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MINISTRY OF HIGHER EDUCATION
AND SCIENTIFIC RESEARCH

HIGHER SCHOOL IN APPLIED SCIENCES
--T L E M C E N--

وزارة التعليم العالي والبحث العلمي

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**Presented by :**

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Theme

# Simulation of Manufacturing Systems

Publicly defended, on 07/14/2021, in front of a jury composed of:

| | | | |
|---|---|---|---|
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College year : 2020 /2021

# *Dedication*

*I dedicate this modest work:*

*To my parents to whom I owe everything and supported me during all my school years*

*To my brother who always had my back and cherish me*

*To my sister who from 6000 miles always encourage me in everything that I do and always has been there for me*

*And last but not least my dear fiancé who has always been patient with me and caring*

*Thanks for believing me even when I don't*

***Rym Bouali.***

# *Dedication*

*I dedicate this work to those who believed in me:*

*My parents, Youssra, Fatima and Mrs BOUDISSA*

*You should be proud of me!*

***Chawki Houssem Eddine BOUKOFA***

## Thanks.

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And Special thanks to all employees of the production unit for the advice they were able to give us during this internship.

## Abstract.

To survive in a competitive market, companies are obliged to understand their manufacturing systems in the most detailed way, not only to gain knowledge about their performances but also capitalize on that knowledge in order to stay competitive.

In this project we used simulation modelling as well as the «Factory Physics®» to perform an analysis on a MEGA-PAPIERS manufacturing line “Robot Plus” with the aim of understanding this line’s behaviour and calculating its performance indicators.



## Résume.

Pour survivre dans un marché compétitif, les entreprises sont obligées de comprendre leurs systèmes de production de la manière la plus détaillée possible, non seulement pour connaître leurs performances mais aussi pour capitaliser sur ces connaissances afin de rester compétitifs.

Dans ce projet, nous avons utilisé la modélisation par simulation « Factory Physics®» pour effectuer une analyse sur une ligne de fabrication de l’entreprise MEGA-PAPIERS "Robot Plus" dans le but de comprendre le comportement de cette ligne et de calculer ses indicateurs de performance.



## ملخص

للبقاء في سوق تنافسية، يتعين على الشركات فهم أنظمة التصنيع الخاصة بها بأكثر الطرق تفصيلاً، ليس فقط لاكتساب المعرفة حول أدائها ولكن أيضًا للاستفادة من هذه المعرفة من أجل البقاء في المنافسة

في هذا المشروع ، استخدمنا نمذجة المحاكاة بالإضافة إلى

«Factory Physics®»

لكي تتمكن الشركات من البقاء في سوق تنافسية فإنها ملزمة بفهم أنظمة التصنيع لديها على النحو الأكثر تفصيلا، ليس فقط لاكتساب المعرفة عن أدائها، بل وأيضا للاستفادة من هذه المعرفة من أجل البقاء على المنافسة.

في هذا المشروع إستخدمنا نماذج المحاكاة بالإضافة إلى"فيزياء المصنع®" لإجراء تحليل على خط تصنيع ضخم لحاسوب الورق "روبوت بلاس" بهدف فهم سلوك هذا الخط وحساب مؤشرات أدائه.

# Summary.

# Table List

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## List of abbreviations.

**CT** Cycle Time

**WIP** Work In Process

**TH** Throughput

**WIPq** Work In Process in Queue

**CTq** Cycle Time in Queue

**Rb** Bottleneck Rate

**Re** Effective Rate

**to** RawTime

**te** Effective Process Time

**ta** Arrival Time

**To** Raw Process Time

**MTBF** Mean Time Between Failure

**MTTR** Mean Time To Repair

**U** Utilisation

**RMI** Raw Material Inventory

**Wo** Critical Work in Process

## GENERAL INTRODUCTION:

The evolution of manufacturing simulation and its softwares has remarkably benefited industries on so many levels, it has shifted the difficulty of dealing with a manufacturing system from the real to the virtual world and consequently reduced the high costs and risks of testing and experimenting with new processes and procedures.

Making use of the enormous and the continuous progress that computers are making, simulating a manufacturing system is a practice that most companies of different sizes do today in order to understand the behaviors of their manufacturing systems and calculate their performances and furthermore experiment with different ideas and methods to see how it would affect the overall functioning of these systems.

During our internship in Megapapier the line "Robot Plus" was the main focus of all the observations we did, not only because it's the most automated and sophisticated manufacturing line they have, but also because it manufactures a big part of their client's demand and their dependency on it was too important to be overlooked.

We spent the first days of our internship trying to learn everything we could about the "RobotPlus" line by interacting with its operators who gained their experience from the long time they've been operating it: the overall process, machines, operators, setup times, breakdowns…etc.

Most of these informations that we gathered from this first step were either qualitative or inaccurate and therefore far from being reliable for any modelling or calculation of any kind. We then decided to look for any documented data about manufacturing times, throughputs or even breakdown but none of that data was collected, the factory was driven only by the manager's intuition which was judged effective as long as it is meeting the client's demand.

However, in the middle of a conversation with the head of production, he stated that their company is very competitive when it comes to costs and quality but not enough when it comes to delays, we understood from him that logistical disadvantages had affected their competitivity when it comes to time and therefore we thought that the understanding of all the time related parameters and collecting such data to estimate cycle times, throughputs and work in process was an absolute necessity in order to be able to act on reducing delays and reduce the effect of the logistical disadvantages.

That's where we decided to focus on gathering as much data from the "RobotPlus" as we could during the short time we had left in our internship, use our desktop application as well as simulation software "Flexsim" to build models and calculate cycle times as well as throughputs and work in process in an attempt to demonstrate a data driven approach into understanding a manufacturing line and offer a guide for the manager's intuition and also experiment with our application in a real case where performance indicators have to be calculated.

Chapter

1

# Generalities on Models & Tools

In this chapter we presented generalities about the simulation and analytical models as well as simulation software Flexsim and Factory Physics Desktop Application

# CHAPTER 1: GENERALITIES ON MODELS & TOOLS:

## 1. FLEXSIM:

### 1.1 INTRODUCTION TO THE SIMULATION:

The complexity of a manufacturing system makes it impossible for different profiles to see it in the same way. For instance a logistical definition and a mechanical definition for a manufacturing system wouldn't be the same.

But from a flow perspective, a simplified representation of a manufacturing system is defined by 3 types of variables:

- ***The boundaries of the system.***
- ***Inputs variables :*** Storage Capacity, numbers of operators
- ***Outputs variables (Performance measures***): changes in stock levels, operator occupancy rates.

This simplified representation gives an overview about what a manager should consider when trying to understand the behaviors and the natural tendencies of a manufacturing system,it also represents the bases of all data that needs to be collected to perform any type of modelling or analysis.

**[Standridge, 2004] «**Analytic models and simulation models are two approaches to explaining and understanding the behavior of systems in general as well as manufacturing systems in particular», and while analytic models involve hypothesis about the structure of the system with some approximations in order to obtain information about the steady and average states of the system, **[Standridge, 2004]** «simulation models track system behavior over time».

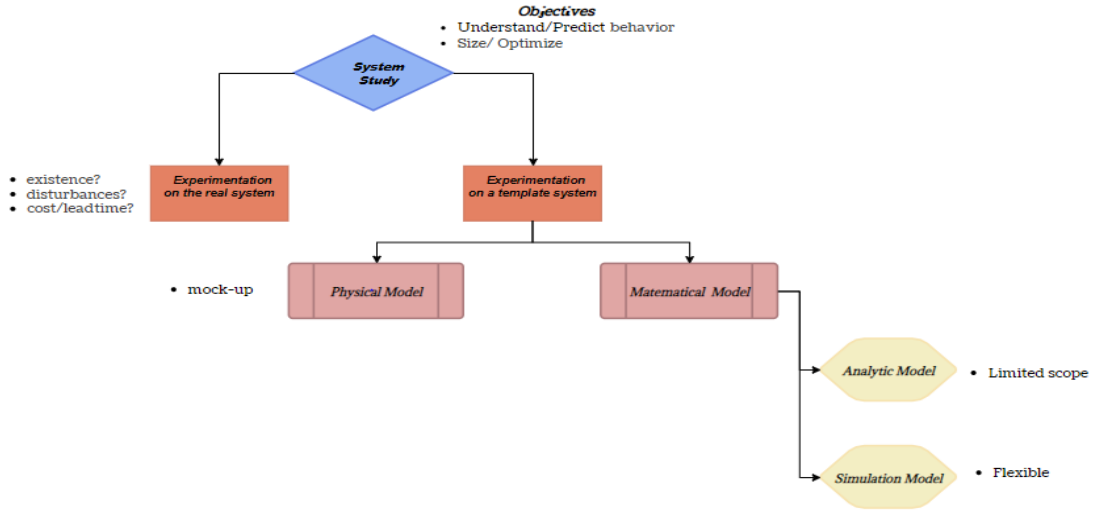


Figure 1: Representation of the system

A simulation is -in most cases- an animated model that mimics the operation of an existing or proposed system, from the day-to-day operation of a bank, to running an assembly line or even assigning staff in a hospital or call center, it consist of :

- Imitating, mimic the behaviour of a real system.
- Predicting the behaviour of a system that does not yet exist

On the other hand when we speak of manufacturing simulation we usually mean discrete event flow simulation which is a specific area of simulation that is widely used to to increase performances, identify problems, improve and evaluate actual or potential process changes within a manufacturing system.

Most simulation software uses **visual programming language** where the user builds a model through linking and manipulating pre-built modules graphically without actually having to write code scripts. Furthermore, 3D rendering is becoming more and more essential and demanded with this kind of software in order to give a reality effect to the model, make it more close to humans then to computers and ease communication with stakeholders that are not familiar with simulation.

Whether it's for analytical purposes (Identify Bottleneck, Size a production system, Measure stock failures) or predictive purposes (anticipate the impact of an increase in production, Test production scheduling, Select alternatives for new investments) or even communication purposes (Demonstrate the potential of installing new equipment) simulation is the go to tool when accuracy is needed and high costs are to be avoided.

## 1.2 DECISIONS FOR SIMULATING:

Using reliable and accurate data and being methodical in simulating a system will increase the chances to obtain a significant result. However knowing that simulation isn't always the answer when it comes to modelling or calculation is also necessary.

The evolution of computers and therefore simulation software has made simulation accessible to everyone and sometimes it is used inappropriately due to the lack of training and experience. The failure to get meaningful results can happen because of inaccurate data or even mistakes in the simulation process itself when in fact the cause of the failure lies in the

application of simulation where it shouldn't be applied

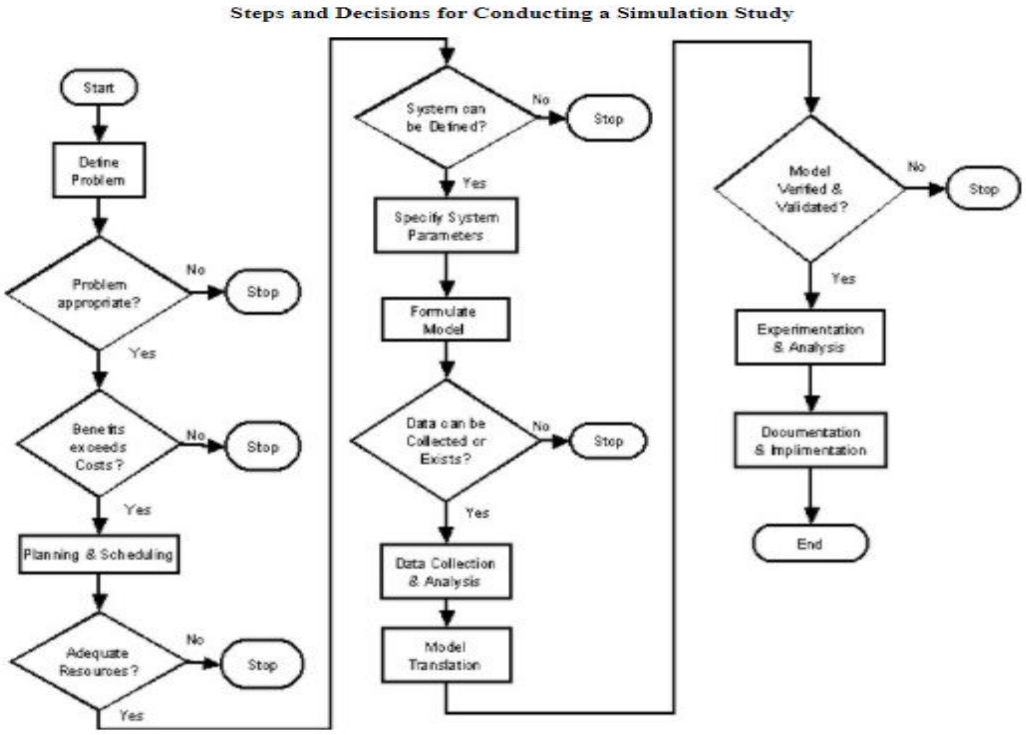


Figure 2: Steps and Decisions for Conducing a Simulation Study

## 1.3 FLEXSIM:

### 1.3.1 INTRODUCTION:

«Flexsim » is a powerful yet easy-to-use software package for simulation modelling. A fast and accurate simulation engine is hidden behind drag and drop controls, drop-down lists, and many other intuitive features that make it accessible for anyone to build a model. All simulation models are created to scale and are presented using 3D visuals, so it becomes easy to view and recognize bottlenecks in the production line or other deficiencies within the system. «Flexsim» also gives decision makers the data to confirm their observations, with impressive data reporting and analysis built right into the software.

