 5	0	1	1	1	1
Machine 6	0	1	1	0	1
Machine 7	1	0	0	0	0
Machine 8	0	1	1	0	1
Machine 9	0	1	1	0	0

The company produces their products as sets, that is how many coils can be produced at a time. The sets are calculated as “maximum layflat capacity/width value”. Layflat is the measurement of the coil differentiated according

Table 3: Machine Production Matrix 2

Machines	Product 6	Product 7	Double Corona	Outer Corona	Inner Corona
Machine 1	1	0	0	0	1
Machine 2	0	1	0	0	1
Machine 3	1	1	0	0	1
Machine 4	1	1	0	0	1
Machine 5	1	1	0	0	1
Machine 6	1	1	0	0	1
Machine 7	0	1	1	1	1
Machine 8	0	0	0	0	1
Machine 9	1	1	0	0	1

to different thicknesses. Figure 3: Layflat calculation according to product's thickness value

Table 4: Layflat Calculation according to Product's Thickness Value

Thickness (mikron)	Max Layflat (mm)
20-100	2600
110	2550
120	2500
130	2450
140	2400
150	2350
160	2300
170	2250
180	2200
190	2150
200	2100

Moreover, it is appropriate to order layflat values in ascending order to minimize setup times of the machines instead of a random or descending order.

Table 5: Example of Orders with Different Layflat Values

Customer	Type of Film	Category of Film	Layflat	Thickness	Width
Customer 1	Product 1	4	1710	30	1100
Customer 2	Product 2	9*	1740	60	973
Customer 2	Product 2	9*	1840	60	1650
Customer 2	Product 2	9*	1890	50	2060
Customer 2	Product 2	9*	1920	45	700

2.2 Problem Definition

Bareks Company wants to use all parallel production lines 7/24 without turning their machines off in their factories both in Menemen and Çiğli that have

seven and two parallel production lines respectively. They need to turn their machines off when the number of machines that are able to produce the orders are more than the number of orders as the machines do not need to work should be turned off. When machines are turned on again and different orders start to come, to meet the requirements of the orders a setup time will be required which is the time to arrange the machines again for different products according to their properties like length, width, layflat values, raw material values and film types. This setup times cause lost time and so the waste as during that time company can also produce more products. Company wants to decrease the number of products that can be produced during that time by minimizing setup times of these machines.

When an order comes it can be produced at multiple machines as the company has some flexible machines. After the orders arrive they are sent to specific machines which will be the most effective choice. This effective choice will be determined by two things according to the meetings with the company. First, the company sent the arrived orders to the machines that produce the same past order as before as these machines are capable of producing these products. Secondly, they determine the machine according to their experience in the field. As the company doesn't have an algorithm to determine the optimized choice of machine they can't schedule machines in order to minimize their setup times, they don't work efficiently and this leads to some tardiness in their schedule and wastes. When a risk of tardiness occurs, the order which has the earliest due date will be produced in another machine if the machine which is defined as more efficient is busy. In that case, the company produced B quality products instead of an A quality product which is not wanted.

3 Review of Resources

The main goal of this project is to minimize the setup time caused by machine usage inefficiency. Thus, the machine usage efficiency will be increased by developing a suitable scheduling method, and it will also increase the production amount per unit time and the compliance of incoming orders with the delivery time to the customer. According to this objective, the algorithms, resources and open source software package considered for use in the report and their explanations are available below.

3.1 Relevant Work in the Literature

3.1.1 Mixed Integer Linear Programming (MILP)

Mixed integer linear programming, a mathematical optimization method, is used to address linear objectives and constraints problems where some or all of the variables must be integers. In MILP, both integer variables (integer values only) and continuous variables (values with real values) are considered. The aim of this program is to find the optimum solution by minimizing or maximizing a certain objective function, taking into account linear constraints [Modos \(2021\)](#). With this method, the decision variables specified in the proposed solution strategy section of the report will be found according to the objective function and constraints using the estimated parallel machine scheduling

prepared for production planning and the data provided by the company as parameters. The objective function value will be provided by the open source optimization solver.

3.1.2 Constraint Programming (CP)

CP can be used for parallel machine scheduling because of its ability to handle complex constraints and dependencies. It is suitable for modeling scheduling problems where various conditions such as machine availability, setup times, and precedence relationships must be considered. CP can explore solution spaces to find optimum schedules, such as constraint variety and search algorithms, making it ideal for scheduling problems with multiple machines and complex constraints [Lopez and Esquirol \(1996\)](#). CP is a programming paradigm used to solve combinatorial problems, including parallel machine scheduling. In this method, the problem is defined by a set of variables, possible values for the variables (domains), and conditions that the solution must satisfy (constraints). The CP solver explores possible combinations of values assigned to the variables while ensuring that all constraints are satisfied. It narrows down the search space by removing infeasible solutions. Thus, CP is an effective technique for solving complex scheduling problems according to [Baptiste et al. \(2001\)](#). In order to optimize setup times in a project, there is a machine availability constraint and a precedence relationship constraint in production due to the delivery times of product orders to customers. In this case, CP is an appropriate method for modeling and from the project perspective.

