Resource Allocation and Capacity Planning for Supporting an E-commerce Luxury Fashion Operation

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The task is not so much to see what no one has yet seen, but to think what nobody yet has thought about that which everybody sees.

Artur Schopenhauer

Abstract

With a reluctant start, luxury fashion has prospered and conquered its place in the digital universe. The most exclusive brands are now starting to interact with consumers both through their own branded online stores and through multi-brand e-tailers. And even though online transactions are purely a segment of the total luxury goods market, the huge success of this new marketplace has been pointing for the power increase of this segment.

The project presented in this document was developed at Farfetch, an online marketplace of luxury goods. In particular at Black&White (B&W) business unit, a full-service agency that provides multichannel e-commerce white-label solutions to luxury fashion brands. It leverages the core systems and services of Farfetch. The global presence of the company, coupled with its unique business model, in which it operates, requires a digital production platform of excellence and the ability to respond to the accentuated growth of this BU.

As a recently born business unit, B&W has blindly trusted the service provided by outsourcing resources in order to fulfil demand. With the aim to address gaps felt in the strategic planning that has implications for the operational planning, this project aims to present valuable insights for future decisions on sizing, timing and type of real assets or resources and the several inherent tradeoffs, facing the limitations that will occur in the future as an inevitable consequence of the BU's strong growth.

In the first stage, a study of the capacity and flow of items within the digital production center is carried out. This study covers all areas involved in the main product flow and aims to understand how the capacity of the different stations and the respective allocation of resources influence the productive process in general.

The project also presents the new infrastructure for B&W digital production center, its capacity configuration as well as an analysis of the expected demand profile. This presentation serves as a basis for creating the opportunity to identify the problematic areas and the chance to improve, taking advantage of the new conditions.

As a result of the project, a combination of optimization models and analysis of several scenarios as decision-support techniques were developed in order to present insights which could help on the daily activities decision making for the operational planning. The proposed solutions, while guaranteeing an increase in the capacity of each of the productive areas for which they are intended, do not necessarily imply an extra capacity investment and, therefore, some strategic insights that can be helpful through an efficient restructure of the existing space in situations of imminent response capacity have been presented. Also, a solution is proposed in order to face the current quality problems in the post production area, once again leading to the conclusion that the restructuring of this area has to face important trade-offs.

Alocação de Recursos e Planeamento de Capacidade numa Operação de Comércio Eletrónico de Moda de Luxo

Resumo

Com um início relutante, a indústria da moda de luxo prosperou e conquistou o seu lugar no universo digital. As marcas mais exclusivas estão agora a começar a interagir com os seus consumidores, tanto através das suas próprias lojas *online* como através de retalhistas multi-marca *online*. Apesar de, atualmente, as transações *online* serem ainda um pequeno segmento do mercado total de bens de luxo, a imensa adesão a este novo conceito tem apontado para um crescimento do poder deste segmento.

O projeto apresentado no presente documento foi desenvolvido na Farfetch, uma plataforma *online* de produtos de luxo. Em particular, na unidade de negócio Black&White (B&W), uma agência de serviços que cria soluções de marca branca, para marcas de moda de luxo que pretendam estabelecer uma via de comércio eletrónico. Esta unidade de negócio utiliza os principais sistemas e serviços da Farfetch. A presença global da empresa, aliada ao seu modelo de negócio único em que opera, requer uma plataforma de produção digital de excelência e com capacidade para responder ao acentuado crescimento desta unidade de negócio.

Como recente unidade de negócio, B&W confiou cegamente o serviço prestado a recursos em regime de outsourcing, de forma a perfazer a procura. Como o objetivo de resolver lacunas no planeamento estratégico que tem implicações no planeamento operacional, este projeto visa apresentar *insights* valiosos para futuras decisões relativas ao tamanho, período de tempo e tipo de ativos ou recursos, assim como os vários *trade-offs* inerentes, fazendo face às limitações que irão ocorrer no futuro por inevitável consequência do forte crescimento desta unidade de negócio.

Numa primeira fase, realiza-se um estudo da capacidade e do fluxo de *items* do centro de produção digital. Este estudo abrange todas as áreas envolvidas no fluxo principal do produto e tem como objetivo perceber de que forma a capacidade das diferentes estações e a respetiva alocação de recursos influência o processo produtivo em geral.

O projeto apresenta ainda a nova infraestrutura construída para a produção digital de B&W, a configuração da capacidade instalada assim como uma análise do perfil da procura esperada. Esta apresentação serve de base para a criação de oportunidade de identificação de áreas problemáticas que podem ser melhoradas.

Como resultado do projeto subjacente a este relatório, uma combinação de modelos de otimização e de análises a vários cenários como técnicas de apoio à decisão são desenvolvidos com o objetivo de apresentar insights que poderão ajudar na tomada de decisão das atividades diárias do planeamento operacional. As soluções propostas, apesar de garantirem um aumento de capacidade e uma utilização mais eficiente de cada uma das estações produtivas a que se destinam, não implicam um investimento em equipamento extra, pelo que se concluiu algumas estratégias úteis através de uma eficiente utilização das condições existentes em situações de iminente capacidade de resposta. É também proposta uma solução para fazer face aos problemas de qualidade atuais na área de pós-produção, concluindo, mais uma vez, que a restruturação desta área passa por t*rade-offs* importantes.

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Contents

Glossary

Go live – When the item’s photos are available to the public on the brand website;

MasterFile – File containing all relevant information to the product creation, for each brand. It contains all items and their detailed information that will arrive to be photographed;

Style Guide - Document that contains specifications for each brand, ways to prepare and photograph different items as well as all the details;

Reshoot – Repeat of the photoshoot for one or more items

Shoot – Photographic session

Target – Output produced

Acronyms

BU – Business Unit

B&W – Black & White Business Unit

JWL – Jewelry

LM – Live Model Stations

LMM – Live Model Men Station

LMW – Live Model Woman Station

QC – Quality Control

RTW – Ready To Wear

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1 Introduction

1.1 Farfetch

In 2008, with the aim of emerging physical experience with a digital platform, which means, give independent fashion boutiques an online retail presence, a virtual boutique marketplace – Farfetch - was born. Started in London by a Portuguese entrepreneur, José Neves, today's European Unicorn, Farfetch, is the online platform to shop the world's best selection of luxury items, from the best high fashion boutiques and brands.

That's what makes Farfetch a unique destination; besides styles that simply couldn't be found anywhere else being available, they are always looking for ways to find and discover new and emerging designers. As well as an unparalleled choice, it also guarantees the very best shopping experience for the customer and the ability and attempt to amaze them every day. Farfetch has a mission – to revolutionize the way the world shops – and it's just starting.

As a worldwide company, Farfetch likes to think big and global as illustrated in Figure 1, with offices currently spread in eleven cities, contents translated into nine languages, ship partners from 190 countries and aiming to achieve 2000 workers from all around the world until the end of 2017.

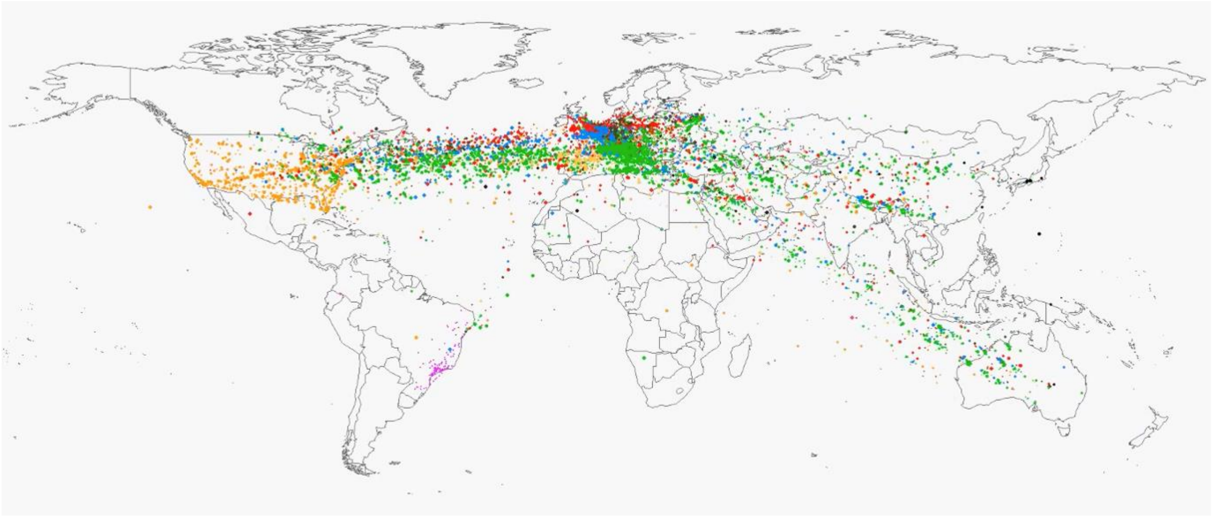

Figure 1 - Global presence of Farfetch

More than a luxury fashion company, Farfetch is a technology company where digital meets fashion. It is now structured into four business units: the major one, Farfetch.com; and other three growing ones, Black&White, Store of the Future and Browns.

This project is integrated into the recently launched Black&White, more precisely into the B&W Production Center.

1.1.1 Farfetch Black&White

"Innovation can mean doing something completely new, but it can also mean making a new combination of things that already exist." (Krogerus, 2012)

After years of tightening relationships with the brands and always with the mindset of trying to and create new, better and more efficient solutions to their needs, Farfetch introduces a unique concept - Black&White.

Created in 2015 and part of the Farfetch Group, B&W is an independently run business unit that wants to offer a multichannel e-commerce solution service to luxury fashion brands and boutiques. It is based on Farfetch's core systems and services and raises them to a proper white-label e-commerce platform. The entire technological infrastructure, for new partners, will be supported by B&W. Side by side with Farfetch, it also provides operational services, such as international payments, fraud prevention, logistics, customer service, supply, production and omnichannel delivery like click-and-collect and in-store returns. In short, B&W provides a service that allows brands to use the company's technology to power their own e-commerce sites and services.

The creation of this new Business Unit (BU) intends to accomplish even more achievements and empower the growth of Farfetch Group, from bringing brands and new boutiques onboard Farfetch platform, to taking full advantage of Farfetch core systems and services and extending the opportunity to improve Farfetch core systems, based on global e-commerce website needs and the increase of Farfetch brand visibility and value.

Since the first release of B&W e-commerce website, which occurred in early 2016, the business unit has been experiencing a fast-paced growth; it has launched about seven e-commerce websites up to now and expects about twenty more new ones to come up in 2018.

1.2 Black & White Project in Production

This project will be carried out in the B&W Production Center, a creative family that works closely together to make sure customers know every last detail about the products before purchasing. There are three primary teams - Styling, Photography, and Post Production - which make sure customers have an engaging, seamless and luxurious experience. This department is focused on continuous improvements and intends to encourage everyone to make the most of their talents and contribute ideas.

As previously mentioned, B&W is a recent innovative BU that is still in its early stage. With the aim to be able to present alternative solutions to brands and also innovate the core business of the parent company, Farfetch B&W is a BU which has been growing in a very fast pace and consistently and changing environment. Thus, the processes were not able to follow the same growth in the most efficient and effective way, especially in the Digital Production Center. With the accelerated growth and the new upcoming brands being on board of this BU, Farfetch production building was no longer sufficient to support B&W production, which brought forth the need for a new building that can respond to the amount of demand expected for 2018. In addition to this construction project, B&W aims to optimize the space required for production. In this way, in case of unexpected production spikes, the company would be able to respond quickly and without constraints.

Unlike Farfetch, the contact is mainly with the brands and not with the boutiques. Therefore, each brand is unique and has their own workflow and their own specifications. So far, with few brands, B&W production was able to plan its capacity and its resources in order to always deliver what was expected. With a sharp growth coupled with the potential that this BU has continuously shown, about twenty new brands want to be part of this creative family. That is why B&W needs to define capacities to each process and clearly understand how and which resources need to be worked in each relevant station of the production center. Only then, is it possible to understand where the opportunities are, and ensure the fulfillment and the unique specificities required by each brand in order to support all business growth.

1.3 Project Motivation and Goals

This project intends to present a capacity strategic vision which involves insights for future decisions on sizing, timing and type of real assets or resources and the several inherent tradeoffs, facing the limitations that will occur in the future as an inevitable consequence of the BU's strong growth. By understanding how the capacity of the processes and the respective allocation of resources, highlighting the critical points of the infrastructure, it would be possible to develop proposals and structured solutions that allow a future vision on how to maximize the space, equipment of the future infrastructure, as well as the allocation of resources in the most efficient way to meet the specifications for each brand.

1.4 Methodology

Considering the goals in the previous subchapter this project was divided into seven main steps. The objective of this methodology is to create the opportunity to identify the problematic areas and the chance to improve.

As in any project, it is important, at an early stage, to clearly understand its context in order to develop and propose efficient solutions later on. Therefore, the method followed in the project can be divided in the following steps:

• Identification of the main areas, processes and teams of the production center using process mapping techniques;

• Study of the capacity of existing flows and processes for each brand;

• Analysis of the demand profile of the production center expected for 2018;

• Identification of the future infrastructure in the main areas of the new digital production building;

• Identification of constraints, comparing the capacity provided by the facilities of the new production building with the expected demand;

• Give life to optimization models and several scenarios as a decision-support technique for the development of proposals and solutions;

• Proposals evaluation.

Along this project an exhausting and laborious mapping processes in the production center was made. It was important to know how B&W process differs from brand to brand and how their specifications influence the different step processes at the different stations. Using process mapping techniques and working closely with the operational production teams to identify how the processes work, it was essential to identify the bottlenecks and the main needs to the correct operation of each relevant station.

1.5 Dissertation Structure

The present document consists of six chapters. In this first chapter a brief presentation of the company and the BU in question as its business model is made, familiarizing the reader with the problem and presenting the approach and methodology followed in the execution of the project.

The second chapter presents the theoretical basis on which this work is based, resulting from a relevant literature search to this project. Thus, this chapter consists of the main subjects relevant for the project. Moreover, process mapping, strategic thinking, strategic planning, strategic capacity, operations research and in particular, linear programming are discussed.

The third chapter describes the current operation in the digital production center, presenting in a fairly detailed way the main areas, processes and respective teams.

The fourth chapter describes how the new production building has been structured and how it is being organized based on the current existing stations and processes described in chapter three.

In the fifth chapter an analysis of the expected future demand alongside with the areas capabilities available in the new building, teams and processes are also presented, in order to determine what the production center future needs will be. Furthermore, what problems and constraints may arise as a result of the strong growth phase that B&W is experiencing. Solutions are presented with a view to solving the problems encountered and described.

Finally, in the sixth chapter, a final reflection on the data and solutions obtained is presented, ending the work with some considerations resulting from the study involved in this project. Future work and developments are also suggested.

2 Literature Review

This section aims to provide a literature review on relevant topics within the scope of this dissertation. Firstly, it is given an introduction over the concept of process mapping as well as the notation used to illustrate processes present in this project. Secondly, the importance of strategic thinking and strategic planning is addressed, followed by a section that outlines the concept of strategic capacity. Finally, the last section focuses on the importance of operation research to solve an array of business and organizational problems, as well as to improve decision-making.

2.1 Process Mapping

Every product or service delivered to a customer requires a process for its realization. In a first analysis it is important to understand what a process consists of. Harrington, (1993) explains that a process is nothing more than a group of logically linked tasks that use the resources of the organization to generate the defined results in order to support its objectives. Johansson J. *et al* (1995) defines a process as the set of linked activities that take an input and transform it in such a way as to add value and create a result that is more useful and effective to the receiver above or below the productive chain. Thus, process mapping consists of structuring a model that illustrates the relationships between the processes, people, data and objects involved in the production of a specific output. (Colquhoun *et al*, 1996) The purpose of process mapping is for organizations and businesses to be able to improve efficiency. Process maps provide insight into a process, help teams brainstorm ideas for process improvement, increase communication and provide process documentation. It also helps to identify bottlenecks, repetition, delays, and inefficiencies that are not easily visible in a given process. They help to define process boundaries, process ownership, process responsibilities and effectiveness measures or process metrics.

Thus, the process mapping must be presented in the form of a graphical language, which allows to expose the details of the process in a gradual and controlled way; encourage concise and accurate description of the process; focus attention on process map interfaces; and provide a process analysis consistent with the project vocabulary (Hunt, 1996). Once the processes have been understood, one can start to change the way the organization manages them to meet its strategic objectives. Once the processes have been worked out, there may be essential information to be used in the organizational design, since it is possible to identify which work functions are interdependent and where coordination and communication are especially important.

Business Process Modelling Notation (BPMN)

The Business Process Modelling Notation (BPMN) is a standard notation for capturing business processes, especially at the level of domain analysis and high-level systems design. Therefore, BPMN is a method of illustrating business processes in the form of a diagram similar to a flowchart. A diagram in BPMN is assembled from a small set of core elements, making it easy for technical and non-technical observers to understand the processes involved.

According to (Dijkman *et al*, 2008), BPMN is made up of a set of elements including objects, sequence flows and message flows. Flow objects, denoted by geometric figures such as circles, rectangles and diamonds, indicate specific events and activities or gateways. Sequence flows links connecting objects, which appear as solid, dashed or dotted lines that may include arrows to indicate process direction. Message flows are used to capture the interaction between processes. Figure 2 provides an overview of BPMN key elements.

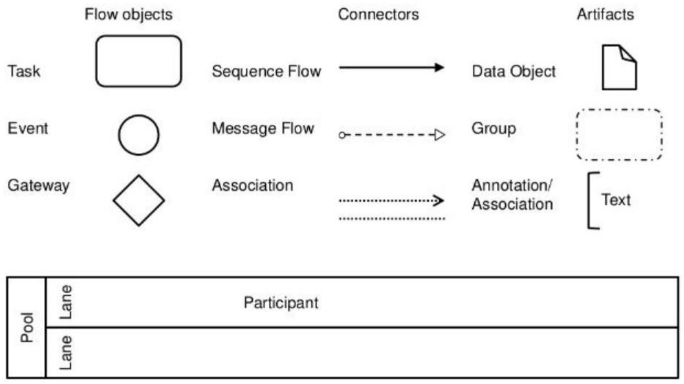

Figure 2 - BPMN elements.
Source: https://www.slideshare.net/breinhold/bpmn-20-introduction

2.2 A Vision of Strategic Thinking and Strategic Planning

The distinction between strategic thinking and strategic planning may often be confusing and, that is why Heracleous (1998) described the differences between strategic planning and strategic thinking as "… strategic thinking and strategic planning involve distinct thought processes, where strategic planning is analytical and convergent, whereas strategic thinking is synthetic and divergent". Later on, Graetz (2002) also reformulated Heracleous's definition and the relationships between strategic planning, thinking and management as illustrated in Figure 3.

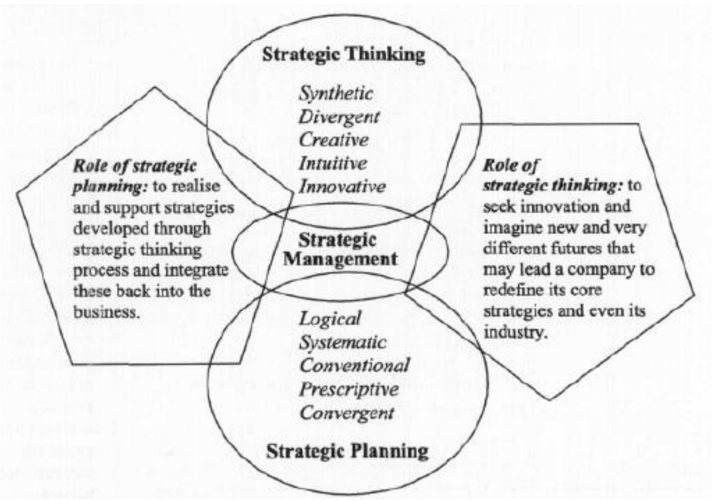

Figure 3 - Relationships between strategic planning, thinking and management.
Source: Graetz (2002)

In distinguishing strategic thinking from strategic planning, Mintzberg's (1991) point of view is as follows: Strategic planning is based on rational, linear and analytical processes and strategic thinking is about more intuitive and open-ended cognition. Strategic planning could be seen as breaking down a goal into multiple steps, formulating how the steps may be implemented, and estimating the anticipated consequences of each of the steps while strategic thinking is about using insight intuition and vision in order to develop a global perspective, of where the organization should be heading.

In brief, it could be considered that:

- Strategic thinking – is the "What" and the "Why" that is what should we be doing and why.
- Strategic Planning – is the "How" and "When" at a very high level.
- Operational Planning – is the specific details of the how and when.

2.2.1 Strategic Thinking

Mintzberg (1991) describes strategic thinking as a particular way of thinking that utilizes intuition and creativity with the outcome being "an integrated perspective of the enterprise". Heracleous (1998) and Liedtka (1998) seem eye to eye when defining strategic thinking as a highly creative, innovative, and unconventional method of thinking. Therefore, strategic thinking focuses on finding and developing unique opportunities to create value by enabling a provocative and creative dialogue among people who can affect an organization's direction. It is the input to strategic planning. Heracleous (1998) proposed strategic thinking as "discover novel, imaginative strategies which can rewrite the rules of the competitive game, and to envision potential futures significantly different from the present." Leading that good strategic thinking uncovers potential opportunities for creating value and challenges assumptions about an organization's value proposition, so that when the strategic plan is created, it targets these opportunities. Still according to Heracleous (1998) there are five elements that define strategic thinking:

- Systems perspective: according to Liedtka (1998) strategic thinking reflects a systems or holistic view that recognizes how the different parts of the organization influence each other;
- Intent-focused: meaning that one of the main concerns of strategic thinking is, and driven by, the continuous shaping and re-shaping of intent.
- Intelligent opportunism: refers that it is fundamental for organizations to seriously consider the input from lower level employees or more innovative employees who may be active in embracing or identifying alternative strategies that may be more relevant at the time.
- Thinking in time: Hamel & Prahalad (1996) strongly believe that strategy is not solely driven by the future, but by the gap between the current reality and the intent for the future.
- Hypothesis-driven: Liedtka (1998) says that the open-mindedness for hypothesis generation and testing will integrate both creative and critical thinking to the processes.

2.2.2 Strategic Planning

Strategic planning is defined as "an organized process through which the organization's leaders may take decision regarding this institution's future and development, in addition to following up on the required procedure and measures towards achieving the desired future, and finding methods to measure the success of these operations' execution" (Saleem & Subhi, 2011). Strategic planning is a tool for organizing the present on the basis of the projections of the desired future. That is, a strategic plan is a road map to lead an organization from where it is now to where it would like to be in the future (M. Mashhadi *et al*, 2007).

According to Pfeiffer (2000), the implementation of a strategic planning process is based on the assumption that the problems are numerous and that it is impossible to deal with them efficiently at the same time. For this reason, planning often starts with an analysis of the environment, where the main issues affecting a particular organization are identified through appropriate techniques. Through this survey, priorities are identified, considering that some problems have a greater weight than others. This reasoning implies the prioritization of the most significant problems and those that cause other problems identified in the analysis. From the choice of priorities, the role assigned to planning is to find ways to eliminate or reduce obstacles or threats to the development of the organization. This will be done by defining the objectives and the implementation of the activities necessary to achieve those objectives.

In short, it is a disciplined effort that produces fundamental decisions and actions that shape and guide what an organization is, who it serves, what it does, and why it does it, with a focus on the future.

Scenario Construction

According to Schoemaker (1995), among the several tools that a manager can use for strategic planning, the one that has the greatest ability to cover the possibilities in minute detail is scenario planning. He notes that: “scenarios are one way to develop sound conceptual frameworks, so that organizations and individuals will be more likely to study the right questions.” By being able to identify needs, trends and uncertainties in an organization’s macro environment, scenario construction stimulates thinking about several possible alternatives, which otherwise might never be considered.

There are six process steps in a scenario planning (Wulf *et al*, 2011):

- Definition of scope
- Perception analysis
- Trend and uncertainty analysis
- Scenario definition
- Monitoring

2.2.3 Strategic Capacity

Every organization is disposed with a large number of resources that perform their activities. The limitation of a resource while performing is quantified by its capacity, which usually is defined as the maximum output rate of that same resource. Strategic capacity planning is a process that aims to balance the use of available resources so that they are used efficiently, resulting in the output level required. Therefore, it involves decisions about *sizing*, *timing* and *type*. In many companies this involves paying close attention to every step of the production process to ensure that little or no waste is created during this process and the cost of production is kept as low as possible, while the greater quantity of goods and services are produced and sold. There are a number of factors that go into strategic capacity planning, including customer demand, for understanding the ability of the company to adjust its operation to meet this demand.

Capacity Investment

When an organization decides on capacity investment, it inevitably has to deal with simple tradeoff: the higher the capacity, the more presumed it can meet required demand, however, at a higher risk and cost. Besides that, capacity strategy decisions often involve multiple tradeoffs:

- *Sizing* concerns about deciding on the capacity level. Here, the fundamental tradeoff lies on deciding between the costs of excess capacity and the costs of capacity shortage, meaning customer waits and competitive effects. The opportunity cost of capacity shortage can be extenuate making use of several methods like putting customers on a waiting list or subcontracting.
- *Timing* refers to when to do capacity adjustments. The key tradeoff here relies on the cost of capacity adjustment and the continuing cost of excess capacity.
- *Type* is another important decision. It involves the type of resources needed for the production of different products or services.