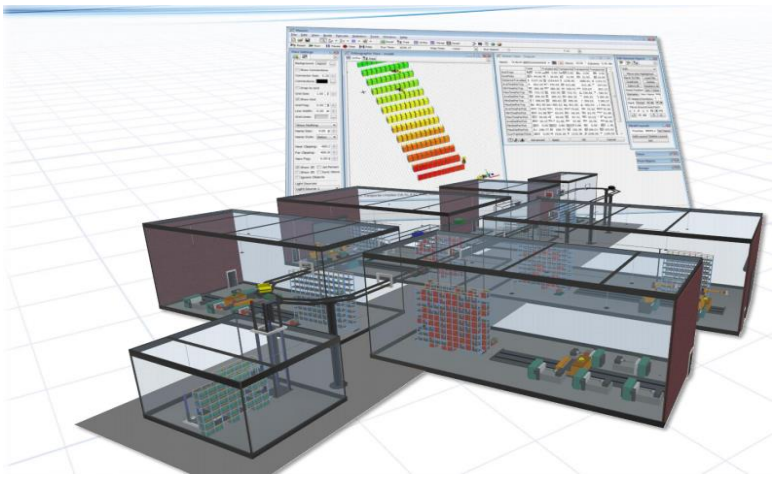

Figure 3: Flexim Software

### 1.3.2 WHO USES FLEXSIM?

Since its initial release in February, 2003, it evolved to meet its users' needs and demands until it became the go-to simulation software for a considerable number of the fortune 500 companies such as Amazon, Nissan, Coca Cola, FedEx...etc. because it supports engineers, managers, and decision-makers who want to validate, improve, or learn more about their existing or planned systems or processes.

### 1.3.3 FLEXSIM SOFTWARE:

Flexsim can be installed in just about any computer running on Windows, mac os or Linux.

The Express version can be freely downloaded for evaluation. The minimum system requirements start at Windows 7, 4 GB of RAM, AMD Radeon or NVidia GeForce cards, and the Microsoft .NET Framework.. Licensing and pricing can be negotiated with the vendor according to the user's needs.

In summary «Flexsim» provides software to model, simulate, analyse, and visualize (in 3D) any system in manufacturing, material handling, healthcare, warehousing, supply chain, and more and its user friendly interface, large library of production entities and it's easy to make interaction made us chose it for this project.

## 2. ANALYTICAL MODELS:

### 2.1 INTRODUCTION TO THE ANALYTICAL MODELS:

Since the early 60's, the behavior of manufacturing systems has been a subject of interest of a lot of studies (Forrester 1961; Hopp and Spearman 2000).

Models, equations and relations were developed each with its own set of notions and concepts and all aiming for a better understanding and control of manufacturing systems. Unlike simulation analytical models are expressed in a mathematical form, **[Standridge, 2004]"***Building an analytic model often involves conceptualizing the system in a predefined structure with some details omitted. Solution of such models typically yields information about long term or steady state average behavior. Analytic models and their solutions provide, at least, a starting point for gaining valuable information about system structure and behavior even if additional information is required".*

#### 2.1.1 NOTIONS AND DEFINITON:

Each analytical model has different terms, notions and scope but in order to use or understand any one of them, a basic knowledge of key words and a basic understanding for their definitions is required. These notions are the basic quantities that represent the main principles of manufacturing system analysis.

- **Raw process time** denotes the time a workstation takes to process a lot.it excludes detractors that may increase the time a lot is on the machine (setup time, breakdown...etc.).
- **Throughput [New, 1994]** *«denotes the number of lots per time-unit that leaves the manufacturing system. At machine level, this denotes the number of lots that leave a machine per time-unit».* The unit is lots/time unit.
- **Cycle time** denotes the time it takes a lot to go through a line, at workstation level this is the time from entering until exiting the workstation. The terms: flow time, throughput time and cycle time are used interchangeably.
- **Work in process** denotes the inventory between the start and endpoints of a manufacturing system. Wip is measured in lots/jobs.

- **Utilization** denotes the fraction a workstation is not idle. Process time as well as all detractors contribute to the utilization. It has no dimension and it can never exceed 1.

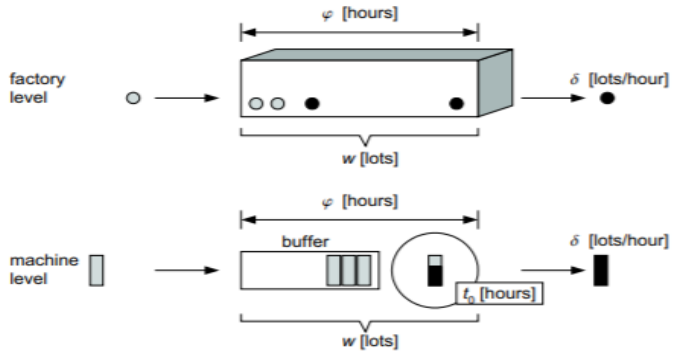


Figure 4: Machine level VS Factory Level

## 2.2 FACTORY PHYSICS:

**[Hopp&Spearman, 2000]** **"***Factory Physics is a systematic description of the underlying behavior of manufacturing systems. Understanding it enables managers and engineers to work with the natural tendencies of manufacturing systems".*

Factory physics is a set of laws, equations and mathematical models developed by Hopp & Spearman with the aim of quantifying parameters of the manufacturing system in order to understand, evaluate and analyse their behaviors.

It proposed an attempt to create a science of manufacturing that manager, engineers can rely on to manage manufacturing system instead of managing by imitation or by buzzword, it defined notion , established hypothesis and then elaborated reliable laws that can be used to perform calculation and draw a general but fairly detailed image of the behavior of a manufacturing system.

From an operations perspective, virtually most manufacturing systems has some shared tendencies. And that's the reason that make the author think of organizing them into one paradigm with the purpose of being a manager's guideline in different manufacturing plants ,rational inquiry to seek a science of manufacturing was employed by establishing basic concepts as building blocks, stating fundamental principles as "manufacturing laws," and identifying general insights from specific practices. The result is an organized framework from which to evaluate and judge various management practices and develop useful intuition about manufacturing systems.

Factory Physics is by definition an analytical model and it is used to calculate, but it is also a methodical thinking approach that balances the use of data and intuition for better manufacturing plants management.

### 2.2.1 BASIC NOTIONS AND QUANTITIES OF FACTORY PHYSICS:

As stated previously, Factory Physics is an analytical model by definition it share basic notions and quantities with all analytical models and it has also its own terms, notions and quantities , here are some of the most important ones:

***re*:** effective rate, or capacity, of a station.

***rb*:** bottleneck rate of a line, defined as the rate of the station with the highest utilization.

***Raw Material Inventory(RMI):*** consisting of the physical inputs at the start of a production process.

***Service level:*** In make-to-order systems, s is measured as the fraction of jobs for which cycle time is less than or equal to lead time. In make-to-stock systems, s is measured as the fill rate, or fraction of demands that are filled from stock.

**TH throughput (TH):**, measured as the average output of a production process (machine, station, line, plant) per unit time.

**To raw process time (To)**, which is the sum of the mean effective process times of the stations in a line.

**Raw time (to):** average natural (no detractors) process time at a station.

**Arrival time (ta):** average time between arrivals to a line or station. At any station, TH = llta.

**Effective time (te):** mean effective process time (average time required to do one job) including all "detractors" such as setups, downtime, etc. It does not include time the station is starved for lack of work or blocked by busy downstream stations.

**Utilization (u)**, defined as the fraction of time a station is not idle for lack of parts.

**Work in process (WIP):** which consists of inventory between the start and end points of a routing.

**Work in process in a queue (WIPq):** average WIP in queue at a station.

**Critical work in process (Wo):** WIP level for a line, which is the WIP required for a line with no variability to achieve maximum throughput (rb) with minimum cycle time (To). For a line with parameters, rb and To, Wo = rbTo·

**Law (Little's Law)**: $WIP = THxCT$

**Law (Best-Case Performance):** The minimum cycle time and the maximum throughput for a given WIP level w.

**Law (Worst-Case Performance)**: The maximum cycle time and the maximum throughput for a given WIP level w.

**Definition (Practical Worst-Case Performance)**: The practical worst-case (PWC) is a realistic possible state of the manufacturing system.

**Law (Labor Capacity):** The maximum capacity of a line staffed by n cross-trained operators with identical work rates

**Law (Variability):** Increasing variability always degrades the performance of a production system.

**Law (Variability Buffering)**: Variability in a production system will be buffered by some combination of

- ✓ Inventory
- ✓ Capacity
- ✓ Time

## 3. CONCLUSION:

In this chapter we presented the two modelling approaches that we'll be using to analyse and understand the behaviour of the «RobotPlus» line as well as the tools that we'll be using to do it.

Using Flexsim will enable us to build an accurate model with strong visuals, and that will make the results easier to communicate with stakeholders that aren't familiar with simulation. And the use of our application will be an experiment to see how far we can push a factory physics analysis and whether we can totally depend on it without the need of other tools and also what insight can it give to a manufacturing manager.

Chapter

2

# Presentation of the Company

In this chapter we present the company MEGA-PAPIERS where we did our internship on their production department, we talk in details about their manufacturing system.

# CHAPTER 2: PRESENTATION OF THE COMPANY

## 1. PAPER THERMAL INDUSTRY

### 1.1 PAPER THERMAL SECTOR:

#### 1.1.1 PAPER THERMAL:

**[Barbara TRUFFI-EFPG]** Thermal paper is a base paper impregnated with several layers of components chemical, giving it thermosensitive properties.

The first thermal paper was made in 1960 in Dayton, Ohio by the NCR laboratories that have shown the advantages of heat transfer over sublimation of pigments, images or texts reproduced directly on the layer of media containing active products. These types of papers were put on the market in 1964, and we find a wide marketing with the "Miniprint Bond" military use. In the 1970s, thermal paper was mainly used in computers. In the 80's, the market expanded with the arrival of facsimile (fax).

Today, the main market for thermal paper is that of barcode labels.

Currently, the world's major producers of thermal paper are the Japanese company Ricoh and the Japanese-German joint venture Kanzan. It should be noted that all European producers operate under Japanese license.

##### 1.1.1.1 USAGE:

The uses of thermal paper cover many areas:

- Labels of different kinds (e.g. bar codes), including those that allow infrared reading;
- Receipts;
- Badges and other safety features;
- Tickets or entry and travel tickets;
- Screenshot in the medical field (radiology, microscopy, ultrasound, scanner...);
- Paper for recorder;
- Thermal Fax. **[Barbara TRUFFI-EFPG]**

Despite the emergence of e-mail on the Internet, the fax continues to grow at a rate of around 10% per year. Formerly used exclusively by businesses, fax is now a consumer good for the general public. In 1998, three out of four fax machines were sold to individuals. Entry-level appliances (prices in the range of 1 kF HT) use thermal paper, the more expensive appliances (prices in the range of 1.5 kF HT at least) use ordinary paper. Fewer and fewer devices use thermal paper printing, because it is criticized for being more expensive (about 10 cents per page), less rigid, and for being poorly preserved. For example, two-thirds of fax machines sold in 1998 operated on plain paper, compared to one-third on thermal paper. Fax thermal paper producers who were unable to convert in time had to close workshops and lay off staff. The Franco-British paper group Arjo Wiggins Appleton closed its thermal paper production site in Cardiff in 1999; in France, the Guérimard plant also stopped producing this type of paper this year.

