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Improving products lead time:

Supply chain proactivity and bottlenecks resolution.

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IBA case study

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Année académique 2021-2022

Travail de fin d'études (TFE) en vue d'obtenir le titre de

Master (60) en Sciences de Gestion

Foreword

Customer satisfaction has become the main goal of companies, regardless of the sector of activity. This customer satisfaction can be expressed through various aspects; product/service quality, price, reliability, longevity, delivery time, after-sales service, etc. These requirements and expectations can be different depending on the customer. Nevertheless, as a company, it is important to find the fundamental elements that contribute to a high level of customer satisfaction, to capitalize on them and thus create value for the company.

In an industrial sector, where manufacturing lead times are difficult to compress, customers expect to be served as quickly as possible. So, how can we meet this kind of frequent demands (shortening the delivery time) while considering internal (capacity, finance, resources, etc.) and external (suppliers, availability, global economic context, etc.) constraints?

It is through this reflection, conducted within the company for which I work (Ion Beam Applications (IBA)), that my work is articulated, with the aim of answering the request of the customers by proposing applicable internal solutions.

Thanks

I would like to thank all the people who have contributed to the realization of this work; my colleagues from the different departments (Sales, MSC, Program, Planning, etc.) and Benoit Nactergal in particular (IBA RPS R&D Director) who provided me with the necessary information and work leads.

I would also like to thank the members of my family, who supported me and proofread this work (Chloé, Pascal, Arnaud, and my mother).

Thank you for your patience and your support. This work is the result of two years of effort, and I am grateful to you.

Summary

IBA is a company that designs, manufactures and markets particles accelerators. This manufacturing process requires a relatively long lead time (12 to 24 months), depending on the type of machines. Our customers are becoming increasingly demanding and are asking for better delivery times.

"How can we meet the market demands for improved delivery times?"

This is the question that the proposed solutions try to answer. But, before we get to the presentation of the actions, it is important to outline the different concepts that are specific to the field of supply chain management. Themes such as the theory of constraints, the bullwhip effect, capacity and flow management, decisions processes, etc. are discussed, to set the theoretical context, allowing the identification of possible improvement paths.

In order to detect the problematic manufacturing steps - the critical paths - a complete map of the whole manufacturing chain is necessary; upstream and downstream. This map has for objectives; to identify critical paths (bottlenecks) and to set up actions in an anticipative way (proactivity) with the aim of bringing practical solutions answering the principal question.

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1. INTRODUCTION

During my "*master in management*" course, we were able to go through the different dimensions of business management: marketing, strategy, human resources, logistics, finance, and control.

At the end of these two years of training, I was able to acquire the knowledge related to the different professions of business management. I was also able to develop my managerial skills, as well as my critical sense, to be able to make responsible decisions, to lead an analytical reasoning, to show creativity, innovation and specially to integrate the socio-economic parameters in a world which evolves quickly. Through this training, I learned to work in a team and to collaborate in order to carry out the different projects that were entrusted to us. These acquired skills will remain essential in my personal development and will be useful in my professional activity.

Through this end-of-study work, I would like to highlight these skills by confronting them to a practical case from the company I am currently working for.

The business world in which we evolve is becoming more and more demanding at all levels, competitiveness, profitability, quality, environmental and societal respect. We must constantly question ourselves and above all "*challenge*" ourselves on our own achievements. This is the context of the case study that I will be addressing in this work.

Customer satisfaction is also part of this demanding and sometimes constraining dynamic, which must lead us to reinvent ourselves and offer solutions that meet expectations. These expectations can put a strain on the internal structure of a company as well as its processes. It becomes essential to find the balance between external customer expectations and the internal processes of the company set up to meet this demand. Being able to meet customer expectations is a source of value creation, reputation, brand image and of course, financial.

The company I am currently working for is facing one of these challenges: improving equipment delivery times. It is with this guideline that I will highlight the different steps to achieve this and in particular by calling upon important aspects of the field of supply chain management: the "*proactive*" management and the resolution of bottlenecks in a production chain.

a. Presentation of the company

I work in a company called "*Ion Beam Applications*" (IBA). This company was founded by Yves Jongen in 1986 in Louvain-la-Neuve (Belgium). Ion Beam Applications SA (IBA) is the world leader in advanced radiotherapy and cancer diagnostic technologies. Its headquarters are still located in the university town. IBA specializes in the manufacture and marketing of particles accelerators. The company's differentiated expertise lies in the development of innovative proton therapy and radiopharmaceutical technologies that provide the field of nuclear medicine with unparalleled precision equipment. The company currently employs over 1,500 people worldwide. IBA has installed equipment throughout the world and has more recently been expanding its installed base in developing markets.

Yves Jongen, IBA founder

IBA business lines

Through its four core businesses: proton therapy, dosimetry, industrial applications and radiopharmaceutical solutions, IBA offers healthcare professionals solutions that enable them to take a fully integrated approach to patient management.

IBA business units:

- Proton Therapy (treatment)

IBA is the world technology leader in the field of proton therapy. Proton therapy is considered to be the most advanced form of radiation therapy in cancer treatment using ionizing radiation. Thanks to the unique properties of protons, tumors can be targeted with greater precision. The protons deposit most of their energy in a controlled area, thereby limiting the exposure of surrounding healthy tissues to potentially harmful radiation.

- Dosimetry (dosimetry)

The Dosimetry business provides hospitals with a full range of monitoring tools and softwares for, for example, calibration and control of their radiotherapy and radiology equipment. This technology is crucial to ensure that the prescribed dose is delivered accurately to the defined area of the body. Accuracy and control are therefore essential to ensure patient safety and proper dose delivery.

- Industrial Applications (sterilization)

Industrial Solutions focus primarily on developing solutions for applications such as medical devices sterilization. These products enable the medical industry to be significantly more environmentally friendly by avoiding toxic chemicals and radioactive materials, as well as the pollution and risks associated with them.

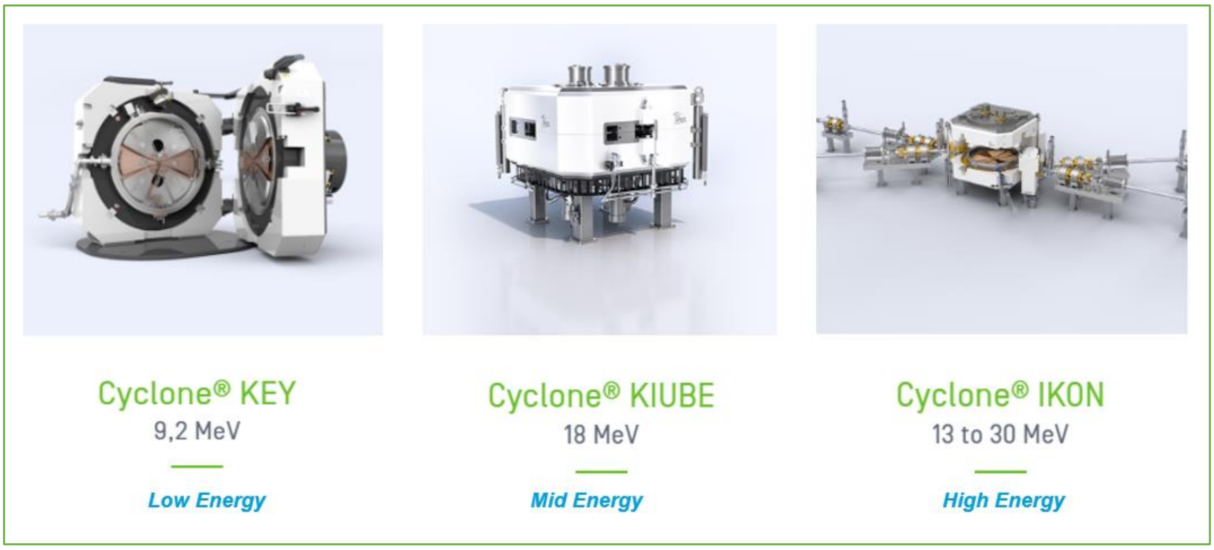
- Radiopharma Solutions (diagnostics)

RadioPharma Solutions develops products used to produce isotopes and radiopharmaceuticals essentials for cancer diagnosis as well as for the fields of cardiology and neurology. We support hospitals and radiopharmaceutical distribution centers by helping them design, build and operate their radiopharmaceutical units.

b. Presentation of the case study

It is on this last business unit (Radiopharma Solutions) that my work will focus. But before getting to the important aspect, it is important to present the products it manufactures and markets: cyclotrons.

