Logical Workflow Analysis based on Multiple Criteria Decision Analysis: Industrial Application for a Make to Order Environment

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Abstract: The aim of this study is to analyze the possible application of multiple criteria decision approach for a relevant workflow analysis in a French printing company. An important result and contribution of this paper will be precisely to show that MCDA could be an important decision tool to analyze and identify the main stream for make to order environment. An overview of the logical structure of the process on how things actually operate on the production, is presented. To summarize, this paper demonstrates and presents a new approach for using MCDA for a workflow analysis and discusses its application in a real case study where production faces various variations.

1 INTRODUCTION

The characterization of a production system is one of the most important steps before any improvement or optimization approach.

In industry, we meet a variety of different workshops and thus of productions systems. The most adopted in industry are: flow shop (FS), Job Shop (JS) and Open Shop (OS); see (Metaxiotis et al., 2001), (Komaki et al., 2019), (Mohan et al., 2019), for a review.

Table 1: Abbreviations.

MCDA	Multiple criteria decision analysis
MTO	Make to order
MCABC	Multiple criteria ABC classification
MCIC	Multiple criteria inventory classification
AHP	Analytic hierarchy process

From a scheduling perspective, the aim of a good workflow process characterization is to identify and determine the workshop configuration, in order to apply suitable and appropriate scheduling rules. However, for MTO environment, and due to the constantly fluctuating stream, the analysis of the whole workflow become very difficult. To address this problem, we used MCDA in order to analyze the process, step-by-step, in detail, across all the product families. The basic idea is to identify and outline the main production stream. Thus, minimizing the number product families required to represent the manufacturing process.

MTO companies are very complex, the flow of material is highly fluctuating and flexible. This flexibility is seen as a key characteristic of successful organizations (Scherrer-Rathje et al., 2014). Several factors lead to increase this flexibility, such as an ever-changing landscape of customer demand or a wide range of customized products. However, this flexibility produces diversity and create variations that makes it hard to manage from a scheduling perspective. In contrast, Accurate scheduling plays also an important role in the success of MTO companies (Lödding et al., 2014). The first step before any scheduling approach is to characterize and determine the process configuration, this step requires a thorough understanding of critical and strategic product families. For MTO organizations that deals

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with thousands of products, it is unrealistic to provide equal consideration to each product. That's why product classification is crucial in order to give more importance to the most valuable ones and focus into the main factors. ABC analysis utilizes hierarchical categorization, the products are partitioned into 3 classes so that their management becomes easier.

In this work we used MCDA based on ABC principle, in order to analyze the manufacturing process step-by-step in detail across all its product families. The main role of this classification in our case study is to makes it easier to deal with and to understand a manufacturing process that faces variations, by breaking it down into three segments. A successful segmentation will allow to point out the most valuable ones, thus it becomes easier to focus, and apply accurate priority rules.

MCABC is a well-known technique traditionally used for inventory management. It is based on the Pareto principle (Pareto, 2007) which denotes that approximately 80% of the effects come from 20% of the causes. This classification, allows to divide items into three different classes A-B-C according to their importance for a selected criterion. Category A is the smallest one but account for the greatest amount of the selected criterion. In contrast, class C items are relatively large in number, but make up relatively small amount the criterion. Items between classes A and C are categorized in category B.

The main aim here is to analyze the process workflow from a new perspective, through all its product families allowing managers to get a clear picture of where the greatest contribution can be made. For the underlying problem two criteria were selected, namely, Sales revenue (SR) and Quantity produced (Q), these criteria are the most representative for the studied process. The objective here is to make a coordinated classification by combining both SR and Q in order to point out the main flow that represents the most relevant product families, the strategic ones, that account for a high sales revenue and high quantity produced.

Summarizing, this paper addresses the use of bi-criteria ABC analysis in classifying product families. We aim here at providing information about the choice of the key criterion as well as the methodology follows to manage the items in each category. The results indicate that ABC classification could be a and efficient tool for understanding the workflow process it enables to pinpoint the key elements of a business so that they can be appropriately managed.

The paper is structured as follows. In the next section we review briefly the existing literature on ABC analysis. Section 3 presents the methodology followed, starting with a brief description of the scope of the study, and then data collection, and ending with data analysis. We then present and discuss the main results derived from the analysis. Finally, we end up the paper with a conclusion as well as future research directions.

2 LITERATURE REVIEW

It is clear that there vast differences among different configurations of production processes: job shop, flow shop, open shop… because the differences among them have an important implications for the choice of the production planning and scheduling system (Silver et al., 2016).Therefore an appropriate characterization and identification of process configuration is an important step in order to define accurate scheduling rules. According to (Kurtzberg et al., 1994), To manage highly complex manufacturing enterprises, ABC utilizes hierarchical, dynamic modeling with recursive control and optimization. At each hierarchical level, the process is partitioned into logical groups so that treatment is simplified and manageable. Further, ABC minimizes the number of parameters required to represent the manufacturing process and ranks contributions of variables to the process by significance.