According to Dixit & Pindyck (1994) investment decisions are defined by three relevant characteristics:

- The investment is usually partially or completely irreversible, by the simple fact that it is extremely hard to recover its full cost.
- There's usually some kind of uncertainty about the future outcome from the investment.
- Some leeway exists regarding investment timing or dynamics.

The tradeoffs are of enormous importance and have a key role to ensure each decision is best aligned with the overall strategic direction. It is also relevant that alongside with the specific tradeoffs, thinking strategically is present to help predict the future of a company. With this it is easier to develop steps on how to get into what has been planned for the future and stay away from paths that may lead to business failure. Moreover, through this kind of thinking and strategy, a business is able to become more adaptable to change (Van Mieghem & Allon, 2015).

2.3 Operations Research

During the military services early in World War II there was an urgent need, thus scientists and engineers were asked to analyse several military problems: to allocate scarce resources to the muliple military operations and to the activities within each operation in a effective manner.The applications of mathematics and scientific methods to military operations was called Operations Research, and as its name implies, operations research involves "research on operations". This term means a scientific approach to decision making apllied to problems that concern how to determine the best design and coordinate a system usually under conditions requiring the allocation of the scarce resources within a organization. Thus, it attempts to solve conflicts of interest among the components of the organization in a way that is best for the organization as a whole. An additional characteristic is that OR frequently attempts to find a best solution also knowned as an optimal solution for the problem under consideration. The breadth of OR application is unusually wide and has been apllied broadly in several areas as transportation, financial planning, health care, telecommunications, manufacturing, construction, public services and the military (Kulej, 2011).According to (Catchpoole *et al*, 2010) the major phases of a typical OR study are the following:

- Define the problem and gather relevant data.
- Formulate a mathematical model to represent the problem.
- Develop a computer-based procedure for deriving a solution to the problem resulting from the model.
- Test the model and refine it as needed.

- Prepare for the ongoing application of the model as prescribed by management.
- Implement.

Therefore, the success of Operations Research in the army attracted the attention of the industrial mangers who were seeking solutions to their complex business problems. Now a days, almost every organization in all countries has staff applying operations research, and the use of operations research in government has spread from military to wide variety of departments at all levels. OR is used in order to facilitate business decision-making, after all, OR is a huge part of planning. Some advantages of OR are:

- Simplifies complexity in the business environment: by relying on sophisticated mathematical models and advanced software tools, operations research can assess all available options facing a firm, project possible outcomes and analyse risks associated with particular decisions. The result is more complete information on which management can make decisions and set policy.
- Maximizes the usefulness of data: depending on the size of the business operations, there are a lot of data that have to be dealt with on a daily basis. Larger operations are faced with millions of information, and going through each and every piece of data can be very time-consuming and, therefore, counter-productive. Through the use of OR techniques and analytical methods, there is a way to handle all those volumes and volumes of data in significantly less time that will lead to being able to make better decisions, faster.
- Optimizes resources: resources are scarce, so businesses have to find ways to make the best use of the resources that are currently available to them, while ensuring that they are of high quality or, at least, with quality that meets the expectations of the end users.

According to Singh Rawat, OR has a wide array of methods and techniques available for solving problems, the common frequently used are linear programming, game theory, decision theory, queuing theory, inventory models and simulation. In addition to the above techniques, some other common tools are non-linear programming, integer programming and dynamic programming.

2.3.1 Linear Programming

A key problem faced by managers is how to allocate scarce resources among activities or projects. Linear programming (LP) is a method of allocating resources in an optimal way. It is one of the most widely used operations research (OR) tools. It has been used successfully as a decision-making aid in almost all industries, and in financial and service organizations. Some relevant applications are described bellow:

- Telecommunication

  According to Atamtürk & Hochbaum (2000) “the problem of balancing the trade-off between acquiring capacity and subcontracting arises in telecommunication as well as in other service industries, where holding inventory is not an option. High costs associated with building, maintaining and upgrading telecommunication networks, forces many firms to lease capacity from network providers for their communication needs rather than build their own network.” Usually, the organization allocates a fixed capacity to the lessee for the duration of the contract, commonly one year, and the lessee pays a fixed cost for this capacity whether it is fully utilized or not. Another cost, a variable one, is charged for the demand beyond the contracted capacity, which may be viewed as subcontracted demand.

- Call Centers

> In operating call centers the major cost factor is the size of the workforce. Once the number of operators to employ has been completely decided, their salary has to be paid even if the anticipated call demand does not materialize. On days when capacity is tight it is possible to employ operators on overtime basis. (Gans & Zhou, 2002) Hiring decisions are usually determined on a monthly basis. This decision is guided by detailed forecasts on the anticipated demand.

Programming problems are about the efficient use or allocation of limited resources to fit desired objectives. Usually, these are characterized by a wide range of solutions that have to satisfy specific conditions for each problem. The so called best solution to a specific problem depends on the overall objective that is to be implied in the problem description. The solution that satisfies all the problem conditions and the respective objective is named "optimal solution". A mathematical model of a given linear programming problem includes a set of linear equations/inequalities which represent the conditions for that same problem and a linear function which reflects the problem objective. Mathematical models are usually the least expensive, easiest and fastest models to develop. However, they introduce the highest degree of simplification in the model representation, opposing the real problem, adding some kind of uncertainty. Therefore, any linear programming problem is an optimization problem since it searches, for the best, among several situations, using a pre-established of optimality (Bronson & Nsdimuthu, 1997).

The construction of a linear programming model follows basic steps (Phillips *et al*, 2007)

- Step 1: Identify unknown variables to be determined, called decision variables and they are represented through algebraic symbols (e.g. x and y or x1 and x2).
- Step 2: List all constraints on the problem and express them as equations (=) or linear inequalities (≤, ≥) in terms of the variables defined in the previous step.
- Step 3: Identify the objective or optimization criteria of the problem, representing it as a linear function of the decision variables. The objective can be either to maximize or minimize.

2.3.2 Bin Packing Problem

The Bin Packing Problem (BPP) is where a set of items must be allocated to a minimum number of identical bins of a given capacity, respecting the items constraints items. The purpose of the BPP is to allocate each item to a bin by minimizing the number of bins used. This allocation must respect the maximum capacity of the bins among other may exist.

The PBP can be modeled as an integer linear programming problem. A formulation is presented below (Martello & Toth, 1990):

$$w_j = weight\ of\ item\ j,$$

$$c = capacity\ of\ each\ bin,$$

$$Minimize\ z = \sum_{i=1}^{n} y_i$$

$$Subject\ to \sum_{j=1}^{n} w_j\, x_{ij} \leq\ cy_i\ , \quad i \in N = \{1, \dots, n\},$$

$$\sum_{i=1}^{n} x_{ij} = 1 , \qquad j \in N,$$

$$y_i = 0 \; or \; 1 \qquad i \in N,$$

$$x_{ij} = 0 \; or \; 1 \qquad i \in N, j \in N,$$

$$y = \begin{cases} 1 \; if \; bin \; i \; is \; used; \\ 0 \; otherwise, \end{cases}$$

3 Current Situation

B&W model is a full-service agency providing end-to-end, multichannel e-commerce solutions exclusively for luxury fashion brands, leaving behind the traditional culture of the parent company, Farfetch, which works mainly with the boutiques. Being aware that this BU works as a service provider for the most exclusive luxury brands in the fashion industry worldwide, it is easy to understand the degree of competence required for the B&W Production Center operation.

In the B&W Production Center, temporarily in Braga, the items from the brands are received, temporarily stored, split by category, photographed, packed and then shipped back to each brand. Occasionally, they are shipped to Farfetch Production Center to be photographed there, since some items are also sold on the Farfetch.com platform. It is in the B&W Production Center that the product – the brands item's photos that are going to their website – is produced. This is the process that gives the customer access to the items in multiple views on the brand's website, until the very last detail. Typically, the time that the brands make the collections in the digital production center available is around 5 days, so the time of production in the stations must be usually between 3 and 4 days, since the remaining time is spent in the logistics areas (scan in, iron, scan out and packing). Thus, the time that the collections are in the digital production center is supposed to be smallest as possible, in order to meet the dates an dalways trying to reduce the logistics lead time, so that the product is available and ready to Go Live on the brand's website on the dates agreed. Around 70% of the items sent by the brands are samples, that is why those specific items must often be shipped back to the brand earlier than others, because they will be used in runaways spread across cities all around the world in the following days. This will push the digital production center to be flexible in order to fulfilled client's demands.

As the new digital production building is still under construction it means that the current facilities where production happens is a temporary space, and that the conditions for the daily tasks in the different areas are not ideal. Also, the accomplishment of the daily tasks are still very rudimentary and with resource to manual tools, ending up introducing errors in the productive process. Being also a fresh operational independent center, and having to obey to the unique specificities of each brand, many operational processes try to be like the ones at the Farfetch's production center, but they are still to be standardized, since the best way to organize and structure this production unit is yet to be understood.

The present chapter consists of a detailed characterization and analysis of the B&W Production Center as it is now, as well as its most relevant teams, areas, process and flows of items within it.

3.1 Presentation of the Productive Team

The productive team has three primary areas - Styling, Photography, and Post Production – that work every day to make sure customers have an engaging, seamless and luxurious experience. This department is probably the most creative and artistic of the B&W BU, focused on continuous improvements and always encouraging everyone on the team to make the most of their talents and contribute ideas. It is therefore essential that the product imagery is reflective of the unique selling point and that it is a key driver in raising the fashion credibility of each site.

As previously referenced, B&W is a recent innovative BU that is still in its early stage. Until now, the production center has always found a way to be able to deliver everything asked by the brands. And because its period of existence is at an introductory phase, the need to hire a core team, which means a fixed team, was not felt. The production has worked mostly with freelancers as a subcontracting scheme, since the demand was quite irregular and with no pattern in time. Therefore, here are presented, by teams, the resources needed to carry out the production for one brand. It is relevant to say that these would be all the necessary resources in case a brand owns all categories of items (clothing, accessories, and jewelry), meaning that the need for these resources may vary depending on the brand, because of the type of items they sell and send to be photographed.

3.1.1 Styling

Stylist

The Stylist's work starts even before the items sent by the brand arrive at the production center. First of all, he ensures all the crucial information about the brands is researched prior to the shot; he studies the brand and checks out the style guide sent by them, all to ensure the most efficient flow during the process. When the items arrive, he checks if all the items listed in the style guide sent by the brand have arrived and also contacts the brand in case any item is missing. After that, he starts organizing the items following the style guide, to improve workflow, he explains the organization of the items to the styling assistant and plans the daily targets depending on the brand and on the volume of items arrived, to make sure they are fulfilled. During the shoot, besides arranging the items properly, he works closely with the photographer on set to direct the model and select best poses/imagery. At the end, he also makes sure that every item was shot in live model.

Using his fashion and brand knowledge, he works with the Senior Photographer Specialist to continuously try and find ways to streamline the process and make it more efficient whilst ensuring the quality is maintained, by developing the brand visual aesthetic and image quality. In Figure 4 it is possible to see the Stylist work on-set.

Figure 4 - Stylist working

Stylist Assistant

The Stylist Assistant's main task is to assist the stylist during the preparation and the shot; he is also responsible for handling luxury clothing items. His work includes multiple tasks: the preparation; handle and prepare items for production process; check received items for defects as well as all the data that support the product on the system; monitor the product flow throughout each process and guarantee that the items are well handled; packing clothing/accessories. All of these tasks are intended to ensure all the quality procedures for their online sale. In Figure 5 is illustrated the stylist assistant working.

Figure 5 - Assistant stylist working

Product Stylist

The Still and Pin Up Product Stylist holds a pivotal role in the styling and photography, providing elevated and consistent imagery. Key responsibilities of a Product Stylist include the styling of clothes in the case of Pin Up, jewelry and all that is accessory - bags, belts, shoes and so on – in Stills. Besides that, he assures that all imagery is consistent and meets the quality standards. The Product Stylist must update and amend guidelines and also bring a consistent style guide. He has major interaction with the Senior Photographer Specialist and works closely with the photographer in order to provide them with the best product position for each brand. Figure 6 illustrates a Product Stylist working.

Figure 6 - Product stylist working

Model

In this context a model is a service provider. Their main role is to wear the brand's clothes and to serve as a visual aid in order to promote their selling on the brand's website. The choice of the model depends a lot on the specifications that the brand intends for the specific collection to be photographed, and also on the manner they feel the model identifies and represents their brand's image. The model is usually chosen by the brand itself. Figure 7 illustrates a model working.

Figure 7 - Model working

3.1.2 Photography

Senior Photographer Specialist

A senior photographer specialist is an element of great importance to the stations since it is he who coordinates several of the resources with the purpose of explaining the creative concept as well as ensuring that the coherence of this concept is fulfilled in all stations. At photography level he is responsible for photography for the brands shot in Portugal; set up and prepare photography station, according to each brands' specification; coordinate the team on set in the absence of head of creative; make sure shotlists are up to date, update and sometimes create guidelines/style guides for both photography and retouching, organizing and managing folders and files, whilst understanding B&W workflow and structure and help to clarify any questions and doubts from post production partner. He is in direct communication with other departments in B&W as well as main Farfetch, regarding website uploads, general problem solving, website response to imagery, resources, equipment. He also has to support on finding extra resources for the team whenever necessary and complete or create spreadsheets or other documents with relevant production information.

Photographer

First off all, the photographer has to setup, organize and maintain the photographic stations and equipment. His main work lies on photo-shooting the items according to the brand's guidelines, working closely with the other photographers and stylist on set to ensure efficient workflow that meets deadlines. In addition, it also has the responsibility to check and ensure all equipment is in good working order and maintain the expected quality of images. Figure 8 illustrates a photographer working.

Figure 8 - Photographer working

Digitec

The Digitec is always on set with the stylist and the photographer. Simultaneously with the shot his main tasks are creating folders for each item; crop the images; make sure each item has all views photographed; fill the shotlist (retouching notes and shop the look) and also assist the photographer whenever necessary. In Figure 9 represents a Digitec working.

Figure 9 - Digitec working

3.1.3 Post Production

Editor

An Editor is responsible for editing and taking a creative direction to achieve high-quality photos in alignment with brand standards, specifications and guidelines previously established while assuring their quality.

The editor's main tasks undergo edit/retouch high volumes of images under tight deadlines and ensure color consistency between image assets.

In order to maintain an efficient workflow and follow a defined process accurately and consistently, the editor collaborates with styling and photography teams to ensure expectations are clearly communicated and achieved. They are encouraged to take initiative to provide feedback and give suggestions to management for new ways to improve the retouching processes, techniques and workflows with the goal of achieving optimal quality and efficiency.

3.2 Items Classification

The classification of existing items in the production center is essential, whether for informational, organizational or control reasons. In the case of B&W, the different categories of items that arrive at the Digital Production Center are perfectly identified as shown in Figure 10.

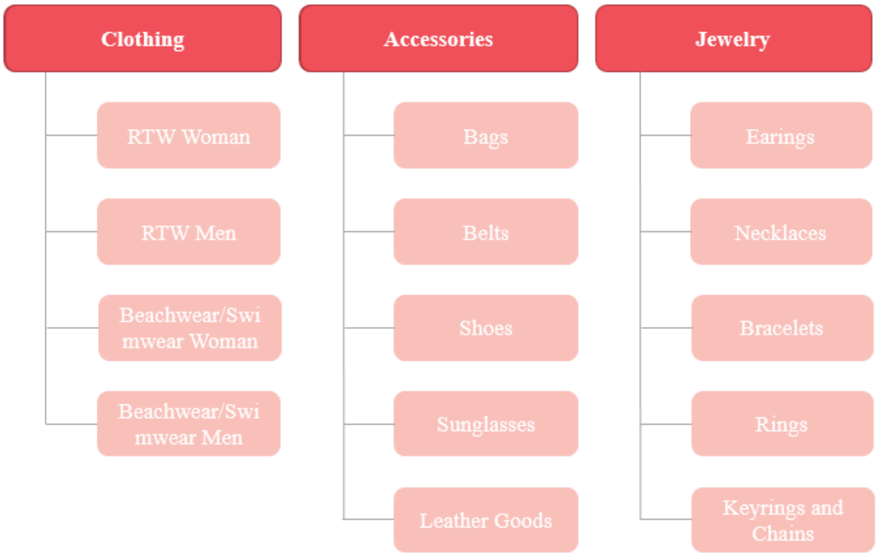

Figure 10 - Item category group

B&W allocates these three category groups into different areas of the production center. Consequently, there is also a divergence in the sequencing of the processes applied to them as described in the next sub-caption. Therefore, the distinction between these three major product categories is fundamental for a better understanding of how the process and the items flow inside the facility.

3.3 Presentation of the Production Center

In the Figure 11 it is exhibited the productive flow within the production center. It is also represented how the different categories of products interconnect with the different stations in the main product flow.

As previously mentioned and as shown below, it is possible to observe that depending on the item category, the items can suffer different flows in the production center. Also depending on the category and the brand intentions, there are items that have to go through several stations and others that only go through one. It is important to mention that all the stations work in parallel and simultaneously, there is no single flow, and as such, items do not have to pass in one station and only then be moved to another.

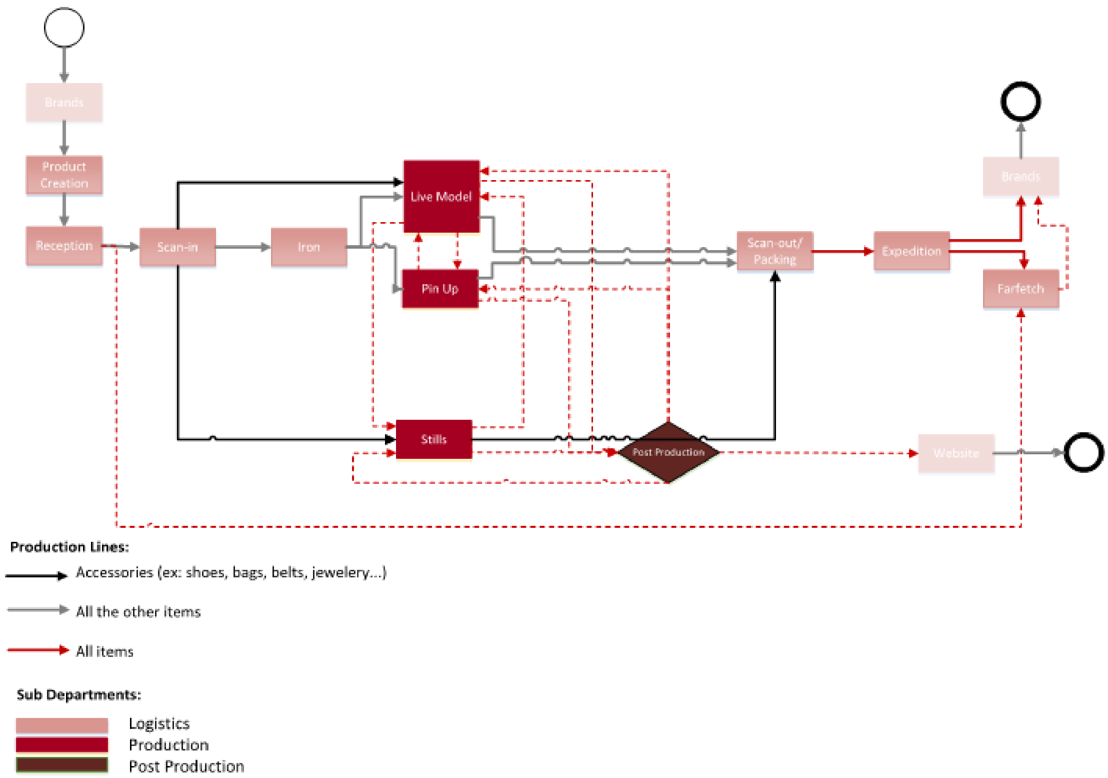

Figure 11 - Process Flow within B&W production center

Items that belong to the accessory category must be photographed in Stills, but some can also be a part of the Live Model outfit. This means that after the scan in, a part of the items follows directly to Stills, and because they can also go to LM, the reaming items can go to LM. The items change stations until being photographed by both. In case of Jewelry, the process follows the same flow as the accessories, with the exception that instead of going to Stills, they follow to the Jewelry station. Clothing items must be photographed in Live Model and in Pin Up. That is, after the scan in and iron (if necessary), part of the items may go to Live Model, and the reaming to the Pin Up station, changing stations until being photographed by both. The selection of which quantities will follow for each station is defined after the scan in, by the stylist and by the product stylist.

Within the Production Center, we can distinguish seven main areas that integrate the main product flow, as exhibited in Figure 12. The most relevant ones for this project are the stations - Live Model Men and Women, Pin Up, Stills and JWL - which are described bellow.

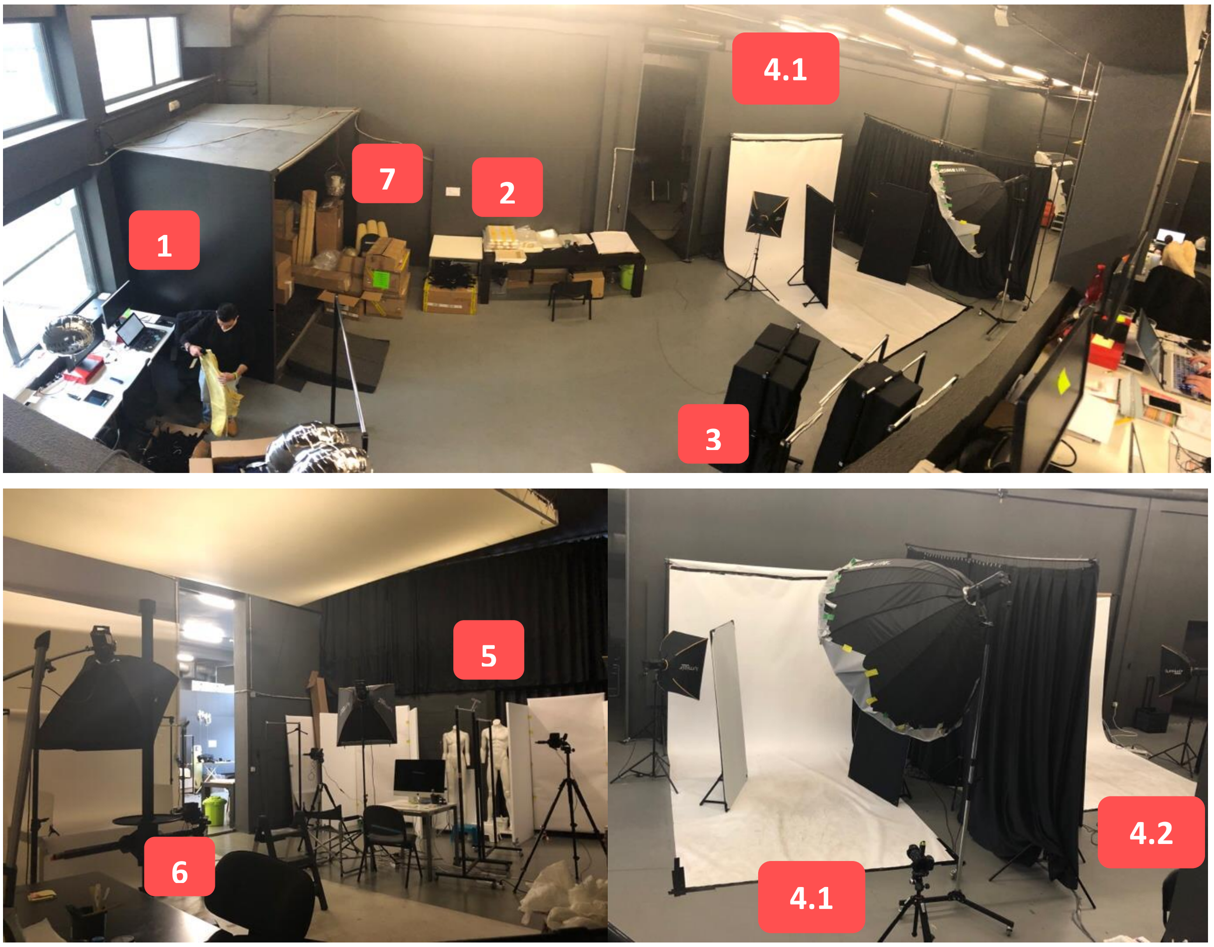

Figure 12 - B&W production center current layout

- Reception (1)
- Scan In (2)
- Iron (3)
- Live Model Men (4.1) and Live Model Woman (4.2)
- Pin Up (5)
- Stills (6)
- Scan-Out and Shipping (7)

A detailed description of each of these areas and their associated processes is presented below.

3.3.1 Reception

The reception is the area where the flow of the items received from the brands, in the production center, begins. The items received come in card boxes mainly from the UK, the USA and Italy, depending on the client and his headquarters. Transportation takes place mainly by air; even though it is more expensive, it is the quickest way, as it reduces significantly the time from product conception to the go live on the website.