IBA RPS markets different types of particles accelerators to produce radiopharmaceuticals used in cancer diagnosis. Depending on their applications, these cyclotrons have different technical characteristics. We classify them into three categories: *"low energy", "mid energy"* and *"high energy"*. A cyclotron is associated with each of these categories.



Cyclone® series – IBA RPS cyclotrons range

Coming back to the case study itself, through this work, I analyzed the way IBA manages the whole production and delivery process of the different products presented. These products go through distinct stages (from design to on-site installation). During the different stages of production, the products may encounter expected and unexpected constraints. It is therefore essential to solve and resolve these constraints, to respect the delivery deadlines planned with the customer. Most of these delivery times are contractual and have a direct impact on IBA's profitability. For example, late deliveries can result in penalties, while early deliveries can, in some cases, be a source of additional revenue.

Supply chain[1] management is therefore a critical and incredibly crucial point in IBA's activities. This management is even more important as it involves numerous parameters (suppliers, raw materials, human resources, etc.) and everything must be orchestrated in such a way that all the stages are carried out according to the planned schedule. Supply chain management is therefore intended to serve as a link between customer demand and the production of goods through a game of constant balance (trade-offs) aimed at optimizing the latter (operational costs, inventory levels, nature of the products, capacity management, profitability, etc.). (Fender and Pimor, 2016).

Constant monitoring of these different parameters is the key to successfully maintaining IBA's commitments to its customers.

c. Main question

This case study analyzed comes from the fact that our customers are more and more demanding. In a competitive environment, it is legitimate for customers to expect a better service level[2], rate, better quality, better financial conditions, etc. Through its business policy, IBA is focused on customer satisfaction as one of its main goals. It is therefore customary to make every effort to satisfy customer requests as far as these wishes are workable.

In our situation, we regularly must deal with one request for most of our projects*:*

"Is it possible to deliver the equipment in a shorter time frame than originally planned?"

Cyclone KEY	Cyclone KIUBE	Cyclone IKON
12 months	**12 months**	**24 months**

Standard production lead time

In order to respond to this request, each prospect is analyzed on a case-by-case basis. Several elements are considered to answer favorably or unfavorably to the request. Aspects such as resources availability, capacity management, priority, workload, and sales forecasts are taken into account. It is not an easy decision to make. Internal constraints and processes in place do not always ease the acceptance of customer requests. It is therefore necessary to be creative to achieve these objectives. We must constantly seek a balance between productivity (in order to serve all customers with a constant rate of service level) and flexibility (in order to serve and respond to certain specific requests).

[1] A supply chain consists of all parties involved, directly or indirectly, in meeting a customer demand. (Chopra S., 2019)

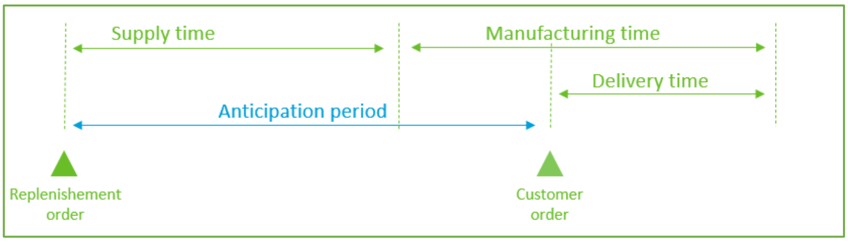
[2] The service level is an indicator used in the supply chain. It corresponds to the percentage of products delivered on time in the required references and quantities, compared to the demand expressed by the customer. It also measures the level of satisfaction of the customer's request in relation to his initial expectations. This indicator could be used as a KPI (Key Performance Indicator) in the future to measure IBA's ability to deliver to customers within the new timeframes expected and desired by the market.

Nevertheless, given that this is a very recurrent request, IBA's teams have undertaken to study the issue more closely, by implementing actions aimed at improving the standard "*lead time*[3]" of the various equipment manufactured and marketed by IBA RPS.

Speed of delivery is one way to measure the performance of a supply chain. The more we can meet a demand that is outside the expected standard, the more competitive we can be with our competitors. It can also be an indicator of reliability in terms of the ability to maintain commitments. It is therefore obvious to constantly ask the following question:

"How do we meet market demands for improved delivery time?"

As we can see, manufacturing lead times are long (from 12 to 24 months) depending on the equipment. It is therefore often necessary to anticipate manufacturing in order to be able to offer the customer a delivery time outside the standard time frame. But it is also important to consider the fact that excessive anticipation can lead to high inventory levels, which is not the desired objective.



Flow management

The cyclotron manufacturing process is relatively technical and complex. Therefore, it is not possible to compress the manufacturing times excessively. For example, it is not possible to halve these times. Currently, the technologies used, and manufacturing methods are the main obstacles to improving lead time. Market studies and feedback from our customers have indicated that lead time should be improved by about 25%. This would correspond to the average of what the competition can also offer.

Cyclone KEY	Cyclone KIUBE	Cyclone IKON
9 months	9 months	18 months

Improved production lead time

These improved lead times are the new manufacturing lead times that will be implemented to meet customer demands. In order to meet these lead times, IBA must organize its supply chain in an optimal way, finding the balance between the costs involved and the profitability expected by management. To do this, IBA needs to have a clear view of its future sales to correctly size its production capacity to allocate sufficient human and financial resources.

It is therefore essential to have this constant view of demand (sales prospects) because it allows strategic decisions to be made, anticipating future needs (stocks, capacity management, economies of scale, etc.). This exchange of information between the various

[3] "*Lead time*" is defined as the time between the beginning of a process and its end. In this case, it would be more exact to speak of "*manufacturing lead time*" which corresponds to the time between the order and the end of production of a product before it is delivered to the customer.

departments (sales, operations, inventory, R&D, etc.) is the key to maintaining this balance, matching supply to demand. This exchange of information takes place during the "*S&OP*[4]" cycle, which allows IBA to focus on the common goal of customer satisfaction. That is, delivering the right product, at the right time, with the right quality and at the right cost.

[4] S&OP = Sales and Operation Planning (See *Chapter 3 - "Supply chain strategy"*)

2. THESIS STATEMENT

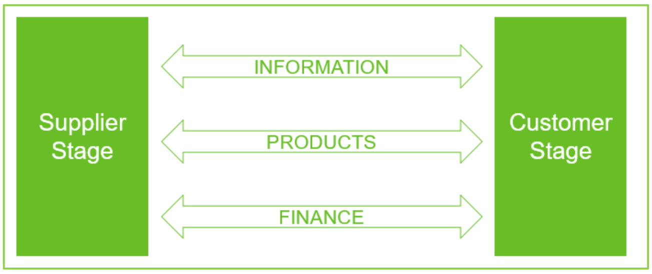
Through this chapter, I will try to highlight the several aspects and theoretical concepts used in the field of supply chain management. These concepts will then allow me to support the analysis methodology used to achieve the objectives of the work.

a. Supply chain – overview and theoretical approach

Before drawing the supply chain of the products used as an example, it is important to go back to the definition[5] of a supply chain. A supply chain can be defined as a set of actors directly or indirectly involved in fulfilling a customer's needs. This includes not only the manufacturer and its suppliers, but also other actors, such as carriers, warehouses and even customers. Each actor performs specific functions to meet customer's needs. These functions can be of various natures; purchase, production, distribution, marketing, operations, after-sales service, etc.

i. The flows of a supply chain

We can therefore say that the primary goal of a supply chain is to satisfy the customer's needs, thus generating profit, while remaining "*cost effective*[6]". And to do this, there are three important flows that must be considered: *the flow of information, the flow of products* and *the financial flow*. (Chopra S., 2019)



The « three flows » in supply chain

- The flow of information[7] :

This flow must be bidirectional. The exchange must be constant between the customer (the manufacturer) and the supplier. The information that circulates between the two must be fed in a regular and qualitative way (status of deliveries, order forecasts, complaints, invoicing, etc.). This flow is extremely important, because it coordinates all the activities of the supply chain and drives the other flows by acting as the brain of the supply chain. The efficiency of the management of this flow will allow to anticipate and foresee the future.