The market for thermal label paper, on the other hand, is in full development. Labels (with barcode) are used in:

- Supermarkets
- Identification of baggage in air transport
- Manufacturing control
- Inventory management
- Identification of vials in analytical laboratories (research, hospitals)
- Handling and transportation systems.

#### 1.1.1.2 DIFFERENT CATEGORIES:

Since the uses of thermal paper are very varied, a particular paper must have specific physical, mechanical and chemical characteristics for its use. Fax thermal paper is in complete decline, but the market for label thermal paper is booming.

Thermal paper for label production shall be resistant to external attacks by water, grease and solvents; it must also be kept for a long time. This is why commercial label thermal papers can be divided into three main categories, depending on their degree of protection and their lifespan. There are:

- ✓ "Normal" papers, for which the heat layer has no protection;
- ✓ Semi-protected papers, for which the heat layer is lightly protected;
- ✓ Protected papers, for which the thermal layer benefits from excellent protection.

#### 1.1.1.3 WEIGHT:

The weight of the paper is an indirect measure of its thickness.
It describes weight of a leaf for a square meter of surface, the thicker a leaf is, the more it has weight.

The weight of a paper is calculated in grams per square meter (gr/m2).

For the same weight, the opacity and handling of the paper vary according to the density of the fibre and paper manufacturing quality. (For a good grip, the matte paper is recommended).

This is a scale of paper thicknesses.

- ❖ 35gr.m² → Newsprint
- ❖ 70gr to 100gr → Printer paper
- ❖ 120gr → Announcements and invitations
- ❖ 135gr →Common flyers
- ❖ 160gr →Cover of a brand name or company brochure
- ❖ 220gr to 300gr → Business cards

#### 1.1.1.4 WHITENESS:

The whiteness of a paper is measured through the index called CIE. The higher the index, the whiter the paper is, the more it values the document. This is a very important value that has a direct impact on the intensity of contrasts for both black and white prints and color.

Papers can then be classified into different categories:

- ❖ Extra white papers CIE 169 and +: These are very qualitative papers for the impressions. They are recommended for important documents, duplex prints...
- ❖ High-whiteness papers CIE 160 to 168: They allow you to obtain a very good color contrast and to have a more printing effect net.
- ❖ CIE 140 to 159 standard whiteness papers: They are used for internal printing, photocopying, fax, drafts...

### 1.1.2 THERMAL PAPER MARKET:

**[Report, 2021]** From the report "Thermal Paper Market Size, Share & Trends Analysis Report By Application (PoS, Tags & Labels, Lottery & Gaming), By Region (Asia Pacific, North America, MEA), And Segment Forecasts, 2021 – 2028" it says that the global thermal paper market size was valued at USD 4.02 billion in 2020 and is expected to grow at a compound annual growth rate (CAGR) of 5.2% from 2021 to 2028. The growing popularity of Point of Sale (PoS) machines to carry out retail transactions is expected to drive the market over the forecast period. The rising importance of labelling/providing a detailed description of constituents in the food & beverage and pharmaceutical industries to beat adulteration practices is also expected to propel the product demand. Moreover, the growing application of Radio-Frequency Identification (RFID) tags in the healthcare industry is expected to remain a favorable factor for industry growth in the near future.

### 1.1.3 REGIONAL INSIGHT:

**[Report, 2021]** Asia Pacific region dominated the market and accounted for over 34% share of total revenue in 2020. The rapid growth of the retail industry coupled with the rising demand for pharmaceutical and healthcare products in the region has led to the growing product utilization for billing operations. In addition, a rising preference for cashless transactions has had a positive impact on the market.

Europe has emerged as a manufacturing hub for dietary supplements and nutritional products owing to the presence of prebiotic manufacturers, such as FrieslandCampina Domo (The Netherlands), and Beneo (Belgium). These companies are progressively adopting the labels and tags to adhere to the labelling standards as well as to prevent adulteration. The MEA regional market is estimated to register the second-highest CAGR from 2021 to 2028.

This growth is credited to the high product demand as a result of an increasing number of retail outlets, shopping malls, and ATMs in Saudi Arabia. The product demand in the U.S. is expected to grow at a CAGR of 3.8% over the forecast period. The presence of major food & beverage manufacturers, such as Tyson, Cargill Foods, JBF, and KFC, in the country, is expected to increase the incorporation of printed labels and tags, which, in turn, is likely to fuel the product demand.

### 1.1.4 KEY COMPANIES

**[Report, 2021]** The global market is highly oligopolistic with fierce price competition between the companies. The market is characterized by tight margins. The profitability of the companies is highly dependent on the cost of raw materials and a high degree of automation to achieve economies of scale in the production process. Furthermore, the industry profit margins vary based on their integration levels. Some of the prominent players in the global thermal paper market include:

- Ricoh Company, Ltd.

- Oji Holdings Corporation
- MPM Ltd.
- Appvion Incorporated
- Jujo Thermal Ltd.
- Lecta Group

### 1.1.5 SEGMENT COVERED

**[Report, 2021]** The report forecasts revenue growth at global, regional, and country levels and provides an analysis of the latest industry trends in each of the sub-segments from 2017 to 2028. For the purpose of this study, Grand View Research has segmented the global thermal paper market report on the basis of application and region:

- **Application Outlook (Volume, Kilotons; Revenue, USD Million, 2017 - 2028)**
  - Point of Sale (PoS)
  - Lottery & Gaming
  - Tags & Labels
  - Others
- **Regional Outlook (Volume, Kilotons; Revenue, USD Million, 2017 - 2028)**
  - North America
    - U.S.
    - Canada
    - Mexico
  - Europe
    - Germany
    - U.K.
    - France
  - Asia Pacific
    - China
    - India
    - Japan
  - Central & South America
    - Brazil
  - Middle East & Africa
    - Saudi Arabia

Table 1: Thermal Paper Report Market Scope

| Report Attribute | Details |
|---|---|
| Market size value in 2021 | USD 4.17 Billion |
| Market volume in 2021 | 2,088.0 Kilotons |
| Revenue forecast in 2028 | USD 6.03 Billion |
| Volume forecast in 2028 | 2,865.6 Kilotons |
| Growth Rate | CAGR of 5.2% from 2021 to 2028 (Revenue Based) |
| Base year for estimation | 2020 |
| Historical data | 2017 – 2019 |
| Forecast period | 2021 – 2028 |
| Quantitative units | Volume in kilotons, revenue in USD million/billion, and CAGR from 2021 to 2028 |
| Report coverage | Revenue forecast, volume forecast, competitive landscape, growth factors and trends |
| Segments covered | Application, region |
| Regional scope | North America; Europe; Asia Pacific; Central & South America; Middle East & Africa |
| Country Scope | U.S.; Canada; Mexico; Germany; UK; France; China; India; Japan; Brazil; Saudi Arabia |
| Key companies profiled | Ricoh Company, Ltd.; Oji Holding Corporation; MPM Ltd.; Appvion Incorporated; Jujo Thermal Ltd.; Lecta Group |
| Customization scope | Free report customization (equivalent to up to 8 analysts' working days) with purchase. Addition or alteration to country regional & segment scope. |

## 2. MEGA-PAPIERS

### 2.1 PRESENTATION OF MEGA-PAPIERS:

It is an Algerian SME (Small Medium Enterprise) specialized in (transformation) and the distribution of all types of graphic arts papers, since 2003 they commercializes their products throughout the national and international territory to professionals, public and private, the most important in the field of printing and publishing.

It is to satisfy the growing qualitative and quantitative needs of their clients that they have developed state-of-the-art production capacity and paper handling and storage of a distribution fleet modern and constantly expanding, from warehouses to international standards and renowned suppliers.

Our company's architecture is based on a simple principle that is ingrained at all levels:

***"Quality. Apply without moderation"***

Their experience, duly and hard-earned, gives them complete control over their job and makes them one of the biggest actors in the Algerian market of paper for arts graphics.

### 2.1.1 COMPANY HISTORY:

**2003:** - Launch of the activity with manual cutters reel and format.

**2005:** - Acquisition of 2 semis trailers IVECO and 2 container gates.

- Acquisition of equipment for handling.

**2006:** - Purchase of real estate, liaison office Ain-Naadja, Algiers

**2008:** - Construction of a logistics base of 7000 m² including 3000 m² covered located in Tlemcen.

**2009:** - Acquisition of industrial cutting equipment in format.

* WILL PEMCO - SHM 1450 DR.

- Acquisition of transport equipment 2 semi-trailers and 2 IVECO vans.
- Acquisition of forklift equipment.

**2012:** - Acquisition of industrial cutting equipment in format.

* WILL PEMCO - SHM 1450 DR.* WILL PEMCO - WRAPMATIC GREEK

* HEIDELBERG - Station MASSICOT POLAR 115

**2013:** - Acquisition of transport equipment 4 VOLVO semi-trailers and 2 vans IVECO.

- Acquisition of industrial equipment for the manufacture of thermal rollers.

* LEMU - BSA 100/1100 Semiautomatic

**2015:** - Purchase of a public company (EX EDIED) transformed into an industrial plant.

- Acquisition of industrial equipment for the manufacture of thermal rollers, Potter rolls and adhesive labels rolls.

* LEMU- Automatic ROBOSUM 2400

* LEMU- Automatic ROBOSUM 2401

* LEMU- Flexo Print Groups

* SIAT - MPL 153

- 1st export operation.

**2016:** - Launch of the new production unit.

**2017:** - Acquisition of industrial equipment for the manufacture of adhesive rolls GTU.

**2018:** - Year of export: 28 operations to different destinations (Tunisia, Italy, Switzerland...)

**2019:** - Acquisition of industrial equipment for the manufacture of thermal rollers

* LEMU-ROBOPLUS
* CONVEQ- Roll slit 1500
* CONVEQ- Core Matic 2000
* LEMU - Flexo Print Groups

### 2.1.2 THE COMPANY IN NUMBERS:

—> DA 290 million in share capital in 2019.

—> 1870 million DA of CA in 2018.

—> 16,000 tons in volume in 2018.

—> 20,000 m² of area of which 10,000 m² is covered.

—> 70 employees.

—> 22 partners worldwide.

—> 400 customers in Algeria.

—> 3 commercial agencies. —> 2 production units.

—>5 countries for export (Tunisia, Italy, Morocco, Switzerland, Spain)

## 2.2 COMPANY POLICY ON THE ENVIRONEMENT:

MEGA-PAPIERS sells environmentally friendly products and suppliers ensure that the products come from sustainably managed forests (it means that all products are FSC and PEFC certified) as they always demonstrate responsibility.

## 2.3 WORKING HOURS:

The working time is 16 hours, which is motto by two team of 8h employees organize the working time in the company according to the requirements of activity.

The work in the factory is based on quality requirements, attention to details, Security and finally the switchover that Mr.Bedjaoui applies between employees to not let them get bored.

## 2.4 PRODUCTION DEPARTEMENT:

The production workshop has several machines (4 coil winding machines, two labeling machines, a Flow Pack, rotary base palletizer and Slitter-rewinder).
There is 4 kinds of machines the most used in the workshop

- ***ROBOTPLUS Machine:***

It's an automatic machine which is the main line of the workshop that could transform all kind of papers with personalized printing even the adhesive paper can be used knowing that it is hard to print on this kind of paper with the little help of operators who found the solutions to make it work.
This machines contains all the compartments of production the final good roller, it is composed from four main compartments: Scroll, Print, and Rewind and finishing line.
More details will be discussed in the following chapters.

- ***Semi-Automatic B-AS110-LEMU(Plotter):***

This the first machine that has been bought, it produces Potter paper using paper-offset Jumbo Coils.
Two different grammages (80g-90g) with different footage (50m with diameter of 50mm-150m with diameter of 76mm) for 80g and (45m with diameter of 50mm-135m with diameter of 76 mm) for 90g, and a 914mm blade, it consists of 3 compartments main: Scroll, Print, and Rewind.