3.3.2 Scan In

In this station, the card boxes are opened and item by item is taken off the box. Each item is carefully analyzed, if it comes with defects, these are photographed for being reported to the brand later. Meanwhile, for each item, the arrival date is filled on MasterFile. After that, the item is put on the rail. It is also at this stage that the items are separated in the rails by category and gender, if applicable, as represented in Figure 13 and in Figure 14.

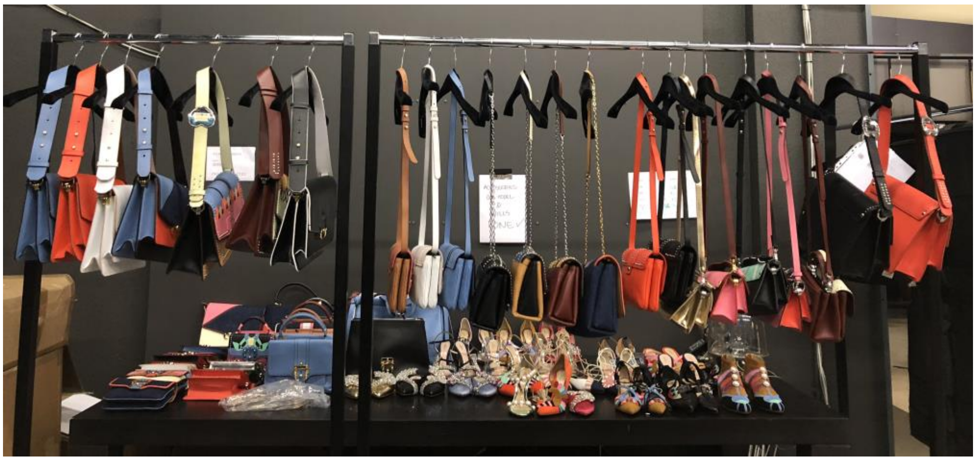

Figure 13 - Accessories category in scan in

Figure 14 – Clothing category in scan in

3.3.3 Iron

It is in this area that the items of the clothing category are ironed. Not all the items in this category go through this station, since it depends on specifications sent by the brand and also on the material of the item in question.

The person responsible for this process is someone from the logistics support team. This area is used typically after the scan in and the use rate is usually low, since it is only used when there are items waiting after the scan in, otherwise they follow straight to the stations.

3.3.4 Live Model Men and Live Model Women

It is in this area that the model wears items from the brand to be photographed. In this station only clothing category items are photographed, and sometimes some accessories, according to the brand specifications and their creative direction, as shown above in Figure 15. This station consists of two functional stations, one intended for female gender photography and the other intended for male gender photography. Apart from the model, there are several human resources that work together so that the final product - the photos - come up with the expected standards. At this station involves the work of the stylist, the stylist assistant, the photographer and the digitec. Also as part of this team there are the hair and makeup specialists and the senior photographer specialist who skip between the two stations, LMW and LMM, in case they are photographing the two genders. Otherwise, they will only be in one station or skip between the two of them with the same gender.

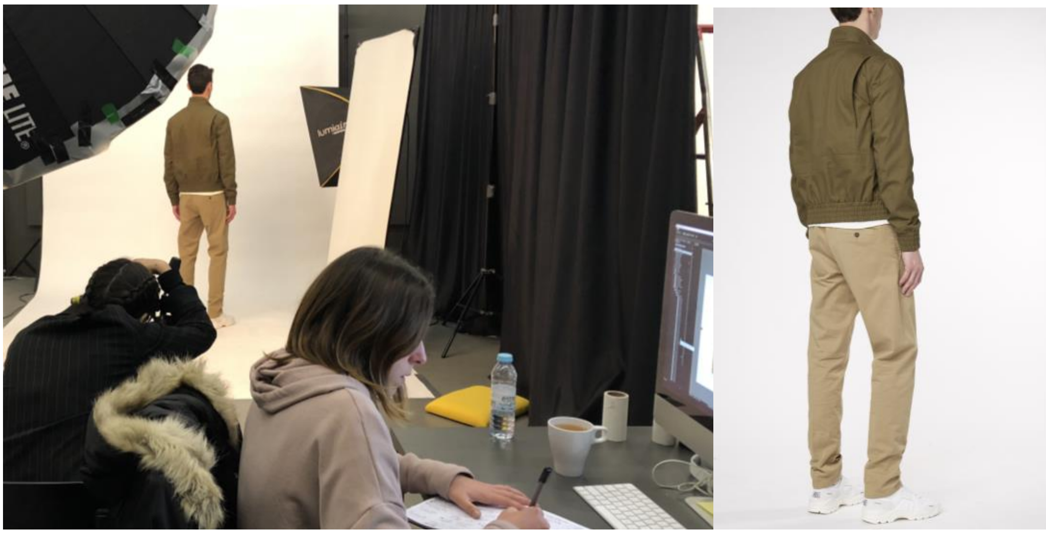

Figure 15 - LM station and LM photo

3.3.5 Pin Up

In this station all the brand clothing items category are photographed in order to have a plan view of the item, as shown in Figure 15. Also, for some specific brands photos are taken so that a three dimension of the item is available for the final customer to see. For the realization of these images, for some brands a support manikin is used.

This station has currently two workstations with the same exact characteristics that work simultaneously. In order for this station to work properly, the team consists of one product stylist, one photographer, one digitec, one stylist assistant and one senior stylist specialist for each workstation. The senior stylist specialist divides his work and time, according to the needs, between the Pin Up and the Stills stations.

Figure 16 - Pin Up station and photo

3.3.6 Stills

The Still station holds a pivotal role in the styling and photography, providing elevated and consistent imagery. Key responsibilities will include the styling of all within the accessories category and also jewelry, assuring that all imagery is consistent and meeting the quality standards. Even though jewelry is a workstation part of Stills, in the following analysis JWL will be treated as an independent station.

This station, just like the Pin Up station, currently has two workstations with the same exact characteristics that work simultaneously. So that this station works properly, the team consists of one product stylist, one photographer, one digitec and one senior stylist specialist for each workstation. The senior stylist specialist divides his work and time, according to the needs, between the Pin Up and the Stills stations.

Figure 17 represents one workstation of stills station and an example of a photo produced in this station.

Figure 17 - Stills station and photo

3.3.7 Scan Out and Shipping

This is the final stage of the production flow. One by one, the items are properly packed by the logistics support team into the card boxes. Meanwhile, the date of packing, for each item, is filled on the Master File, in order to have it registered. It is also here that the boxes are placed in a waiting area, with all the shipping documents securely attached, and await the arrival of the transport vehicle of the shipping company. This ends the flow of the items in the production center.

3.4 Post Production

As already mentioned, Post Production is one of the three primary areas that integrate the B&W production creative family. Nevertheless, since the early beginning of this BU, this team has always worked resorting to an outsourcing service that was never settled along with the other two primary areas, Styling and Photography, in the production center, even though they are closely linked. It is in this area that the photos are edited to, later on, be uploaded to the brand's website. In Figure 18 two photos are represented, one without edition and another already edited.

Figure 18 - Example of a photo before being edited, on the left, and after being edited on the right

Currently, what happens continues under conditions already described, that is, using the outsourcing service. After a brand shooting is completely over, the product – the photos of the items – is sent to one of two digital companies, based in London, to be later edited, according to the guidelines and specifications requested by the brand. These guidelines and specifications are usually sent sometime before the photos are edited to clarify any doubts that may arise, and to ensure that the information was conveyed in a clear manner so as not to delay the editing process. Once the product has been edited, it is sent back to B&W production center, which forwards it to the respective brand for approval. In an ideal situation, a previous QC would be done when receiving the product from the external editing companies, avoiding sending the product with errors, directly to the brands. Often this QC has not been possible due to the work volume increase that the production center has been receiving, so there are no resources available to carry out this step before being sent to the respective brands. As result of the absence of this important step, along with the fact that the editing process is done by external companies that do not come in contact with the rest of the creative team, many of the photos are not edited correctly or do not comply with the guidelines previously established by the brands. When these mistakes happen, the photos have to be sent back to these companies for being corrected. The frequency with which these errors have occurred has been estimated to be about 50%, which means that about half of the photos that are edited are rejected by the brands and have to be corrected in order to be uploaded into the brand’s website. These problems have affected B&W's quality of service to brands, leading to inevitable delays in final product delivery and brands discontent, affecting B&W's image as a service provider for luxury brands.

Recently, another alternative to these outsourcing companies has been tried out. Also using the outsourcing system, specific amounts of photos were sent to Portuguese external editors, who occasionally edit photos for Farfetch.com, as freelancers, and are relatively familiar with the level of exigency demanded by brands. In the same way that the guidelines were previously sent to the companies in UK to avoid work with poor quality and without fulfilling the requested requirements, these were also sent, with some advance, to the freelancers. Although the photos are, usually, returned to the production with better quality, the percentage of photos that have to be corrected has still been large, once again because there is no direct contact with the other two primary areas, Styling and Photography, in order to maintain consistency.

With the increase and growth of the BU and as time passes, this post production outsourcing option has continually proved as unsustainable, for reasons already mentioned and also because of the elevated cost, which does not reflect an efficient and reliable work.

4 B&W Digital Production Center for 2018

B&W steady growth, supported by the increase of upcoming brands and the significant increase in the expected demand, has natural implications on how the production operation is structured.

The present chapter consists of a detailed characterization of the infrastructure of the new B&W Production Center which brings back operation capacity to the production, since the previously used infrastructure clearly operated above capacity, not being able to cope with the rapid and accelerated growth expected for 2018. It is expected that this new infrastructure is already completed and properly equipped to absorb production from January 2018 onwards. Therefore, the following analysis are made based on the conditions announced in this chapter.

In this chapter, it is also presented the expected demand of the production center, for the period of the year 2018, in order to help understand the future human resources needs for the production operation, as well as capacity needs.

Considering the expected demand for the year considered, the productive capacities of each station and for each brand are also presented, since these have characteristics, regarding both the category of the items they sell and the level of exigency, considerably different.

4.1 Capacity Installed in the New B&W Digital Production Center

In order to give back operation capacity to support the digital production of the new upcoming brands as well as to keep pace with the rapid and continuous growth of this BU, a new digital production center building is being built. In Figure 19 the capacity installed and the conditions that will be part of this new facility are exhibited. Therefore, the new facility will be equipped with three cells, each with one LMW station, one LMM station, one Stills station and one Pin Up station. Since the amount of items in jewelry category sent by the brands has been quite low when structuring the new building, it was considered that only one station of this type would be needed and it would not be integrated into any particular cell, along with the other stations.

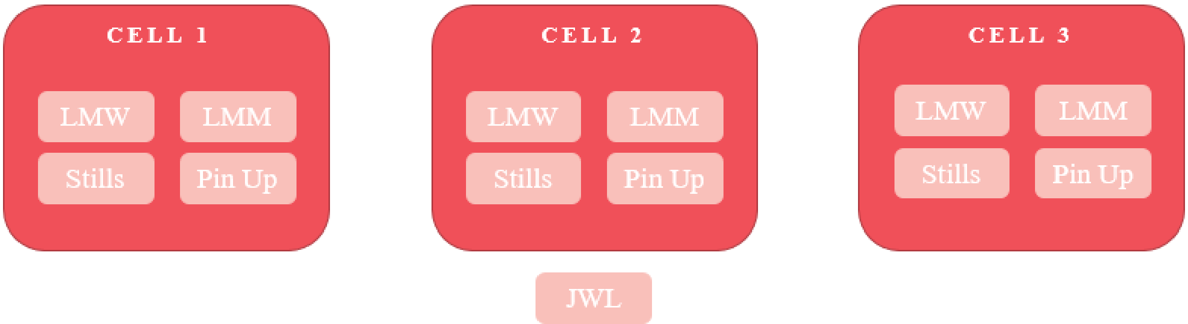

Figure 19 - B&W digital production center installed capacity configuration

Since this digital center intends to provide an exclusive and excellence service for some of the most luxury and prestigious brands worldwide, one of the strategies adopted by the BU concerning the digital production center is that there are no mixed brands within it. This means that two or more different brands cannot be produced within the same cell. Each cell, along with its respective stations, is allocated only to one brand until the production for that brand in the different stations of that cell is finished. The cells and their stations present the same rigid structure, which means that the four stations are allotted to only one cell. In the case of the JWL station, this rigid structure no longer occurs, the JWL station will work as a mobile structure and can be allocated to any of the 3 cells whenever necessary.

The strategic decision not to mix brands within the digital production center does not only create privacy and protect ownership of brand's new collections from being released, but also creates an inmost, unique and personalized service for each.

4.2 B&W Production Center Expected Demand Analysis

The demand profile of the digital distribution center has seasonality on an annual basis. The demand soars considerably in the summer and in October, as it would be expected, since these are the times of the year in which Autumn-Winter and Spring-Summer collections are received for later release to the public. Although there are clearly two times of the year in which the arrival of the product is more conducive, many of the brands send parts of collections, and not everything at once; hence, there are seasonable peaks in the arrival of items, but in less quantity. This trend can be seen in Figure 20, which represents the annual demand behavior expected for 2018.

Figure 20 - Expected demand in items

Even though eighteen new brands and seven current ones are expected, there are only nineteen brands represented (in which, fifteen new), since only these will be produced in the production center in question.

Seasonality of demand, as described earlier, has unavoidable implications for the occupation and the operation of the digital production center. This expected demand growth requires a careful analysis in order to measure the impact that will be felt in the digital production center, either in terms of flows of items or in terms of required resources aligned with the capacity installed.

Resources requirements are expected to increase with the demand growth. Increasing the level of production impacts inevitably not only on the requirements of resources but also on the capacity planning for the performance of all the digital production center activities. Growth will also put increased pressure on processes related to the flow of items inside the facility. However, having concluded that the flow of items is not, at the time, a source of concern, it is actually about the problems of strategic resource allocation and capacity planning that the analysis and the subsequent development of solutions are centered.

4.3 Productive Capacity of the Stations

The productive capacity of the stations (LMM, LMW, Pin Up, Stills and Jewelry) was studied in this project with the purpose of realizing what restrictions in the main processes could limit the responsiveness of the production center. Besides that, it was important to understand what and how many resources are needed in order to keep the needed capacity in the different stations. Currently, the B&W Digital Production Center operates on a single shift basis on weekdays. Occasionally, and to be able to meet the deadlines, it also works holidays and weekends; at weekends it operates only on Saturdays, also with only one shift. It is hoped that, with the new building and the consequent improvement on the conditions for production, only one shift will continue to be held, but from now on only just on working days.

Until now, the registration of the capacity of the stations was not made, and having each brand unique specifications, it was very difficult to understand what was the capacity for that specific brand in each station, which deeply reflects on how much time a shoot would take, and also what are the resources needed to meet the capacity in order to accomplish the deadlines establish with the brands.

4.3.1 Different Brands Impact on Each Station Production Capacity

As previously mentioned, each station receives certain categories of articles, that is why the determination of the capacity (target) of the different stations of the B&W digital production center is not immediate, as it depends not only on the installed capacity in the stations. For each brand two variables should be considered in this calculation, the percentage of items received that goes to each station, meaning that for some brands there are stations that may not be used; and on the specifications required by the brand, which is reflected in the level of exigency, and for this reason in a higher or lower processing time.

For each brand, data were collected to quantify not only the percentage of items that goes to each station, but also capacity of the stations. Table 1 presents relevant information collected concerning the five main relevant processes of the production center: Live Model Woman, Live Model Man, Pin up, Stills and Jewelry stations. As described in the previous sub-chapter referring to the expected demand, this table will also only consider the brands that will be produced in the center, since the detailed information about the reaming ones is not relevant. For each brand it is presented the percentage of articles that go to each station and the number of items that can be produced in each one, in one shift of eight hours, that is, in one day.

Table 1 - Percentages and targets per station

	Percentages per Station					Targets per Station				
Brands	LMW	LMM	PIN UP	STILLS	JWL	LMW	LMM	PIN UP	STILLS	JWL
A	0,98	-	0,98	0,2	-					
B	-	0,66	0,66	0,34	-					
C	-	0,55	0,55	0,43	0,01					
D	0,66	-	0,66	0,33	0,01					
E	0,29	-	0,29	0,69	0,02					
F	0,76	-	0,76	0,24	-					
G	0,17	0,74	0,91	0,09	-					
H	-	-	-	1	-					
I	-	-	-	1	-	**CONFIDENTIAL**				
J	0,6	-	0,6	0,3	-					
K	-	-	-	1	-					
L	0,59	0,14	0,73	0,23	0,05					
M	0,26	0,21	0,47	0,49	0,03					
N	0,44	0,12	0,57	0,38	0,01					
O	0,86	0,86	0,48	0,15	-					
P	0,61	-	0,61	0,17	0,22					
Q	0,06	0,66	-	0,25	0,03					
R	-	0,87	0,54	0,09	-					
S	-	-	0,76	0,18	0,03					

In order to obtain targets for each brand and station it was assumed that both the resources and the equipment available for each station are continuously used to the maximum of their capacity, which means that for both Stills and Pin Up stations it is considered that both the workstations are always working. Data concerning brands already produced in the B&W production center were estimated taking into account previous shoots. For data concerning the upcoming new brands, for the percentage of items going to the different stations, data were collected according to items category sold on the Farfetch.com platform through Farfetch database, and an estimation was made as represented in the table above. The targets values concerning the new upcoming brands were estimated considering the level of exigency similar to brands already produced in B&W.

It is important to highlight that the percentage of items that go to each station, from each brand, can vary significantly depending on the collections sent. On the other hand, the quantity produced per day for a particular brand may also vary, depending on the robustness of the items in a particular collection, and this variation is usually very slight. In this way, the values presented in the table above are only approximations of the reality, since there is still no detailed information about the type of items to be received for each brand, in 2018.

4.4 Number of Human Resources Needed for Each Stations

Below, in Table 2, a summary of the human resources required for the full functioning of the stations is presented. This means that for the LMW and LMM stations the team consists of four resources; for Pin Up and Stills there are two teams, one for each workstation, making up four resources, the same happening to JWL, whose team also has four resources.

Only the resources stylist, product stylist, styling assistant, photographer and digitec were considered in this table, since they are the resources with more interest and relevance for the study and later analysis in chapter five.

Resources like senior photographer specialist and hair and makeup were not considered. The senior photographer specialist was not considered since this resource is already part of the current B&W core team, and will not suffer variations regardless of demand. The hair and makeup resource was not also considered since its use rate is very low and for that reason won't be considered as a possible member of the core team; so it is assumed that it will always be subcontracted.

Table 2 - Necessary resources for each station

Human Resources	LMW	LMM	PIN UP	STILLS	JWL
Stylist	1	1	0	0	0
Product Stylist	0	0	2	2	1
Stylist Assistant	1	1	2	2	1
Photographer	1	1	2	2	1
Digitec	1	1	2	2	1

5 Strategic Resource Allocation and Capacity Planning

In the course of this project a study of all the areas and processes that integrate the main product flow of the production center was carried out, excluding areas such as reception, scan in, iron, scan out and shipping, since they were not relevant to the study in question. The areas in which limitations were identified, namely the Live Model Man, Live Model Woman, Pin Up, Stills, Jewelry stations, and Post Production will be presented with particular detail, as it is here that the needs for strategic insights are met, so as to fit their capacity needs imposed by the company's growth.

The contribution of this project is to give qualitative and quantitative insight into the reality here presented regarding capacity planning and resources allocation which involve budgeting practices and relevant tradeoffs in decision making. The optimal hedging strategy often leads to unbalanced capacities, in the sense that no single demand scenario may exist that implies full utilization of all resources. The strategy of the BU, especially in the digital production, should be taken into account in the development of the strategic resource allocation and capacity planning, since decisions such as changing the constrains presented in the previous chapter can have important implications in the flow of items and also in the way the business is run at the time. Thus, this chapter aims to present proposals developed with a view to give valuable insight in order to make more efficient decisions regarding resource allocation and capacity planning, in order to solve imminent problems that may arise with the BU growth. For each of the areas identified as problematic or relevant plans have been suggested that will allow a more critical view for a better future planning, resources allocation and available capacity.

Proposals that are considered viable in the medium term, will be presented since the present study was considered only for one year period. Most of the solutions presented are modular, which means that they can be combined to find the ideal solution for a certain period of time. Scenarios are also presented with the aim to allow the digital production center to maintain the production system without disruptive or considerable investment as well as to avoid solutions that require deeper and therefore more costly changes. Also in this chapter a proposal to solve the problems felt in the post production area was developed.

5.1 Strategic Resource Allocation and Capacity Planning of the Stations

Now that a new infrastructure, with all the necessary conditions for digital production, will be available, it is necessary to give strategical insight in order to provide the operating manager with relevant information to an efficient use, not only of the resources, but also of the installed capacity in order to meet the deadlines agreed with brands.

Capacity Required

At an early stage, it was necessary to analyze whether the conditions now granted for the B&W digital production were sufficient to meet the expected demand, already referred to in Chapter 4. In order to find it out the requested capacity, for each month, it was necessary to assess how long it would take to produce each brand, in each station. Since, the number of items to be photographed (expected demand), the percentage of that items which goes to each station, and the target for each station and brand, significantly influence the production times, Equation (1) was used to obtain production times for brands in each month. Table 3 shows production times for January brands as an example, and in Appendix A this study is presented for all months of 2018.

$$Production\ Time_{tb} = \frac{demand_{tb} * (items\ \%\ per\ studio)_{tb}}{target_{tb}} \quad (1)$$

Where:

t is the month

b is the brand

Table 3 - January brands production time

Brand	LMW	LMM	PIN UP	STILLS	JWL
C	0	8	7	5	1
E	5	0	4	8	1
G	2	9	10	1	0
M	3	3	6	6	1
N	8	3	9	5	1
Total number of days	18	23	36	25	4

After this analysis was carried out for all months of the year, the production time of each brand was obtained, in each station, under the conditions previously stated in Chapter 4. It is important to note that all the values related to production times, both those presented above and those presented throughout this chapter, already consider the slack resulting from stations setup times, unexpected reshoots, technical changes in equipment or interruptions, which are an integral part of the production process.

The restriction already described in Chapter 4, which consists of each cell can only produce one brand at a time, means that one cell is obligatorily blocked for a specific brand until all the items from that brand are photographed in all stations. By imposition of this restriction, means that as long a station is running inside the cell for a particular brand, the cell will be locked for that same brand until that station finishes producing it. Being aware that all stations within a cell work in parallel, the previous restriction will impose that the station that has the longest production time, that is, that takes the longest time to produce, will dictate the time of production of that brand in the production. This happens because as long as there are items to be produced in one of the stations of a cell, even if there are stations in that cell that are no longer in use, they cannot be used to produce another brand. Therefore, the production time, for each month, and for the brands produced in that period is presented also in Appendix A.

At the moment, there is only information on what will be the demand for each brand for all months of the year 2018 will be. There is no information as to what is the range of days of the month in which the production for a particular brand will have to happen is, since, as already mentioned, the dates are only announced by the commercial team with about 1 month, or less, in advance. Hereupon, it is assumed that, when this information is already available, the allocation of the brands will, whenever possible, be done in a way to minimize the number of cells used, and consequently the number of required resources. It is assumed the maximum capacity is fixed, due to the fact that the available area is limited and there is virtually no possibility to add capacity by building a new facility when the demand for capacity evolves to an unexpected high level.

With the aim to be able to provide strategic insights on the capacity planning of the new infrastructure, with production times already calculated for each month and for the respective brands, it was important to realize not only how the configuration of the productive stations of the new building influences the fulfillment of the demand, but also if according to this configuration, it would be possible to meet the expected demand for each month.

Therefore, in order to determine whether, according to the configuration presented, the number of cells available is sufficient, with the minimization of the number of cells as assumption, an adaptation of Bin Packing Problem optimization model, described in the literature, using linear programming, described below, was formulated.

Index:

$t \in \{1, 2, \dots, 12\}$ – number of months

$b \in \{1, 2, \dots, 19\}$ – number of brands

Parameters:

d_{tb} - Demand in month t by brand b

c_t - Capacity of a cell on month t

Decision Variables:

y_t - Number of cells needed in month t

Objective Function: Minimize the number of cells used in the digital production center

$$Min\, z = \sum_t y_t$$

Subject to:

Capacity constraint:

$$\sum_b d_{tb} \leq c_t * y_t, \forall t$$

$$y_t \geq 0, \forall t$$

In order to obtain results, being aware of the objective function, variables and constraints of the optimization model, the CPLEX software was used. Appendix B shows the implemented code as well as the result of the stated conditions. Table 4 shows the number of cells needed to meet demand, for all months of the year concerned.

Table 4 - Number of cells required to meet demand for 2018

Months	Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Available Capacity	3	3	3	3	3	3	3	3	3	3	3	3
Current Scenario	2	1	3	2	1	4	4	1	3	4	2	1

It can be seen from the table above that for the months of June, July and November, under the conditions described in Chapter 4, the configuration of the stations of the new building is insufficient to meet the expected demand requirements since de number of cells needed is greater than the number of cells available.