- A Genetic Algorithm for the Unrelated Parallel Machine Scheduling Problem with Sequence Dependent Setup Times

In this study, there are $N = 1, \dots, n$ jobs that need to be processed on exactly one machine from a set of m parallel machines. Each job consists of a single task that requires a certain processing time. When the processing times of jobs depend on the machine to which they are assigned, the machines are considered unrelated. This is also the most realistic case that generalizes to uniform and identical machine cases. The setup times between jobs need to be taken into account. The setup times considered in this paper are both sequence- and machine-dependent, i.e., the setup time between jobs j and k on machine i is different from the setup time between jobs k and j on the same machine. The most emphasized optimization criteria are to minimize the makespan and maximum completion time (C_{max}). In summary, this paper presents a genetic algorithm for the unrelated parallel machine scheduling problem in which machine and job sequence dependent setup times are considered [Vallada and Ruiz \(1996\)](#). The paper also compares the genetic algorithm with the outputs of other possible algorithms. This article will show the comparison of the algorithms for the project model and the algorithm being worked on and will help in preparing the most optimal result

- Google OR-Tools

Google OR-Tools is an open source constraint and linear programming solver. It is suitable for solving algorithms and models such as Constraint Programming, Mixed Integer Linear Programming, Linear programming, knapsack algorithms. It is compatible with Python, which we chose to use in the project, and is also the most suitable open source software to solve the model written for the project proposal.

3.2 Engineering Standards and Regulations

Some of the main objectives of this project are to increase the efficiency of machine usage and the amount of product produced per unit time, to ensure that daily energy consumed is used efficiently and to reduce waste. Also, since Bareks produces high value added polyethylene film, it should continue environmental sustainability by minimizing the damage to the environment. At the same time, the company provides services with a 100 percent customer satisfaction approach with its structure that adopts quality as a principle. There are a few relevant engineering standards and regulations that need to be reviewed regarding the specified goals. Bakioğlu Holding Bareks' engineering standards and regulations focus on sustainability, quality and environmental responsibility. The first of these is ISO 14001, which is the international standard of the Environmental Regulation System for organizations related to waste reduction, and ISO 14064 has certificates of compliance with the international standards of the Carbon Footprint Management System. ISO 9001 is the international Quality Management System standard for manufacturing organizations and ISO 50001 is the international standard of Energy Management Systems, and Bareks is obliged to comply with these standards as an organization. In addition to these standards, ISO 45001 Occupational Safety and Management Systems and ISO 27001 Information Security Management System must also comply with international security standards. In addition, it has ISCC (International Sustainability and Carbon Certification) and RecyClass certificates, which are international sustainability standards.

4 Proposed Solution Strategy

4.1 Critical Assumptions

Critical assumptions are listed as follows:

- The date of the order is assumed to be the starting date of the production schedule.
- The machines work 7/24.
- The setup time is assumed to be asymmetric.

4.2 Major Constraints

Major constraints are listed as follows:

- Odor-sensitive products cannot be produced after another product causes odor.

- Product 5 film type series and Product 6 series should not be planned back-to-back. The formulations of both orders are difficult.
- If an order for product 12 and product 13 has arrived, a product 20 film type must be planned behind it.

4.3 Objectives

This project aims to decrease and ultimately minimize setup times between different products to reduce waste and lost time. Since the product groups are similar, the aim is to achieve the given goals and in turn, make sure that the company delivers their products on the given due dates and production lines' efficiency are increased.

4.4 Solution Approach

We will use 5 different solutions to approach this problem. To achieve our objective these 5 approaches will be combined. To include constraints and find the optimized way, an Integer Programming Model will be used. Both with this model and with a Product Grouping for Set Up Time Reduction approach, we aim to use resources in the most efficient way possible while reducing the setup times and manual work required. Moreover to increase the productivity in 9 different parallel production lines a Constrained based Scheduling Algorithm will be used. On the other hand, to determine the ordering patterns a Heuristic Algorithm approach will be conducted. Finally, to combine all of our work and reflect it to real life an Interactive Scheduling Interface will be established by using Python.