- ***Automatic Machine ROBOSUM-LEMU(Paper Thermal):***

This machine specializes in the production of small thermal rollers in using thermal paper-type mother coils for different weights and footage.
It is composed from four main compartments: Scroll, Print, and Rewind and finishing line.

- ***LEMU GTU-530 Machine:***

It's an automatic machine that transforms adhesive paper into labels, with different slats, different dimensions and different shapes.

### 2.4.1 RAW MATERIALS:

- Jumbo coils of several types of Papers, in general thermal Paper.

Table 2: Raw Material Jumbo Coil

| Family | Weight of Paper | Laize x Meter | Weight |
|---|---|---|---|
| adh | thermique eco 72 | 1500x8000 | 64680 |
| | | 925x4000 | 4558,4 |
| | | 967x4000 | 5956,72 |
| | | 1000x4000 | 1232 |
| | couche brillant 80 | 1500x8000 | 108240 |
| | offset 75 | 1000x2000 | 942 |
| | | 490x4000 | 1023,12 |
| ncr | 55 | 1040x10500 | 7207,2 |
| | | 660x10500 | 4573,8 |
| | | 1000x10500 | 30607,5 |
| | | 480x10500 | 1386 |
| couche b1f | 80 | 1530x16200 | 116989,92 |
| | | 700x16200 | 19958,4 |
| offset | 80 | 106,7x11500 | 1963,28 |
| | 80 | 850x11500 | 2346 |

| | | | |
|---|---|---|---|
| | **60** | **900x11200** | **12096** |
| | **80** | **650x11200** | **3494,4** |
| | **70** | **650x9000** | **4504,5** |
| **macule** | | **1200x8000** | |
| **thermosoudable** | | **1200x8000** | |

- Box for the final products.
- Palette to store the box
- Mandrels
- Cardboard Mandrels
- Plastic Film

### 2.4.2 THE FINISHED PRODUCTS:

***Cash registers*:** The Company offers a wide range of paper roll for cash register.

Available in supermarkets, restaurants, shops, cafes...

***Bank*:** MEGA-PAPIERS offers thermal rollers for ATMs that provide accounting documentation for completing a bank transaction.

***Electronic payment type:*** The Company offers rolls of thermal paper for electronic payment terminals (also called TPE) are electronic devices capable of reading data a credit card, record a transaction, and communicate with a remote authentication server.

***Thermal adhesive:*** The Company offers a scalable range thermal adhesive labels. Used as a means of communication to inform the consumer about the content of product he wants to buy for traceability through reading the barcode, for labelling..

.

***Access automatic, Park meter, Interactive terminal:*** The Company offers rolls of thermal paper used as consumable for access control units, Park meter, interactive terminal...

***Custom Rolls:*** To post, sell products, make ads...

***Fax Roll:*** The Company offers a complete range of Fax rollers for all types of machines...

## 2.5 LOGISTICS IN MEGA-PAPIERS:

In Mega-Papiers; logistics is a true tool of competitiveness that aims improve the coordination of business services and mobilize them to pursue a common objective: customer satisfaction.

The objective of corporate logistics is both short-term (optimization of daily physical flows) and medium-term (action plans put in place to optimize production and storage parameters).

Mega-Papiers has therefore set up a whole logistics department to manage volumes vert important import/export operations under the best conditions, to optimize their capacities production, to minimize breakdowns and to meet all their demands at the right time.
It is for the fulfilment of their commitments towards their customers that they have also made the choice to integrate transport and delivery into their range of services.

The company fleet consists of:

- ✓ 12 semi-trailers.
- ✓ 2 10T (ratcheted) trucks.
- ✓ Several commercial vehicles.

## 2.6 COLOR CODE IN MEGA-PAPIERS:

The Production Workshop is distinguished by 3 coloured areas in Dark Blue, Light Blue, and Grey, then a fourth area for storage. As:

- The Grey space is reserved for walkers.
- The Dark Blue space reserved for handling operations, which means for carts and forklift.
- The clear blue space is reserved for machines.

## 2.7 HANDLING SYSTEM IN MEGA-PAPIERS:

In the paper industry, handling plays a key role. The raw material, although voluminous, it is very sensitive to movements and shocks, it must be handled carefully. A damaged spool deeply alters the quality of the final product. It is for this reason, the company has the best forklifts (fork...)

## 2.8 STORAGE OF MATERIALS IN MEGA-PAPIERS:

Warehouses have been adapted to the needs of the paper industry in accordance with international standards.
The traffic lanes are arranged so as to avoid angles, sharp curves, inclined planes, ramps with a steep gradient, narrow passages and low ceilings, as well as for packaging warehouses control the degree of ambient humidity, block sunlight, control ambient temperature.

## 2.9 SUPPLIERS OF MEGA-PAPIERS:

For the quality of their products, MEGA-PAPIER supplies itself to the best:

- ✓ **Jujo thermal**: Japanese multinational whose European paper production center is in Finland.
- ✓ **Koehler thermal paper:** German group specialty paper manufacturer.
- ✓ **Torras papel**: Spanish group specialty paper manufacturer.

- ✓ **Mitsubishi Paper Mills**: Japanese multinational whose European production center thermal paper is in Germany.

## 2.10 CUSTOMERS OF MEGA-PAPIERS:

- ✓ **TECHNO:** is an Algerian company specialized in the distribution of Supplies of Offices, Computer Consumables, Stationery, Products School and Fine Arts.
- ✓ **B.A.D.R. Bank Printing**
- ✓ **A.G.B Bank Printing**
- ✓ **F.A.B.S**

Chapter

3

# Simulation of Manufacturing system

## MEGA-PAPIERS

In this chapter we explain how we simulated the line «ROBOTPLUS» of MEGA-PAPIERS on Flexsim and the Desktop Application

# CHAPTER 3: SIMULATION OF THE MANUFACTURING SYSTEM MEGA-PAPIERS

## 1. INTRODUCTION

MEGA-PAPIERS, the company where we did our internship for 15 days is a powerful company in the transformation of paper, they lead the market in the national territory because of their product quality and they are even competitive internationally because of their good price of the product with such a good quality.

The strength of the company is in their sales forces, they work with their customers to ensure their needs are met and to nurture a strong business relationship because of the various products they can offer to their clients and the personalized product, they can produce any types of rollers with different sizes and they have the ability to make threesome colors impressions which is something that they only have in the Algerian market.

### 1.1 LINES OF THE WORKSHOP:

In our study we considered the machines as lines due to their sizes and because the machine itself is composed of the multiples others machines.

The workshop of MEGA-PAPIERS contains 6 big lines and a Rewinder (Refondeuse), those lines are existed in 3 types:

- **Manual lines** where the operator do most of the work.
- **Semi-automatic lines** that needs the operators only in the last part for finishing the product by wrapping them with film paper.
- **Automatics lines** that does need the operators' only for some product inspection and to repair breakdowns they will appear.

➢ **Line 1:**

This line is the «*B-AS110-LEMU*» that can produces plotter and thermal paper rollers with the most help of the operators that they do 90% of the work, this line is composed of 4 machines: «Dévidoir», «Impression» with only one color, «Accumulator » and the «Decoupage » which the main robot of the line.

➢ **Line 2 & Line 3:**

These lines have the exact same flowshop one of them is called «*ROBOSUM-LEMU*»**,** they produces only small rollers of thermal paper with many different sizes and impressions. These lines are semi-automatics that need the help of operators

They are composed of 9 machines:

«Dévidoir» this part does not work on a continuous flow, «Impression» with only 2 colours, «Accumulator », «Decoupage», «Frappage», «Mise en lot», «Filmeuse», «Four», and the last

one is «Mise en caisse» that is made by a an operator who has an important role to inspect the product whether they are good or has to be rework or has to be considered as a scrap.

- **Line 5:**

This line is the «LEMU GTU-530» which is an automatic line that produces only label rollers made by adhesive paper it has a different technology and process than the other lines because the adhesive paper which has special parameters.

This line is composed of 4 machines: «Dévidoir», «Decoupage-etiquette », «Rembobinage Chute» and the «Decoupage» which the main robot of the line.

- **Line 6:**

This line is the same as line 5 it's only composed of manuals machines the whole process is done by only the operator.

This line is composed of 4 machines: «Dévidoir», «Decoupage-etiquette », «Rembobinage Chute» and the «Decoupage » which the main robot of the line.

- **Rewinder (Refondeuse):**

This machine is considered really important in the company because it is kind of the key of their success, it is the machine that can transform the brutal Jumbo Coil to a personalized Jumbo coil, and they are the only company that owns it in the market of Algeria which made them the leader of the market

- **Line 4:**

This is the main line of the whole workshop which is called «ROBOTPLUS», in our study case we only focused on this line because it is the only automatic the line and contains all the machines needed to produce the very final product

We will discuss about this line in details in the following chapters.

## 1.2 THE VARIETY OF PRODUCT:

The company of MEGA-PAPIERS has several types of products, from standard products to customizable products.

The product are defined by 3 families that represent the 3 type of paper; Thermal Paper the most successful in the Algerian market also the international one specially in Italy, the offset paper mostly used for the plotter product which used for the architects and the fax and finally the adhesive paper specialized for the labels which are used in our daily life.

- **Mega Therm :**

It's the family that represent the rollers that are made by thermal paper with different sizes:

| Customer | Size | Customer | Size |
|---|---|---|---|
| Spot | 80x205x17, 5 | - | 60x235x40 470m |
| Alger Post | 80x205x17,5 | - | 60x145x40 145m |
| - | 80x205x17,5 | - | 60x200x40 500m |
| Fransa Bank | 80x205x17,5 | - | 60x30m |
| SGA | 80x205x17,5 | - | 57x78m |
| - | 80x200x25 | - | 57x60m |
| Alger Post | 80x200x25 | - | 57x50m |
| CNEP | 80x200x25 | - | 57x47m |
| CNEP Offset | 80x200x25 | Standard | 57x41m |
| AGB | 80x200x25 | - | 57x40,5m |
| Sogral | 80x78m | Offset | 57x29m |
| - | 80x78m | - | 57x30m |
| Sotumag | 80x75m | - | 57x29m |
| Turtles | 80x74m | - | 57x27m |
| Standard | 80x74m | - | 57x24m |
| - | 80x69m | - | 57x19m |
| - | 80x60m | - | 57x17m |
| - | 80x40m | - | 57x15m |
| - | 80x19m | - | 57x13,5m |
| - | 80x15m | - | 57x20m bet |
| - | 210x25 | - | 57x9m |
| - | 110x24m | | |
| - | 110x30m | | |

Table 3: Product of Mega Therm

- **Mega Plotter:**

It's the family that represent the plotter rollers that are made by offset paper with different sizes:

| Customer | Size |
|---|---|
| Standard Plotters | 50 m |
| Standard Plotters | 50m/ 90° |
| Standard Plotters | 150m |
| Standard Plotters | 1067x50m |

Table 4: Product of Mega Plotter

- **Mega Label:**

It's the family that represent the label rollers that are made by adhesive paper with different sizes:

| Customer | Size |
|---|---|
| - | 100x123x500m |
| - | 100x123x126m |
| - | 100x123x45m |
| Standard | 100x100 |
| - | 100x150 |
| - | 100x58 |
| - | 100x58x18,5 |
| - | 100x58x30,8 |
| Standard Offset | 80x50x158,8m |
| - | 60x65 |
| - | 50x25x55,5m |
| - | 45x35 |
| - | 58x104 |
| | 58x43 |
| - | 50x30x45m |
| - | 50x30x31,8m |
| Vignette | 40x20 |
| - | 40x20 |

Table 5: Product of Mega Label

## 2. SIMULATION WITH FLEXSIM

During our internship in Mega papier the line "Robot Plus" was the main focus of all the observations we did, not only because it's the most automated and sophisticated manufacturing line they have, but also because it manufactures a big part of their client's demand and their dependency on it was too important to be overlooked.