Later on, in an attempt to understand why the conditions of the new building were not sufficient to meet the demand for the year in question, the average of the occupancy rate, for each of the stations, was calculated, as exhibited in Table 5. These figures were calculated by taking into account the number of days that the studios are available for use, considering only working days and the previously calculated production times for the year in question, which correspond to the number of days that they will be used.

Table 5 - Occupancy rate per station

Station	LMW	LMM	PIN UP	STILLS	JWL
Occupancy Rate	30 %	26 %	47%	39%	4%

Through this analysis it is possible to realize that the occupancy rates are quite low, and that no station reaches a rate of at least 50%, which means that the occupation time of the stations does reach half of the time that they are available. One of the reasons why these percentages are so low can be, once again, the restriction that allows only one brand allowed per cell, since in many cases, as reflected in the table above, some of the stations are no longer in use, and are just waiting for the longer station of the same cell to finish producing, so they can be used again.

As previously mentioned, brands usually provide very short periods of time for the production of their collections, periods which must be strictly respected. In this way, another study that should be analyzed is the production time of each brand in each station. Table 6 shows the average, in days, of the production time of brands, in each of the respective stations, respecting the conditions and restrictions described in Chapter 4, for the year concerned.

Tabela 6 - Average of production time (days) for each station

Station	LMW	LMM	PIN UP	STILLS	JWL
Average Production Time (days)	6	6	7	5	1

From the table above it is possible to verify that many production times are over the 3-4 threshold, which is typically the time range available for the production in the stations given by brands. These figures show that production may be compromised, since, on average, more days are needed to meet the demand.

Since the stations have a low occupancy rate and, even so, the configuration of the stations cannot fulfill the demand, it can be concluded that, under the conditions presented, the capacity planning of the stations does not reflect the most efficient use of the capacity installed. It is now important to develop solutions and action plans to prepare the infrastructure for the upcoming growth.

Resources Required

The type and amount of resources, which are prime economic factors of production, are relevant determinants of the network's production abilities and limitations. Therefore, another important need for the digital production center growth, for the year in question, is trying to understand not only the best; but also the most efficient and least expensive way of allocating resources, in this case teams to the different stations. In order to reach the required number of teams, it would be necessary to estimate the number of production days required for each station, which means working days for the teams. It is relevant to state that a team is hired per day, regardless of whether production takes less than that; so it only makes sense that whole numbers are displayed regarding the working days for each station. Table 7 shows the working days required for each station and for each month in order to meet demand, under the conditions presented earlier.

Table 7 - Working days required for each station for 2018

Months	LMW	LMM	PIN UP	STILLS	JWL
Jan	18	23	36	25	4
Feb	11	3	13	9	1
Mar	13	33	35	19	3
Apr	20	3	28	25	3
May	3	3	6	20	1
Jun	57	35	73	39	4
Jul	22	33	37	44	4
Aug	3	3	10	7	2
Sept	19	15	31	33	3
Oct	47	36	61	35	4
Nov	12	6	20	32	2
Dec	3	3	6	6	1

Subcontracting is very useful for organizations to improve their response to demand, which can be highly variable sometimes. However, deciding when and how many teams to subcontract it not easy. So, to answer this and to face important trade-offs between capacity allocation and subcontracting an analytical model was developed optimizing the interrelated capacity level and subcontracting, to satisfy demand over the consider period. Thus, for the resources allocation, an optimization model using linear programming, was formulated, in order to understand, for each station, what is the most efficient and least expensive way for the allocation of teams is. In the following formulation it was consider that teams may be contracted as core team or as an outsourcing service.

Index:

$t \in \{1, 2, \ldots, 12\}$ – number of months

$s \in \{1, 2, \ldots, 5\}$ – number of stations

Parameters:

x_{ts} - Number of working days required for month *t* in station *s*

n_t - Number of days a core team works in month *t*

c_s - Cost per year of a core team of station *s*

d_s- Daily cost of a subcontracted team of station *s*

Decision Variables:

y_s - Number of teams belonging to the core team in station s

w_{ts} - Number of days that will be needed in subcontracting regime, in month t in the station s

Objective Function: Minimize cost related to hiring as core teams or as subcontracting service

$$Min\ z = \sum_{s} y_s * c_s + \sum_{t} \sum_{s} w_{ts} * d_s$$

Subject to:

Capacity constraint:

$$y_s * n_t + w_{ts} \geq x_{ts}\ \forall\ t, s$$

Non-negativity constraints:

$$y_s \geq 0\ \forall\ s$$

$$w_{ts} \geq 0\ \forall\ t, s$$

For the n_t parameter only working days were considered. Regarding the costs c_s and d_s, for each station, a sum of the average cost of each resource belonging to the station team was considered. It was considered that the daily cost of subcontracted team is about 1,8 times higher than the daily cost of core team. It is important to highlight the daily cost of a core team is lower than that of a subcontracted one. However, an important trade off must be considered, as hiring a core team requires annual employment contracts.

Also, for this formulation, it was used the software CPLEX in order to obtain results. Appendix B shows the implemented code as well as the result of the stated conditions. The result obtained for the number of teams, for each station, in case core teams are hired, is shown in Table 8, and the number of days required, for each station and for each month, for subcontracting teams is shown in Table 9.

Table 8 - Optimal number of core teams for each station

Station	LMW	LMM	PIN UP	STILLS	JWL
Number of core teams	1	1	2	2	0

Table 9 - Optimal number of subcontracting days for each station

Months	LMW	LMM	PIN UP	STILLS	JWL
Jan	0	1	14	3	4
Feb	0	0	0	0	1
Mar	0	12	14	0	3
Apr	0	0	8	5	3
May	0	0	0	0	1
Jun	36	14	52	18	4
Jul	0	11	15	22	4
Aug	0	0	0	0	2
Sept	0	0	11	13	3
Oct	25	14	39	13	4
Nov	0	0	0	11	2
Dec	0	0	0	0	1
Total number of days	61	52	153	85	32

5.1.1 Scenario 1 – Use of both LMW and LMM Stations

This scenario was developed based on an analysis of the available equipment in the productive stations area, not only with a view to reduce the processing time in the LM station but also aiming at a better utilization of the installed capacity. Currently, the LMW station is only used for producing brands that sell items to the female gender. In an analogous way, for the LMM station is only used to produce brands that sell the masculine gender. The simultaneous use of the two stations, LMM and LMM, only happens when producing a brand that sells items for the two genders, women and men. However, this solution offers an inefficient use of the equipment, since if there is a brand that only sells items for one gender, only one of the stations will be in use, the one of the gender that the brand sells, the other station will be unavailable because it is part of the same cell. This proposal is feasible, since both stations have identical technical configurations, being named LMW and LMM only by pure convention. On the other hand, a limitation of this proposal is that the possibility of using both stations (LMW and LMM) it is only viable if the brand is willing to use two different models, one for each of the stations.

The privileged criteria of the digital production management center are the rapid response capacity, that is, the ability to meet the dates agreed with brands, a more efficient use of installed capacity and, of course, the investment. It is considered that an appropriate solution to achieve the project objectives and also to meet the operational requirements will be the use of the second station. This means that, for any brand that sells items for only one gender, it will be consider the use of the two available stations, LMW and LMM, instead of using only one.

Figure 21 represents a comparison between the average production times of the current scenario, that is, in the case of a brand that only sells for a gender, which only uses the station corresponding to that same gender, and the new one, the use of both LM stations. It is possible to observe the decrease in the production time inherent to the replacement of the current system by the new one.

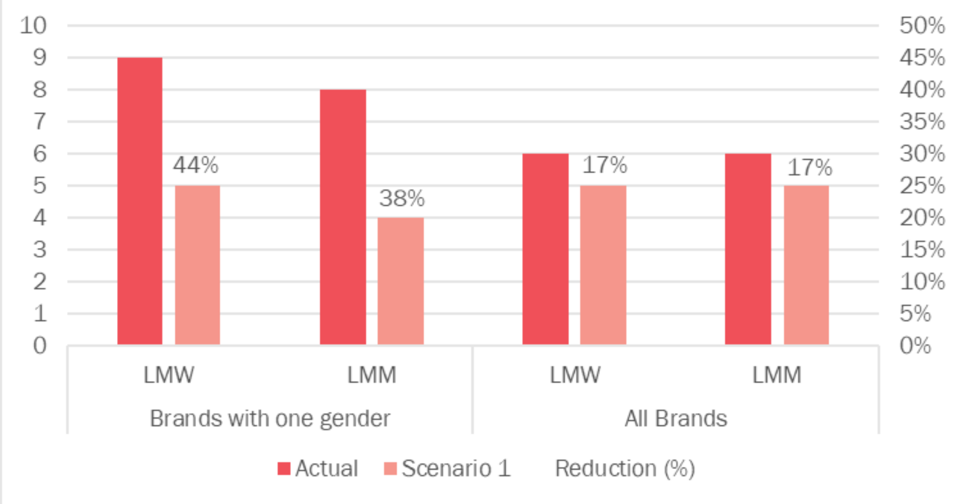

Figure 21 – Comparison between production times for LM station

In order to understand if this scenario had any impact on the number of cells needed for the year in question, for those cases where LM's stations was the longest station and therefore the station that dictated the production time of a brand, the new duration values obtained were replaced. With the application of this scenario, the result is that if for a brand the duration corresponding to the LM station continues to be the longest comparing with the remaining stations, this will continue to be the stations that will dictate the duration of production. Otherwise, if with the application of this scenario, the value that dictates the duration of the brand it is not the one regarding the LM station, the new value will be the one relative to the station that has the highest production time, becoming this the value that dictates the time of production of the brand.

With the production values new values, the optimization model regarding the number of cells required was run again in the CPLEX program presented in Appendix C. Table 10 shows the comparison between the number of cells needed for the current scenario and for the new one, for each month of the year in question.

Table 10 - Number of cells required under scenario 1

Months		Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Number of cells	Actual	2	1	3	2	1	4	4	1	3	4	2	1
	Scenario 1	2	1	3	2	1	4	4	1	3	3	2	1

Regarding the resources allocation, the corresponding optimization model, making use of linear programming, was also run again, in the CPLEX software, now with the new working day values required for the LMW and LMM stations. Under the conditions of the scenario presented, for the LM stations, Table 11 presents the results of the number of teams to hire as core team and Figure 22 presents the total number of days that the production will have to resort to subcontracting teams, comparing with the current scenario.

Table 11 – Optimal number core teams under scenario 1

Station	LMW	LMM	PIN UP	STILLS	JWL
Number of core teams	1	1	2	2	0

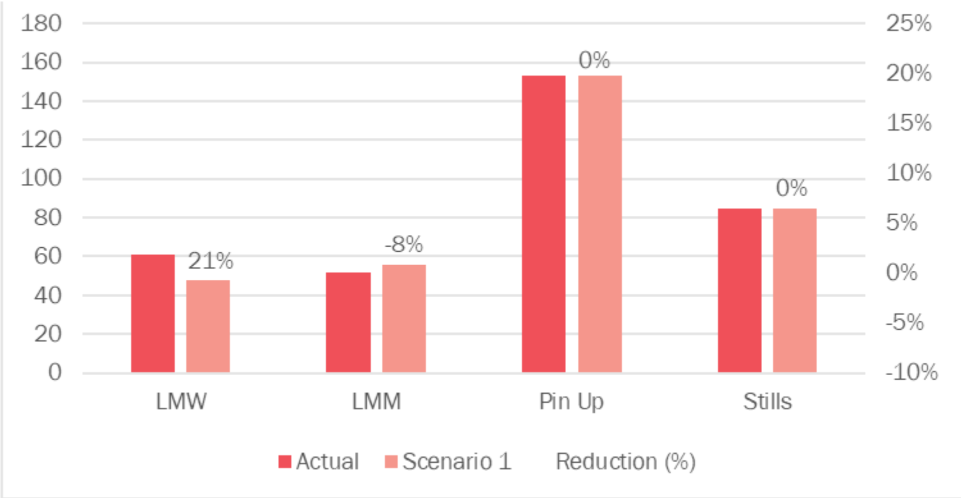

Figure 22 - Optimal number of subcontracting days under scenario 1

5.1.2 Scenario 2 - Use of 3 Pin Up Workstations

The scenario presented in this section appears as an alternative or complement to the scenario previously presented. If Scenario 1 proves to be insufficient to cover the demand for a given period, and thus unable to meet the deadlines imposed by brands, scenario two can be combined, with the aim to reduce the production time of brands in the Pin Up station, which, consequently, can generate available time to produce the remaining demand.

This second alternative to change the way the installed capacity is being used consists of adding one more workstation to the Pin Up stations. Currently, for each cell, the Pin-Up station is equipped with two workstations. The proposed addition of one more workstation to the Pin-Up stations does not mean an acquisition of one more workstation for each of the 3 available stations, one in each cell. By challenging the rigid structure of the stations in each cell, referred to in Chapter 4, the proposal is that the stations within the cells become mobile structures, thus allowing the mobility of workstations within the three available cells, whenever necessary. This proposal was conceived not only because the production time for the Pin Up station is high, which may compromise the deadlines established by brands, but also because, with some frequency, in case the stations are fixed as in the initial conditions, they cannot be used, ending up with unused capacity due to the restriction that prevents a cell from producing more than one brand at a time. In this sense, adding another workstation to a Pin-Up station would simply be the reallocation of a Pin-Up workstation that is not being used in a given cell, to another Pin Up station in a cell that is producing, by adding capacity, when necessary.

Like the solution presented previously, the implementation of this system aims at the reduction of the production time of this station by adding of available capacity. However, the addition of a workstation to the station will reflect on the need for one more team, since a team is needed for each workstation to run properly. By implementing this scenario it is important to understand the reductions in the production time of the Pin-Up station, resulting from the added capacity. A comparison is made between the actual average production time of the Pin-Up station and the average production time obtained by adding another workstation. This information can be consulted in Figure 23, which highlights a decrease in production time by 29%.

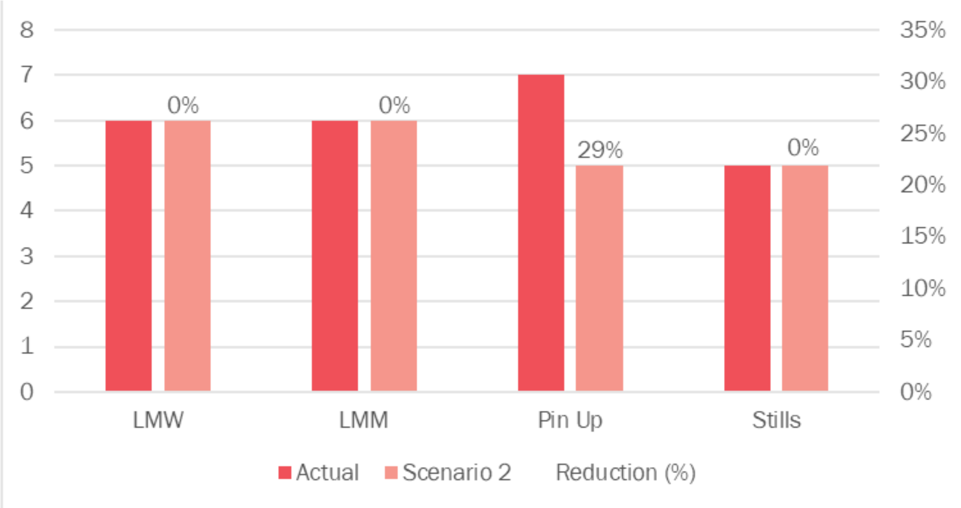

Figure 23 - Comparison between production times for Pin Up station

Also, to understand if this scenario had any impact on the number of cells needed to meet demand, for the year in question, the same methodology used in Scenario 1 was also followed for this scenario. This means that for a given brand, if the production time in the Pin-Up station continues to be the highest, when compared with the other stations, this value will be replaced with the value resulting from this scenario. Otherwise, the value that dictates the brand production time will now be the one corresponding to the station that has the longest production time, for that same brand.

With the new values, the optimization model regarding the number of cells required was run again in the CPLEX program and are presented in Appendix D. Table 12 shows the comparison between the number of cells needed for the current scenario and for the new one, for each month of the year in question.

Table 12 - Number of cells require under scenario 2

Months		Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Number of cells	Actual	2	1	3	2	1	4	4	1	3	4	2	1
	Scenario 2	2	1	3	2	1	4	4	1	3	3	2	1

Once again, the optimization model regarding the allocation of resources, using linear programming, was run, in the CPLEX software, now with the new working day values required for the Pin-Up station. In Table 13, regarding the Pin-Up team, is exhibited the number of teams that will be, now, make up the core team under this scenario. In Figure 24 it is presented a reduction of 0,64% in the number of days that the production will require for subcontracting service for the Pin-Up team, under this scenario.

Table 13 - Optimal number of core teams under scenario 2

Station	LMW	LMM	PIN UP	STILLS	JWL
Number of core teams	1	1	3	2	0

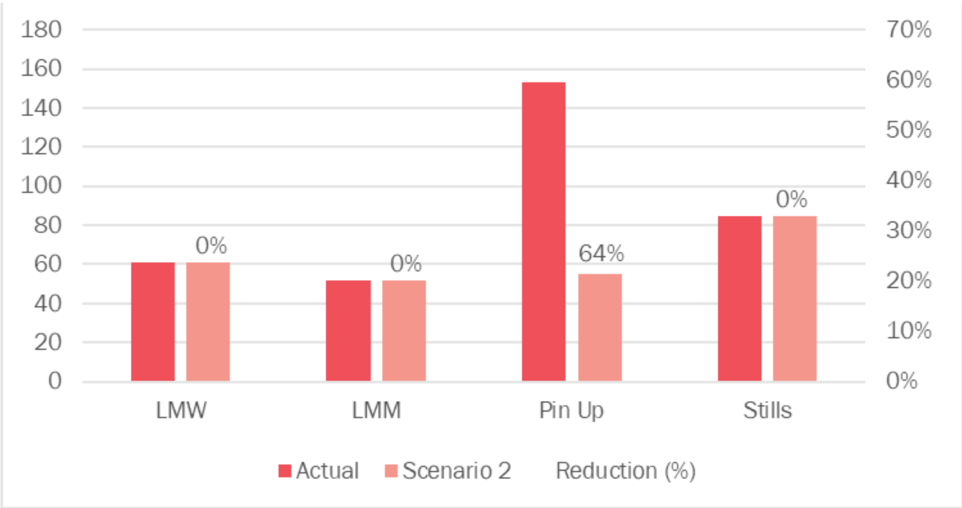

Figure 24 - Optimal number of subcontracting days under scenario 2

5.1.3 Scenario 3 – Use of 3 Stills Workstations

Once again, the scenario presented in this section appears as an alternative or complement to both scenarios presented earlier. A third alternative to change the way the installed capacity is being used is the addition of one more workstation in the Stills stations. As in Pin Up stations, currently the Stills station has each cell is equipped with two workstations. Following the same logic as in the previous scenario, the proposed addition of one more workstation to the Stills stations does not mean an acquisition of one more workstation for each of the 3 available stations, one in each cell. As the JWL station is a station with similar technical configurations to Stills, and since it is already mobile, with an average usage rate of about 4%, it is proposed in this study the use of the JWL station as the third workstation of the Stills stations. In addition, if for some reason the JWL station is not available, since there is only one, again, challenging the rigid structure of the stations of each cell, referred to in Chapter 4, the proposal is that the stations within the cells become mobile structures, thus allowing the mobility of the stations and workstations, whenever necessary, since these are often unavailable to be used. In this sense, adding another workstation to a Stills station would simply be the allocation of a workstation that is not being used at a Stills station to one Stills station that is producing, adding capacity, whenever necessary.

As in the previous scenario, the implementation of this system aims to reduce the production time of this station by adding of available capacity. However, the addition of a workstation to the station once again will reflect the need for one more work team, since a team is needed for the operation of each station.

After the implementation of this scenario, the reduction in the average production time for the station in question, resulting from the change of capacity was also calculated. In Figure 25 exhibits a production time reduction of 20%, for the Stills station, inherent to the option for this scenario.

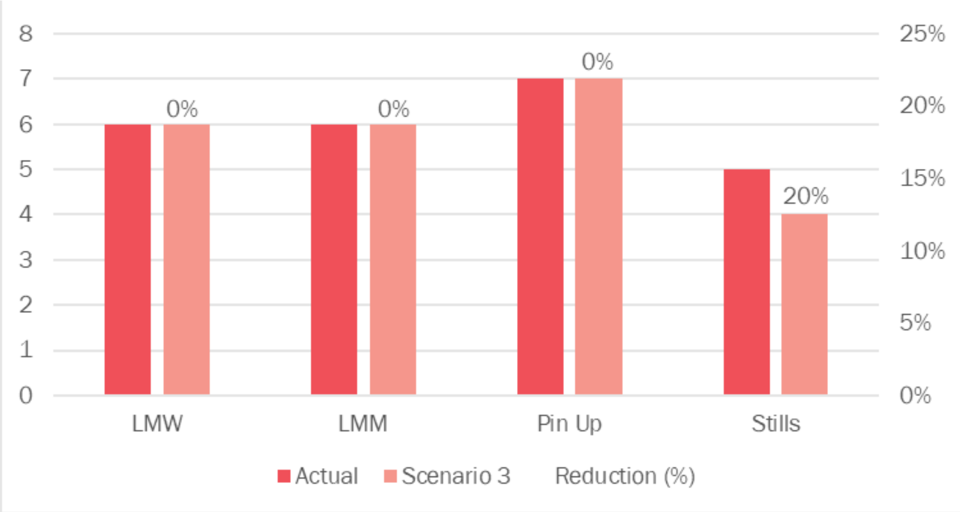

Figure 25 - Comparison between production times for Stills station

Under the conditions presented in this scenario, and to understand the impact on the number of cells needed to meet demand, for the year in question, the same methodology used in the previous scenarios was followed for scenario 3. The optimization model regarding the number of cells required was run again in the CPLEX program. Table 14 shows the comparison between the number of cells needed for the current scenario and for Scenario 3, for each month of the year in question.

Table 14 - Number of cells required under scenario 3

Months		Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Number of cells	Actual	2	1	3	2	1	4	4	1	3	4	2	1
	Scenario 3	2	1	3	2	1	4	4	1	2	4	2	1

In Table 15, regarding the Stills team, it is exhibited the number of teams that will be now part of the core team. In Figure 26 it is possible to observe a decrease of 79% regarding the number of days that the production will require for the subcontracting service for the Stills team. The results regarding this scenario are presented in Appendix E.

Table 15 - Optimal number of core teams under scenario 3

Station	LMW	LMM	PIN UP	STILLS	JWL
Number of core teams	1	1	2	3	0

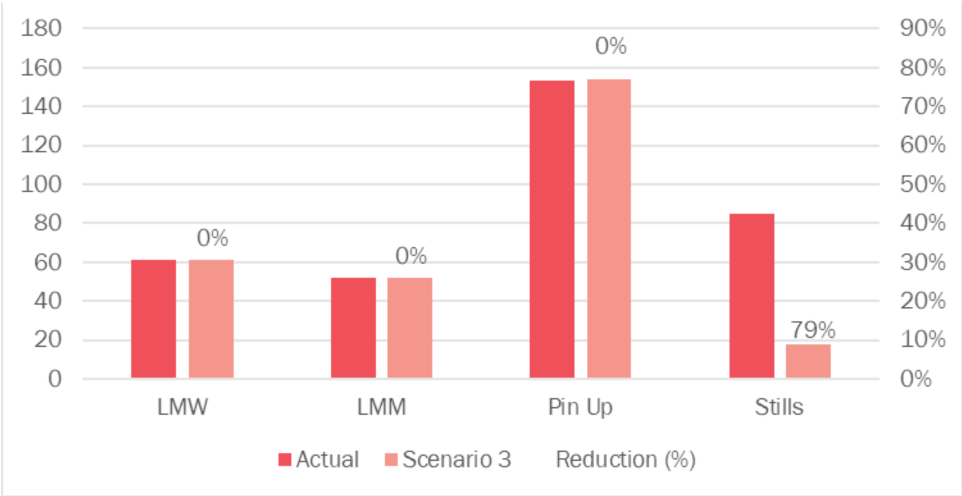

Figure 26 - Optimal number of subcontracting days under scenario 3

5.1.4 Scenario 4 – Combination of Scenario 1, 2 and 3

As previously mentioned and since all scenarios previously proposed are independent and appears as alternatives, or complement to each other, it is pertinent to propose another scenario that consists of the joint application of all previous ones. In this way, the proposals enunciated in each of the previous scenarios will now be applied simultaneously. Thus, the proposal for this scenario consists of brands that only sell one gender using both LM stations, instead of using only one, and regarding the pin up and stills station, these will be both constituted by three workstations, instead of two. By analyzing this last scenario it will be possible to see the impact of the application, not only of an isolated scenario, but, in this case, of all scenarios applied together, making a better management of the installed capacity in the building and considering the option that the stations inside of the cells will be flexible, by becoming mobile structures.

As in the previous scenarios, the implementation of these settings for each station aims to reduce the production time of the LM, Pin Up and Still stations, by adding available and unused capacity. As already mentioned, with the addition of a workstation both the Pin Up and Stills stations will reflect the need for two more teams in each of the stations, since a team is needed for the operation of each workstation.

Figure 27 exhibits a summary of the production time reduction, already calculated for previous scenarios, for each of the stations considered in this scenario.