[5] A supply chain is a network of organizations (suppliers, factories, distributors, customers, logistics providers...) that take part in the manufacture, delivery, and sale of a product to a customer" (Le Moigne R., 2017).

[6] Cost control and profitability

[7] The flow of information is certainly the most principal factor to have an optimal management. A constant exchange between the different actors allows for a better anticipation of needs, and therefore a better response to demand. It is through this axis that we can be "*proactive*".

- The flow of products:

This flow is usually unidirectional unless manufacturing processes require it. This physical flow is usually the movement of a good from point A (supplier) to point B (customer). It is the most obvious flow within a supply chain because it is usually tangible and visible.

- The financial flow:

The financial flow indicates the movement of money, going from a customer to their supplier. These money flows can be of several kinds (money, credit notes, etc.) and can be made in several times for the same good.

These three flows are fundamental in the management of the supply chain and must be managed correctly and efficiently because it brings a real added value to the company by providing a competitive advantage. Otherwise, it would be detrimental to the company's performance.

ii. Decisions in a supply chain

The decisions that are taken at the level of each flow must be aimed at optimizing the supply chain to improve performances. Of course, depending on the nature of the company's activities, each flow will require a greater or lesser degree of attention. The decisions to be taken into consideration improve (optimize) the supply chain can be classified into three categories. (Chopra S., 2019)

- Supply chain strategy and design: *long-term vision*

The decisions made during this phase determine how the supply chain will be structured in terms of resource allocation, production process, capacity management, subcontracting of certain activities, warehousing, manufacturing site, etc. This structure must obviously meet the company's strategic ambitions and, above all, the expected performances.

- Supply chain planning: *medium-term vision*

The decisions taken during the planning phase will have as main objective, the maximization of the supply chain performance by considering the constraints described during the strategic decision phase. This phase mainly takes into account the demand forecasts which will allow to set up the supply and production plan.

- Supply chain operation: *short term vision*

At the operational level, orders are processed in an active and tangible way. It is during this phase that each order is produced. Having set the strategy and planning upstream, we focus on the operational activities to meet the demand.

Strategy, planning and operation have an impact on profitability and especially on the performance of the supply chain. The decisions that are made in these various categories will have an impact on the success of the business through their effectiveness and proper implementation.

iii. Supply chain

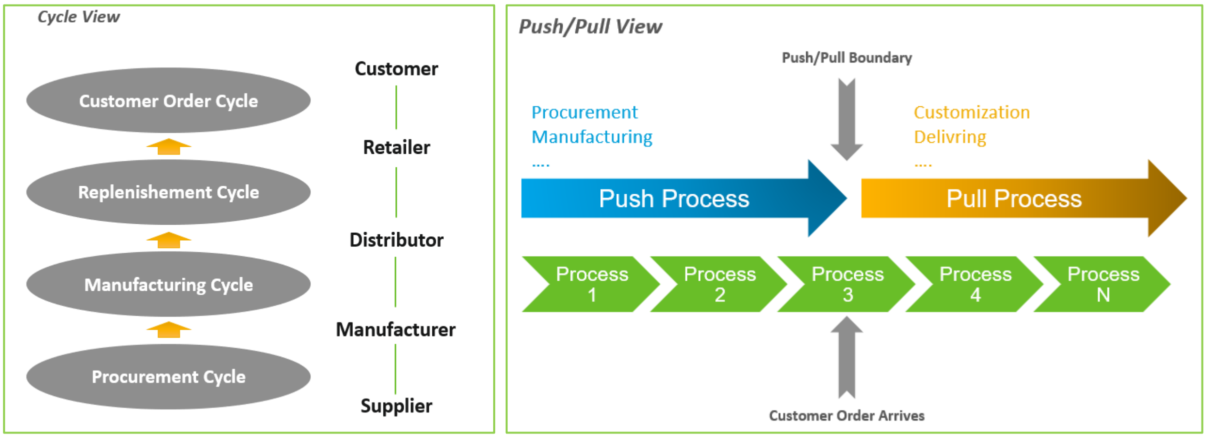
The supply chain can be considered as a succession of flows and processes with the aim of satisfying the customers by providing him with the product/service they need. It is therefore important to define these processes in a precise way, identifying the owners of these processes, their responsibilities and the results expected by them within the supply chain (cycle view). (Chopra S., 2019)

- Push/pull processes
  - *Push process (speculative process)*

The "*push*" process initiates production by anticipating customer's demand, which is expressed in sales/production forecasts. The precise demand is considered as unknown, so we anticipate the quantities to be manufactured by referring to forecasts. Factually, this means that we start manufacturing before receiving the orders.

  - *Pull process (reactive process)*

The "*pull*" process initiates production of products only when the order arrives. Manufacturing only begins when the order enters the system. This process can be considered as being "*reactive*" because it only starts when the customer issues an order.



Cycle view and Push/Pull view of supply chain[8]

In summary, push/pull processes can be considered useful when defining a supply chain strategy. On one hand, the purchasing functions can respond to "*push*" processes because this makes it possible to have all the sub-equipment available when it is time to start manufacturing. On the other hand, the production functions can respond to "*pull*" processes. It is important to correctly define which activities require anticipation and which activities can start when the order arrives in the system.

b. Improving products « lead time »

In an increasingly competitive and demanding environment in terms of quality, companies are more and more solicited. Faced with competition and market demand, companies must differentiate themselves while remaining successful in their field. One of the means of

[8] Source: Chopra S., 2019

differentiation in the field of particles accelerators is the "*lead time*" that can be guaranteed by the manufacturer to its customer.

As we saw earlier, the delivery times for equipment offered by IBA RPS are relatively long (from 12 to 24 months) depending on the product. It is therefore important to devote energy and resources to improving this lead time. The goal is to differentiate ourselves from the competition and consequently gain market share by responding to customer's demand with better lead times than those initially planned. To this end, IBA and the various departments concerned (R&D, manufacturing & supply chain, industrialization, installation, etc.) have undertaken several actions to meet this market demand. Of course, some processes have lead times that are difficult to compress and, in addition, the complexity of manufacturing this state-of-the-art equipment does not allow for considerable time savings. Only certain steps can be optimized. And it is on these few steps that optimization solutions will be proposed in the following chapter.

In order to answer this problem, two aspects are analyzed: the proactivity and the resolution of critical paths (bottleneck).

i. Proactive management

As explained above, the purpose of a supply chain is to meet a customer's need. We have also seen that IBA RPS products have a long manufacturing lead time. The manufacturing processes must run smoothly and continuously to meet the deadlines. If problems are met during the various stages, the expected lead time will be extended and IBA will not be able to meet its commitments. On the other hand, if we can anticipate certain supply and manufacturing stages, IBA will be able to improve the planned deadlines. It is this anticipation activity that will enable IBA to optimize these processes.

Proactivity[9] can be defined as *« an action or approach that is often the result of thinking ahead to save time. »*[10]

IBA's supply chain is rather complex because it involves not only internal activities controlled by IBA (employees), but also external parties over whom IBA has less control. This outsourced part mainly concerns procurement and purchasing. To reduce the risk that may be associated with this outsourcing, a "*proactive*" approach must be taken to mitigate this risk and thus ensure business continuity. This will prevent IBA from being caught short in case of an unforeseen event. While this may not completely cover the unexpected, it will help mitigate its impact.