### 2.1 ROBOTPLUS LINE:

The « Robot Plus» line was our main focus during the internship and it is composed of 9 machines and an operator:

- Devidoir
- Impression
- Accumulateur
- Découpage
- Frappage
- Mise en lot
- Filmeuse
- Four

- Mise en caisse(Operator)
- Scotcheuse

  - The machine «Decoupage» controls the rate at which the machines that precedes it work (it is the only machine with the possibility to setup the speed) -it pulls jobs from them-
  - The machines that precede «Decoupage » works at a continuous flow: a Jumbo coil is placed at the « Devidoir» and the next machines keep pulling the paper until the Jumbo coil is consumed.
  - The flow at «Decoupage » changes from continuous flow to batch processing, all the machines that succeed it works the same with different batch sizes.

Pre-production times are composed from :

- Changing the jumbo coil
- Changing the print layer

The first station is working on continuous flow until the jumbo coil is consumed so we consider that:

- The Processing batch size is the number of rolls that can be made from one Jumbo coil to calculate it we use the following equation :

**Number of rolls = (Length of the Jumbo coil /length of the roll) x (Height of the Jumbo coil /Height of the roll)**

In the “mise en lot” machine a batch is formed, its size is pre-defined and depends on the client’s demand and the conditioning chosen by the company. The difference in Process batch sizes between Station 2 and Station 3 and the non-existence of a move batch (Jobs are moved one by one) causes waiting times for some jobs.

## 2.2 COMPONENTS OF THE FLEXSIM SIMULATION:

The simulation contains 11 components with different kinds of fixed resources and task executers:

### 1) Bobine Mere:

It is a source resource that create jumbo coil with a setup that depends on the numbers of cycles in consuming only one Jumbo coil with a size of 1360mmx15000m and the number of cycles is 202.

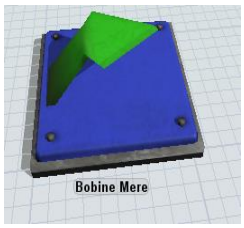


Figure 5: Bobine Mere

In the triggers section we added on the creation of the 2025 cycle which the number of cycles of all the products presented in Table 6, the model receive a message to stop the animation and at the same time end the model run/replications.

### 2) Devidoir:

It is a processor resource that works at a continuous flow, it pulls and strengthens the paper with a process time that has been taken from the data that we collected in our training journey which we found with different values, and that made us chose to work with a normal distributions that contains mean value and standard deviation value.

The setup changes from one jumbo coil to another has been considered as an availability because all the machines stops working while the changes are made.

In this process we also added the «Impression» and «Accumulator» time

Adding the first part of the next machine «Decoupage» because of the batch processing 17

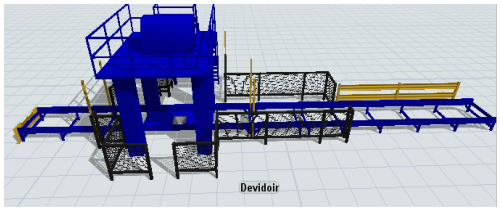


Figure 6: Dévidoir

### 3) Decoupage:

It is a separator resource that include the second part of «Decoupage» where the rollers are separately sticked and the part of flipping the rollers with splitting them in 17 small rollers.

This separator is concerned when the Jumbo coil is changed so we include the availability on it as breakdown, we also added some triggers ‘On the Exit’ to Change 3D shape and Size of the item to have a visual close to the real product.

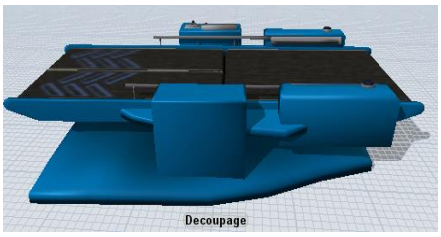


Figure 7: Decoupage

### 4) Frappage:

It is a processor resource that include only the part where the small rollers are knocked to remove the excess from the mandrel of the rollers

This processor is concerned when the Jumbo coil is changed so we include the availability on it as breakdown

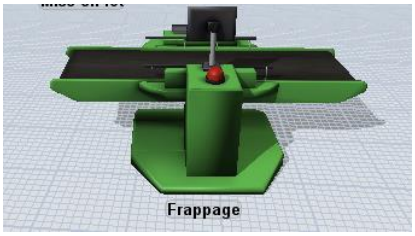


Figure 8: Frappage

### 5) Papier Film:

It is a source resource that create plastic film which is going to be used in the machine of «Mise en lot» To plasticize the rollers in batch of 5 above and below.

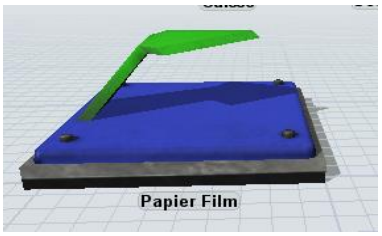


Figure 9: Papier Film

### 6) Mise en Lot:

It a combiner resource that combine between the plastic films that it's out from the source "Papier Film" and a batch of 5 small rollers that it is out from the previous machine "Frappage"

This processor is concerned when the Jumbo coil is changed so we include the availability on it as breakdown

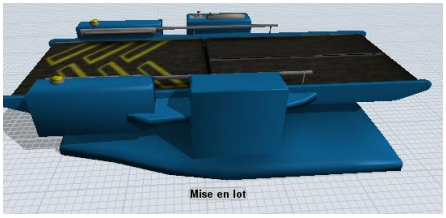


Figure 10: Mise en Lot

### 7) Four:

It is a processor resource that will heats the plastic film to fit exactly the 5 small rollers and at the end of the process there is going to be an operator called «Adnane» that pick this packed batch and put it into a box to the next machine «Scotcheuse».

This processor is concerned when the Jumbo coil is changed so we include the availability on it as breakdown

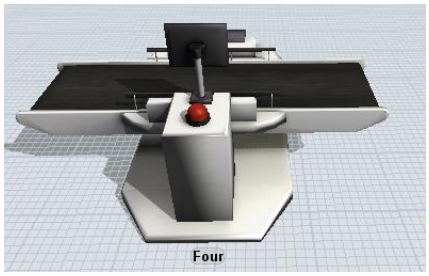


Figure 11: Four

### 8) Operator «Adnane»:

The operator «Adnane» has two task to execute, the first one is to transport the outputs from the source «Caisse» to the machine «Scotcheuse» and the second is to transport the output from the «Four» machine to the «Scotcheuse» machine.

And at the end of these two task he will be released and will have to return near the «Four» machine


Figure 12: Adnane

### 9) Caisse:

It is a source resource that creates box which will contain 50 small rollers with a batch of 5 and it going to be transported to the «Scotcheuse» machine by an operator «Adnane»

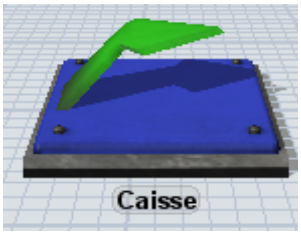


Figure 13: Caisse

### 10) Scotcheuse:

It a combiner resource that combine between the Box that it's out from the source "Caisse" and will contain 50 small rollers with a batch of 5 that it is out from the previous machine "Four".

This processor is concerned when the Jumbo coil is changed so we include the availability on it as breakdown.

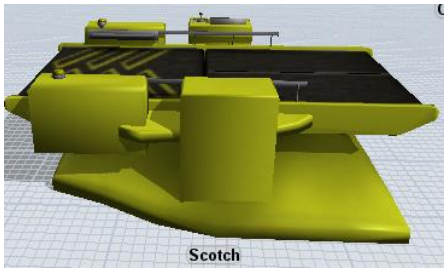


Figure 14: Scotcheuse

### 11) Operator «Karim»:

The operator «Karim» has only on task to execute, which is to transport the outputs from the «Scotcheuse» machine to the Rack «Palette».

And at the end of this task he will be released and will have to return near the «Scotcheuse» machine.


Figure 15: Karim

### 12) Palette:

It is a Rack resource called «Palette» that can contain only 36 box or less as it happens in the real workshop. It is a floor storage with 6 bays and 6 levels.

In the simulation it exist 20 rack like «Palette» that are named after the product they will be contained and the size of any rack depends on the demand of the products

| Order | Demand / Roll | Box | Palet | Last Box |
|---|---|---|---|---|
| Zara | 4500 | 90 | 2,5 | 18 |
| Bershka | 6800 | 136 | 3,77777778 | 28 |
| Stradivarius | 6800 | 136 | 3,77777778 | 28 |
| Massimo | 1700 | 34 | 0,94444444 | 34 |
| Oysho | 3400 | 68 | 1,88888889 | 32 |
| Zara Home | 5100 | 102 | 2,83333333 | 30 |
| Pull&Bear | 5100 | 102 | 2,83333333 | 30 |
| SGH | 1000 | 20 | 0,55555556 | 20 |
| Total | 34400 | | 19,1111111 | |

Table 6: Demand of the Orders per Box

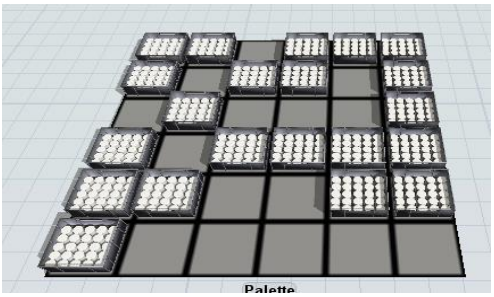


Figure 16: Palette

# Chapter 4

# Analysis and Interpretation

In this chapter we presented the analysis of the Robot Plus line than we interpreted the results

# CHAPTER 4: ANALYSIS AND INTERPRETATION:

## 1. GENERAL INTRODUCTION:

In a simulation process, documenting data, results and how we gets them is a necessary step in order to be methodical and precise, it also enables us to trace errors or abnormalities in our model to its origin and correct it or at least understand it.

Therefore, in this chapter we will walk through our simulation process using Flexsim, from the early phase of data collection to the interpretation of results and performance measures.

## 2. SIMULATION CASE:

During our internship in MEGA-PAPIERS, the main focus was on a client's order of 74x79 cash register rollers.

The company received orders (different order sizes) for the same product with personalized printing from eight different clients:

| **Client** | **Order size** |
|---|---|
| Zara | 4500 |
| Bershka | 6800 |
| Stradivarius | 6800 |
| Massimo | 1700 |
| Oysho | 3400 |
| Zara home | 5100 |
| Pull&Bear | 5100 |
| SGH | 1000 |
| **Total** | **34400** |

Table 7: Order size of the clients

The manager had 30 days to deliver and decided to work on the Robotplus line, so during the whole internship the Robotplus line worked exclusively on 74x79 rollers (with an exception of an urgent demand that will be discussed later).

Due to all the above, in the simulation model we considered:

- Roboplus line
- 1 product (74*79 personalized for each client)
- 8 orders

The quantities and performance measures that we would be considering as results are:

- **TH**: throughput
- **CT**: cycle times
- **WIP**: work in process
- **u**: Utilization

## 3. DATA COLLECTION:

At first, our plan was to ask and look for all the manufacturing data that the company has collected or stored so that we can then process it and rely in the useful ones, but the first barrier that we encountered was that no data is collected in the workshops, except for records on daily production size (the enormous variety of products made those also impossible to use).

The backup plan was to collect as much data as we could, although the results wouldn't be as accurate as doing an extended data collection process, but it would give insights and information about Roboplus and show the usefulness of simulation and it could help us create a model that is the equivalent of a foundation stone when the company establishes a data collection strategy.

### 3.1 WORK SCHEDULE:

Megapapier has a 5 days' work week, one 8h 30 min shift a day starting from 8 am including two breaks :

| Break time | Break duration |
|---|---|
| 10 am | 15 min |
| 12 am | 30 MIN |

Table 8: The duration and time of breaks

Megapapier's work schedule was considered in our model as the following figure shows:

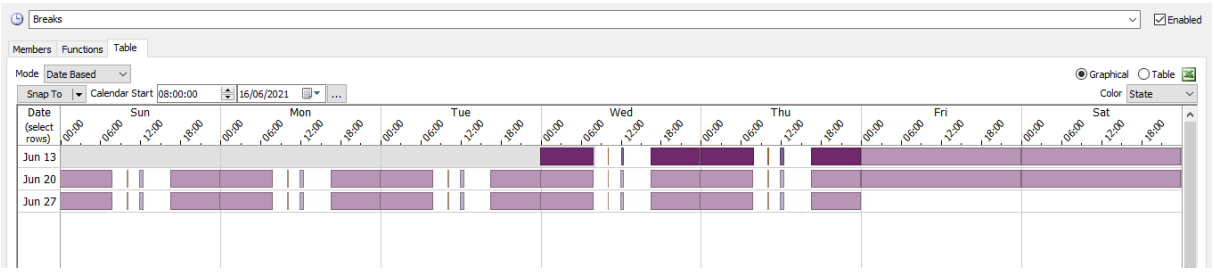


Figure 17: MEGA-PAPIER Work Schedule

## 3.2 SETUP TIMES AND BREAKDOWNS:

By interacting with the operators and the manager, we understood that breakdowns were so random in nature, duration and frequency therefore considering a data collection in such a small period wouldn't help us achieve a good overall familiarity with their natures or estimation for the durations and frequencies.