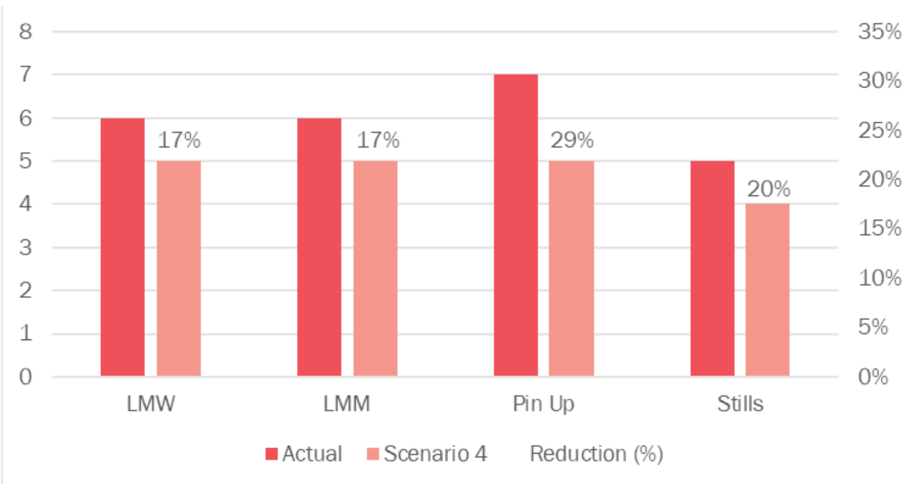

Figure 27 – Comparison of stations production times under scenario 4

An important goal in the implementation of this scenario is to see how the reduction of the production time, now in all stations simultaneously, with the exception of the JWL station, will impact on the number of cells needed, for each month, in order to meet demand for the year in question. It is also in this scenario that the impact is expected to be more significant compared to the other scenarios, since there is a significant reduction of the average production time in all the stations, with the exception of JWL, also meaning that the production time of the station that will dictate the production time of each brand for each month will also, inevitably, be lower. As a consequence of production times being significantly smaller, for each brand and month, the amount of time the digital production center is producing will also decrease, thus, allowing the allocation of extra demand. Results regarding this scenario are presented in Appendix F. Table 16 exhibits a comparison of the results regarding the cells' need for meeting demand, under the initial conditions and the conditions regarding the present scenario.

Table 16 - Number of cells require under scenario 3

Months		Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Number of cells	Actual	2	1	3	2	1	4	4	1	3	4	2	1
	Scenario 4	2	1	2	2	1	3	3	1	2	3	2	1

Represented in Table 17 is the ideal number of teams to be hired as a core team for the present scenario. In Figure 28 a summary is presented concerning the number of days that production will have to resource to subcontracting teams, already presented in the previous scenarios.

Table 17 - Optimal number of core teams under scenario 4

Station	LMW	LMM	PIN UP	STILLS	JWL
Number of core teams	1	1	3	3	0

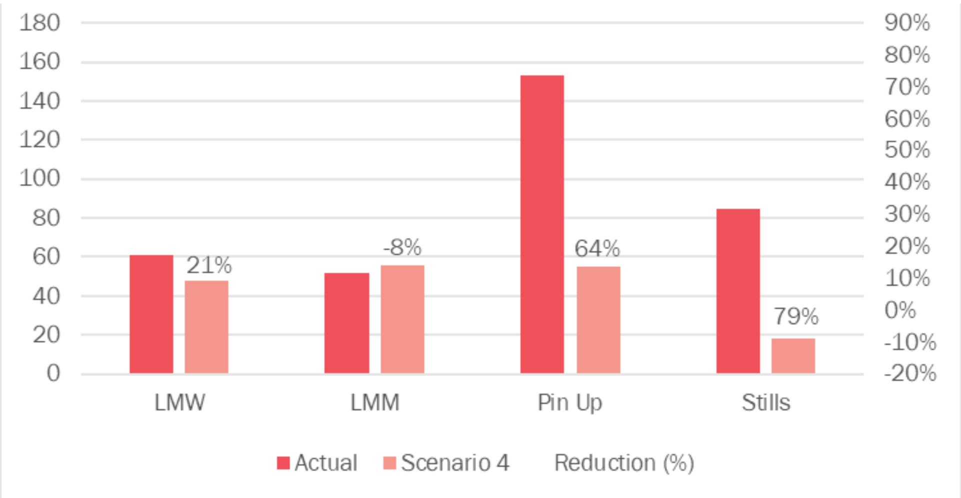

Figure 28 - Comparison of the number of subcontracting days under scenario 4

5.1.5 Data-Driven Insights

After the conditions for the new production center have been presented in Chapter 4, the present chapter was used to, first, calculate the capacity and resource requirements in order to meet the conditions presented. With the same objective, the necessary resources were calculated as core team or as subcontracting regime.

With the configuration for the new digital production center calculations from the current scenario regarding the number of cells require to meet demand, and in Table 4 is presented that under the conditions in which the new digital production center is presented the new building is insufficient, in the medium term, to meet demand for the period considered. Also sustained by the occupancy rate presented in Table 5 it is possible to understand the use of installed capacity was not being efficient, it became necessary to develop solutions and adaptations that would allow the productive platform to increase and monetize its capacity to respond to the strong growth that BU is experiencing.

Four different solutions have been proposed in order to find feasible solutions in order to respond to future needs. Table 18 shows, in addition to the comparison between the current capacity of this area and the require capacity in order to meet demand, the require capacity of the digital production center, through the option for each of the presented scenarios. The analysis of the table 18 shows that, for June and July, none of these individually applied solutions will be sufficient to respond to the required needs in order to meet demand for 2018. However, as mentioned earlier, the fact that they are modular and independent solutions makes them combinable. Therefore, a fourth scenario has been elaborated in which the proposal will be to combine all the previously proposed solutions simultaneously. Also from Table 18, it is possible to observe that in scenario 4 and for the months affected, the productive center is able to respond to the demand for the considered period.

Table 18 – Comparison of required cells under all scenarios

Months	Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Available Capacity	3	3	3	3	3	**3**	**3**	3	3	**3**	3	3
Current Scenario	2	1	3	2	1	**4**	**4**	1	3	**4**	2	1
Scenario 1	2	1	3	2	1	**4**	**4**	1	3	**3**	2	1
Scenario 2	2	1	3	2	1	**4**	**4**	1	3	**3**	2	1
Scenario 3	2	1	3	2	1	**4**	**4**	1	3	**4**	2	1
Scenario 4	2	1	2	2	1	**3**	**3**	1	2	**3**	2	1

Table 19 represents a comparison between resources needed as part of the core team and those as subcontracting regime, both for the initial conditions and for scenarios 1, 2, 3 and 4 and Figure 29 regards the number of outsourcing days for all scenarios.

Table 19 - Summary comparison table for core teams

Core Teams	LMW	LMM	PIN UP	STILLS
Current scenario	1	1	2	2
Scenario 1	1	1	2	2
Scenario 2	1	1	3	2
Scenario 3	1	1	2	3
Scenario 4	1	1	3	3

Figure 29 shows a reduction in the days it will be necessary to use subcontracted teams, with the application of some of the different scenarios in each of the stations.

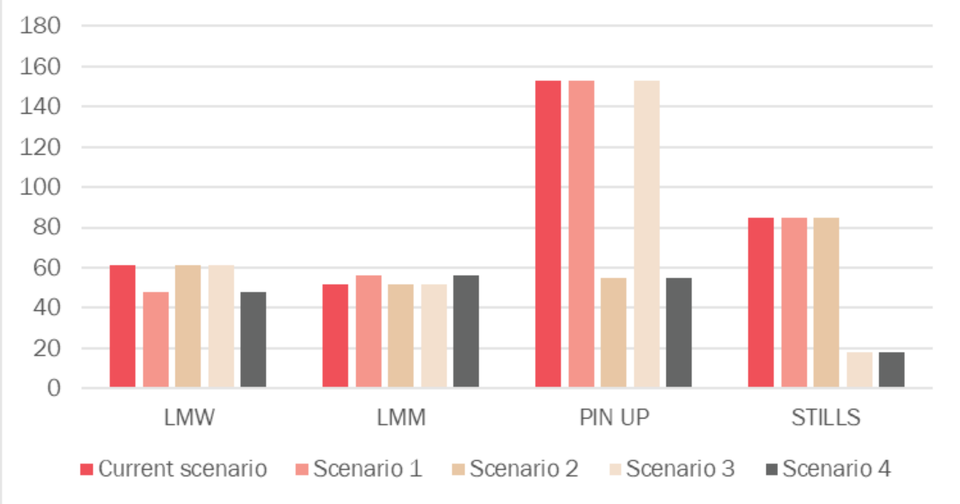

Figure 29 - Comparison for outsourcing days for all scenarios

Table 20 presents the differences of cost values related to the allocation of resources in the core team regime and in the subcontracting regime are also presented. It also shows that for all scenarios, these costs are always lower than the initial conditions.

Table 20 – Costs comparison for all scenarios

Scenarios	Total Cost (€)
Current Scenario	505 350
Scenario 1	502 200
Scenario 2	468 500
Scenario 3	480 950
Scenario 4	500 950

5.2 Post-Production Restructuring

Post Production is a key area of B&W Production, as this is the last area that interacts with the product and also the one that completely ends the production process, providing the final product to brands. The precarious quality that BU has encountered so far in the final product has very strong impact in B&W's image shown not only to current brands, but also to prospective and potential brands. It is, therefore, urgent that a restructuring should be made over the post production area, since it reflects the quality of the whole vast process. In this sense, a proposed resolution for this deficit area is devised in this section.

One of the critical factors that has contributed to a poor quality of the edited images is the fact that the image editing is being done by a team external to the rest of the production. Therefore, as a proposal to restructure this crucial area is the creation of an internal team of editors, which will be allocated to a section in the new building, thus allowing greater and closer communication between the 3 main areas that shape the production - Styling, Photography and Post Production. In this proposed solution it is also considered the possibility, when necessary, of using freelancers as a subcontracting regime. It is not envisaged that the UK companies referred to above may be used, where appropriate, as the quality risks are too high to continue to apply to these undertakings.

In order to understand what would be the resources needed to be able to meet demand – in this case, the photos that need to be edited – would be, it would be necessary to realize how many photos would have to be edited for each month of the year 2018. In Figure 30 demand values in items are presented. It is considered that for each item, on average, 5 photos are produced by the stations, which will have to be later edited.

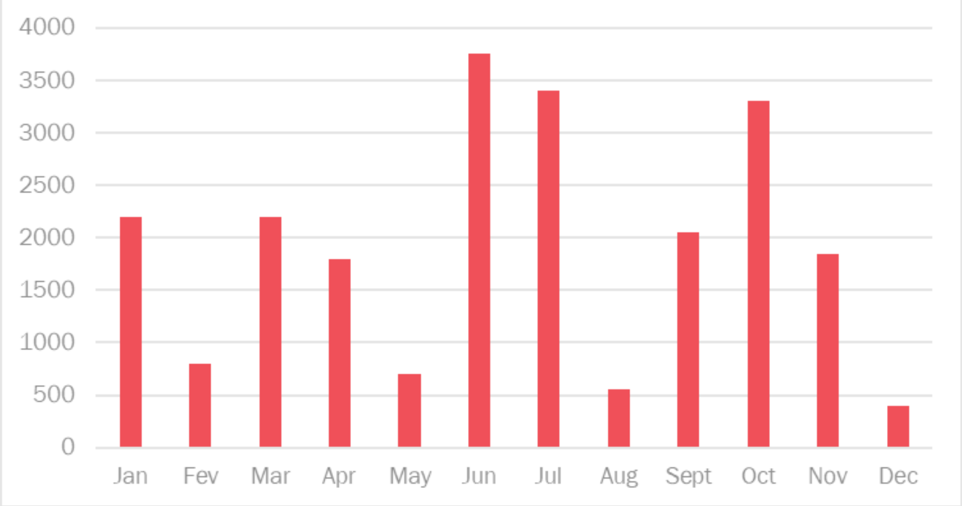

Figure 30 - Number of items to be edited

Therefore, following this line of reasoning, in an attempt to try to understand not only the best but also the most efficient and least expensive way of allocating resources, in this case editors, an adaptation of the linear programming model, used in the scenarios related to productive stations, was made with the aim of being able to respond to the present problem. The assumptions of the model developed and presented below are the same as those of the previous ones, considering the possibility of contracting editors as core team and under a subcontracting regime.

Parameters:

x_t - Number of items that need editing for month t

c_t - Number of items that an editor can finish in month t

a - Cost per year of a core team editor

d - Daily cost per item of a subcontracted editor

Decision Variables:

y - Number of editors belonging to the core team

w_t - Number of items that will need to be edited in subcontracting regime, in month t

Objective Function: Minimize cost related to hiring as core teams or as subcontracting service

$$Min\ z = y * a + \sum_t w_t * d$$

Subject to:

Capacity constraint:

$$y * c_t + w_t \geq x_t, \forall t$$

Non-negativity constraints:

$$w_t \geq 0, \forall\, t$$

$$y \geq 0$$

As assumptions, only working days were considered and it was assumed that each editor has the ability to edit seven photos per day, each with an average of six images. The results regarding to this proposed solution are presented in Appendix G. In Table 21 it is presented the number of editors to contract as core team, and in Figure the number of items, per month, in on which it will be necessary to resort to subcontracted editors. For the proposal presented, the annual cost to the company would be 186 868 euros, thus ensuring the number of photos to be edited for each month.

Table 21 - Optimal number of internal editors

Post Production	
Number of editors as core team	4

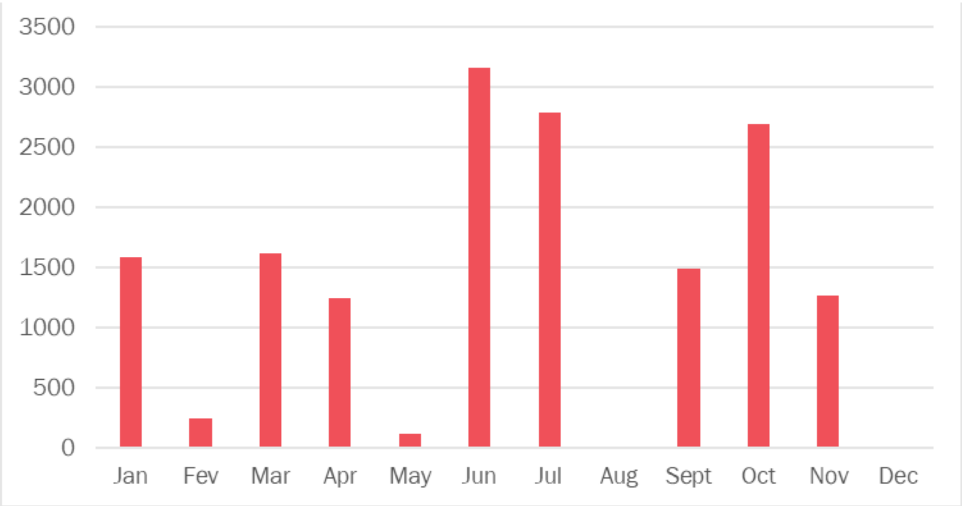

Figure 31 - Optimal number of items to be produced in outsourcing

The costs related to image editing by each external company X and Y, and by freelancers, it is known that company X practices a cost per image about 17 times higher than the company Y and about 20 times higher than a freelancer. Table 22 presents a comparison between the costs for each of the options – the one that the Post Production uses, and the proposed solution.

Table 22 - Summary costs table

Editing Company	Total Cost (€)
X	3 905 400
Y	234 600
Freelancers	193 200
Proposed Solution	186 868

As it can be seen from the table above, the present proposal presents the most economical solution, compared to the other alternatives. However, it is possible to verify that the solution proposed consists only of hiring four internal editors, leaving all the remaining photos to be edited in the previously described regimes, thus keeping unresolved the critical problem that arise from subcontracting; so, the quality problems remains, since these editors are not in close contact with the other areas, styling and photography, as it was proposed.

6 Conclusions

The initial objective of this project was the development of proposals and structured solutions that would allow managers gain valuable insights into how to maximize the utilization of the resources and equipment of the digital production center and to efficiently respond to the business future needs. However, the course of the project raised new needs that, when satisfied, proved intermediate results for the project and for the B&W BU itself to be useful.

In an initial phase, the conditions under which the digital production center is currently operating are presented. In this phase it was also presented the way the in which item’s category received by brands may influence the flow of those same items within the production center. An imminent need for restructuring the Post Production area was also identified.

Next, the conditions under which the digital production center will operate are presented, since a new building was designed to cope with the considerable growth of the BU. The production time of each brand was presented in each of the different stations to be used, for all the months of 2018. Here were also presented the conditions and the restrictions that the new facility presents, as well as the expected demand for the period of time considered. For some brands, some production times were assumed taking into account production times of brands with similar characteristics, since there is still some uncertainty associated with the type of items to be received from the brands, due to the lack of an operating system that registers a history for each brand. A view of the resources needed for the proper run of the stations were identified in order to understand future needs.

Chapter 5 was used to, first, calculate the capacity and resource requirements in order to meet the conditions presented. With the same objective, the necessary resources were calculated as core team or as under subcontracting regime. In an initial analysis having concluded that under the conditions in which the new digital production center is presented it, the new building is insufficient, in the medium term, to meet demand for the period considered and also being sustained by the lower occupancy rate, for each of the stations, that indicated that the use of installed capacity was not being efficient, it became necessary to develop solutions and adaptations that would allow the productive platform to increase and monetize its capacity to respond to the strong growth that BU is experiencing.

Four different solutions have been proposed aiming at a more efficient use of installed capacity which reflect a significantly decrease of the production time of each station, and therefore an increase of the responsiveness of this area. Scenario 1 corresponds to a solution that aims at a more efficient use of LM installed capacity, since it exists and is, in some cases, available. The solutions presented in scenarios 2 and 3 correspond, as in Scenario 1, to a more efficient use of the installed capacity for the Pin Up and Stills stations, respectively. The solutions presented do not require significant restructurings in the production stations, or large investments, so the scenarios presented represent solutions that were considered applicable and viable to the digital production center. After a careful analysis of the three proposed scenarios it is possible to conclude that, for two of the months of the period consider, none of these individually applied solutions will be sufficient to respond to the required needs in order to meet demand for 2018. However, and as mentioned earlier, the fact that they are modular and independent solutions makes them combinable. Therefore, a fourth scenario has been elaborated in which the proposal will be to combine all the previously proposed solutions simultaneously. The application of this scenario concludes that for the months affected and for the conditions previously considered, the productive center is able to respond to the demand for the considered period.

As it would be expected, a better utilization of installed capacity for each of the proposed scenarios also leads to a reduction in the production times, which will inevitably be reflected in the days it will be necessary to use subcontracted teams. It can be concluded that for all scenarios, these costs are always lower than the initial conditions, holding that efficient management of resources also reduces the investment required.

It is important to highlight that the aim of this project is, through a macro view, to give valuable and useful insights to the daily operational management regarding decisions in the digital production center. There are many factors that influence these decisions, so the solutions presented here aim to show the possible improvements in situations of imminent response capacity; therefore, the application of these solutions must meet the counterparts mentioned when describing the proposed scenarios. The option for each of the solutions, or the combination of them, will have to be carefully made for each particular brand and for a given period of time, if it proves necessary, as there often would have to be an important trade-off between being able to respond to demand and minimizing costs. By adding capacity inevitably one more team is added, plus the cost. With these considerations, it becomes clear that the need to apply the proposed solutions is not always present, which implies a critical spirit by the decision maker. However, in case of this need, the proposed solutions show flexibility to the digital production center to be able to respond to critical situations.

The requirements arising from the capacity increase are largely determined by the BU's outlook and growth plans. If demand is difficult to predict, focus should be kept on developing restructurings as smooth and flexible as possible. Both the lack of capacity and the excess of capacity inevitably generate additional costs to adapt to the current reality of the digital production center.

Regarding the proposal of solution to the problems described in the post production, this solution being the hiring of a team of internal editors concludes that the solution presented as optimal allocates only four resources as internal editors, since the cost of subcontracting is considerably lower. By only adding four internal editors it means that around 70% of the work would be done on a subcontracting basis. Once again, there will have to be an important trade-off between choosing a more economical solution or a solution that, although more expensive, could have highly significant impact on improving quality, which was the initial goal when formulating this solution.

At this stage, and remembering the major importance of post-production, being the last stage of the productive process that gives rise to the final product, it will not be prudent for the trade-off to be made in order to minimize costs. Like any business at its early and growing stage, this is the period when the higher investments are made, and also some of the most important ones. In this sense, the proposed solution does not seem feasible, taking into account the urgent need to solve the post-production quality problem. It is considered that an investment should be made in order to increase the quality of this last stage, improving the final product and the reliability of the B&W business in order to give great satisfaction to their clients, the brands, and to attract new ones.

6.1 Limitations

One of the limitations of this work lies in the study of solutions considering only the demand requirements, per month, and its influence in the capacity of response, only on a macro scale, since its unknown what will be the time interval, in the month, that brands will send their collections.

Another relevant limitation is the fact that in the presented solutions it has been assumed that the allocation of brands is always done in a way that minimizes the number of cells needed and consequently the number of teams required. As mentioned earlier, the time periods in which the collections are being produced in the digital production center are usually quite low. Combining with the fact that brands often have little flexibility in choosing the dates for the digital production to happen, it shows that in reality, due to the demand and the low flexibility inherent to the business, it will not always be possible to allocate brands with the aim of minimizing the number of cells to be used.

Also, due to the tremendous growth experienced by this BU, many of the elements that were and still are part of B&W production were forced to surmount and instead of being really good at doing some particular task, they became really good at learning how to do new things. In addition, due to the constant need to achieve what is desired by brands, these elements were marked by two important characteristics, agility – the ability to quickly spot and exploit opportunities - and by absorption – the strength to withstand punishment and weather sudden shifts. Thus, in the proposals presented when assigning teams to specific stations, is disregard the possibility of existence of multipurpose resources that know and can perform different jobs in different stations. Therefore, the allocation of specific teams to each station is also an important limitation of the proposed solutions, since in case there is a lack of resources in a team, if available, a resource from another team may be able to fill that gap.

6.2 Final Considerations and Future Work

For any strategic decision it is imperative to start with a vision of the future. As described earlier, several factors influence capacity strategy. It is essential that a model is created incorporating all possible factors, with data as close as possible to reality. The most feasible way to do this is to build forecasts – visions or predictions about the future.

One of the most difficult tasks in this work was the collection of data, since, as already mentioned, being a recent BU and still growing, many of the processes are still extremely manual and absent from a tool that registers several information about the brands and their collections. In order to be able to obtain more reliable forecasts, either of demand, about how brand collections are composed, production times or control of the product in the digital production center, it is essential to use an operating system that registers the different activities within the digital production center. In addition to infrastructure flexibility, forecasting and alignment with the B&W BU's overall strategy and objectives can be useful in a number of ways, as it enables to acknowledge future demand needs and their impact on the capacity of the production center. Thus, the better this analysis, the better the cost efficiency will be, either in daily operation or investments made.

With the change of production to the new facilities, in the medium term, a perception of the item’s flow within the new space for the digital production center alongside with a study of an efficient layout to adjust the needs required is considered indispensable for the sustainability of the BU's logistics operation, given the strong growth it is experiencing and the level of service required for this platform. Thus, the relevance of this work is not only concerned with some strategical insights for the daily operation decisions, but also with the presentation of viable and modular solutions that will be an important basis in the decision making of possible new adaptations to the stations structure and layout.

Another proposal for future work would be the study of the allocation of internal editors by teams. In this way, each team will be responsible for editing certain brands. Thus, editors would be allocated to certain teams depending on the type of editing needed and based on their best skills and interests. Having made this allocation, although editors know how to edit all brands, they would become specialized in editing specific brands. This type of allocation could bring interesting and promising gains in the post production area since specialized workers tend to become independent employees once they have learnt about the skills which are required to do the daily assignment and tasks also, productivity is fast and in high number as time isn’t wasted.