This ability to anticipate is key to optimizing lead time in our case study. It is important to consider the information communicated throughout the supply chain, without going to the extreme of over-anticipating, due to a misinterpretation of needs. This phenomenon is known

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[9] In contrast, a "*reactive*" attitude will be to adapt to disruptions as they occur. This is characteristic of agile and flexible supply chains that have the ability to quickly adjust manufacturing tactics and operations. (Gligor and Holcomb, 2012)
In terms of risk management, reactivity is perceived as costly and uncertain in its implementation. Planning (proactivity) is therefore preferred to it (Lavastre et al., 2012, p. 835)

[10] Source : https://www.linternaute.fr/dictionnaire/fr/definition/proactive/

as the "*bullwhip effect*". This phenomenon essentially describes the coordination and communication problems within a supply chain. It can be observed when planning fluctuations (sales forecasts) are misinterpreted. The more different steps in the supply chain, the more the effect intensifies. The main cause is the variation in demand. The consequences are increased costs, decreased service level, decreased customer satisfaction, and decreased profitability of the supply chain. (Chopra S., 2019)

Long manufacturing cycles, as in this case study, are identified as potential drivers of the bullwhip effect. With long lead times, information distortion is more likely to occur and a slight change in the demand estimate will imply a significant change in inventory. This will result in a significant change in order quantity and thus an increase in variability. (Simchi-Levy et al. 2009))

Proactive management of the supply chain will consist of increasing the cooperation of internal and external stakeholders in order to reduce the risk of information distortion. The following elements can be used as a guide to manage this proactivity[11] :

- Collecting the data:

Obtaining information upstream and downstream of the supply chain will allow you to respond to potential unforeseen changes before they become major problems.

- Analysis of the entire supply chain:

Analyzing the supply chain as a whole will help identify and strengthen critical points in the system and thus gain efficiency.

- Close collaboration with suppliers (internal and external):

It is essential to stay in constant contact with suppliers (external) and with the different departments (internal). The permanent exchange of information between the different actors is essential.

- Anticipation of problems:

Setting up preventive warning signals is the most effective way to deal with problems as they arise.

- Implementing alternative solutions:

If the original plan does not work, have one or more alternative plans. The alternative plans will allow you to stay in a "*proactive*" mode rather than falling into a "*reactive*" mode.

- Know the critical suppliers:

Determine critical suppliers and identify them in the supply chain. The disruptions that can be caused by these suppliers must be estimated according to the potential loss of revenue that

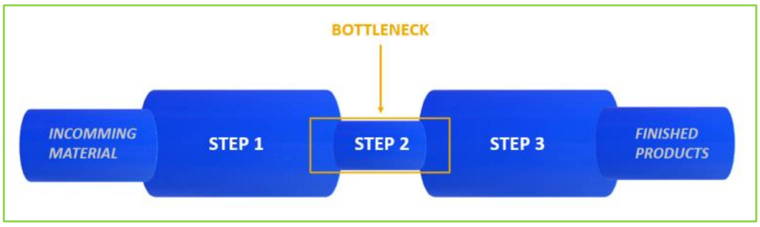
[11] Source : https://www.newcastlesys.com/blog/how-to-design-a-proactive-supply-chain

they can cause for the company, and not only by the weight of the expenses that they generate.

These are only a few examples that can be adapted according to the company's priorities and especially according to the characteristics of the products concerned. Each company may have certain internal constraints that would not allow the effective implementation of this proactive management: capacity problems, financial limits, supplier uniqueness, resource availability, etc.

ii. Bottleneck

In a supply chain, a “bottleneck” can be defined as a manufacturing step where the workflow is greater than the maximum capacity that can be handled during that step. The direct consequence is the slowing down of this workflow in the production process, which creates a bottleneck. This means that during this stage the maximum capacity is used, but the flow cannot be processed fast enough to be transferred to the next stage. The "*theory of constraints*[12] " explains this phenomenon perfectly.



Bottleneck in a supply chain

The theory of constraints is a management philosophy that aims to maximize throughput. By finding the constraint that limits the flow, we will try to work on it in order to increase the system's flow. In the field of manufacturing, the theory of constraints will make it possible to identify the bottlenecks that limit the flow of the entire system and to exploit them to improve it. (Hohmann C., 2009)

The origins of bottlenecks can be as diverse as there are steps in a supply chain; insufficient capacity, limited resources (human, financial, etc.), lack of communication, heavy workload, etc. With these few examples, we see that each origin can appear at any stage of manufacturing. From the supply of raw materials to the delivery to the customer.

This theory puts forward 5 steps that serve as a guideline:

- Step 1 - Identification of the constraint
    - Location of the bottleneck within the supply chain.
- Step 2 - Exploiting the constraint
    - Make better use of the resource that is in capacity constraint.
- Step 3 - Subordinate the constraint
    - Set the same pace as the other steps. Do not go faster than the bottleneck.

[12] The theory of constraints is a management philosophy that was first applied in the field of industrial production before being extended to other fields. It consists in focusing on the performance of constraints that have limited resources to improve the overall performance of a system. It was popularized by the work of Eliyahu Goldrat in the 1970's. (Hohmann C., 2009)

- Step 4 - Raising the capacity
    - Increase capacity by adding more resources.
- Step 5 - Return to Step 1
    - Identify the new bottleneck, which may have moved elsewhere in the system.

Whatever the cause of the bottleneck, it is vital to identify it, as it can cause more than just a slowdown in the manufacturing process. As explained, it can lead to loss of revenue for the company, customer dissatisfaction, employee stress, lower service levels and lower product quality. The easiest way to do this is to first draw a precise picture of the entire manufacturing flow. To illustrate in a clear and graphic way the whole manufacturing process, from the order of raw materials to the delivery to the customer.

For this reason, a good knowledge of the company and its manufacturing processes is needed. IBA RPS products are manufactured according to the "*assembly line*[13]" model. The causes commonly known in this type of model can be classified into two categories:

- Capacity:

For the past 3 years, IBA RPS has had some commercial success and orders have increased exponentially. The teams must manage more and more orders with resources that are not increasing in the same way. This inevitably creates capacity problems throughout the supply chain, both at IBA and at suppliers

- Waiting times:

The manufacture of cyclotrons is relatively complex. These are products that require a high degree of technical mastery and often quite specific resources throughout the manufacturing process. Since the manufacturing model (assembly line) does not allow for the switching of steps when work accumulates due to an increase in orders, the throughput will remain the same.

c. Goals

The main goal of this case study is the implementation of actions to improve the lead time of the products (see Chapter 1 - Main question). The goal is to offer actions that reduce the "*standard lead time*" to "*improved lead time*".

In order to achieve this ultimate goal, two sub-objectives have been set:

- Objective 1: to be proactive within its supply chain

In the manufacturing process, which is relatively important in terms of lead times, the type of actions that have been taken to reduce the lead times of the different production stages will be highlighted. The objective is to show practically the actions taken internally and externally that have a direct impact on the improvement of lead times.

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[13] An "*assembly line*" is a production process that breaks down the manufacture of a good into different steps that are performed in a predefined sequence. Semi-finished products move from one workstation to another. Parts are added in sequence until the final assembly is produced.

- Objective 2: Bottleneck resolution

The bottlenecks that currently pose a problem and limit productivity capacity will be identified through a mapping of physical flows. Once identified, the causes of these phenomena will be studied and clarified. And finally, solutions will be advanced to mitigate and improve these critical paths.