That's why we decided to pass on collecting data for breakdowns and not use it in our model, however we designed a daily log model that the company can use in the future:

<table>
<tr><td colspan="3">Date :3/05 /1998</td><td>Operateur :</td><td>Ligne :</td><td>Type de produit :</td></tr>
<tr><td colspan="2" rowspan="2">Nombre de caisse produites</td><td colspan="4">Avec impression :</td></tr>
<tr><td colspan="4">Sans impression :</td></tr>
<tr><td>Arrêt</td><td>1ER</td><td>2EME</td><td>3EME</td><td colspan="2">4EME</td></tr>
<tr><td>Durée (s)</td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Motif</td><td></td><td></td><td></td><td colspan="2"></td></tr>
</table>

Figure 18: Daily log model

In order to simplify the process of referencing the breakdowns and to eliminate clutter on the daily log, we proposed a simple three digits code 0.0.0:

- The first digit represents the type of breakdown: 0 for energy breakdowns, 1 for setup, 2 for technical breakdowns, and three for non-referenced breakdowns.

In the case of a frequent non-referenced breakdown, the code can be extended to include it and reference it by 3 while the number 4 can be used for the other non-referenced breakdowns.

- The second digit represents the station where the breakdown occurred (0 can be used if the breakdown isn't machine related.

| Type d'arrêts | Code |
|---|---|
| Changement de cliché | 1.2 |
| Changement de bobine | 1.1 |
| Changement de robot | 1.2 |
| Changement de film | 1 .5 |
| Pannes techniques | 2.0<br>2.1<br>2.2<br>2.3<br>2.4<br>2.5<br>2.6 |
| Coupure d'énergie | 0.2 |
| Autre : | 3.0<br>3.1<br>3.2<br>3.4<br>3.5<br>3.6 |

Figure 19: Type of Breaks Code

**NB**: this is a model that can be coded in case of the use of an information system, it also can be modified to include every type of breakdowns that the manager deems useful to track and record.

However, for setup time we were able to observe a number of the jumbo coil setups as well as the printing layer changes, we calculated a meantime and used it as follows:

- **Jumbo Coil Setup:**

| | Jumbo Coil 1 | Jumbo Coil 2 | Jumbo Coil 3 | Jumbo Coil 4 | Jumbo Coil 5 | Jumbo Coil 6 | Jumbo Coil 7 | Jumbo Coil 8 | Jumbo Coil 9 | Jumbo Coil 10 | Jumbo Coil 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jumbo Coil 1 | 0 | 1800 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jumbo Coil 2 | 0 | 0 | 1800 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jumbo Coil 3 | 0 | 0 | 0 | 1800 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jumbo Coil 4 | 0 | 0 | 0 | 0 | 1800 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jumbo Coil 5 | 0 | 0 | 0 | 0 | 0 | 1800 | 0 | 0 | 0 | 0 | 0 |
| Jumbo Coil 6 | 0 | 0 | 0 | 0 | 0 | 0 | 1800 | 0 | 0 | 0 | 0 |
| Jumbo Coil 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1800 | 0 | 0 | 0 |
| Jumbo Coil 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1800 | 0 | 0 |
| Jumbo Coil 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1800 | 0 |
| Jumbo Coil 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1800 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jumbo Coil 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 9: Setups of Jumbo Coil

This setup occurs when a jumbo coil is consumed, the operators stop the line and put a new jumbo coil in the «Devidoir» machine.

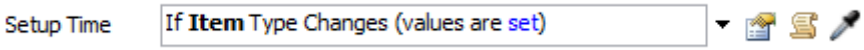


Figure 20: Setup of Jumbo Coil in Flexsim Model

- **Print layer setup:**

| | Zara | Bershka | Stradivarius | Massimo | Oysho | Zara Home | Pull & Bear | SGH |
|---|---|---|---|---|---|---|---|---|
| Zara | 0 | 1200 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bershka | 0 | 0 | 1200 | 0 | 0 | 0 | 0 | 0 |
| Stradivarius | 0 | 0 | 0 | 1200 | 0 | 0 | 0 | 0 |
| Massimo | 0 | 0 | 0 | 0 | 1200 | 0 | 0 | 0 |
| Oysho | 0 | 0 | 0 | 0 | 0 | 1200 | 0 | 0 |
| Zara Home | 0 | 0 | 0 | 0 | 0 | 0 | 1200 | 0 |
| Pull & Bear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1200 |
| SGH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 10: Setups of Print layer

This setup is specific to the printed product, the printing layer used for the previously manufactured product will be replaced by the one for the new product as shown in Table 6.

To include this setup into our Flexsim model we used a Process Flow to have more control and not be limited by the ressources entry zones.

Using a process Flow is more abstract than using FlexSim's 3D drag and drop modelling tools; it gives the user more freedom,flexibility and control over the logic that the model runs with.

The Process Flow of our model represents the seven printing layer setups,in four steps, as shown in Figure 21:

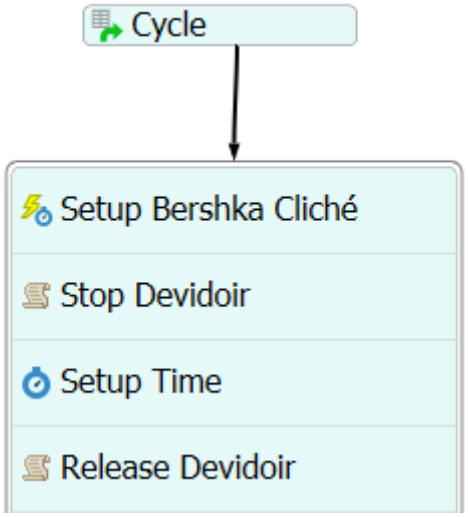


Figure 21: Process Flow of Print layer Setup (Bershka)

- Cycle :

a source that creates tokens that will be used to count the number of cycles.

- Setup “Order” Cliché

This event waits for numbers of tokens that represent the number of cycles used to produce all the product order as follows:

| Order | Demand / Roll | Demand /Cycle |
|---|---|---|
| Zara | 4500 | 265 |
| Bershka | 6800 | 400 |
| Stradivarius | 6800 | 400 |
| Massimo | 1700 | 100 |
| Oysho | 3400 | 200 |
| Zara Home | 5100 | 300 |
| Pull&Bear | 5100 | 300 |
| SGH | 1000 | 59 |
| Total | 34400 | 2025 |

Table 11: Demand per Roll / Demand per Cycle of orders

When the number of the cycles for the order is reached , this event will give an order to the next step.

- Stop Devidoir:

This is the actual command to stop the process “Devidoir” for the setup.

- Delay

The duration that the process will be stopped (setup duration).

- Resume Devidoir

Ending the stop, putting the process back to work;

## 3.3 PROCESSING TIME:

The jumbo coil is processed by cycles, the size of a cycle is 17 rollers so basically a jumbo coil is composed of 202 cycles. On some machines processing is executed by cycle and on other machines by roller.

We observed different cycles/rollers on different machines and recorded the duration on each station we then represented the data on a histogram to choose a probabilistic distribution that fits our data here is an example for the 3rd machine’s processing time:

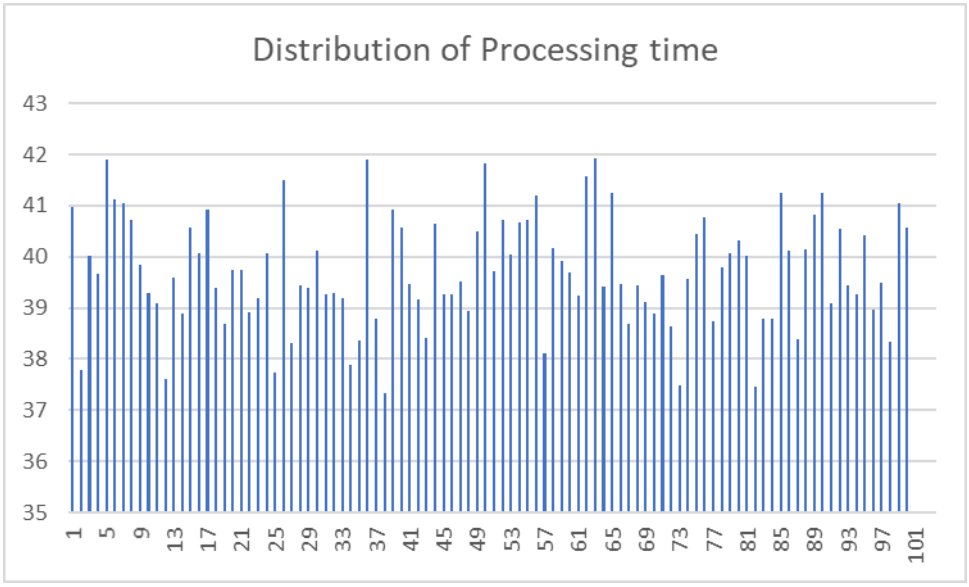


Figure 22: Distribution of Processing Time

After checking the shapes and the value, we decided to go with a normal distribution, a simple reorganization of this data will make a nearly perfect bell-shaped normal distribution.

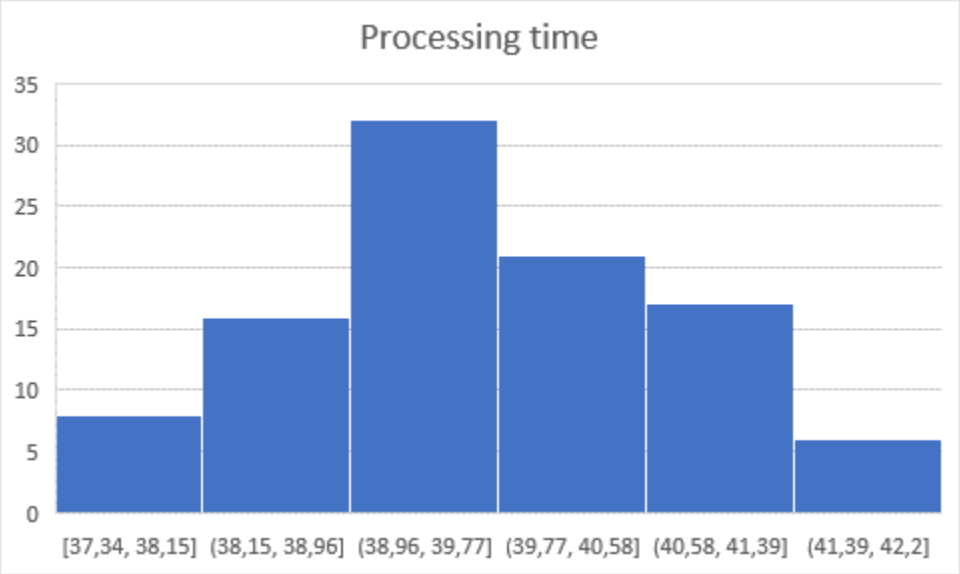


Figure 23: Histogramme of Processing Time

We treated collected data for every process the same way, and most of it followed the same distribution.

Therefore, we calculated mean time and standard deviation of processing for each station:

| Station<br><br>Parameters | Processing mean time | Processing time standard deviation | Setup mean time |
|---|---|---|---|
| **Devidoir** | **109** | **1,57** | **1800** |
| **Decoupage** | **39,67** | **1,10** | / |
| **Frappage** | **42,02** | **2,1** | / |
| **Mise en lot** | **4,375** | **0,757** | / |
| **Four** | **27,45** | **0,49** | / |
| **Scotcheuse** | **2** | / | / |

Table 12: Parameters of the Stations

Also, every machine has a different process batch:

| Station | Process batch size |
|---|---|
| 1 | Continuous |
| 2 | 17 |
| 3 | 1 |
| 4 | 1 |
| 5 | 5 |
| 6 | 50 |

Table 13: Process Batch Size of Stations

At the end of the line boxes of 50 rollers in 5 rollers packs are sealed, put into pallets waiting with the inventory to be delivered.