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APPENDIX A: Calculation of Production Times

Calculation of production times in the stations per month:

January		LMW	LMM	PIN UP	STILLS	JWL
	C	0	8	7	5	1
	E	5	0	4	8	1
	G	2	9	10	1	0
	M	3	3	6	6	1
	N	8	3	9	5	1
	N of days require	18	23	36	25	4

February		LMW	LMM	PIN UP	STILLS	JWL
	J	8	0	7	3	0
	M	3	3	6	6	1
	N of days require	11	3	13	9	1

March		LMW	LMM	PIN UP	STILLS	JWL
	R	0	8	8	1	0
	Q	1	9	0	3	1
	B	0	11	11	6	0
	L	9	2	10	3	1
	N	3	3	6	6	1
	N of days require	13	33	35	19	3

April		LMW	LMM	PIN UP	STILLS	JWL
	S	0	0	6	2	1
	D	9	0	8	4	1
	F	8	0	8	3	0
	H	0	0	0	10	0
	M	3	3	6	6	1
	N of days require	20	3	28	25	3

May		LMW	LMM	PIN UP	STILLS	JWL
	I	0	0	0	14	0
	M	3	3	6	6	1
	N of days require	3	3	6	20	1

June		LMW	LMM	PIN UP	STILLS	JWL
	O	8	8	4	2	0
	A	14	0	12	3	0
	B	0	11	11	6	0
	E	6	0	5	10	1
	G	2	9	10	1	0
	J	8	0	7	3	0
	L	9	2	10	3	1
	M	3	3	6	6	1
	N	7	2	8	5	1
	N of days require	57	35	73	39	4

July		LMW	LMM	PIN UP	STILLS	JWL
	R	0	8	8	1	0
	Q	2	14	0	5	1
	C	0	8	7	5	1
	D	9	0	8	4	1
	F	8	0	8	3	0
	H	0	0	0	10	0
	K	0	0	0	10	0
	M	3	3	6	6	1
	N of days require	22	33	37	44	4

August		LMW	LMM	PIN UP	STILLS	JWL
	S	0	0	4	1	1
	M	3	3	6	6	1
	N of days require	3	3	10	7	2

September		LMW	LMM	PIN UP	STILLS	JWL
	R	0	1	1	1	0
	E	5	0	4	8	1
	G	2	9	10	1	0
	I	0	0	0	14	0
	L	9	2	10	3	1
	M	3	3	6	6	1
	N of days require	19	15	31	33	3

October		LMW	LMM	PIN UP	STILLS	JWL
	Q	1	4	0	2	1
	O	8	8	4	2	0
	O	14	0	12	3	0
	B	0	11	11	6	0
	C	0	8	7	5	1
	F	8	0	8	3	0
	J	6	0	5	3	0
	M	3	3	6	6	1
	N	7	2	8	5	1
	N of days require	47	36	61	35	4

November		LMW	LMM	PIN UP	STILLS	JWL
	R	0	3	3	1	0
	S	0	0	3	1	0
	D	9	0	8	4	1
	H	0	0	0	10	0
	K	0	0	0	10	0
	M	3	3	6	6	1
	N of days require	12	6	20	32	2

Dec		LMW	LMM	PIN UP	STILLS	JWL
	M	3	3	6	6	1
	N of days require	3	3	6	6	1

Calculation of production times of brands per month:

	Brands																	
Month	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Q	R	S
1			8		8		10						6	9				
2										8			6					
3		11										10	6			9	8	
4				9		8		10					6					6
5									14				6					
6	14	11			10		10			8		10	6	8	8			
7			8	9		8		10			10		6			14	8	
8													6					4
9					8		10		14			10	6				1	
10	14	11	8			8				6			6	8	8	4		
11				9				10			10		6				3	3
12														6				

APPENDIX B: CPLEX results for the current conditions

<u>CPLEX model for the number of cells require:</u>

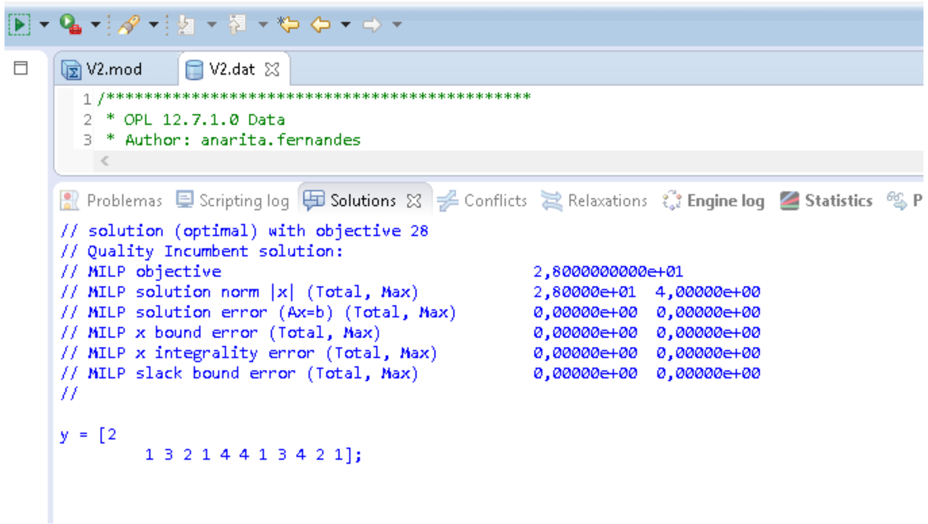
V2.mod | V2.dat

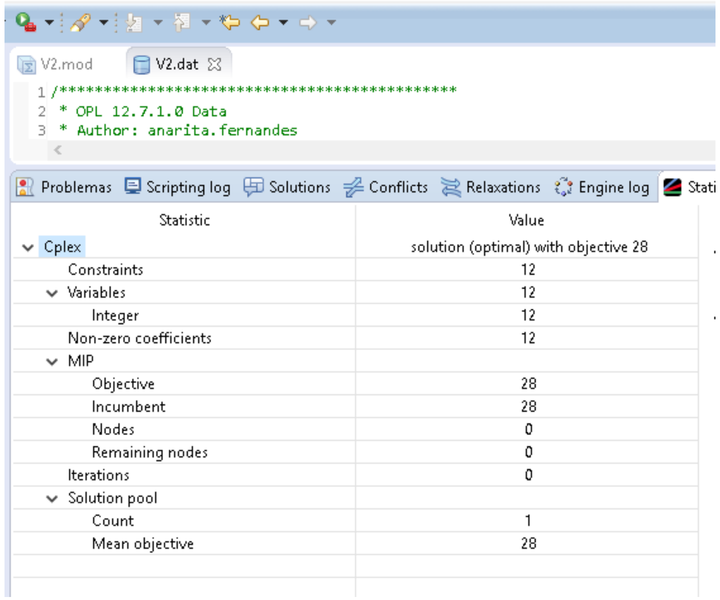
```
/*********************************************
 * OPL 12.7.1.0 Model
 * Author: anarita.fernandes
 * Creation Date: 14/12/2017 at 14:12:52
 *********************************************/
 int b=...; //number of brands
 int t=...; //number of months

 range brands=1..b;
 range time=1..t;

 float demand[time][brands]=...; //demand per month and brand
 float capacity[time]=...; //capacity per month
 float x[time][brands]=...;



 //variables


dvar int y[time];

 minimize sum(t in time) y[t];

subject to {
    forall (t in time)
      capacity_c: //capacity constrain
      sum (b in brands) x[t][b]*demand[t][b]<=capacity[t]*y[t];


}
```

V2.mod | V2.dat

```
/*********************************************
 * OPL 12.7.1.0 Data
 * Author: anarita.fernandes
 * Creation Date: 14/12/2017 at 14:12:52
 *********************************************/


 b=25;
 t=12;


 //Read data
 SheetConnection my_sheet("BWprev18IC.xlsx");

 demand from SheetRead(my_sheet, "'Allocation'!G3:AE14");
 capacity from SheetRead(my_sheet, "'Allocation'!C3:C14");
 x from SheetRead(my_sheet, "'Allocation'!G20:AE31");
```

CPLEX results for the number of cells require:





CPLEX processing time for the number of cells require:

<u>CPLEX model for the allocation of resources:</u>

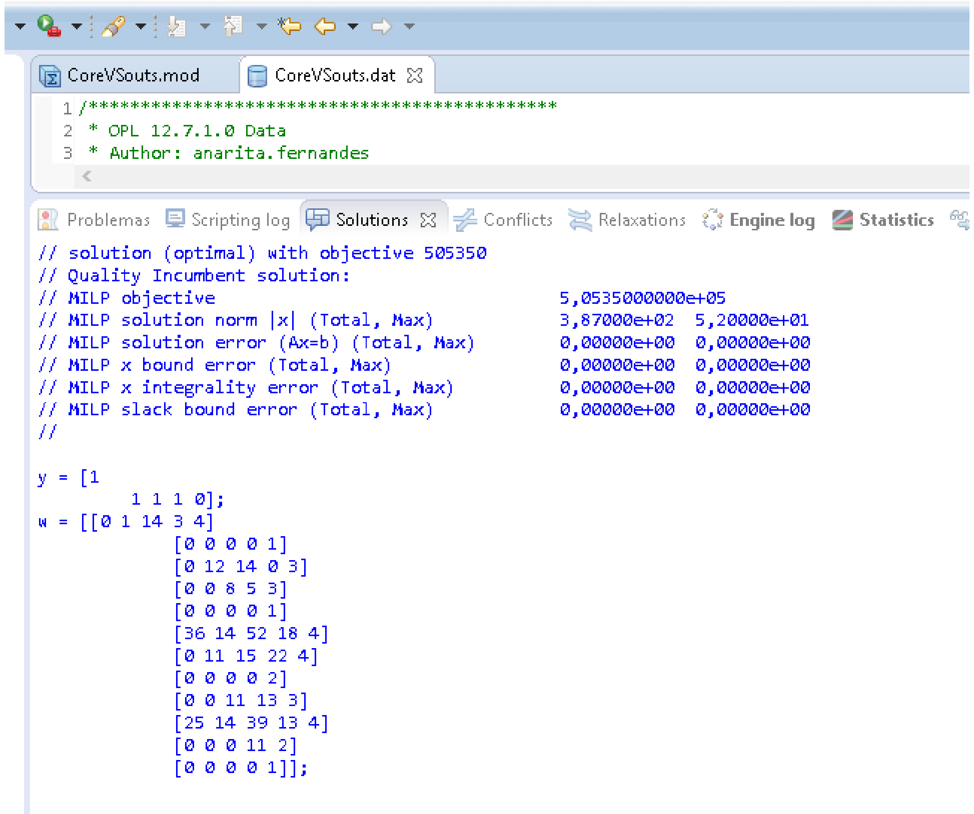
CoreVSouts.mod

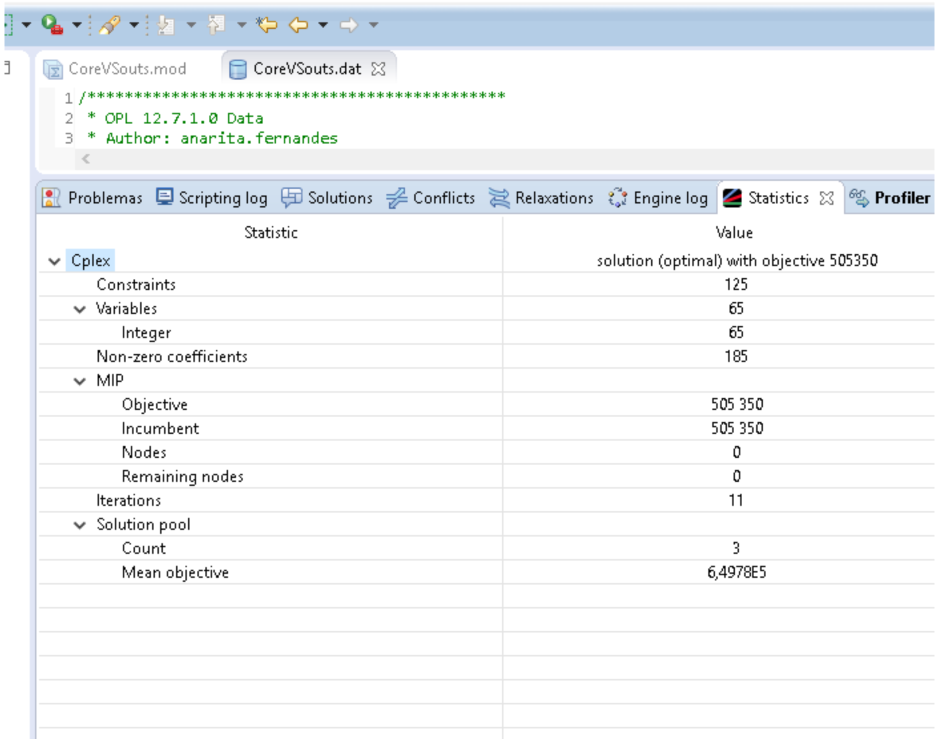
```
/*********************************************
 * OPL 12.7.1.0 Model
 * Author: anarita.fernandes
 * Creation Date: 05/01/2018 at 10:40:28
 *********************************************/
//parameters

 int t=...; //number of months
 int s=...; //number of studios

 //parameters
 range time=1..t;
 range studios=1..s;

 float x[time][studios]=...; //number of production days in month t, studio s
 float c[time]=...; //number of production days that a core team is able to do in month t

 float cy[studios]= ...; //anual cost of a core team
 float cd[studios]=...;//daily cost of an outsourcing team

  //variables
 dvar int y[studios]; //number of permanents teams in the studio s for one year
 dvar int w[time][studios]; //number of days of outsourcing work on studio s




 minimize sum(s in studios) y[s]*cy[s] + sum(t in time, s in studios) w[t][s]*cd[s];
 subject to {
 forall (s in studios, t in time)
 y[s]* c[t]+ w[t][s] >= x[t][s];

}
 subject to {
 forall (t in time, s in studios)
 w[t][s]>=0;
}

subject to {
 forall (s in studios)
 y[s]>=0;
}
```

CoreVSouts.dat

```
/*********************************************
 * OPL 12.7.1.0 Data
 * Author: anarita.fernandes
 * Creation Date: 05/01/2018 at 10:40:28
 *********************************************/

 s=5;
 t=12;


 //Read data
 SheetConnection my_sheet("Teste.xlsx");

x from SheetRead(my_sheet, "'InicialConditions'!D5:H16");
c from SheetRead(my_sheet, "'InicialConditions'!B5:B16");
cy from SheetRead(my_sheet, "'InicialConditions'!C19:C23");
cd from SheetRead(my_sheet, "'InicialConditions'!D19:D23");

 //Write data
 y to SheetWrite(my_sheet, "'InicialConditions'!K6:O6");
 w to SheetWrite(my_sheet, "'InicialConditions'!K9:O20");
```

CPLEX results for the resources allocation:





CPLEX processing for the resource allocation:

APPENDIX C: Production Times and CPLEX results for Scenario 1

<u>Calculation of production times in the stations per month:</u>

January		LMW	LMM	PIN UP	STILLS	JWL
	C	4	4	7	5	1
	E	3	2	4	8	1
	G	2	9	10	1	0
	M	3	3	6	6	1
	N	8	3	9	5	1
	N of days require	**20**	**21**	**36**	**25**	**4**

February		LMW	LMM	PIN UP	STILLS	JWL
	J	4	4	7	3	0
	M	3	3	6	6	1
	N of days require	**7**	**7**	**13**	**9**	**1**

March		LMW	LMM	PIN UP	STILLS	JWL
	R	4	4	8	1	0
	Q	1	9	0	3	1
	B	5	6	11	6	0
	L	9	2	10	3	1
	N	3	3	6	6	1
	N of days require	**22**	**24**	**35**	**19**	**3**

April		LMW	LMM	PIN UP	STILLS	JWL
	S	0	0	6	2	1
	D	5	4	8	4	1
	F	4	4	8	3	0
	H	0	0	0	10	0
	M	3	3	6	6	1
	N of days require	**12**	**11**	**28**	**25**	**3**

May		LMW	LMM	PIN UP	STILLS	JWL
	I	0	0	0	14	0
	M	3	3	6	6	1
	N of days require	**3**	**3**	**6**	**20**	**1**

June		LMW	LMM	PIN UP	STILLS	JWL
	O	8	8	4	2	0
	A	7	7	12	3	0
	B	5	6	11	6	0
	E	3	3	5	10	1
	G	2	9	10	1	0
	J	4	4	7	3	0
	L	9	2	10	3	1
	M	3	3	6	6	1
	N	7	2	8	5	1
	N of days require	**48**	**44**	**73**	**39**	**4**

July		LMW	LMM	PIN UP	STILLS	JWL
	R	4	4	8	1	0
	Q	2	14	0	5	1
	C	4	4	7	5	1
	D	5	4	8	4	1
	F	4	4	8	3	0
	H	0	0	0	10	0
	K	0	0	0	10	0
	M	3	3	6	6	1
	N of days require	**22**	**33**	**37**	**44**	**4**

August		LMW	LMM	PIN UP	STILLS	JWL
	S	0	0	4	1	1
	M	3	3	6	6	1
	N of days require	**3**	**3**	**10**	**7**	**2**

September		LMW	LMM	PIN UP	STILLS	JWL
	R	0	1	1	1	0
	E	3	2	4	8	1
	G	2	9	10	1	0
	I	0	0	0	14	0
	L	9	2	10	3	1
	M	3	3	6	6	1
	N of days require	**17**	**17**	**31**	**33**	**3**

October		LMW	LMM	PIN UP	STILLS	JWL
	Q	1	4	0	2	1
	O	8	8	4	2	0
	O	7	7	12	3	0
	B	5	6	11	6	0
	C	4	4	7	5	1
	F	4	4	8	3	0
	J	3	3	5	3	0
	M	3	3	6	6	1
	N	7	2	8	5	1
	N of days require	**42**	**41**	**61**	**35**	**4**

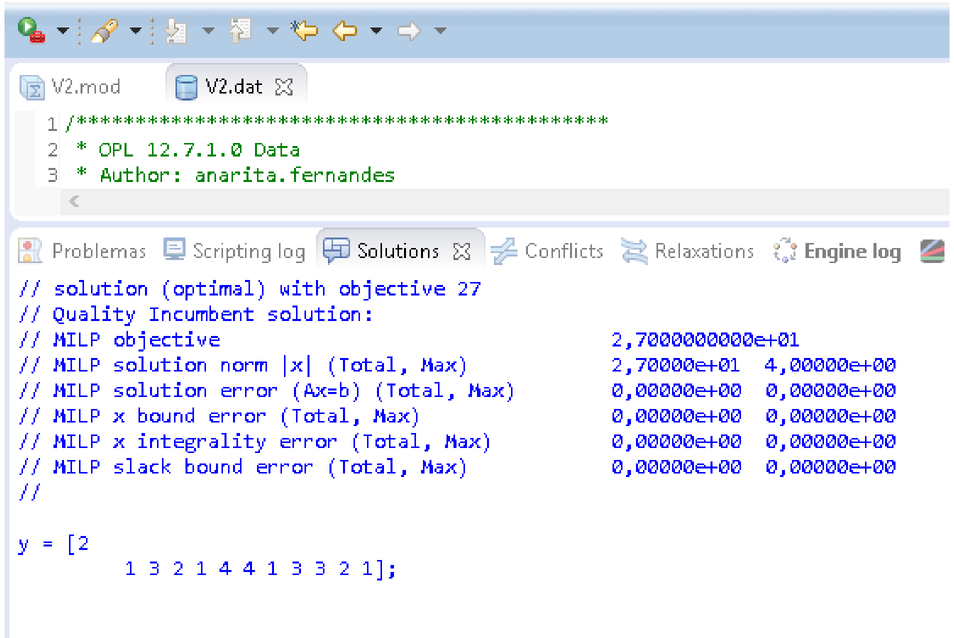
November		LMW	LMM	PIN UP	STILLS	JWL
	R	1	2	3	1	0
	S	0	0	3	1	0
	D	5	4	8	4	1
	H	0	0	0	10	0
	K	0	0	0	10	0
	M	3	3	6	6	1
	N of days require	**9**	**9**	**20**	**32**	**2**

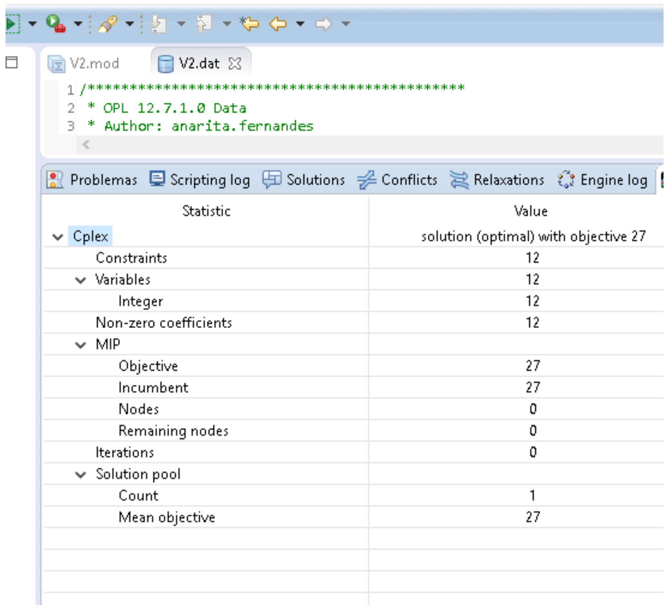
Dec		LMW	LMM	PIN UP	STILLS	JWL
	M	3	3	6	6	1
	N of days require	**3**	**3**	**6**	**6**	**1**

Calculation of brands production times per month:

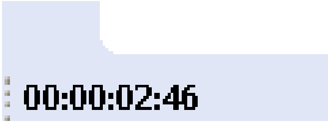
Month	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Q	R	CK
	Brands																	
1			7		8		10						6	9				
2										7			6					
3		11										10	6			9	8	
4				8		8		10					6					6
5									14				6					
6	12	11			10		10			7		10	6	8	8			
7			7	8		8		10			10		6			14	8	
8													6					4
9					8		10		14			10	6				1	
10	12	11	7			8				5			6	8	8	4		
11				8				10			10		6				3	3
12													6					

CPLEX results for the number of cells required:

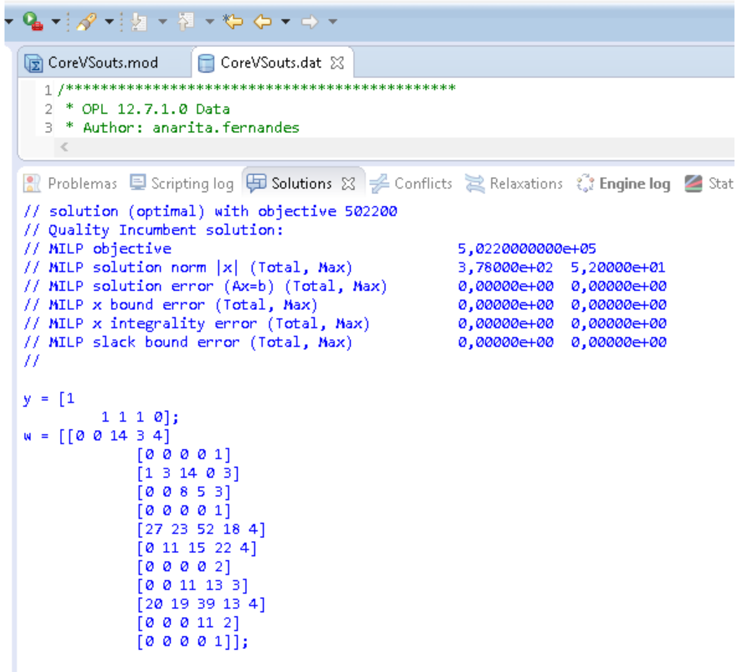


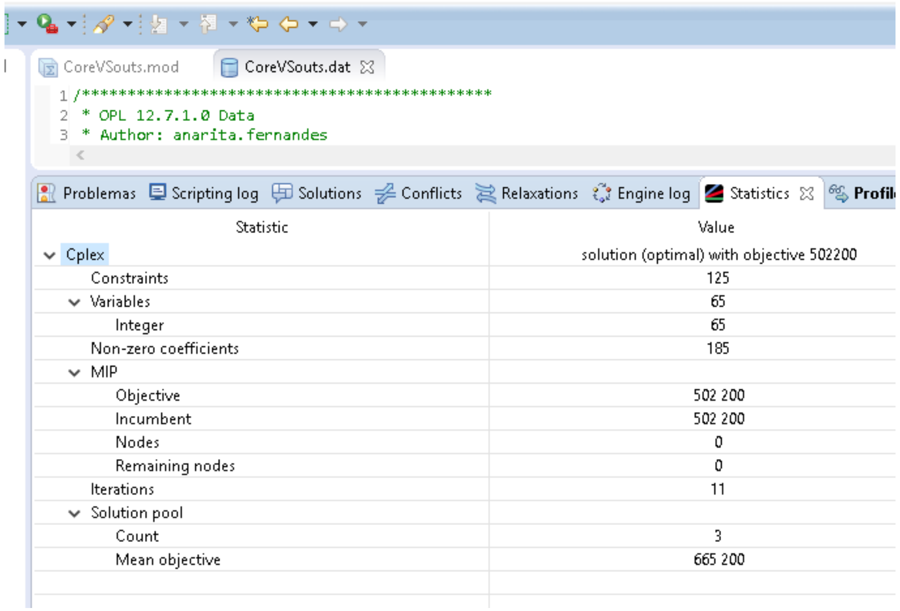


CPLEX processing for the number of cells required:



CPLEX results for the resources allocation:





CPLEX processing for the resources allocation:

APPENDIX D: Production Times and CPLEX results for Scenario 2

<u>Calculation of production times in the stations per month:</u>

January	LMW	LMM	PIN UP	STILLS	JWL
C	0	8	5	5	1
E	5	0	3	8	1
G	2	9	7	1	0
M	3	3	3	6	1
N	8	3	6	5	1
N of days require	**18**	**23**	**24**	**25**	**4**

February	LMW	LMM	PIN UP	STILLS	JWL
J	8	0	5	3	0
M	3	3	3	6	1
N of days require	**11**	**3**	**8**	**9**	**1**