Table 6: Indices

Symbol	Description
$i = 1, \dots, 10$	Number of Product Types
$j = 1, \dots, 9$	Machine Numbers
$t = 1, \dots, t_{max}$	Time Horizon

Table 7: Parameters

Symbol	Description
D_{it}	Demand for product i at time t
C_j	Production capacity of machine j
$T_{ii'}$	Setup time between products i and i'

Table 8: Decision Variables

Symbol	Description
x_{ijt}	Number of product i produced in machine j at time t
$s_{ii'jt}$	If product i' will be produced after product i in machine j at time t .

$$\min \sum_{j \in J} \sum_{t \in T} s_{ii'jt} T_{ii'}, \quad (1)$$

s.t.

$$\sum_{t \in T} \sum_{i,j \in A} x_{ijt} = 0 \quad (2)$$

$$\sum_{j \in J} x_{ijt} \geq D_t \quad \forall i \in I \quad \forall t \in T, \quad (3)$$

$$x_{ijt} \geq 0 \quad \forall i \in I, j \in J, t \in T, \quad (4)$$

$$x_{ijt} \leq C_j \quad \forall i \in I, j \in J, t \in T, \quad (5)$$

$$s_{ii'jt} \in \{0, 1\} \quad (6)$$

- (2) aims to ensure that some products cannot be produced in some machines.
- (3) ensures that the number of products manufactured on the time horizon t , is bigger than or equal to the demand in that same time horizon.
- (4) ensures that the number of products manufactured cannot be under zero.
- (5) ensures that the number of products produced in machine j is smaller than or equal to the capacity of that machine.
- (6) is a domain constraint.

5 Outcome and Deliverables

5.1 Outcome

The main purpose of this project is to develop a Decision Support System (DSS) that will minimize production times while ensuring that all delivery deadlines are met. The system will help Bareks streamline its production processes by providing a structured and automated approach to scheduling, which is currently done manually and can be prone to errors. In simple terms, a DSS is a tool that uses data and mathematical models to help decisionmakers solve complex problems more efficiently. For Bareks, this means having a system that can analyze production constraints, such as machine capacities and order priorities, and generate an optimized schedule. By integrating the DSS with Excel, we aim to make the system compatible with Bareks' current workflow while improving speed and accuracy through Python-based algorithms. The expected outcomes of the project include reducing the time spent on manual scheduling, improving the utilization of production lines, and enabling faster adjustments to changing customer demands. Ultimately, the DSS will allow Bareks to deliver on time while minimizing production costs and delays.

5.2 Deliverables

The project will deliver a Decision Support System (DSS) tailored to optimize Bareks' production scheduling processes. This system will be built to address the company's key operational challenges and improve overall efficiency. The DSS will include the following key components:

- **Optimized Scheduling Module:** This module will generate schedules that minimize production times and align with delivery deadlines by using advanced algorithms. It will consider constraints such as machine capacity, order priorities, and setup times to create feasible and efficient plans.
- **Python-Excel Integration:** The system will feature seamless integration with Excel, allowing Bareks to use existing data formats while improving processing speed and reducing manual work. This ensures compatibility and an easy transition to the new system.

The focus of the deliverables is to provide a system that is practical and directly applicable to Bareks' production environment. Instead of investing time in training sessions or introducing unrelated tasks, the emphasis will be on immediate operational improvements. The project's primary aim is to reduce the workload on manual scheduling, improve resource allocation, and minimize setup times. By streamlining these processes, the DSS will directly contribute to enhancing Bareks' production capacity and reliability.

5.3 Benefits to the Company

The DSS and its associated deliverables will provide Bareks with significant operational advantages, enhancing various areas of production planning and execution:

- **Cost Savings and Enhanced Efficiency:** By reducing the time and labor involved in manual data handling and scheduling, the DSS will free up resources, allowing team members to focus on high-value tasks like quality control and strategic planning, thereby raising Bareks' overall productivity.
- **Improved Data Accuracy and Dependability:** By automating data entry, the system will lower the likelihood of errors in scheduling and resource management. Enhanced data accuracy will contribute to reliable production schedules, minimizing delays, and increasing customer satisfaction through timely deliveries.
- **Greater Flexibility and Scalability:** The adaptable structure of the DSS will allow Bareks to adjust production schedules swiftly in response to fluctuations in customer demand, supporting responsiveness. This flexibility also enables Bareks to expand its operations as needed without major infrastructure changes.
- **Enhanced Support for Strategic and Data-Driven Decision-Making:** Through the system's integration of historical data analysis alongside real-time

forecasting capabilities, Bareks can efficiently anticipate production needs, project demand, and allocate resources with precision. This data-driven planning approach promotes sustained operational optimization, positioning Bareks competitively within the packaging sector for long-term success.

In conclusion, the DSS represents a substantial enhancement to Bareks' production planning capabilities. With its advanced analytics, automation, and real-time data integration, this system will empower Bareks to operate with heightened efficiency, adaptability, and accuracy, supporting the company's objectives for sustainable, scalable growth in a competitive market environment.

