A real life case study of an integrated problem with production and transportation constraints

Manuel Iori¹, Marina Vinot¹₂

¹ University of Modena and Reggio Emilia, DISMI, 42122 Reggio Emilia, Italy
   manuel.iori@unimore.it

² Université Clermont Auvergne, LIMOS UMR 6158, 63178 Aubière, France
   marina.vinot@isima.fr

Mots-clés: Optimization, Scheduling, Routing.

1 Introduction

This paper introduces a concrete integrated problem with production and transportation constraints. Integrated problems can be encountered in many decision contexts within companies [1]. This is the case of Eurofluid Hydraulic, a large company specialized in the manufacturing of manifolds for hydraulic equipment, with a factory located in Reggio Emilia, Italy.¹ Eurofluid Hydraulic realizes the production of special components in cast iron, steel and aluminum, in accordance with personalized drawings and specifications by customers. For each component, the manufacturing process consists of a sequence of drilling operations performed by computer numerical control machines, and repositioning operations performed manually by workers on bays. The factory in Reggio Emilia is composed of 5 machines and 13 bays including: 3 bays for manual operations, 2 for incoming flow, 1 for outgoing flow, and others used for visual control, quality check and similar operations.

The problem can be formulated as a combination of assignment, scheduling and routing decisions. The aim is to ensure a good quality of service to customers, by meeting due dates of the ordered products. The production is organized around several actors, machines for the drilling part, bays for the operational part, a shelving for the storage of all products and a robot, named 'Meccano', in charge of making all the movements of the products among all the actors. This is why the production heavily depends on the proper functioning of the robot, which is a critical resource of the system.

2 Problem description

In this integrated problem, we consider a set P of requested products (p = 1,...,|P|). Each requested product is defined by a total quantity qₚ of items to manufacture and by a due date dₚ for the production of all the items. A set M of machines (m = 1,...,|M|) and, a set B of bays (b = 1,...,|B|) are used for the production with a single robot and a single shelving.

Movements of the robot. The robot allows the movement of products from the shelving, the machines and the bays to the shelving, the machines and the bays in any combination. It is the only intermediary among all these actors. The robot is able to move in three dimensions:

- in length by means of a rail mounted on the ground
- in height to serve the different levels of shelving, machines and bays.
- in width to allow exchange of products between the rear part consisting of shelving and the front part consisting of bays and machines.

¹https://www.eurofluid.it/en
The speed of the robot depends on its load (empty or not) and its axis of movement.

**The operating sequence of a product.** The total quantity $q_p$ of items in a product $p$ has to be produced in batches. Each batch has size $\delta_p$, and each item associated to a product $p$ requires $\varphi_p$ operations. All this information makes it possible to define the total number of operations $N_{tot}^p$ for a product, including $N_m^p$ operations on machines, $N_b^p$ operations on bays and $N_s^p$ operations on the shelving, that are necessary to manufacture all the items of $p$. They can be computed as follows:

$$N_{tot}^p = N_m^p + N_b^p + N_s^p,$$

$$N_m^p = \frac{q_p}{\delta_p} + \varphi_p - 1, \quad N_b^p = N_m^p + 1, \quad N_s^p \in [2; N_m^p + N_b^p + 1]$$

The operating sequence of a product follows some basics rules:
- it starts and ends at the shelving;
- each machine operation is preceded and is followed by a bay operation;
- if a machine/bay is not available to process a product then the product will have to wait in the shelving. The number of operations on the shelving is therefore variable.

Two extreme cases can be exhibited:
1. The product never returns to the shelving between the machine/bay operations.
2. The product always returns to the shelving between the machine/bay operations.

An example to concretely detail case 1 is shown in Table 1 and concerns a product $p$ defined by $q_p = 4$, $\delta_p = 2$, and $\varphi_p = 2$. At the beginning there are four raw items in the shelving, two of them are processed at a bay and then at the machine. The two resulting semi-finished products are then processed at a bay where the two remaining raw items are added. The four items are then processed at the machine and at a bay where the two finished products are removed. The two remaining semi-finished products are then processed at the machine and at a bay in order to removed the last two finished products. The sequence ends with the transportation of the four finished products to the shelving.

<table>
<thead>
<tr>
<th>Operations</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{op}$</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>$B_{op}$</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M_{op}$</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TAB. 1: Sequence of shelving ($S_{op}$), bay ($B_{op}$ ) and machine ($M_{op}$) operations for 4 items of a product

### 3 Conclusions and perspectives

This paper introduces a simplified version a real life case study of an integrated problem with production and transportation constraints. Two MILP based on a disjuntive model are proposed to solve the two extreme cases presented with makespan minimization. We are now directing our research towards a dynamic algorithm in order to take all the constraints into account, and to propose a solution in agreement with the reality of the production.

### References