### 3.4 SIMULATION RUN:

After building the model on Flexsim using the previously mentioned quantities, we build a dashboard to extract the performance measures and parameters that we need.

We ran it for 17 days considering one shift:

**08:00 am 16/06/2021 to 00:00 01/07/2021**

For us to consider as many scenarios as possible, we set a high number of replications to a high value of 3000.

## 4. RESULTS AND PERFORMANCE MEASURES:

### 4.1 FLEXSIM ANALYSIS

Results from the Flexsim simulation were as follows:

- Utilization:

From 3000 replication on the Flexim model we got the result below:

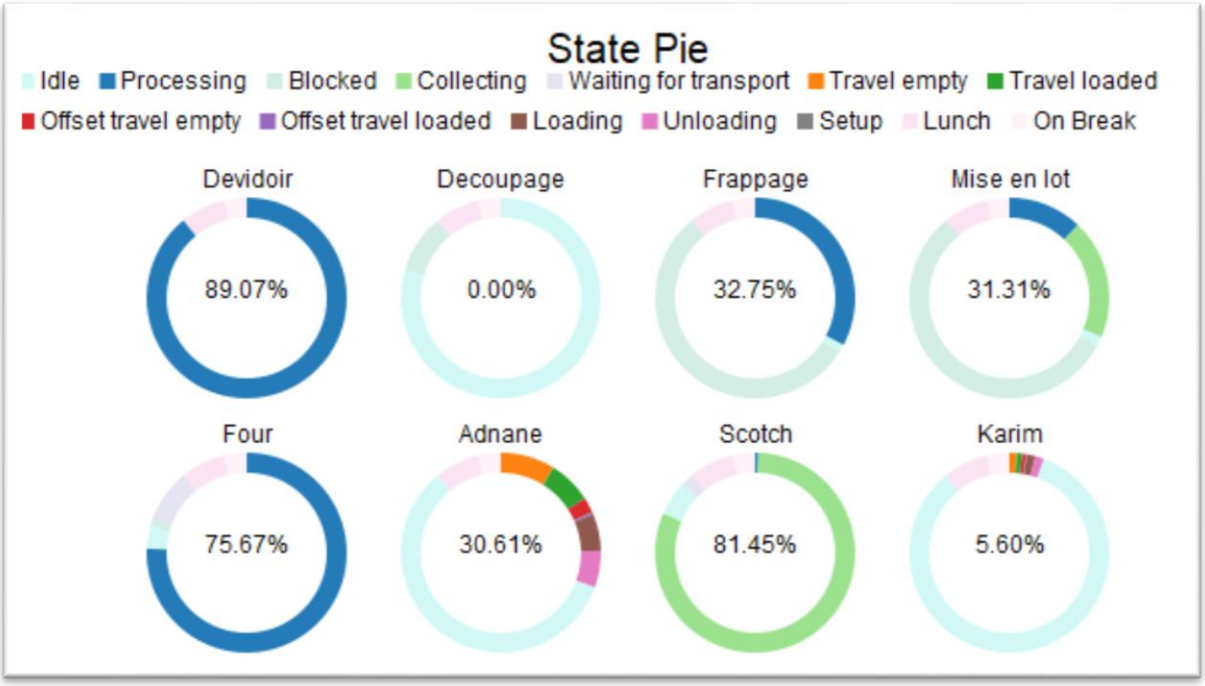


Figure 24: Result From Flexsim Report - Utilization -

We have gathered all these results on the following table and histogram to visualize it :

| Station | Utilization % | Station | Collecting % |
|---|---|---|---|
| **Devidoir** | **89.67%** | **Mise en lot** | **19.26%** |
| **Decoupage** | **31.5%** | **Scotcheuse** | **80.90%** |
| **Frappage** | **32.75%** | | |
| **Mise en lot** | **12.05%** | | |
| **Four** | **75.67%** | | |
| **Scotcheuse** | **0.54%** | | |

Table 14: Utilization and Collecting of Stations

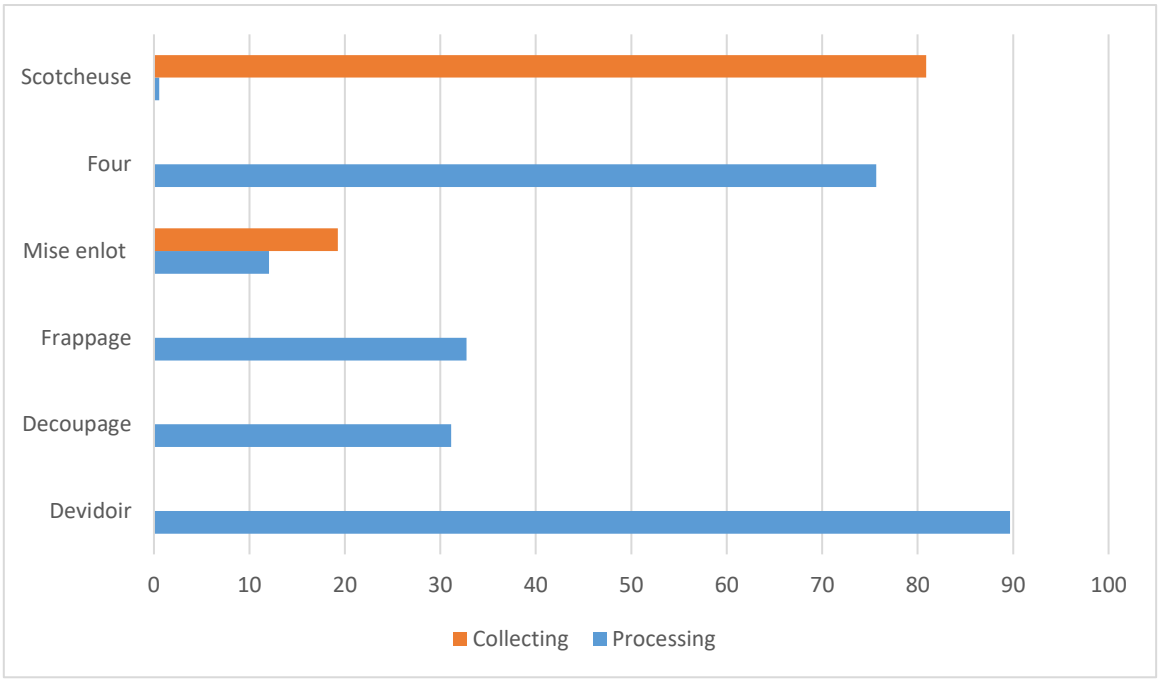


Figure 25: Histogram of Utilization and Collecting of Station

A first look at these results shows that the bottleneck station is the process «Devidoir » which has the highest utilization. Which is true because it works on a continuous process. It is a double-edged advantage; i.e. higher machine utilization rates allows amortizing these machines faster, which is advantageous. On the other hand, if we increase the rate of use of the machines without taking into account other factors (maintenance, wear rate... etc.), we risk causing a significant increase of work in process (WIP). Therefore, it is better to stop the machine rather than overproduction. The best way is to use the machine to make the right product in the right quantity at the right time.

We also noticed that the combiner “Scotcheuse” has the lowest utilization with a significant collecting utilization because of the size of the process batch.

Those previous interpretations are the reason why we choose to not take these two previous stations as consideration that it will distort our result in the next performance measurements.

Therefore, we made a decision to take from the station “Decoupage” to the station “four” as consideration in the next performance measurement.

- Cycle Time, Throughput, Work in progress :

The performance measures (CT, TH, WIP) for each station are as follow:

| Station/Parameter | TH(rolls/seconds) | CT(seconds) | WIP(Rolls |
|---|---|---|---|
| **Decoupage** | **0.0081** | **52.9094** | **0.4286** |
| **Frappage** | **0.1375** | **75.4601** | **10.3758** |
| **Mise en lot** | **0.0275** | **5.9348** | **0.1632** |
| **Four** | **0.0274** | **34.933** | **0.9572** |

Table 15: Perfomance Measurment of Stations

Little law is applied on these quantities:

$$TH = WIP/CT$$

As an example for the first, station "Decoupage"

$$TH = \frac{0.4286}{52.9094} \rightarrow TH = 0.0081\ rolls\ per\ seconds$$

For the two last station, the throughput rate is for a batch of five (0.0257 batch / second) the throughput rate per roller can be calculated by simply multiplying the batch throughput rate by batch size:

| Station\Parameter | TH(rolls/seconds) |
|---|---|
| Mise en lot | 0.1375 |
| Four | 0.1370 |
| Decoupage | 0.1377 |

Table 16: Throughtput per Roll

The performance measures for the whole line Robotplus that we took from the analysis of the Flexsim model of 3000 replication are presented in the figures below:

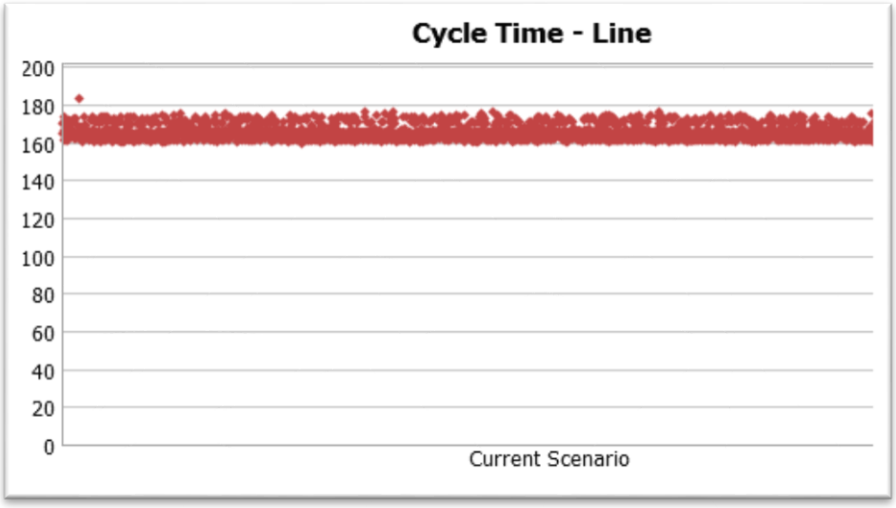


Figure 26: Result From Flexsim -Cycle Time-

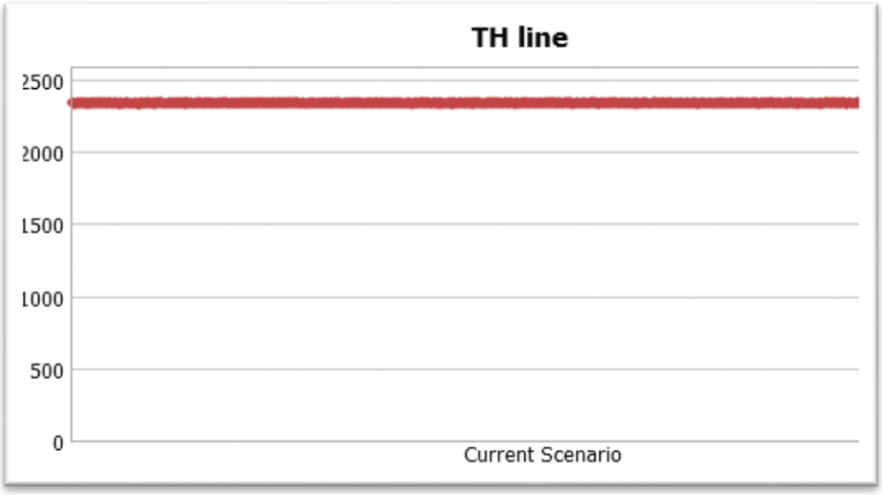


Figure 27: Result From Flexsim -Throughput-

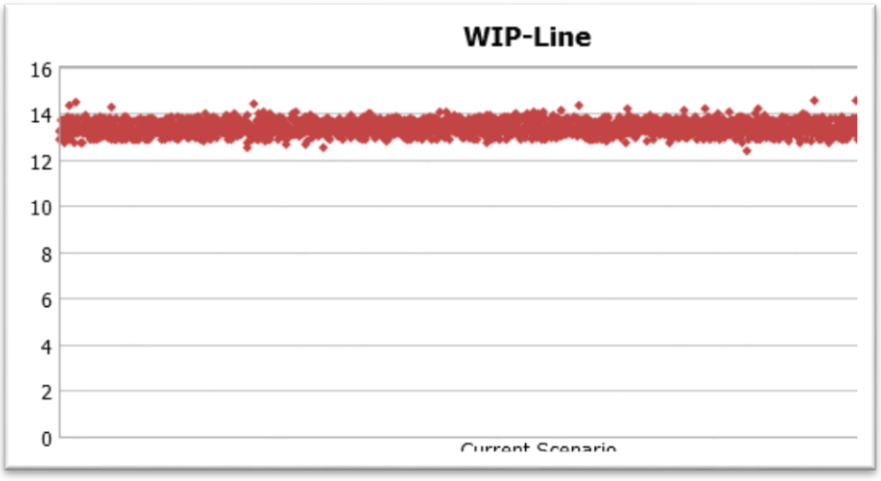


Figure 28: Result From Flexsim -Work in Process-

From this report of Flexim model we took an average of the performance measurement in relation of these 3000 replication and we presented the result on the table below:

| TH(rolls/ seconds) | CT(seconds) | WIP(rolls) |
|---|---|---|
| 0.0710 | 170.6423 | 12.1182 |