6 Project Plan and Work Package Assignments

First of all, efforts were made to divide the project into various stages, create a balanced plan that would comply with the deadlines, and prepare different work packages, to keep the good distribution of the workload. These work packages are, respectively, the analysis of the problem, modeling, verification, validation, user interface prototype, and pilot study. The distribution to be made according to this situation is as follows:

- Work Package 1: Problem Analysis

Problem analysis is a critical stage to understand the current situation and identify problems. Within the scope of this work package, meetings were held with academic and industry consultants. In these meetings, it was understood that there was a problem of delays arising from machine setup times during production. The problem here is to minimize these times by optimizing the scheduling to increase productivity. All team members contributed to this stage of the project. The responsibility for organizing the meetings generally belongs to Buse Yüksekayalı, who is the CP of the group

- Work Package 2: Modeling

This work package includes the creation of the model to be used in the project solution and research on schedule optimization models. Various open-source software are being researched in order to ensure that the model to be used in the project provides the most effective and efficient solution. After the confirmation expected from the company, it will be determined which tool will be used. At this stage, all team members contribute to the creation of the model. Ahmet Değirmencioglu and Onurhan Ünal will mainly take part in the model solution process.

- Work Package 3: Verification

At this stage, tests will be conducted with various data to ensure the accuracy of the model created. The verification process, which evaluates whether the model outputs meet expectations, is an important step toward increasing the reliability of the project. Liya Fındık and Fatma Küçük will be mainly responsible for this stage.

- Work Package 4: Validation

At this stage, it will be checked whether the model works by the real data. Necessary evaluations will be made to ensure that the model gives consistent and meaningful results. Pınar Aydınelli and Cem Yeni will undertake the analysis and result evaluation tasks during the validation process.

- Work Package 5: Pilot Study

A pilot study will be conducted to observe how the model works in practice and to evaluate its impact in the real world. The pilot study will play an important role in seeing how effective the model is in the operational environment and identifying areas for improvement. Buse Yüksekayalı will be responsible for the planning, implementation, and analysis of the results of the pilot study.

- Work Package 6: User Interface Prototype

A user-friendly interface prototype will be developed to enable the model to interact with end users. The interface is planned to be designed to provide users with easy access to the results of the model. Ahmet Değirmencioğlu and Onurhan Ünal will be primarily responsible for this phase.

All phases can be seen Gantt Chart below:

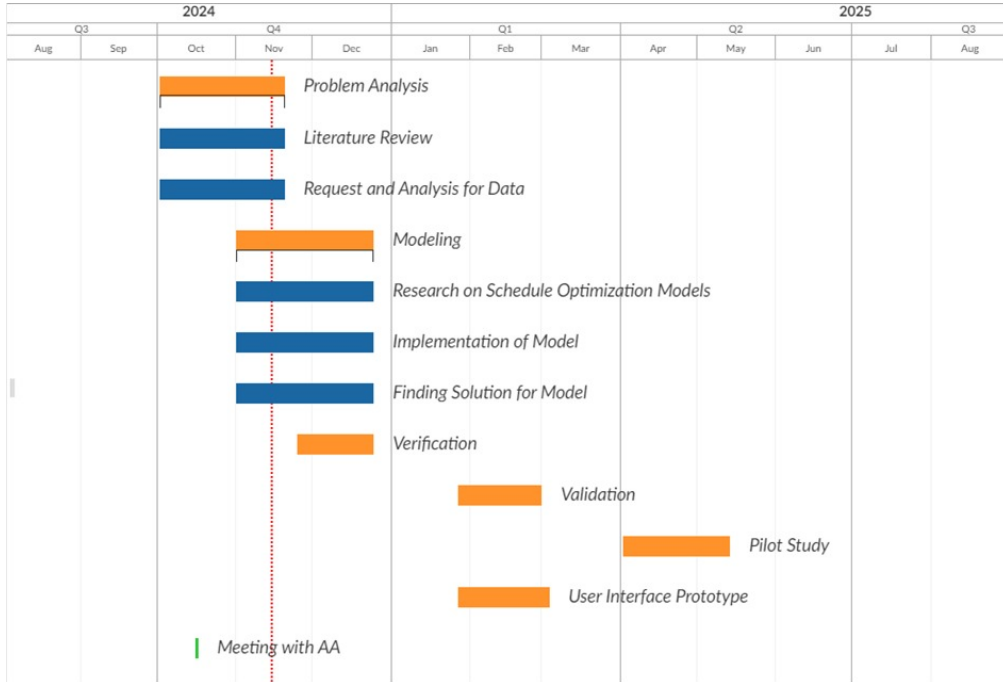


Figure 1: Gantt Chart of the Project

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