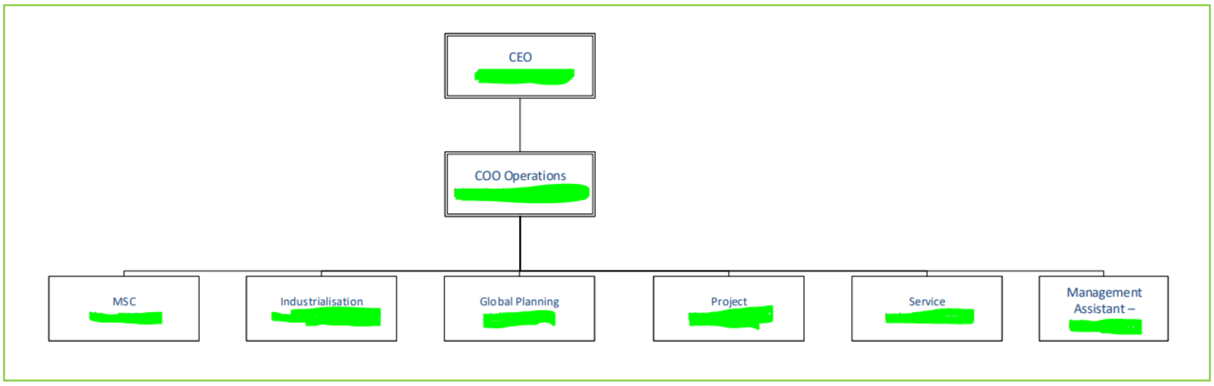
3. METHODOLOGY

In order to achieve the objectives (see *Chapter 2 - Goals*), it is necessary to first understand how IBA's supply chain structure is organized. Therefore, mapping the physical flow of the products studied upstream and downstream of the supply chain will allow us to understand and highlight the important steps in the manufacturing process, identify the important suppliers and thus determine the critical paths (bottlenecks) that have a direct impact on lead time.

a. IBA supply chain structure and production process

IBA is a manufacturing company. It has internal competence centers but must also call upon external competences (subcontracting). In other words, some activities are managed and carried out internally by IBA staff at the Louvain-La-Neuve site, while other activities are managed and conducted directly by subcontractors.

As explained in *Chapter 1 - Presentation of the Company*, IBA is divided into four business lines, each with a specific area of expertise. Nevertheless, these business lines are not totally independent entities and must therefore share certain resources. Some departments serve all the business lines: human resources, legal, finance, quality and operations. It is this last department (operations) that oversees the manufacturing of the different products, from design (R&D) to delivery on site (transport), including purchasing, needs planning and industrialization. The decisions concerning the manufacturing processes are taken at the level of the MSC (Manufacturing Supply Chain) sub-department.

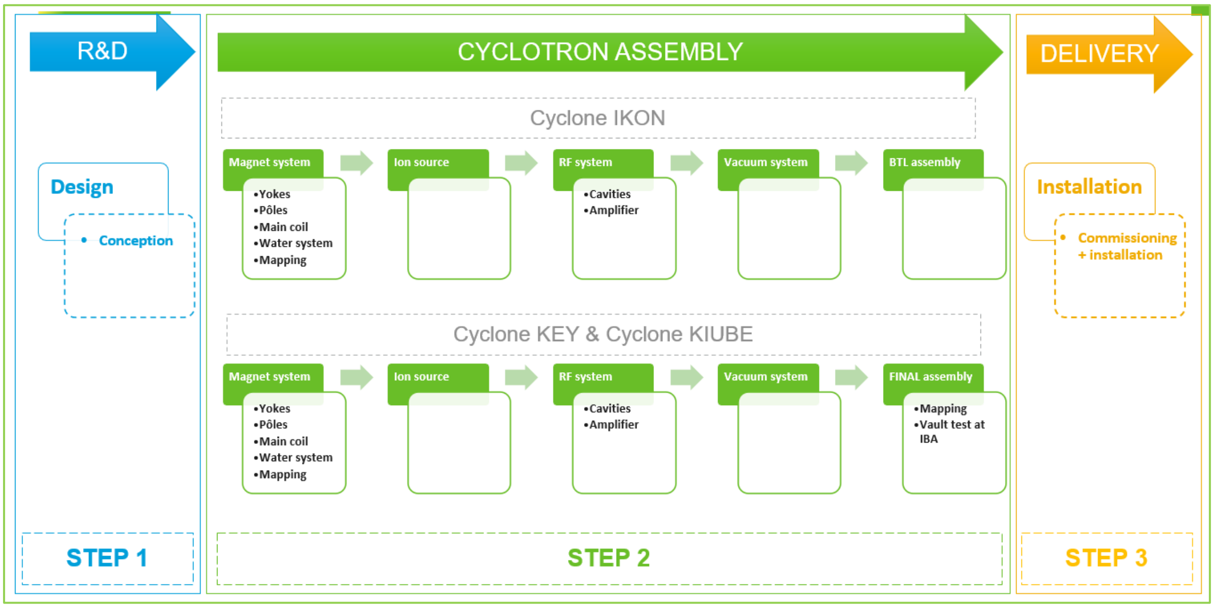


Organization chart of the Operations department

These different departments and sub-departments serve all business lines and share certain resources. The MSC sub-department oversees purchasing, logistics and production. All this while taking into account the company's financial and capacity (infrastructure) constraints.

b. Sequencing and mapping of physical flows

To return to the products studied (see Chapter 1 - Presentation of the case study), they follow very precise stages that have a rigorous chronological sequencing. It is particularly difficult, if not impossible, to switch these steps. It is a "*hybrid*" type of work organization combining the "*assembly line*[14] " and "*project*[15]" methods.



Stages of manufacturing a cyclotron[16]

Step 1 corresponds to the design of the cyclotron and the determination of the machine's characteristics. Since 2016, IBA RPS has undertaken a redesign of its product portfolio by reducing its catalog and implementing identical production synergies on the three machines in the portfolio[17]. In practical terms, this allows the cyclotrons to be produced using the same resources.

Step 2 corresponds to the production lead time. At IBA, this is the time when the cyclotron is put into production until it is finished (ExWork machine). This means that at the end of stage 2, the machine is available for shipment to the site and installation can begin.

Step 3 is the delivery and installation of the machine at the customer's site. Thanks to the identical design of the machines, the fitters and installers can work on any type of machine.

[14] The equipment is grouped into production lines and is arranged in a sequence that follows the sequence of the different manufacturing operations. Each product follows the same manufacturing circuit. (Le Moigne R., 2019)

[15] The product keeps a fixed location. The necessary equipment and components are moved to this location as production progresses. (Le Moigne R., 2019)

[16] Note: this diagram is a simplified version of the different manufacturing steps of a cyclotron.

[17] The Cyclone KIUBE was developed in 2016 following a desire to reduce production costs and improve the technical characteristics of the previous model; the Cyclone 18. A complete re-design has allowed the restructuring of the product's supply chain. Thanks to the development of this new cyclotron, the Cyclone IKON was designed in 2020 on the same technical basis and largely inspired by the design of the Cyclone KIUBE and especially aiming at reducing the size of its predecessor, the Cyclone 30. The Cyclone KEY was designed in 2022 with the same idea as its two predecessors. Since 2022, IBA RPS has had cyclotrons in its portfolio based on the same design and with an almost identical supply chain for all these cyclotrons, except for a few details. This has the impact of saving time in terms of training for fitters and installers, which contributes to the improvement of installation lead time compared to previous versions that had standard lead times higher than those currently proposed for the Cyclone KEY, the Cyclone KIUBE and the Cyclone IKON. By restructuring the supply chain with these new designs, the impact on the carbon footprint has also been reduced, as these machines are now all assembled at the same supplier, which was not the case before.

It is no longer necessary to call on specific profiles for this or that type of machine. The resources are shared and are competent to perform the installation tasks regardless of the type of cyclotron.

Regardless of the type of cyclotron (Cyclone KEY, Cyclone KIUBE or Cyclone IKON), these steps are identical for each machine. The element that makes the lead time vary is the size of the cyclotron. The Cyclone KEY (9 MeV) and Cyclone KIUBE (18 MeV) cyclotrons have the same lead time standard of 12 months, because in terms of size, they are compact machines, while the Cyclone IKON (30 MeV) is a larger machine that requires a standard lead time of 24 months to be manufactured. In summary, it is the technical characteristics that influence the lead time.

