Toward a scheduling model for the metal accessories’ suppliers for the fashion industry

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Abstract: The goal of the paper is to present a scheduling model for companies producing metal accessories for the fashion industry. Starting from the description of the challenges that fashion Supply Chain (SC) actors have to face with, the focus has been moved towards the relevance of scheduling problems in that sector. After a literature review on optimization models for the fashion industry, the boundaries of the model have been listed, defining indices and parameters, decision variables, constraints and the Objective Function (OF). Finally, the model has been validated through a case study conducted on a mechanical company. The main result of this paper is the definition of a set of rules suitable for these kind of companies and the validation of the proposed linear integer optimization model in a real scenario, using a commercial spreadsheet and an open source solver. Consequently, the industrial applicability of the proposed tool in the analysed industry has been demonstrated.

Keywords: Metal Accessories, Fashion, Scheduling, Optimization

1. Introduction

Production Planning and Control (PP&C) has been deeply analysed in the literature, both in general terms and focusing on specific industries. The fashion industry is one of the sectors where many contributions can be found, even if most of them are related to the brand owners’ perspective. Recently, focal companies have faced with an increasing attention to Critical Success Factors (CSFs) such as high-quality products, compliance with delivery dates, cost reduction, and sustainability issues (May et al., 2015). As a consequence, all of the SC actors, including metal accessories suppliers, have been required to improve their performances by the brand owners, in line with the increased market pressure. This evidence is related to the fact that these results cannot be obtained operating at a single-company level, but considering the entire SC, because the outstanding quality of a final product is strictly linked to that of one of its components and, in the same way, the delay of the final product depends on components delays. Moreover, this correlation is even more critical in industries, such as the fashion one, where “time” represents the key word for being competitive on the market, due to the short product lifecycle. Finally, the high product variety and a fragmented supply base increase even more the complexity of the SC network and, consequently, the need of a structured production planning at all the supply chain levels, because all the actors should be perfectly aligned to the delivery date for fulfilling the demand on-time.

According to this, the work aims to promote a more structured scheduling culture along these companies, developing an easy-to-use and affordable tool able to satisfy most of the critical requirements related to the high service level that these companies, mostly Small Medium Enterprises (SMEs), have to guarantee.

The paper is organized as follows. In Section 2, we have presented an overview of the fashion industry, with a focus on the metal accessories suppliers, followed by a brief literature review on production planning and scheduling models. The proposed model has been detailed in the Section 3, and the evidences of its empirical application on a mechanical company has been shown in the Section 4. In the last section, we discuss the main conclusions and further developments of this work.

2. Fashion SC and optimization models

2.1 Overview on the fashion SC

As widely recognized in the literature, one of the main criticalities of the fashion SC is the high uncertainty of the demand (Ait-Alla et al., 2014; Hu et al., 2013; d’Avolio et al., 2015). Moreover, in the recent years the fashion product lifecycle has become even shorter than in the past, increasing the need of compressing the time to market for being competitive. On the other hand, fashion customers ask for a higher service level, mainly in terms of quality. For balancing these opposite aspects (i.e. short time to market and high quality product), several authors have developed scheduling models for production process in the fashion SC, even if most of the cases are focused on the retail companies’ perspective (Ait-Alla et al., 2014; Hu et al., 2013).

In fact, other actors involved in the fashion SC, such as the metal accessories suppliers, have never been deeply analysed in the literature, despite their relevance from an economical point of view. Looking at the Italian scenario, for example, they covered more than 3.5 B€ of revenues in 2015, including more than 250,000 companies (most of
them SMEs) and occupying more than 14,000 employees (www.camom.gov.it).

One of the main reason of the lower attention to these suppliers in the past literature, compared to that one related to leather’s or textile’s ones, is that metal accessories do not represent at the customers’ eyes the fashion product, differently from the other components. This is also demonstrated by the fact that metal accessories makers belong to the mechanical industry, even if processes and CSFs of these companies are similar to the ones working for the fashion industry.

In order to understand the peculiarities of these companies, a remark of fashion product features and their technological cycle is reported. In particular, metal accessories are usually composed by two or more elements, assembled together in the final step of the production process. Each component can follow a different workflow due to several factors, mainly linked to functional, aesthetic and economical aspects. After the production of the semi-finished items, through moulding or shaving removal, the production cycle continues with some mechanical operations (e.g. vibration, vibratory finishing, drilling, cutting). Then, these items have to be covered by one or more precious metals, such as gold, palladium and ruthenium, through an electroplating process. Last, the items have to be assembled, pass the quality control, be packaged and delivered to the focal company or façonists in order to be applied on the final product.