The objective in this work is to use ABC principle which is defined as a powerful decision-making tool that identifies items that have a significant impact on an overall criterion (Yu, 2011). The use of this classification tool will allow to identify the major product families -class A- that represents potentially the largest value and provides us with an insight of the process configuration that represents the most important and valuable product ranges.

ABC analysis uses most of the time the dollar usage criterion. However, several researchers have proposed methods that consider other factors than annual dollar usage. (Benito E. Flores et al., 1987) were the first researchers who outlined the importance of considering multiple criteria in the ABC analysis. They introduced the idea of a matrix-based approach for the multi-criteria ABC classification. A joint criteria matrix was put forward within the ABC framework by means of considering two criteria, their approach was tested on an industrial application. They highlighted that the use of the matrix can provide managers with an explicit method for taking a range of criteria into account. Other various approaches for addressing the MCDA problem have been proposed in the literature for the purpose. (Cohen et al., 1988) and (Ernst et al., 1990) have used cluster analysis to group similar items. The analytic hierarchy process (AHP) (Saaty, 1987) has been employed in many MCIC studies (F.Y. Partovi et al., 1993) (Gajpal et al., 1994).Heuristic approaches based on artificial intelligence, such as genetic algorithms (Guvenir et al., 1998) and artificial neural network (Fariborz Y Partovi et al., 2002), have also been applied to address the MCIC problem.

To summarize, there have been many contributions in the literature which have concentrated on the application of ABC classification for inventory control. However, and to the best of our knowledge, it has been rarely studied for a relevant process analysis. In this paper, we are striving to propose a simple joint criteria matrix based on (Benito E. Flores et al., 1987) method, in an MTO environment, in order to categorize product families into classes that require somewhat different strategies for planning and scheduling. This classification allows to reflect the main flow and provide managers with a thorough understanding of critical and strategic product families, allowing to focus attention, and give more importance to them.

3 METHODOLOGY

This section provides a brief overview of the case study and describes the use of MCABC for an industrial company for its process analysis.

3.1 Case Study

Our study was conducted in a packaging printing company based in France. That mainly uses make to order policy, characterized by multiple flows that merge. Mapping and analyzing the whole process at the same time is not easy and usually not even feasible. Thus, the mapping process should begin from the main strategic flow. This company produces, converts and prints flexible packaging. Some examples of products manufactured are: pouches, reels, sheets and labels. Each product P goes through several processing operations depending on its product family or manufacturing operating range, such as printing, coating, perforation and lamination.

Assume that we have N ranges of manufacturing g (g =1,…, N), that have to be classified as A, B or C, according to C_r criteria .In particular let the performance of the n^{th} operating range in terms of each criteria be denoted as X_{nc_r} . Let us also assume that the larger the score of an item g in terms of these criteria is, the greater is the chance that the item be classified as an A class item.

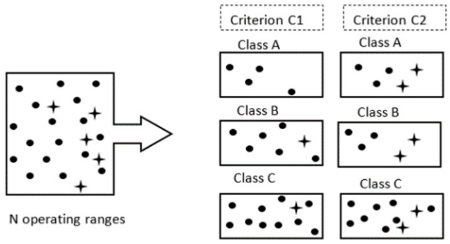

Figure 1: ABC classification.

Complex computational tools are needed for multi-criteria ABC classification (Ramanathan, 2006). (B.E. Flores et al., 1986) have developed a joint criteria matrix in the case of two criteria, the combination of these two criteria leads to the definition of nine distinct product classes ranging from AA (upper grade) to CC (lower grade). The model can be represented in a practical way in the form of a joint matrix criteria, as shown in Figure 2. As indicated by the arrows, the classification rule for a AB and BA with AA, AC and CA with BB and BC and CB with CC (Chen et al., 2008).

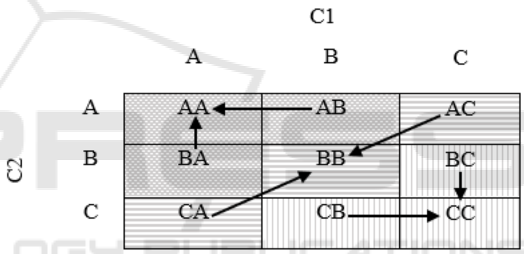

Figure 2: Bi-criteria joint matrix.

3.2 Multiple Criteria Analysis

For this particular study, the steps to conduct this classification were as follows: 1) Key criteria selection, 2) Data collection 3) Data analysis.