March	LMW	LMM	PIN UP	STILLS	JWL
R	0	8	5	1	0
Q	1	9	0	3	1
B	0	11	8	6	0
L	9	2	7	3	1
N	3	3	3	6	1
N of days require	**13**	**33**	**23**	**19**	**3**

April	LMW	LMM	PIN UP	STILLS	JWL
S	0	0	4	2	1
D	9	0	5	4	1
F	8	0	6	3	0
H	0	0	0	10	0
M	3	3	3	6	1
N of days require	**20**	**3**	**18**	**25**	**3**

May	LMW	LMM	PIN UP	STILLS	JWL
I	0	0	0	14	0
M	3	3	3	6	1
N of days require	**3**	**3**	**3**	**20**	**1**

June	LMW	LMM	PIN UP	STILLS	JWL
O	8	8	3	2	0
A	14	0	8	3	0
B	0	11	8	6	0
E	6	0	3	10	1
G	2	9	7	1	0
J	8	0	5	3	0
L	9	2	7	3	1
M	3	3	3	6	1
N	7	2	5	5	1
N of days require	**57**	**35**	**49**	**39**	**4**

July	LMW	LMM	PIN UP	STILLS	JWL
R	0	8	5	1	0
Q	2	14	0	5	1
C	0	8	5	5	1
D	9	0	5	4	1
F	8	0	6	3	0
H	0	0	0	10	0
K	0	0	0	10	0
M	3	3	3	6	1
N of days require	**22**	**33**	**24**	**44**	**4**

August	LMW	LMM	PIN UP	STILLS	JWL
S	0	0	3	1	1
M	3	3	3	6	1
N of days require	**3**	**3**	**6**	**7**	**2**

September	LMW	LMM	PIN UP	STILLS	JWL
R	0	1	1	1	0
E	5	0	3	8	1
G	2	9	7	1	0
I	0	0	0	14	0
L	9	2	7	3	1
M	3	3	3	6	1
N of days require	**19**	**15**	**21**	**33**	**3**

October	LMW	LMM	PIN UP	STILLS	JWL
Q	1	4	0	2	1
O	8	8	3	2	0
O	14	0	8	3	0
B	0	11	8	6	0
C	0	8	5	5	1
F	8	0	6	3	0
J	6	0	4	3	0
M	3	3	3	6	1
N	7	2	5	5	1
N of days require	47	36	42	35	4

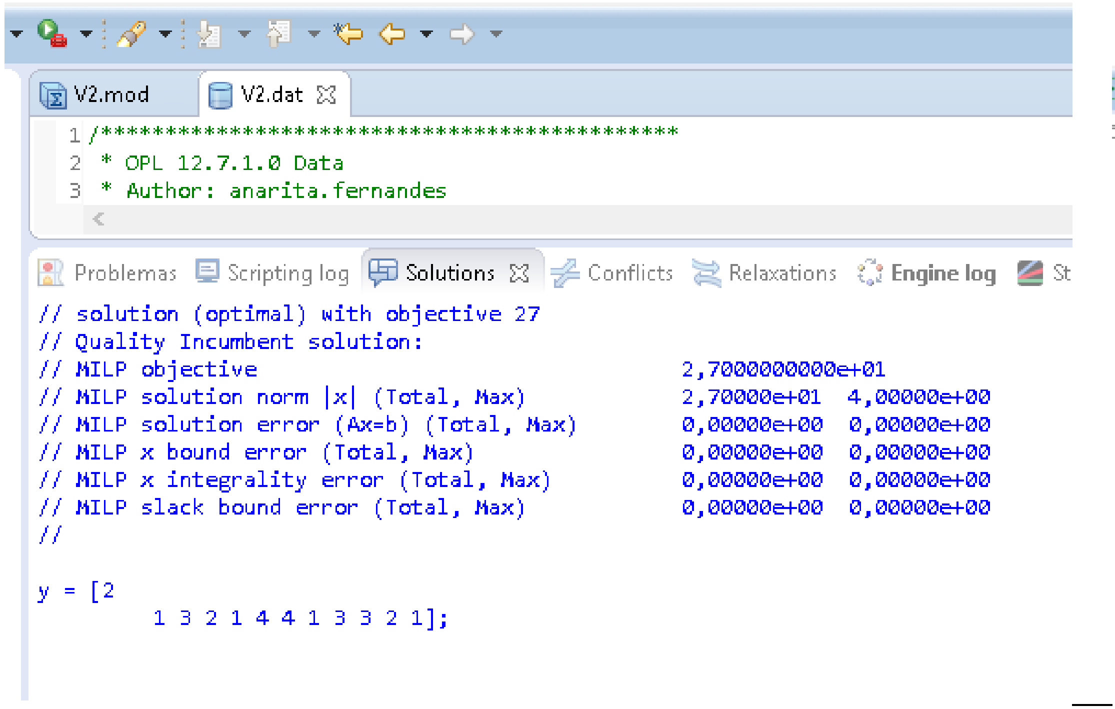
November	LMW	LMM	PIN UP	STILLS	JWL
R	0	3	2	1	0
S	0	0	2	1	0
D	9	0	5	4	1
H	0	0	0	10	0
K	0	0	0	10	0
M	3	3	3	6	1
N of days require	**12**	**6**	**12**	**32**	**2**

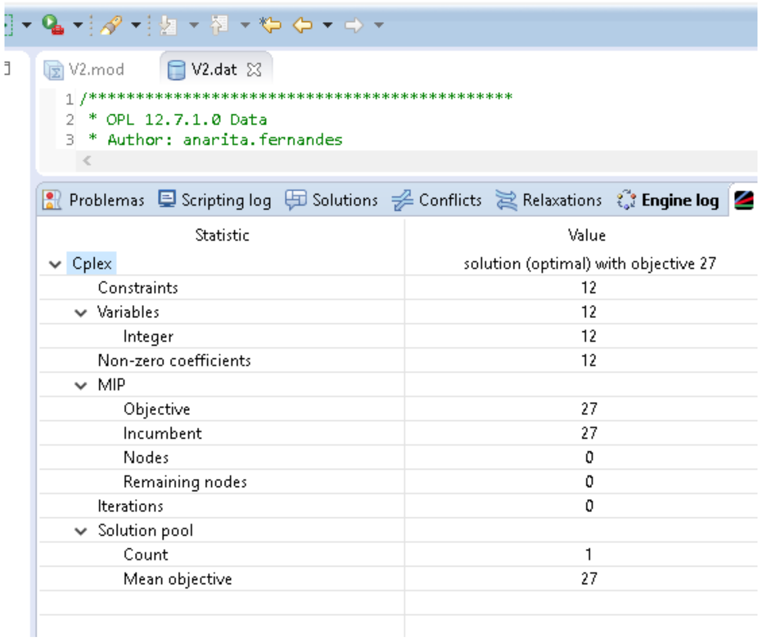
Dec	LMW	LMM	PIN UP	STILLS	JWL
M	3	3	3	6	1
N of days require	**3**	**3**	**3**	**6**	**1**

Calculation of brands production times per month:

	Brands																	
Month	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Q	R	S
1			8		8		9						6	8				
2										8			6					
3		11										9	6			9	8	
4				9		8		10					6					4
5									14				6					
6	14	14			10		9			8		9	6	7	8			
7			8	9		8		10			10		6			14	8	
8													6					3
9					8		9		14			9	6				1	
10	14	11	8			8				6			6	7	8	4		
11				9				10			10		6				3	2
12													6					

CPLEX results for the number of cells required:

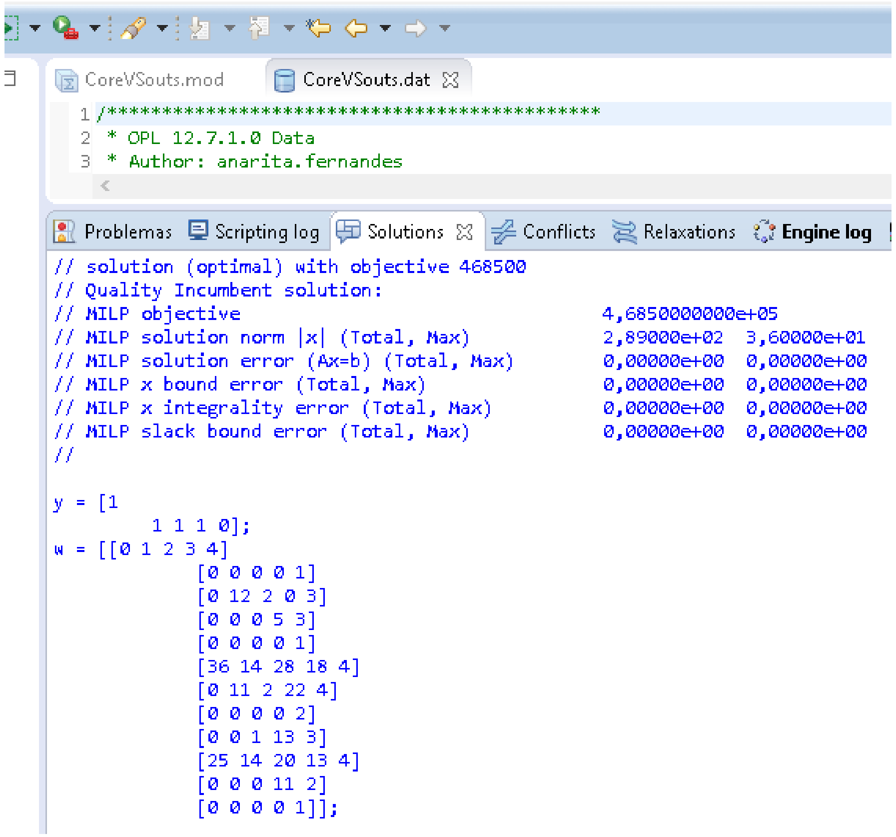




CPLEX processing for the number of cells required:

00:00:03:21

CPLEX results for the resources allocation:

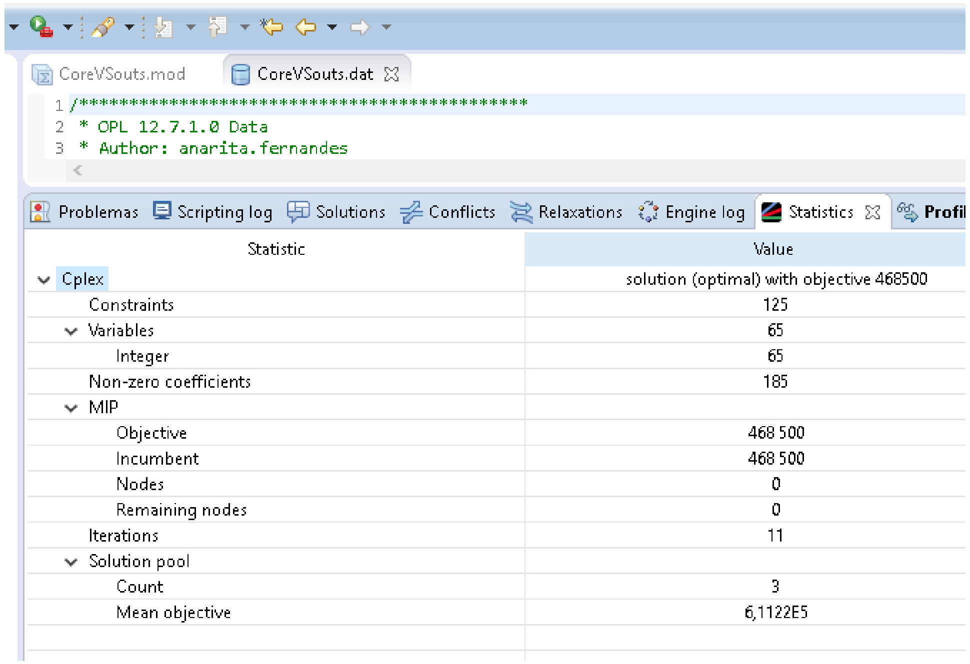


CoreVSouts.mod CoreVSouts.dat

```
1 /*********************************************
2  * OPL 12.7.1.0 Data
3  * Author: anarita.fernandes
```

Problemas Scripting log Solutions Conflicts Relaxations Engine log

```
// solution (optimal) with objective 468500
// Quality Incumbent solution:
// MILP objective                                4,6850000000e+05
// MILP solution norm |x| (Total, Max)           2,89000e+02  3,60000e+01
// MILP solution error (Ax=b) (Total, Max)       0,00000e+00  0,00000e+00
// MILP x bound error (Total, Max)               0,00000e+00  0,00000e+00
// MILP x integrality error (Total, Max)         0,00000e+00  0,00000e+00
// MILP slack bound error (Total, Max)           0,00000e+00  0,00000e+00
//

y = [1
         1 1 1 0];
w = [[0 1 2 3 4]
             [0 0 0 0 1]
             [0 12 2 0 3]
             [0 0 0 5 3]
             [0 0 0 0 1]
             [36 14 28 18 4]
             [0 11 2 22 4]
             [0 0 0 0 2]
             [0 0 1 13 3]
             [25 14 20 13 4]
             [0 0 0 11 2]
             [0 0 0 0 1]];
```



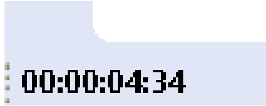
CoreVSouts.mod CoreVSouts.dat

```
1 /*********************************************
2  * OPL 12.7.1.0 Data
3  * Author: anarita.fernandes
```

Problemas Scripting log Solutions Conflicts Relaxations Engine log Statistics Profil

Statistic	Value
Cplex	solution (optimal) with objective 468500
Constraints	125
Variables	65
Integer	65
Non-zero coefficients	185
MIP	
Objective	468 500
Incumbent	468 500
Nodes	0
Remaining nodes	0
Iterations	11
Solution pool	
Count	3
Mean objective	6,1122E5

CPLEX processing for the resources allocation:



APPENDIX E: Production Times and CPLEX results for Scenario 3

Calculation of production times in the stations per month:

January	LMW	LMM	PIN UP	STILLS	JWL
C	0	8	7	4	1
E	5	0	4	6	1
G	2	9	10	1	0
M	3	3	6	4	1
N	8	3	9	4	1
N of days require	**18**	**23**	**36**	**19**	**4**

February	LMW	LMM	PIN UP	STILLS	JWL
J	8	0	7	2	0
M	3	3	6	4	1
N of days require	**11**	**3**	**13**	**6**	**1**

March	LMW	LMM	PIN UP	STILLS	JWL
R	4	4	8	1	0
Q	1	9	0	3	1
B	5	6	11	6	0
L	9	2	10	3	1
N	3	3	6	6	1
N of days require	**22**	**24**	**35**	**19**	**3**

April	LMW	LMM	PIN UP	STILLS	JWL
S	0	0	6	1	1
D	9	0	8	3	1
F	8	0	8	2	0
H	0	0	0	7	0
M	3	3	6	4	1
N of days require	**20**	**3**	**28**	**17**	**3**

May	LMW	LMM	PIN UP	STILLS	JWL
I	0	0	0	7	0
M	3	3	6	4	1
N of days require	**3**	**3**	**6**	**11**	**1**

June	LMW	LMM	PIN UP	STILLS	JWL
O	8	8	4	1	0
A	14	0	12	2	0
B	0	11	11	4	0
E	6	0	5	7	1
G	2	9	10	1	0
J	8	0	7	2	0
L	9	2	10	2	1
M	3	3	6	4	1
N	7	2	8	3	1
N of days require	**57**	**35**	**73**	**26**	**4**

July	LMW	LMM	PIN UP	STILLS	JWL
R	0	8	8	1	0
Q	2	14	0	3	1
C	0	8	7	4	1
D	9	0	8	3	1
F	8	0	8	2	0
H	0	0	0	7	0
K	0	0	0	7	0
M	3	3	6	4	1
N of days require	**22**	**33**	**37**	**31**	**4**

August	LMW	LMM	PIN UP	STILLS	JWL
S	0	0	4	1	1
M	3	3	6	4	1
N of days require	**3**	**3**	**10**	**5**	**2**

September	LMW	LMM	PIN UP	STILLS	JWL
R	0	1	1	1	0
E	5	0	4	6	1
G	2	9	10	1	0
I	0	0	0	7	0
L	9	2	10	2	1
M	3	3	6	4	1
N of days require	**19**	**15**	**31**	**21**	**3**

October	LMW	LMM	PIN UP	STILLS	JWL
Q	1	4	0	1	1
O	8	8	4	1	0
O	14	0	12	2	0
B	0	11	11	4	0
C	0	8	7	4	1
F	8	0	8	2	0
J	6	0	5	2	0
M	3	3	6	4	1
N	7	2	8	3	1
N of days require	**47**	**36**	**61**	**23**	**4**

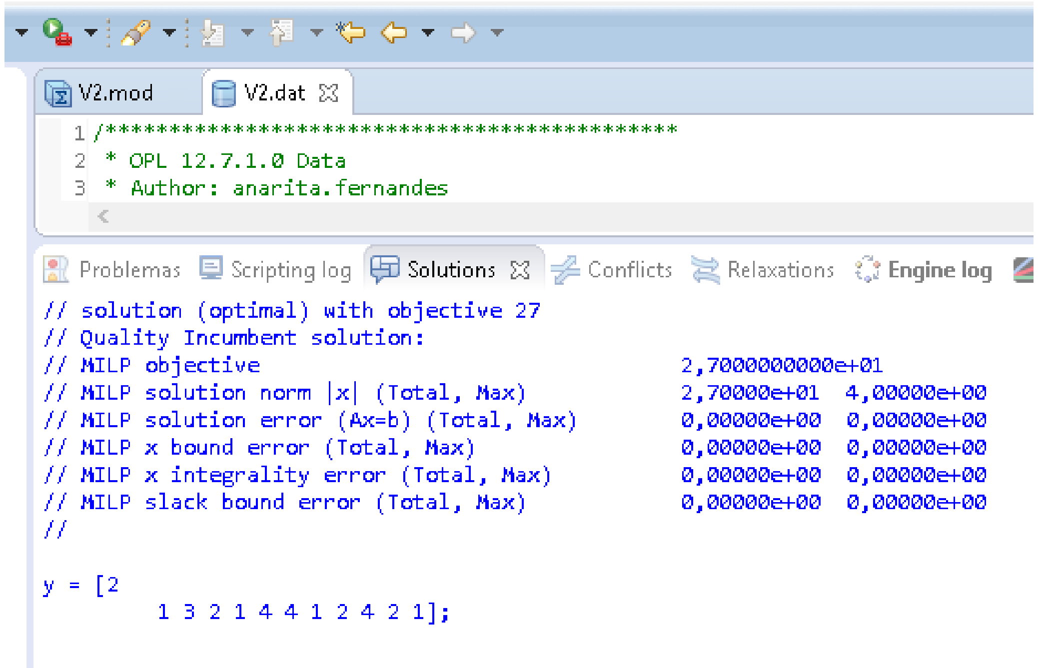
November	LMW	LMM	PIN UP	STILLS	JWL
R	0	3	3	1	0
S	0	0	3	1	0
D	9	0	8	3	1
H	0	0	0	7	0
K	0	0	0	7	0
M	3	3	6	4	1
N of days require	**12**	**6**	**20**	**23**	**2**

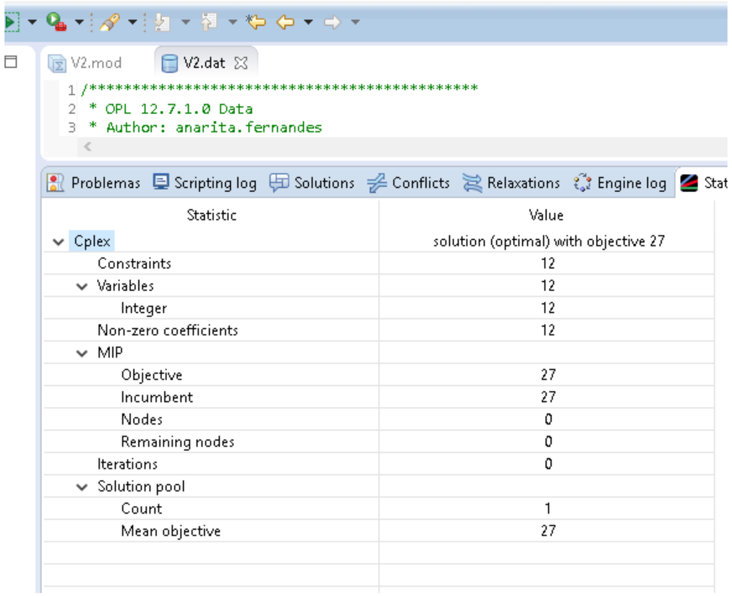
Dec	LMW	LMM	PIN UP	STILLS	JWL
M	3	3	6	4	1
N of days require	**3**	**3**	**6**	**4**	**1**

Calculation of brands production times per month:

	Brands																	
Month	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Q	R	S
1			8		6		10						6	9				
2										8			6					
3		11										10	6			9	8	
4				8		8		7					6					6
5									7				6					
6	14	11			7		10			8		10	6	8	8			
7			8	9		8		7			7		6			14	8	
8													6					4
9					6		10		7			10	6				1	
10	14	11	8			8				6			6	8	8	4		
11				9				7			7		6				3	3
12													6					

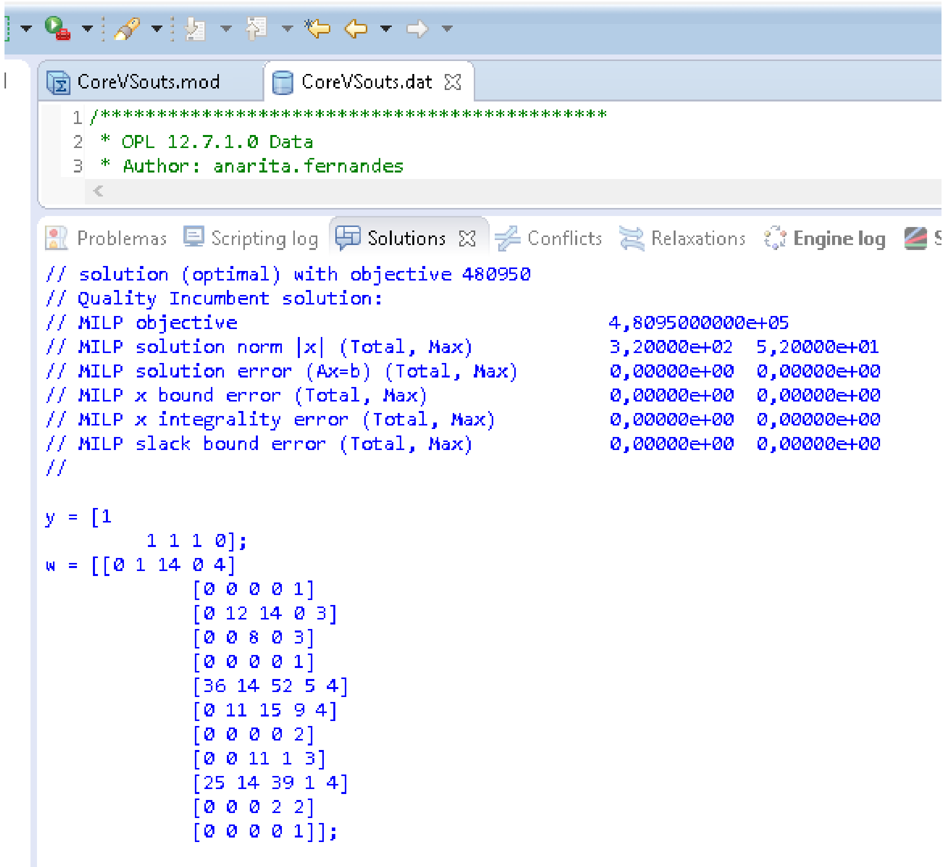
<u>CPLEX results for the number of cells required:</u>

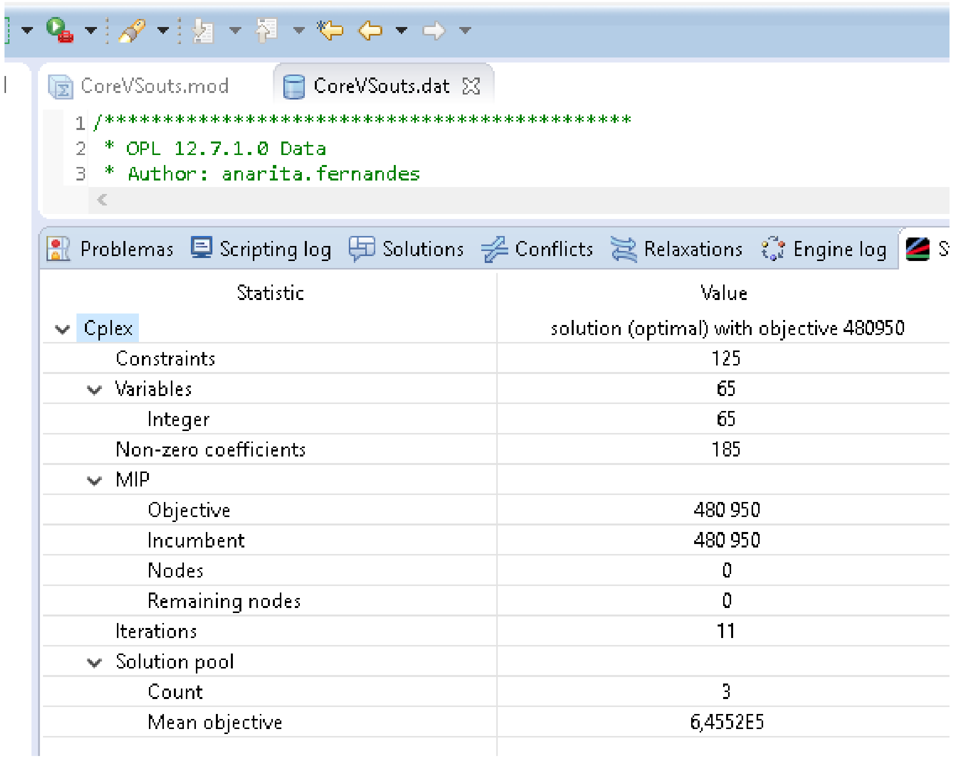




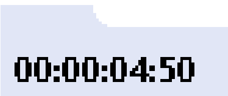
<u>CPLEX processing for the number of cells required:</u>