A graphical representation of this process is shown in Figure 1.

![Figure 1: Metal accessories production process](image)

2.2 Scheduling optimization models review

PP&C optimization of a multi-level SC, composed by several small companies (mostly SMEs) coordinated by a big company (which usually is the brand owner in the fashion industry), is a widely discussed topic, analysed by researchers from different point of view.

In the scientific literature, several different approaches in the definition of scheduling formulation can be found. Published reviewing papers on scheduling (Maravelias, 2012; Mendez et al., 2006; Phandern et al., 2011; Mula et al., 2010; Ribas et al., 2010) study different problems, moving from single to parallel machines, job or flow shop, and considering different level of data aggregation (i.e. strategic, tactical and operative).

Focusing on contributions regarding the fashion industry, the reviewed papers consider many different parameters, which sometimes are not calculated in the same way moving from one to another works. For example, scheduling model can include finite or infinite capacity, and finite capacity can be considered in terms of hours per resource (Rahmani et al., 2013) or units per resource (Ait-Alla et al., 2014), both referred to a single period.

Looking at other parameters, differently from the majority of the other works, Rahmani et al. (2013) distinguish between regular-time and overtime production (with relative different capacity and costs). In their model, setup times and costs are also included, but setup times are independent from jobs sequence.

Ait-Alla et al. (2014) present a mathematical model for production planning considering the order allocations on different production plants, characterized by different lead times and production costs. The case study they have conducted involves a fashion apparel supplier.

Guo et al. (2015) and Wong et al. (2014) have studied how to increase manufacturers’ performance supporting production monitoring and scheduling through RFID (Radio Frequency Identification). The pilot manufacturing company included in the work of Guo et al. (2015) is a medium-sized dothing manufacturer producing casual wear and sportswear, while Wong et al. (2014) have collected experimental data from a labour-intensive manufacturing company producing knitted products in China.

Rose and Shier (2007) present a two-stage-approach model that follows the logical structure of cutting and packaging problems and is solved using a mixed integer linear program.

Considering the OFs, costs minimization represents the main purpose of the reviewed works, even if several authors consider multi-objective production planning problem in the labour-intensive manufacturing industry, in general (Bertrand and Van Onjien, 2008; Wong et al., 2014; Wu et al., 2011) or specifically in the fashion segment (Ait-Alla et al., 2014; Hu et al., 2013). The OFs included in the reviewed works are several, moving from minimize the production costs (Ait-Alla et al., 2014), to minimize the tardiness (Ait-Alla et al., 2014; Bertrand and Van Onjien, 2008; Guo et al., 2015; Wong et al., 2014), the throughput and the idle time (Guo et al., 2015; Wong et al., 2014), the hiring and layoff costs associated with the change of workforce level (Rahmani et al., 2013), and the total setup, inventory and backorder costs (Rahmani et al., 2013).

Analysing real world industrial problems, it is usual the co-existence of multiple optimization objectives (Wong et al., 2014). Considering multiple OFs per model (i.e. multi-objectives scheduling problems), these are often solved translating all the OFs in monetary terms, defining a total cost that has to be minimized. For example, time measures are converted in holding or penalty costs that companies have to sustain for advances and delays respectively (Ait-Alla et al., 2014). Guo et al. (2008) use weighted sum method to turn multi-objective problems to single-objective ones.
3. Model description and discussion

According to the literature, we propose a multi-objective integer linear optimization model with a weighted sum OF. The linearity of the model, with a low complexity in its implementation, is due to the dimension of metal accessories suppliers. The weighted sum OF reflects the commercial agreement between these companies and the brands: different weights for different sub-objectives. Moreover, a solution implementable with an open source solver and a commercial spreadsheet has been chosen according to their low IT investment capability.

The model is explained through the following sections: Indices and Parameters, Decision Variables, Objectives, Constraints.

First section includes the model inputs, which are the items to be scheduled that are listed in the production orders coming from fashion companies, typically characterized by short visibility and small lots with a high fragmentation. In the same section, the anagraphical data (e.g. suppliers and resources lists) are included. Some variables (e.g. set up and lead times) are then listed but not used in the case study, for simplifying the first step of model implementation.

The proposed model generates a production plan that indicates the quantities for each ordered item that should be produced per period, distinguishing between regular-time and overtime hours, start and end dates for that production, and involved resources. These data are described in the Decision Variables section.