3.2.1 Key Criteria Selection

This work began with selecting key criteria that fulfil and characterize the studied organization. It is recognized that there is no universal methodology for criteria selection. The main idea is the selection of an optimal manufacturing process which considers the most significant and important criteria for the process. Thus, the problem has to be observed as a multi - criteria problem. These criteria depend on the nature of the industry and may include: average revenue, lead time, demanded volume, total delay …, they should meet management's objectives and be the most representative for the process

For the underlying organization, let us consider two criteria: annual revenue (AR) and the demand volume (DV) per product range. These criteria are the most relevant for the studied organization because:

- The sales revenue (SR): SR Is the yearly amount realized by a group of products that have the same manufacturing operations. It allows to visualize clearly the importance of the different ranges for the company. It makes it possible to determine which ranges make the biggest contribution for the overall revenue.
- Demand volume (DV): is the average yearly quantity produced per product family. Provides details about the products that occupies the most the workshop. In this way, it is possible to understand how the total quantity is distributed among different product types.

3.2.2 Data Collection

The monthly data of all the tasks involved in the production process were obtained from the industry for a period of one year, using SQL query.

The data collected has been analysed using the Excel sheet, the products were grouped into families according to their operating ranges. A product family is defined as a group of products that pass through similar processing steps.

The overall data of the product families involved in the production system were interpreted, and summarized based on two criteria: the sales revenue and the produced quantity.

The sales revenue associated with each product family was obtained using (1), and the quantity produced was calculated using (2).

- Calculation of sales revenue per operating range SR (G_n):

$$\mathrm{SR}(\mathrm{G_n}) = \sum_{\mathrm{G}=1}^{\mathrm{n}} \sum_{\mathrm{p}=1}^{\mathrm{m}} \mathrm{Q(P)} * \mathrm{UP(P)}\ , \forall\ \mathrm{G} = \mathrm{G_n} \qquad (1)$$

- Calculation of the quantity produced per operating range $\mathrm{Q(G_n)}$:

$$\mathrm{Q}(\mathrm{G_n}) = \sum_{\mathrm{G}=1}^{\mathrm{n}} \sum_{\mathrm{p}=1}^{\mathrm{m}} \mathrm{Q(P)} \quad , \forall\ \mathrm{G} = \mathrm{G_n} \qquad (2)$$

According to each criterion, the operating ranges were ranked in descending order starting with the largest value to the smallest. The cumulative percentage was then calculated and two distinct Pareto distributions were performed.

For each product family G_n , the percent of quantity produced Q and the selling revenue is mentioned in Table 2.

Table 2: MCABC using annual Euro usage, and produced quantity based on a joint matrix.

Range	% SR	% Q	ABC classification		
			Optimal Classification	SR	Q
G1	20%	16%	A	A	A
G2	10%	12%	A	A	A
G3	8%	9%	A	A	A
G4	7%	7%	A	A	A
G5	7%	6%	A	A	A
G6	7%	5%	A	A	B
G7	7%	3%	A	A	B
G8	6%	3%	A	A	B
G9	5%	2%	A	A	B
G10	5%	2%	A	A	B
G11	4%	2%	B	B	B
G12	3%	2%	B	B	B
G13	3%	7%	A	B	A
G14	2%	2%	B	B	B
G15	2%	2%	B	B	B
G16	2%	1%	C	B	C
G17	2%	1%	B	B	B
G18	2%	9%	B	B	A
G19	2%	1%	B	B	C
G20	2%	3%	B	B	B
G21	2%	3%	B	B	B
G22	1%	2%	B	C	B
G23	1%	10%	B	C	A
G24	1%	1%	C	C	C
G25	0%	5%	B	C	A
G26	0%	1%	C	C	C
G27	0%	1%	C	C	C
G28	0%	0%	C	C	C
G29	0%	0%	C	C	C
G30	0%	0%	C	C	C
G31	0%	0%	C	C	C
G32	0%	0%	C	C	C
G33	0%	0%	C	C	C
G34	0%	0%	C	C	C
G35	0%	0%	C	C	C
G36	0%	0%	C	C	C
G37	0%	0%	C	C	C
G38	0%	1%	C	C	C
G39	0%	2%	C	C	B

Table 2: MCABC using annual Euro usage, and produced quantity based on a joint matrix (cont.).