CPLEX results for the resources allocation:





CPLEX processing for the resources allocation:



APPENDIX F: Production Times and CPLEX results for Scenario 4

<u>Calculation of production times in the stations per month:</u>

January		LMW	LMM	PIN UP	STILLS	JWL
	C	4	4	5	4	1
	E	3	2	3	6	1
	G	2	9	7	1	0
	M	3	3	3	4	1
	N	8	3	6	4	1
	N of days require	**20**	**21**	**24**	**19**	**4**

February		LMW	LMM	PIN UP	STILLS	JWL
	J	4	4	5	2	0
	M	3	3	3	4	1
	N of days require	**7**	**7**	**8**	**6**	**1**

March		LMW	LMM	PIN UP	STILLS	JWL
	R	4	4	5	1	0
	Q	1	9	0	2	1
	B	5	6	8	4	0
	L	9	2	7	2	1
	N	3	3	3	4	1
	N of days require	**22**	**24**	**23**	**13**	**3**

April		LMW	LMM	PIN UP	STILLS	JWL
	S	0	0	4	1	1
	D	5	4	5	3	1
	F	4	4	6	2	0
	H	0	0	0	7	0
	M	3	3	3	4	1
	N of days require	**12**	**11**	**18**	**17**	**3**

May		LMW	LMM	PIN UP	STILLS	JWL
	I	0	0	0	7	0
	M	3	3	3	4	1
	N of days require	**3**	**3**	**3**	**11**	**1**

June		LMW	LMM	PIN UP	STILLS	JWL
	O	8	8	3	1	0
	A	7	7	8	2	0
	B	5	6	8	4	0
	E	3	3	3	7	1
	G	2	9	7	1	0
	J	4	4	5	2	0
	L	9	2	7	2	1
	M	3	3	3	4	1
	N	7	2	5	3	1
	N of days require	**48**	**44**	**49**	**26**	**4**

July		LMW	LMM	PIN UP	STILLS	JWL
	R	4	4	5	1	0
	Q	2	14	0	3	1
	C	4	4	5	4	1
	D	5	4	5	3	1
	F	4	4	6	2	0
	H	0	0	0	7	0
	K	0	0	0	7	0
	M	3	3	3	4	1
	N of days require	**22**	**33**	**24**	**31**	**4**

August		LMW	LMM	PIN UP	STILLS	JWL
	S	0	0	3	1	1
	M	3	3	3	4	1
	N of days require	**3**	**3**	**6**	**5**	**2**

September		LMW	LMM	PIN UP	STILLS	JWL
	R	0	1	1	1	0
	E	3	2	3	6	1
	G	2	9	7	1	0
	I	0	0	0	7	0
	L	9	2	7	2	1
	M	3	3	3	4	1
	N of days require	**17**	**17**	**21**	**21**	**3**

October		LMW	LMM	PIN UP	STILLS	JWL
	Q	1	4	0	1	1
	O	8	8	3	1	0
	O	7	7	8	2	0
	B	5	6	8	4	0
	C	4	4	5	4	1
	F	4	4	6	2	0
	J	3	3	4	2	0
	M	3	3	3	4	1
	N	7	2	5	3	1
	N of days require	**42**	**41**	**42**	**23**	**4**

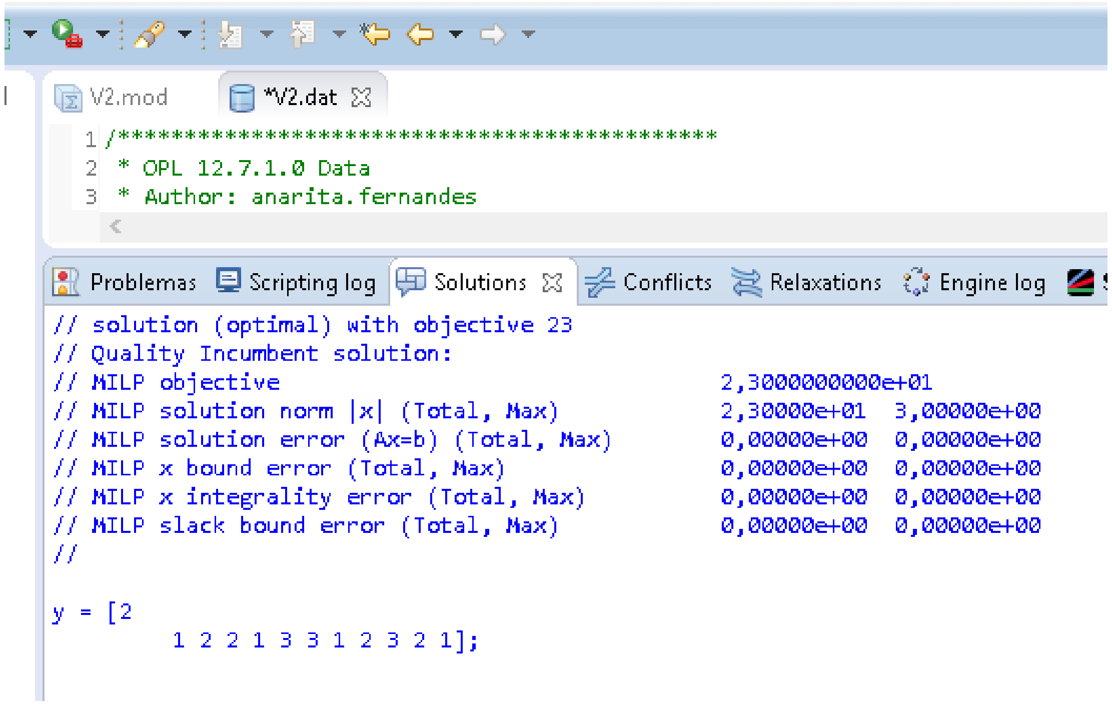
November		LMW	LMM	PIN UP	STILLS	JWL
	R	1	2	2	1	0
	S	0	0	2	1	0
	D	5	4	5	3	1
	H	0	0	0	7	0
	K	0	0	0	7	0
	M	3	3	3	4	1
	N of days require	**9**	**9**	**12**	**23**	**2**

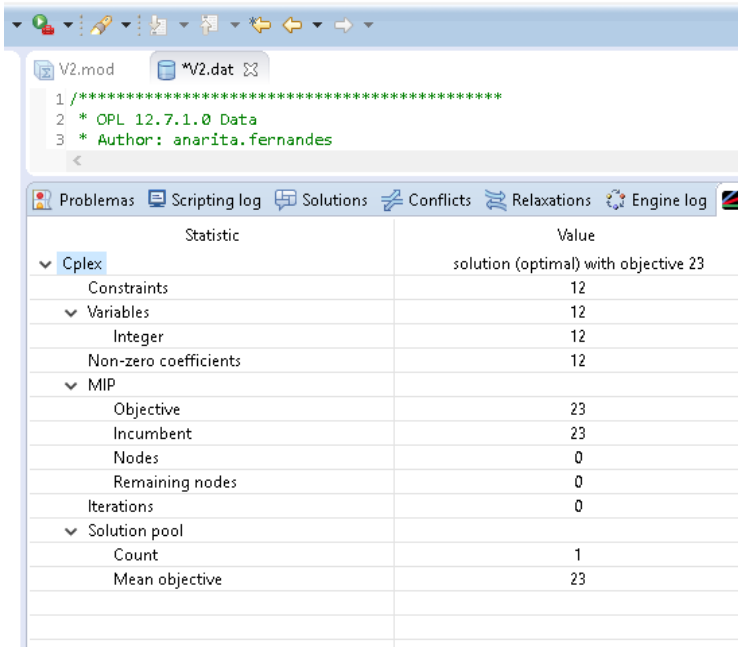
Dec		LMW	LMM	PIN UP	STILLS	JWL
	M	3	3	3	5	1
	N of days require	**3**	**3**	**3**	**3**	**1**

<u>Calculation of brands production times per month:</u>

	Brands																	
Month	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Q	R	S
1			5		6		9						4	8				
2										5			4					
3		8										9	4			9	5	
4				5		6		7					4					4
5									7				4					
6	8	8			7		9			5		9	4	7	8			
7			5	5		6		7			7		4			14	5	
8													4					3
9					6		9		7			9	4				1	
10	8	8	5			6				4			4	7	8	4		
11				5				7			7		4				2	2
12													5					

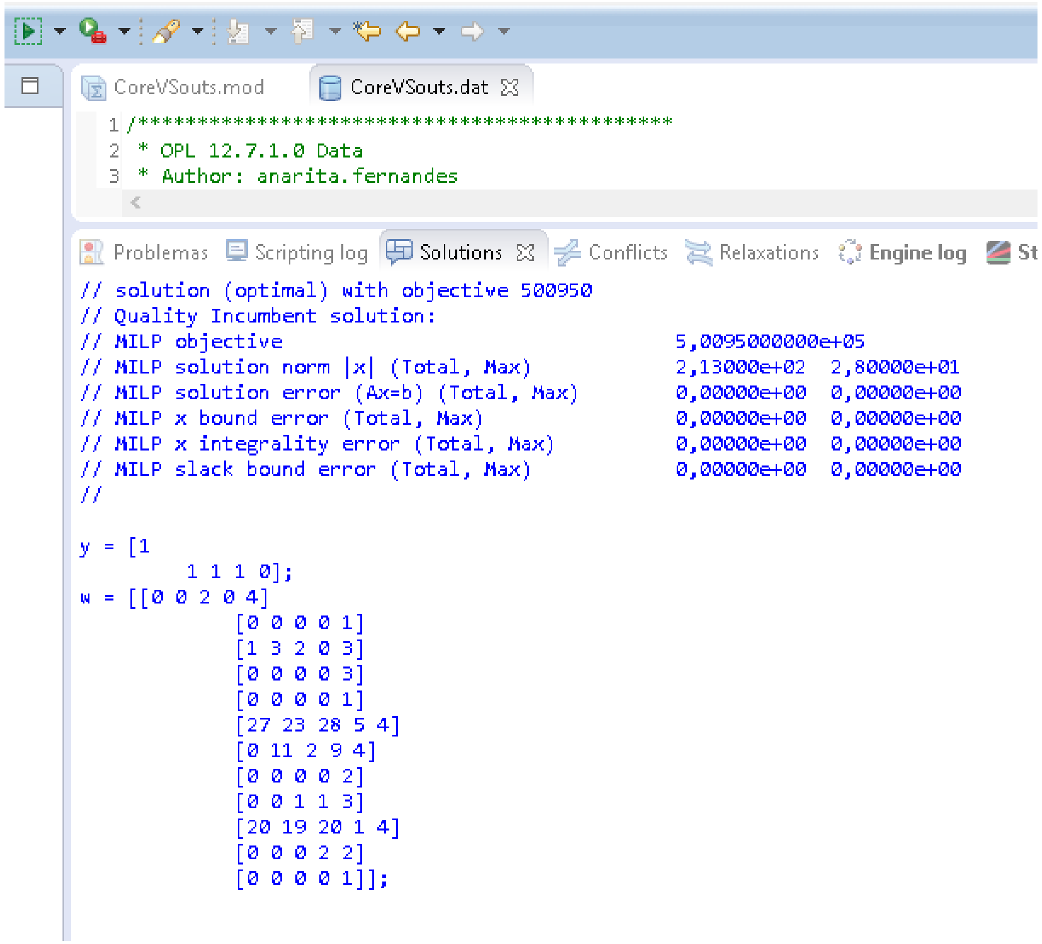
<u>CPLEX results for the number of cells required:</u>

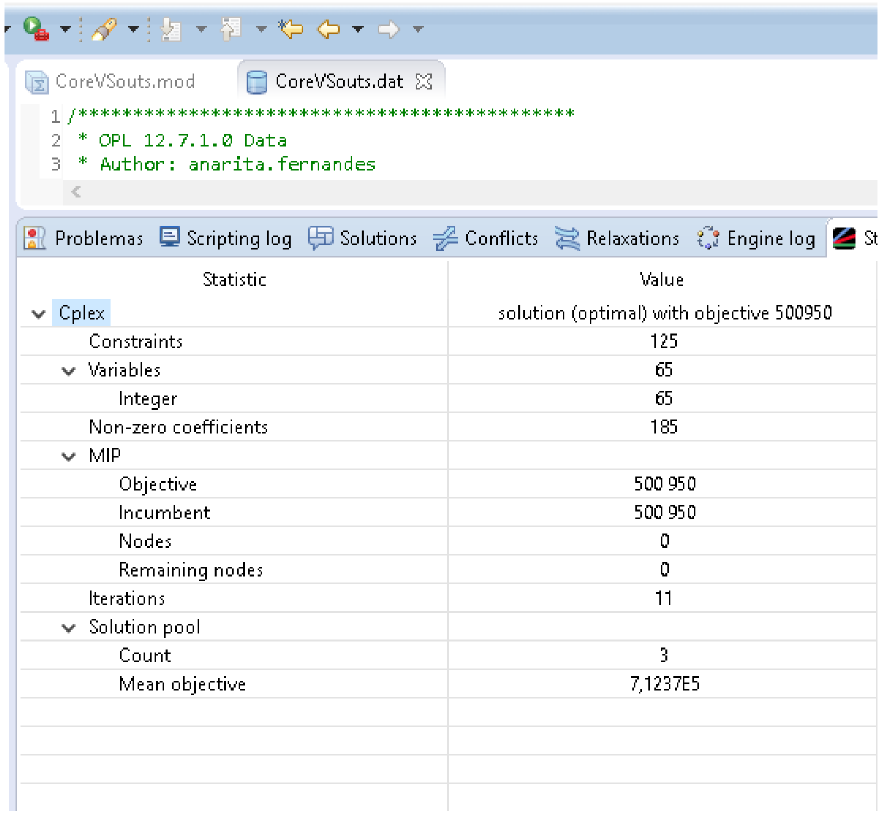




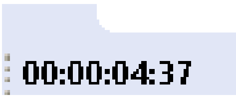
<u>CPLEX processing for the number of cells required:</u>

<u>CPLEX results for the resources allocation:</u>





<u>CPLEX processing for the resources allocation:</u>



APPENDIX G: CPLEX results for Post Production Restructuring

<u>CPLEX model for Post Production:</u>

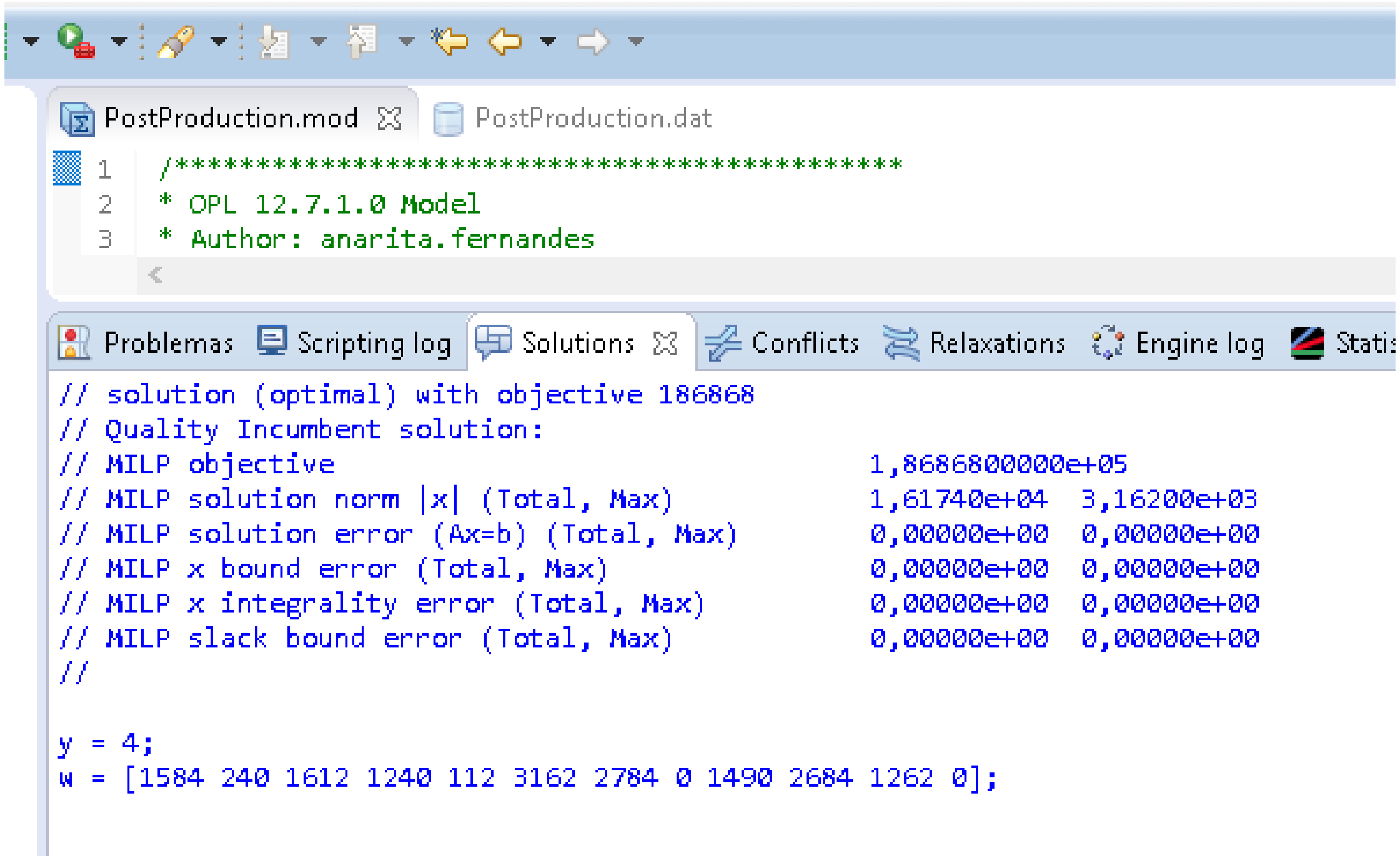
*PostProduction.mod

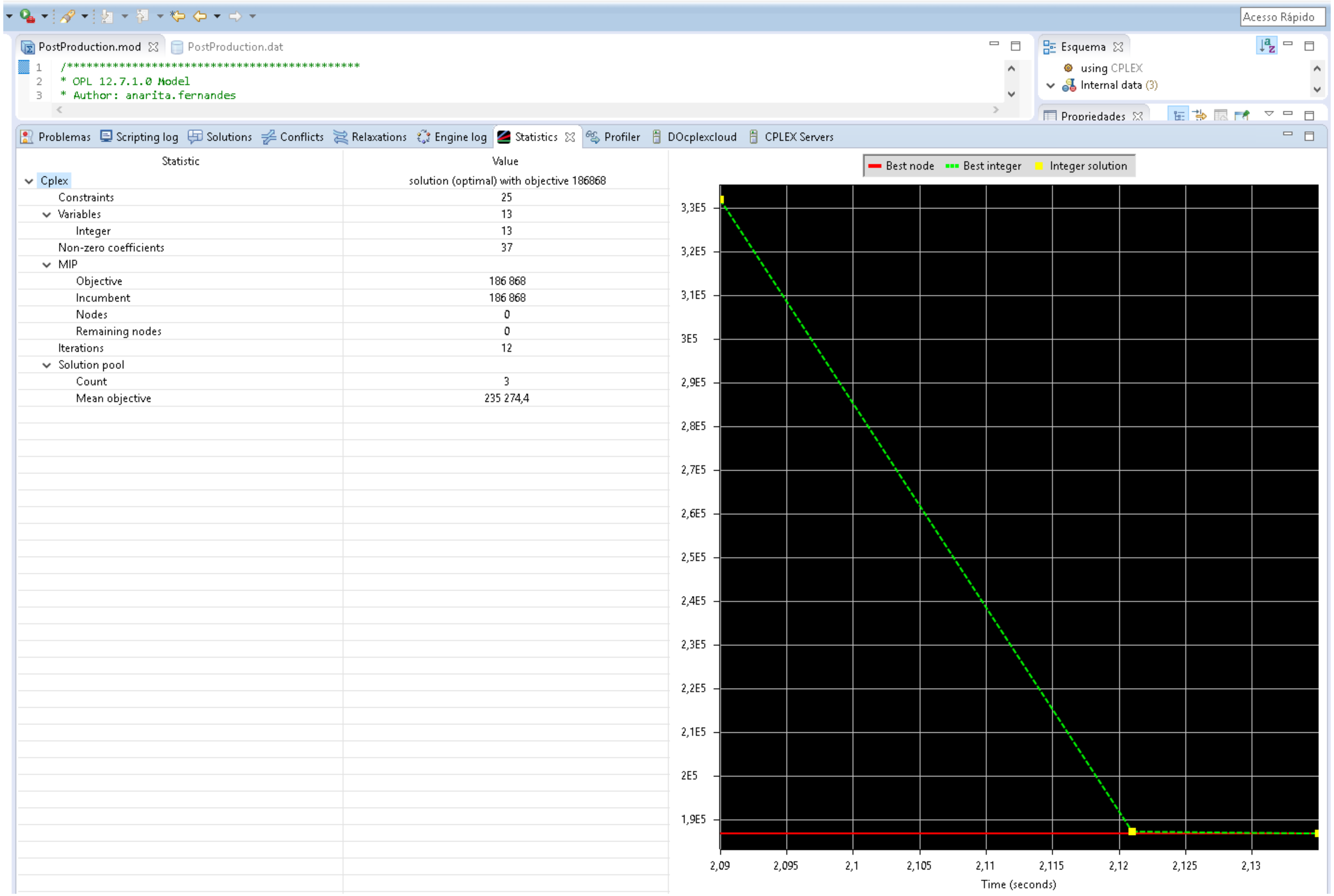
```
/*********************************************
 * OPL 12.7.1.0 Model
 * Author: anarita.fernandes
 * Creation Date: 05/01/2018 at 22:06:32
 *********************************************/

int t=...; //number of months


//parameters
range time=1..t;

float x[time]=...; //number of items to be edited in month t
float c[time]=...; //number of items that an internal editor is able to do in month t

 //variables
dvar int y; //number of internal editors for one year
dvar int w[time]; //number of items that an outsourcing editor will have to do

float cy= Confidential ost of an internal editor per year
float cd= Confidential t per item of an outsourcing editor


minimize  y*cy + sum (t in time) w[t]*cd;
subject to {
forall (t in time)
y*c[t]+ w[t] >= x[t];

}
subject to {
forall (t in time)
w[t]>=0;
}

subject to {
 y>=0;
}
```

PostProduction.dat

```
/*********************************************
 * OPL 12.7.1.0 Data
 * Author: anarita.fernandes
 * Creation Date: 05/01/2018 at 22:06:32
 *********************************************/

t=12;


//Read data
SheetConnection my_sheet("PostProduction.xlsx");

x from SheetRead(my_sheet, "'Sheet1'!B4:M4");
c from SheetRead(my_sheet, "'Sheet1'!C7:C18");

//Write data
//y to SheetWrite(my_sheet, "K6:O6");
//w to SheetWrite(my_sheet, "K9:O20");
```

CPLEX model for Post Production:





Acesso Rápido
PostProduction.mod
PostProduction.dat
/***
* OPL 12.7.1.0 Model
* Author: anarita.fernandes
Esquema
using CPLEX
Internal data (3)
Propriedades
Problemas
Scripting log
Solutions
Conflicts
Relaxations
Engine log
Statistics
Profiler
DOcplexcloud
CPLEX Servers
Statistic
Value
Cplex
solution (optimal) with objective 186868
Constraints
25
Variables
13
Integer
13
Non-zero coefficients
37
MIP
Objective
186 868
Incumbent
186 868
Nodes
0
Remaining nodes
0
Iterations
12
Solution pool
Count
3
Mean objective
235 274,4
Best node
Best integer
Integer solution
3,3E5
3,2E5
3,1E5
3E5
2,9E5
2,8E5
2,7E5
2,6E5
2,5E5
2,4E5
2,3E5
2,2E5
2,1E5
2E5
1,9E5
2,09
2,095
2,1
2,105
2,11
2,115
2,12
2,125
2,13
Time (seconds)

CPLEX processing time for Post Production model:

00:00:02:15