The Constraints have been grouped into the following category: demand fulfilment, available capacity, activated resources, positive and integer scheduled quantity. The Objectives that characterized the OF are described within the last section.

3.1 Indices and Parameters

(1) \( I = \{1, 2, \ldots, IIN\} \): the indices for the items (i.e. the object that can be included in a production order, commonly called Stock Keeping Units - SKUs in the fashion industry). IIN is the number of the items.

(2) \( TT = \{1, 2, \ldots, TTN\} \): the indices for the planned periods. TTN is the number of the scheduled periods.

(3) \( PP = \{1, 2, \ldots, PPN\} \): the indices for the production phases. PPN is the number of the resources.

(4) \( RR = \{1, 2, \ldots, RRN\} \): the indices for the resources (i.e. the resources - machineries, personnel, ... which can process the production order). RRN is the number of the resources.

(5) \( RQ_{i,p,t} \): the requested quantity of the item \( i \in I \) for the production phase \( p \in PP \) in \( t \in TT \).

(6) \( RDD \): the requested delivery date of the item \( i \in I \). RDD \( \in TT \).

(7) \( PIB_{i,p} \in \{0,1\} \) is a Boolean variable to indicate if the production phase \( p \in PP \) is included (i.e. \( PIB_{i,p}=1 \)) or not (i.e. \( PIB_{i,p}=0 \)) in the operational cycle of the item \( i \in I \).

(8) \( RSB_{i,t} \in \{0,1\} \) is a Boolean variable to indicate if the resource \( r \in RR \) is available (i.e. \( RSB_{i,t}=1 \)) or not (i.e. \( RSB_{i,t}=0 \)) for the supplier \( i \in SS \) in \( t \in TT \).

(9) \( PIRB_{i,t,p} \in \{0,1\} \) is a Boolean variable to indicate if the production phase \( p \in PP \) for the item \( i \in I \) can be processed (i.e. \( PIRB_{i,t,p}=1 \)) or not (i.e. \( PIRB_{i,t,p}=0 \)) by the resource \( r \in RR \).

(10) \( DSC_{i,t,r} \): the daily standard capacity for the production phase \( p \in PP \) conducted by the resource \( r \in RR \) in \( t \in TT \).

(11) \( DOC_{i,t,r} \): the daily overtime capacity for the production phase \( p \in PP \) conducted by the resource \( r \in RR \) in \( t \in TT \).

(12) \( DPSQ_{i,t,p} \): the daily preassigned standard quantity (i.e. quantity assigned in the regular worktime during previous schedule) for processing the production phase \( p \in PP \) of the item \( i \in I \) using the resource \( r \in RR \) in \( t \in TT \).

(13) \( DPOQ_{i,t,p} \): the daily preassigned overtime quantity (i.e. quantity assigned in the overtime during previous schedule) for the production phase \( p \in PP \) of the item \( i \in I \) using the resource \( r \in RR \) in \( t \in TT \).

(14) \( SUC_{i,t,r} \): the standard-time unitary cost (i.e. single-item cost assigned in the regular worktime) for processing the production phase \( p \in PP \) of the item \( i \in I \) using the resource \( r \in RR \).

(15) \( OUC_{i,t,r} \): the overtime unitary cost (i.e. single-item cost assigned in the overtime) for the production phase \( p \in PP \) of the item \( i \in I \) using the resource \( r \in RR \).

(16) \( OT_{i,t,r} \): the operational time for the production phase \( p \in PP \) of the item \( i \in I \) using the resource \( r \in RR \).

(17) \( SUT_{i,t,k} \): the set-up time for the production phase \( p \in PP \) of the item \( i \in I \), worked after \( k \in I \), using the resource \( r \in RR \).

(18) \( LT_{p,t,k} \): the lead time for the production phase \( p \in PP \) of the item \( i \in I \) using the resource \( r \in RR \).

(19) \( dw \): the delay-related weight for the item \( i \in I \).

(20) \( aw \): the advance-related weight for the item \( i \in I \).

(21) \( ow \): the cost-related weight for the item \( i \in I \).

(22) \( prw \): the processing time-related weight for the item \( i \in I \).

3.2 Decision Variables

(1) \( DSSQ_{i,t,p} \): the daily scheduled standard quantity (i.e. quantity scheduled in the regular worktime) for processing the production phase \( p \in PP \) of the item \( i \in I \) using the resource \( r \in RR \) in \( t \in TT \).