G40	0%	1%	C	C	C
G41	0%	4%	B	C	A
G42	0%	0%	C	C	C
G34	0%	0%	C	C	C
G44	0%	0%	C	C	C
G45	0%	2%	C	C	B
G55	0%	0%	C	C	C
G56	0%	0%	C	C	C
G57	0%	0%	C	C	C
G58	0%	2%	C	C	B
G59	0%	2%	C	C	B
G60	0%	2%	C	C	B
G61	0%	3%	B	C	A
G62	0%	0%	C	C	C
G63	0%	0%	C	C	C
G64	0%	0%	C	C	C
G65	0%	0%	C	C	C

The operating ranges are categorized into A, B and C classes, where class A contains the strategic ranges, that should receive the most important attention. B class items are less important and C class items are of very low importance

Class A workflow map was then drawn allowing to vizualize clearly the flow structure of the major product ranges that contribute the most to the success of the company.

3.2.3 Data Analysis

Once items have been grouped into clusters, the target value stream can be identified by simply drawing all class A product families.

The close examination of class A map has revealed a regularity in the logical structure of the flow (Figure 3) which is characterised by a linearity. The exact process map with all details cannot be disclosed due to confidentiality reasons. A macro logical workflow process is developed in Figure 4. It shows the current state map that was constructed; the boxes in the map represent the processing steps and the number inside the box is the number of machines at each process. The machines are grouped by stage E (e = 1,…, 9). Each stage E is made up of a set of me machines (me ⩾1) of the same trade, of the same production capacity or of different production capacity, Called mixed parallel machines (hybrid). The logical workflow map offers a clear outlook on the process configuration, it outline the most relevant stream, so that adequate scheduling rules can be properly applied .

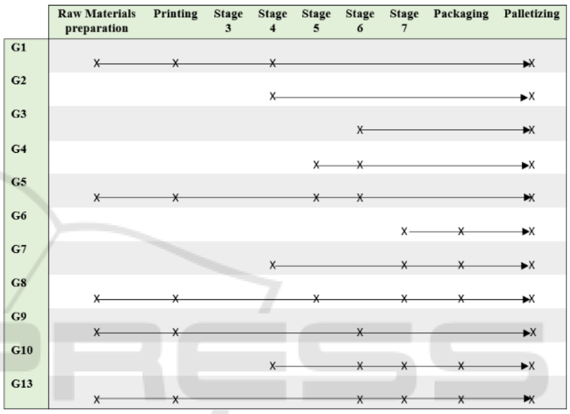

Figure 3: Class A workflow.

Class A workflow mapping highlights that the workflow tend to be linear, e.g. there is no going back to an earlier stage. but flexible in the sense that from a product to another one, the operating ranges involved might be different. The operating ranges of each product is predefined according to the processing requirements. We note very well that all the ranges of class A are linear, this means that this zone can be assimilated to a flexible and hybrid Flow shop workshop with skipping (following the manufacturing range).

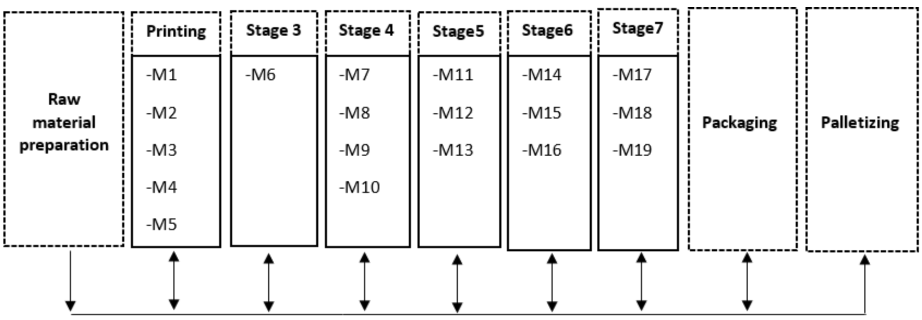

Figure 4: Logical workflow.

4 CONCLUSIONS

It is not easy to analyze the workflow in the case of complex production processes characterized by multiple flows that merge. To address this problem, the basic idea in this study was to execute a thorough process analysis through all product families in order to identify the main flow using MCABC, under two criteria: Selling revenue and quantity produced, these criteria are the most relevant for the studied firm. This aggregation has allowed to reduce significantly the number of product families requiring extensive management attention.

The analysis of the different ranges involved in the studied process, has allowed to obtain, analyze, and reflect on a set of information of high importance and understand the complexity of the process. This work contributed to a better knowledge of the company, bringing a greater degree of detail on the evolution of the industrial activity, allowing to verify the importance of certain ranges, and highlight those with high value for the company. To summarize, this work enables us to define the appropriate configuration of the process: Hybrid and flexible flow shop, which have an important role in defining suitable scheduling rules taking into account the most significant parameters.

As future research, we try to compare the logical workflow to the physical layout, and then, to propose an arrangement of machines that suits the main logical flow which will enable the manufacturing process to be carried on efficiently.

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