Due to the specificities of cyclotron manufacturing, the scarcity of suppliers is a determining factor because this is a niche field of activity. The suppliers in charge of the manufacturing of the different sub-assemblies can be defined as critical suppliers to whom particular attention must be paid.

STAGE	TASK NAME	PROVIDER	LOCATION
STEP 1	Design & conception	**IBA**	Belgium
STEP 2	Magnet system	**Dillinger**	Germany
	Ion source	**D-Pace**	New Zealand
	RF system	**Karl Hugo**	Belgium
	Vacuum system	**Sumitomo**	Japan
	BTL assembly	**Graux**	Belgium
STEP 3	Delivery & installation	**IBA**	**On site*

List of suppliers and locations

- Dillinger[18]:

Dillinger is a company supplying steel plates. Steel is the main part of a cyclotron. It is the starting point of the manufacturing process, to which are added the other subsystems of the cyclotron. The quality of steel required by IBA must meet specific standards. Steel is a material that is traded according to market prices and quantities bought.

- D-Pace[19]:

D-Pace is a New Zealand company that supplies components needed in the particles accelerators industry. The ion source is a major part of the cyclotron, as it is through this equipment that the particle beam is created. D-Pace's field of expertise is so advanced that there are very few competitors offering the same equipment at the same quality.

- Karl Hugo[20]:

Karl Hugo is a company located in Belgium, in Liege more precisely. They are specialized in the construction and assembly of various industrial machines. They are active in the field of mechanical engineering, welding, machining, and assembly. Karl Hugo is an incredibly

[18] https://www.dillinger.de/d/fr/corporate/dillinger/groupe/index.shtml
[19] https://www.d-pace.com/?p=about
[20] https://www.karlhugo.com/fr/entreprise

important supplier, because it is to this company that IBA subcontracts the assembly of the various components of the cyclotrons once the components have been procured from the different suppliers. It is the meeting point for all cyclotron subassemblies.

Karl Hugo assembly hall

- Sumitomo[21]:

Sumitomo Heavy Industry (SHI) is a Japanese company active in various fields (energy, shipbuilding, medical, defense, chemical, precision engineering...). It is the supplier of the pumping system (vacuum pumps). This element is used to create the necessary vacuum to accelerate the particles in the best conditions.

- Graux[22]:

Graux is a Belgian company located in Momignies (Chimay). They are specialized in the design, manufacturing and assembly of mechanical components for industrial machines. They are also active in the field of welding, machining, and assembly. Graux is in charge of manufacturing and assembling elements called "*Beam Transport Line*" (BTL). These are sub-assemblies required for the Cyclone IKON product. The Cyclone KEY machines are never equipped with these elements, while the Cyclone KIUBE machines are equipped with them on approximately 1 time out of 30 machines.

- IBA:

At the supply chain level, IBA is responsible for the entire manufacturing process of its particles accelerators. This includes everything from design to on-site installation. Coordination of purchase orders and manufacturing orders with suppliers is managed internally through the various processes and departments involved. Some tasks are performed internally and others directly at the suppliers. The necessary infrastructure and equipment are the main reasons for using subcontractors. The Cyclone KEY and Cyclone KIUBE are repatriated to the IBA site in Louvain-La-Neuve to undergo the final testing phase before

[21] https://www.shi.co.jp/english/company/history/index.html
[22] https://graux.be/entreprise/

shipment to the installation site. The Cyclone IKON, on the other hand, undergo the final test phase at the Karl Hugo assembly plant. This is a strategic decision that has been made. The capacity of the IBA production site does not currently allow it to meet all the needs of the other business lines with which IBA RPS shares the final test areas.

IBA factory in Louvain-La-Neuve

The following map shows the physical flow of the sub-assemblies necessary for the manufacture of cyclotrons. We can observe that this physical flow covers a rather large area in terms of geographical space.

Product components flow[23]

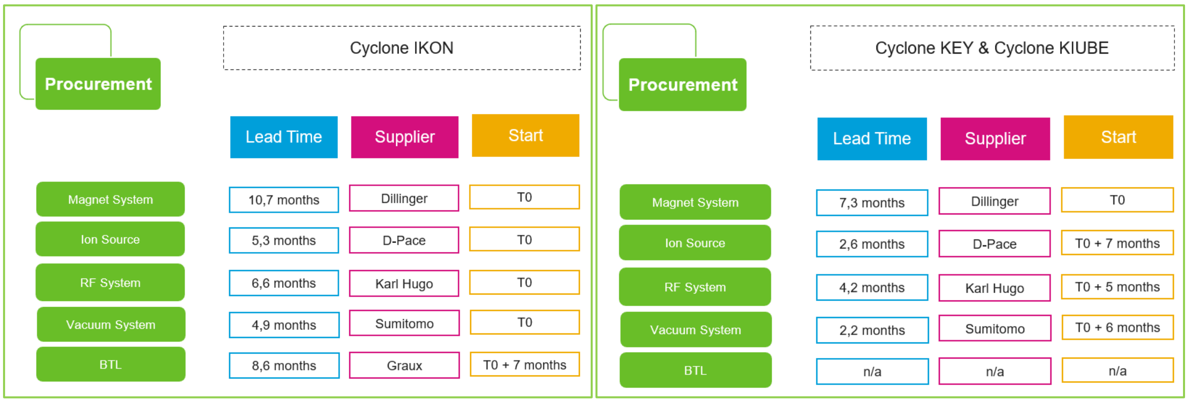
We have seen that the manufacture of cyclotrons follows a hybrid production process (production line and project). The different sub-assemblies are produced at the suppliers facilities and then they are transported and assembled in the assembly plant (Karl Hugo). We can therefore distinguish two stages in the manufacture of cyclotrons: *the supply stage* and *the assembly stage*.

- Supply stage:

This step is key in the manufacturing process, as it will determine the rest of the operations. As explained above, the cyclotron is a complex machine composed of several sub-assemblies which are custom-made for the most part, the realization of these is entrusted to

[23] See *Annex 3 – Cyclotron sub-systems*

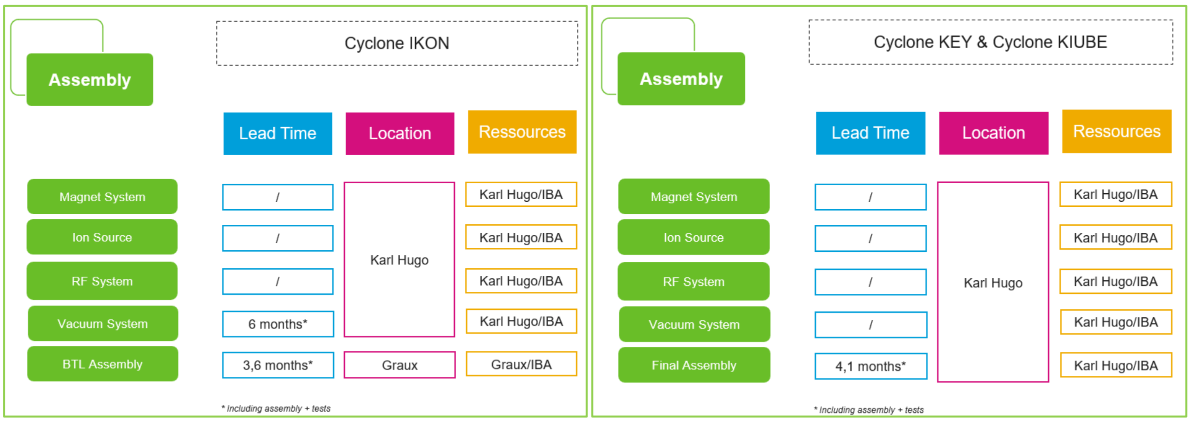
subcontractors. The slightest problem in the supply of these sub-assemblies will de facto delay the manufacture of the machine. During this phase, IBA is entirely dependent on its suppliers.