Table 17: Performance Measurment of RobotPlus Line

## 4.2 FACTORY PHYSICS:

Factory Physics is an analytical model by definition it shares basic notions and quantities with all analytical models and it has also its own terms, notions and quantities , here are some of the most important ones:

Law (Little's Law): $WIP = THxCT$

Critical work in process (Wo): WIP level for a line, which is the WIP required for a line with no variability to achieve maximum throughput (rb) with minimum cycle time (To). For a line with parameters, rb and To, $Wo = rbTo$ ·

Factory physics talks about 3 principale cases that can analyse the behaviour of our manufacturing system:

- Best case :

The minimum cycle time and the maximum throughput for a given WIP level w.

$$CT_{best} = \begin{cases} To & if\ w \leq Wo \\ w/rb & otherwise \end{cases}$$

$$\mathbf{TH_{bes}} \begin{cases} w/To & if\ w \leq Wo \\ Rb & otherwise \end{cases}$$

- Worst case :

The maximum cycle time and the maximum throughput for a given WIP level w.

$CT_{worst} = wTo$

$TH_{worst} = 1 / To$

- Particular worst case (PWC°

The practical worst-case (PWC) is a realistic possible state of the manufacturing system.

$CT_{pwc}=To+(w-1)/rb$

$TH_{pwc}=\frac{w}{(Wo+w-1)}*rb$

So we used those three cases in our manufacturing system for $w = 12.11$we got this :

| Cases | Best | PWC | Worst |
|---|---|---|---|
| CT | 113.51 | 194.66 | 1375.53 |
| TH | 0.1067 | 0.06225 | 0.0088 |

The following graph represent work in process versus cycle time as well as the performance of the line:

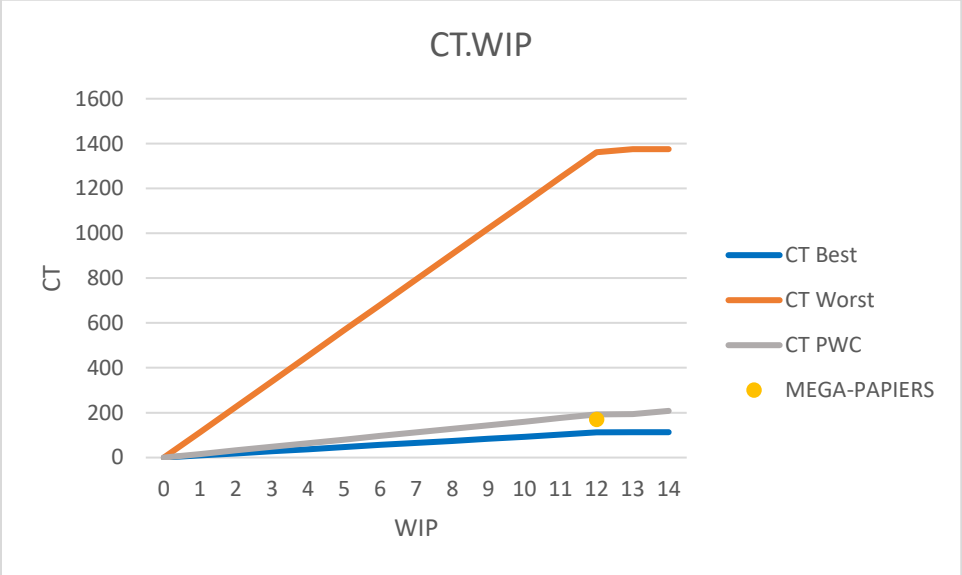


Figure 29: Graph Cycle Time VS Work in Progress

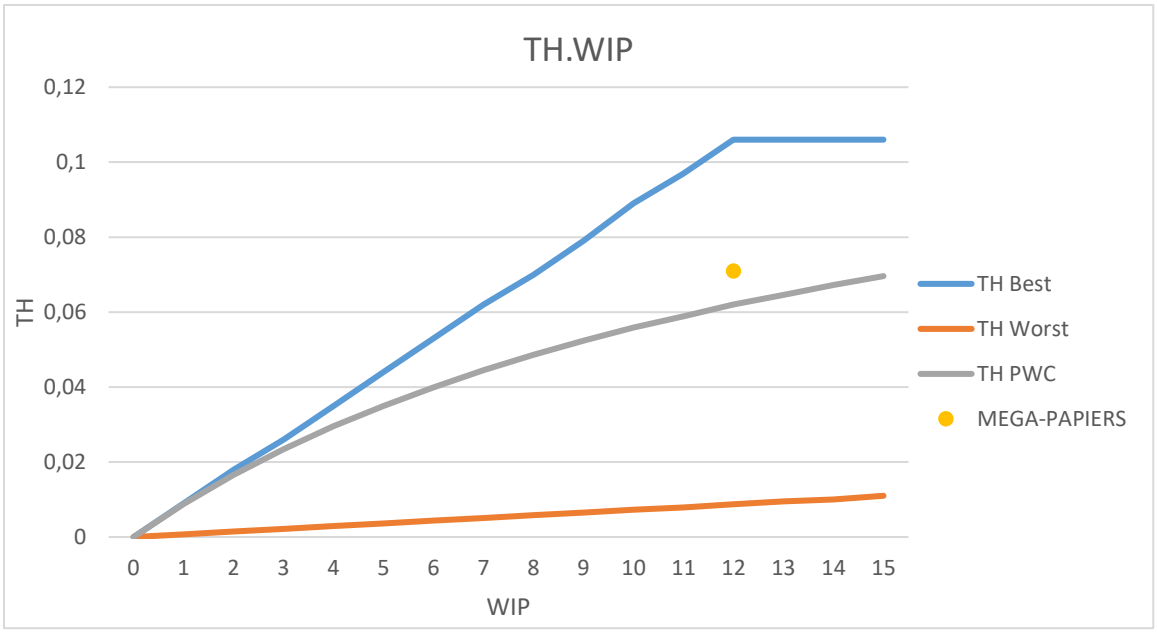


Figure 30: Graph Throughput VS Work in Progress

From the Figure 25 and Figure 26, we notice that the cycle time and the throughput of the line is located between the best case and the particular worst case and that shows perfectly the behaviour of the system without considering any breakdowns of any type.

The previous positioning of the robot plus line in comparison to the best, worst and practical worst case, may give the impression that the line is actually doing well, that's far from being true.

In our simulation model we didn't consider any type of breakdowns, so the performance measures we got represent a nearly ideal functioning that this line would never have.

To prove this point, we decided to add a random failure estimated through a few breakdowns we witnessed while observing the line in order to notice the importance of gathering the data concerning the breakdowns and considering them:

| **Breakdown** | **Time** |
|---|---|
| **MTBF** | uniform(180, 300, 1) |
| **MTTR** | exponential(0, 1000, 1) |

Table 18 : Time of a Random Breakdown

After positioning the ROBOTPLUS line's performance a 2nd time we got the following graph:


Figure 31: Graph Throughput VS Work in Progress - With Breakdown-

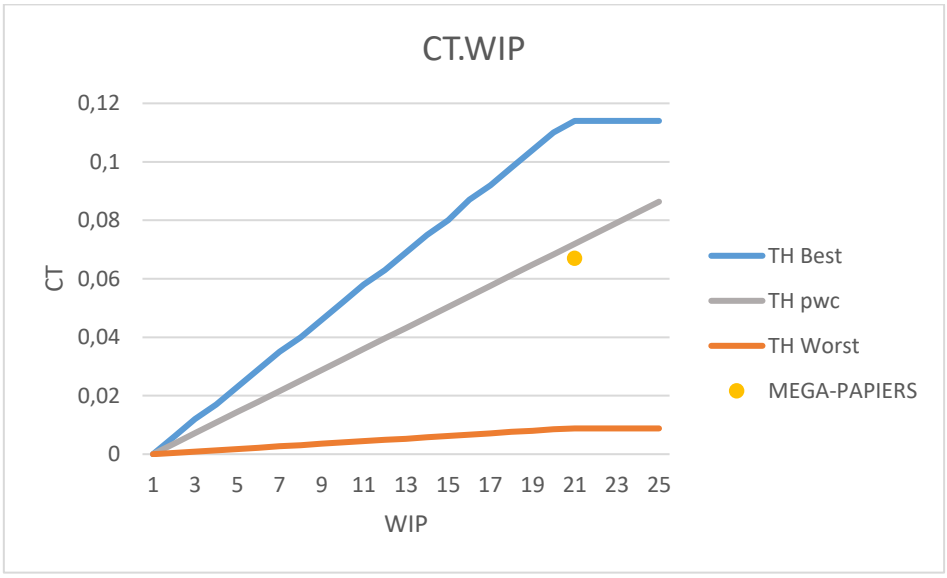


Figure 32: Graph Cycle Time VS Work in Progress - With Breakdown-

By simply adding a random underestimate breakdown, the graph shows that Roboplus performance is below the practical worst case.

This gives a more realistic glimpse into the robot plus actual performance, compared to cycle times the breakdown's time considered can drastically affect throughput.

A performant maintenance strategy could prevent a lot of the breakdowns we witnessed, for example there were breakdowns that occurred because there wasn't enough glue in the rewinding machine.

Although achieving a performance as the one we first measured or eliminating the breakdowns are far from being realistic objectives, an effective maintenance and a good tracking and record of such data can make the real difference concerning RobotPlus performance.

## GENERAL CONCLUSION:

Flexsim is a powerful tool to simulate manufacturing systems thanks to its flexibility and modern 3D rendering. The intuitive and user friendly interface simplified the process of simulation for us and helped us gain a lot of time with less effort.

MEGA-PAPIERS as a company that has dominated the Algerian market, making use of their expertise and resources, and they succeeded to export to the international market. However to compete on that level, a deeper understanding of their manufacturing system and control over it was necessary. They already have strengths when it comes to quality and costs but time is of essence.

Simulating the “RobotPlus” line has helped communicate its behaviours to the managers. Details about cycle times and our observations and the collected data about setup times, breakdowns and scheduling can open a new perspective if taken seriously.

Our work helped MEGA-PAPIERS realize the necessity of establishing a system to collect real time data about manufacturing and treat it.

## BILBIOGRAPHICAL & WEBOGRAPHIC RESEARCH:

**[Hopp & Spearman, 2008]** Wallace J. Hopp, Mark L. Spearman. Factory Physics. 3rd edition. Illinois: Waveland Press, 2008, 720 p

**[Report, 2021]** Thermal Paper Market Size, Share & Trends Analysis Repor**t** By Application (PoS, Tags & Labels, Lottery & Gaming), By Region (Asia Pacific, North America, MEA), And Segment Forecasts, 2021 – 2028, Published on February 2021

**[TRUFFI-EFPG**] Barbara TRUFFI-EFPG, Le Papier thermique (12 Décembre 2000)