(2) \( DOSQ_{i,t,p} \): the daily scheduled overtime quantity (i.e. quantity scheduled in the overtime) for the production phase \( p \in PP \) of the item \( i \in I \) using the resource \( r \in RR \) in \( t \in TT \).
The objectives considered in the model can be classified into two types: the first deals with the optimization of the total processing cost, and the second with the minimization of the total processing time.

1. Minimize the costs:
   \[ \text{Minimize } \sum_{e \in E} \text{Costs}(C_e) = \sum_{e \in E} \left( \sum_{p \in PP} \text{Costs}_p(e, r) \right) \]

2. Minimize the delays:
   \[ \text{Minimize } \sum_{e \in E} \text{Delays}(D_e) = \sum_{e \in E} \left( \sum_{p \in PP, r \in RR} \text{Delays}_p(e, r, t) \right) \]

3.3 Constraints

1. Demand fulfillment:
   \[ \forall i \in II, \forall p \in PP, \sum_{e \in E, t \in TT} (DSSQ_{p,i,t} + DYOQ_{p,i,t}) = \sum_{e \in E, t \in TT} RQ_{p,i,t} \]

2. Available standard-time capacity:
   \[ \forall i \in TT, \forall p \in PP, r \in RR, \sum_{e \in E} \left( DSSQ_{p,i,t} + DYOQ_{p,i,t} \right) \leq DSC_{p,i,t} \]

3. Available overtime capacity:
   \[ \forall i \in TT, \forall p \in PP, r \in RR, \sum_{e \in E} \left( DSOQ_{p,i,t} + OT_{p,i,t} \right) \leq DOC_{p,i,t} \]

4. Activated resources:
   \[ \forall i \in TT, \forall p \in PP, r \in RR, i \in II, \text{DSOQ}_{p,i,t} \cdot PIRB_{p,i,t} = \text{DSOQ}_{p,i,t} \]

5. Positive scheduled standard-time quantity:
   \[ \forall i \in TT, \forall p \in PP, r \in RR, i \in II, \text{DSOQ}_{p,i,t} \geq 0 \]

6. Positive scheduled overtime quantity:
   \[ \forall i \in TT, \forall p \in PP, r \in RR, i \in II, \text{DSOQ}_{p,i,t} \geq 0 \]

7. Integer scheduled standard-time quantity:
   \[ \forall i \in TT, \forall p \in PP, r \in RR, i \in II, \text{DSOQ}_{p,i,t} = \text{int} \]

8. Integer scheduled overtime quantity:
   \[ \forall i \in TT, \forall p \in PP, r \in RR, i \in II, \text{DSOQ}_{p,i,t} = \text{int} \]

3.4 Objectives

The objectives considered in the model can be classified into two types: the first deals with the optimization of the total processing cost, and the second with the minimization of the total processing time.

1. Minimize the costs:
   \[ \text{Minimize } \sum_{e \in E} \text{Costs}(C_e) = \sum_{e \in E} \left( \sum_{p \in PP, r \in RR, e \in TT} (\text{SU}_{p,i,t} + \text{DSOQ}_{p,i,t} + \text{OU}_{p,i,t} \cdot \text{DSOQ}_{p,i,t}) \right) \]

2. Minimize the delays:
   \[ \text{Minimize } \sum_{e \in E} \text{Delays}(D_e) = \sum_{e \in E} \left( \sum_{p \in PP, r \in RR, e \in TT} (\text{SU}_{p,i,t} + \text{DSOQ}_{p,i,t} + \text{OU}_{p,i,t} \cdot \text{DSOQ}_{p,i,t}) \right) \]
validated by the production manager of the analysed metal accessories supplier.

5. Conclusion

In the last years, the increased pressure in the fashion industry for compressing the time-to-market makes scheduling efficiency an even more relevant leverage for all the involved companies for being competitive in the market. As a matter of fact, improving performances of each actor can increase the overall SC performance, decreasing operations costs, processing time and delivery delays and advances.

According to this, the present paper deals with the definition of a scheduling model for the companies producing metal accessories for the fashion industry.

The optimization model presented in this work has been developed using a linear open source engine, in order to be successfully used by these companies, which are mostly SMEs with low investment capability in IT solutions. The model has been tested using real data from a metal accessories supplier as inputs. The use of simulation tools to complement the mathematical models, considered by several authors, represents a possible future research for our study.

Moreover, future steps of the research will include the sustainability concept into the OF and the definition of price ranges varying with lots dimensions.

References