Procurement stage

- Assembly stage:

Once the parts have been supplied, they are assembled according to a precise chronology. The assembly takes place partly at the supplier Karl Hugo, but also at IBA for some specific parts. It is also during this phase that the various conformity tests are conducted to validate the machine before it is shipped to the site. During this phase, IBA is dependent on Karl Hugo's production capacity, but above all on its internal (IBA) resources (human resources).

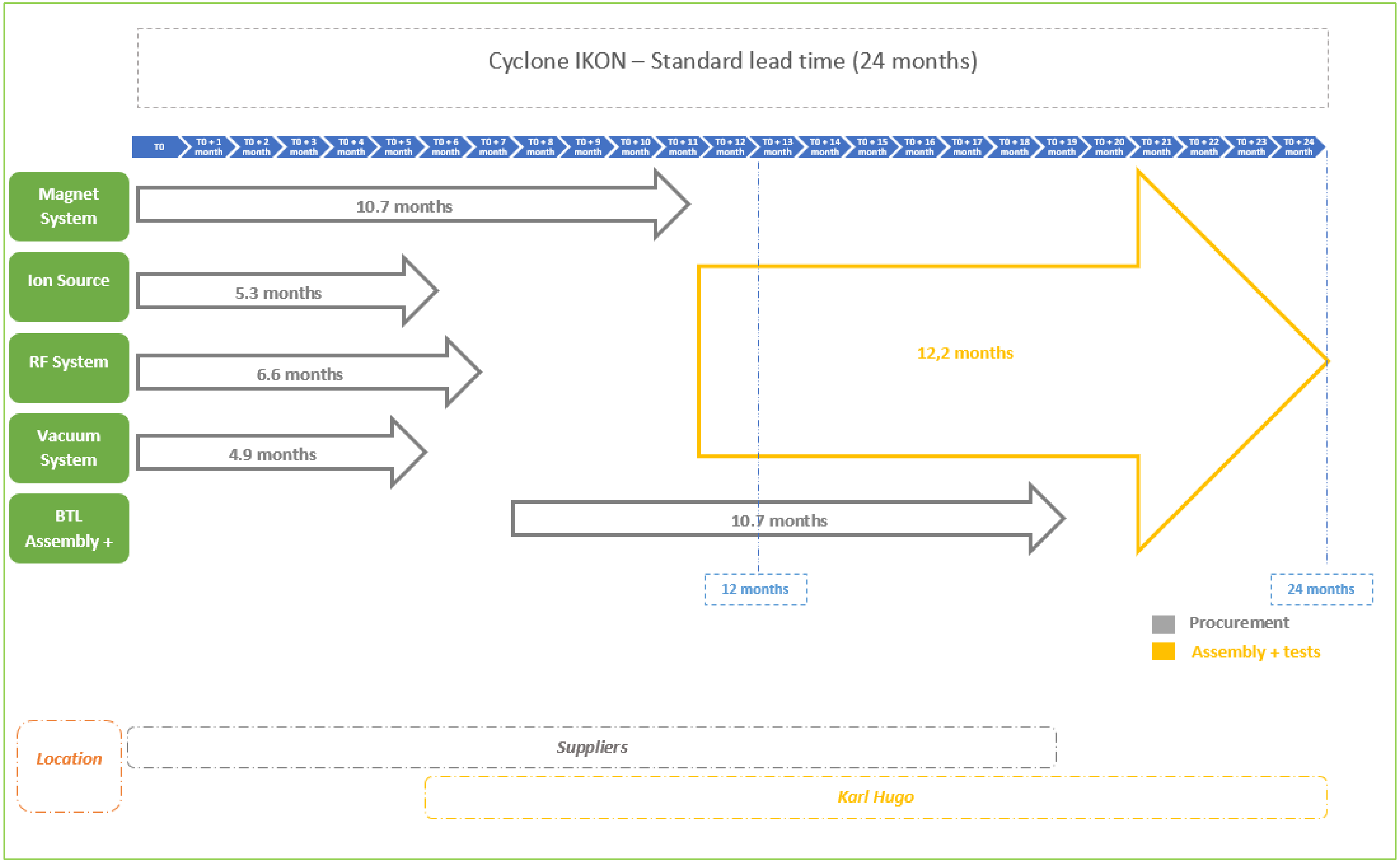


Assembly stage

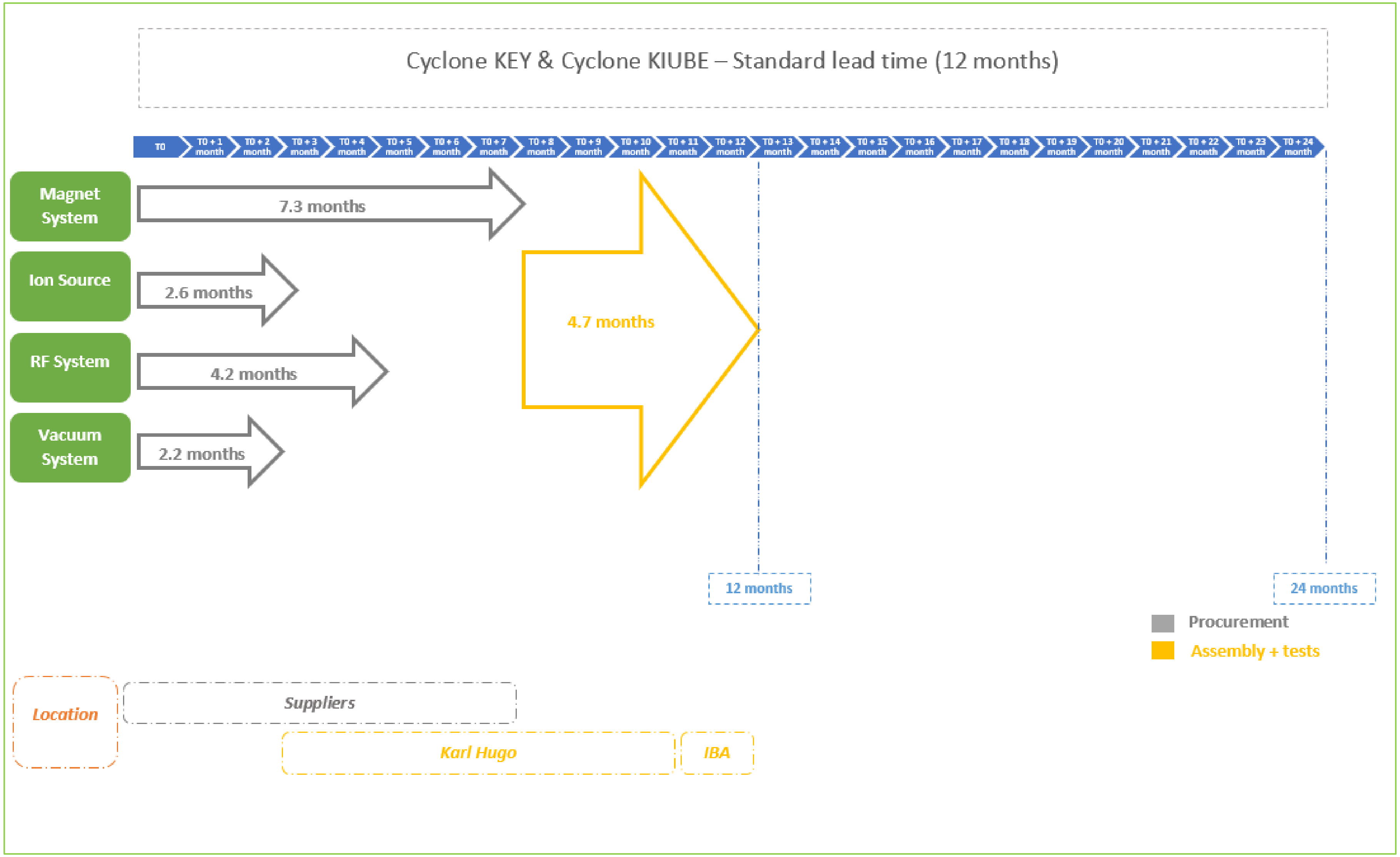
During the procurement phase, IBA is dependent on its suppliers for delivery times of various subassemblies. The sourcing process is therefore essential to ensure that deadlines are met.

During the assembly phase, IBA is dependent on the capacity of the assembly plant and the availability of resources (internal and external). The process of forecasting future activities and sales is essential to plan the capacity needed to manufacture the machines.

The following diagrams merge all the production processes and their execution time according to the type of cyclotron.



Standard production planning – Cyclone IKON



Standard production planning – Cyclone KEY & Cyclone KIUBE

c. Supply chain planning

In order to meet the objectives, the machine manufacturing process starts upstream of the supply chain with an estimate of sales volumes per product. This is the "*forecasting*" stage, which is fed regularly through meetings that are part of the S&OP cycle. The goal is to match the sales plan with the production plan, with the ultimate goal of satisfying the customer by delivering the right product to the right place at the right time. Thanks to these forecasts, the supply chain can anticipate the needs and resources needed to meet the demand. Once the sales forecasts have been established, the Manufacturing & Supply Chain (MSC) department is responsible for coordinating these needs (components and resources) with the supply chain.

i. Sales forecasting

As explained, demand forecasting (sales forecasting) is used to estimate the quantities and products to be manufactured. This step is important at IBA because it directly determines the supply and allocation of resources. This forecast is carried out in collaboration with the sales department and the planning department, for a one-year period. These forecasts are updated monthly through meetings between the two departments concerned. The sales assumptions are based mainly on prospects with whom advanced contacts are made. These sales assumptions are not based on the history of previous years, but consider not only sales targets, but also IBA's production capacity.

Cyclone KEY (9,2 MeV)			
	2021	2022	2023
Sales forecast/Order intake[24]	1	2	4
Availability[25]	9 months		

Industrial and commercial plan – Cyclone KEY

Cyclone KIUBE (18 MeV)			
	2021	2022	2023
Sales forecast/Order intake	12	14	14
Availability	9 months		

Industrial and commercial plan – Cyclone KIUBE

Cyclone IKON (30 MeV)			
	2021	2022	2023
Sales forecast/Order intake	1	2	1
Availability	18 months		

Industrial and commercial plan – Cyclone IKON

The above tables are the number of machines to be put into production. These tables allow the planning of future operations and indicate the expected lead times. These long-term sales targets allow to set up an industrial and commercial plan at the strategic level of the organization.

[24] Corresponds to budgeted sales orders.
[25] Corresponds to the targeted lead time (*targeted lead time*).

This plan is also intended to help making decisions on the management of necessary resources (production capacity, human resources, storage capacity, subcontracting, procurement, investment, etc.). Since this production plan is taken at a strategic level, it is designed in consultation with the various departments (sales team, finance, operations, etc.) before being validated by management.

The industrial and commercial plan also aims to meet market demand, i.e., to reduce manufacturing times and thus satisfy customers. The estimation of sales makes it possible to anticipate the quantities to be supplied and produced.

ii. Sourcing and purchasing

Once the industrial plan has been set up, the actual quantities to be supplied by type of product can be calculated; *the planning of component requirements*[26] . Once the calculation of the needs is defined, the procurement can be carried out with the suppliers.

The sourcing strategy must support the company's strategy at several levels (cost reduction, better quality, reduced environmental impact, reduced risks, etc.) by using several levers:

- Volume concentration:

Consolidate suppliers, pool product volumes, broaden contract terms, consolidate purchases upstream of the supply chain, etc.

- Volume consolidation:

Consolidate suppliers, aggregate product volumes, broaden contract terms, consolidate purchases up the supply chain, etc.

- - Restructuring of the relationship with suppliers [27] :

Establish key suppliers, set up partnerships, integrate the supply chain, re-evaluate the "*make or buy*" strategy, etc.

- Product Specification Improvement:

Streamline and standardize components, redesign products, analyze product value, optimize costs, etc.

iii. Production

Requirements planning takes into account not only the supplies, but also the resources needed for production. During this phase, capacity management must be considered. This consists of verifying whether sufficient resources are available to achieve the industrial and commercial objectives.

[26] MRP (Material Requirements Planning): Material Requirements Planning, also known as Net Requirements Planning, etc., is a function that determines the quantity of all components needed to produce the products in the "*Industrial and commercial plan*" and when each of these components should be available. It uses data on bills of materials, inventories, and the production plan. (Le Moigne R., 2017)
[27] The critical suppliers: Dillinger, Karl Hugo, D-Pace, Sumitomo.

The production strategy will depend on the type of product:

- Cyclone IKON: *Chase strategy*

The Cyclone IKON is produced in the quantities ordered. Because of its cost and the low quantity of machines to be manufactured in the coming years, this production strategy aims at limiting the stocks of finished products. – « *Project*[28] » production

- Cyclone KEY & Cyclone KIUBE: *Level production strategy*

These machines are produced according to a smoothed schedule. The production rate is constant, which creates a stock. When the demand is lower than the quantity produced and when the demand is higher than the quantity produced, this stock is consumed. This production strategy allows to stabilize the production rates while reducing the production costs. – « *Commercial*[29] » production

The advantage of the Cyclone KEY and Cyclone KIUBE production plan is that the production rate is constant. This has the advantage of allowing IBA to interchange machines and customers. In other words, it allows the allocation of machines to be changed according to delivery priorities, rather than according to the customer. This is not the case with Cyclone IKON, which are allocated according to customers and not according to delivery times.

d. Identification of critical paths (bottlenecks)

Now that the physical flow map and the manufacturing schedule have been established, it is possible to highlight (identify) any steps that are considered critical throughout the production cycle.

Up to now, a simplified version of the operation chronology has been presented. With the use of the "*Microsoft Project*[30]" software and by generating a Gantt chart, the teams were able to identify these critical paths. Thanks to the Gantt chart, it is possible to identify the tasks that can influence the lead time thanks to the sequencing of the production flow that are determined in this graph. Indeed, the Gantt chart allows to determine the dates of realization of a project, to identify the existing margins on certain tasks and specially to visualize the delay or the progress of the project.

On the Gantt chart, the critical paths[31] appear in red:

- Magnet assembly:
    - *Steel purchasing (90 to 100 days)*: Corresponds to the time required to supply the steel. It is the main element of the cyclotron.

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[28] The Cyclone IKON is a complex product and is manufactured in small quantities. During the entire manufacturing process, the machine does not change location (Karl Hugo).

[29] The Cyclone KEY and Cyclone KIUBE are produced in a repetitive way and to reach a high level of stock to cover the demand which can fluctuate.

[30] Microsoft Project allows for the planning of projects. It allows, among other things, their prioritization, the links between tasks, the estimation of their duration, the workload necessary for each task. Etc.

[31] See *Annex 6 – Bottlenecks illustration*

  - *Nickel platting (30 days):* Corresponds to an "*optional*" stage of production that can be negotiated with the customer, only at the signing of the purchase contract, which makes it difficult to anticipate this stage[32].
  - *Mapping (90 days)*: Corresponds to the step that consists in machining the steel so that it corresponds to the desired characteristics to meet the physical properties necessary for the "*magnet*". Precision machining.
- Final assembly:
  - *Cyclotron assembly & test (60 to 100 days):* Corresponds to the stage during which the functionality tests are performed. They are either performed at Karl Hugo for the Cyclone IKON, or at IBA for the Cyclone KEY and Cyclone KIUBE. Only a limited number of machines can be tested simultaneously at IBA (capacity management of the test areas).
- (Installation[33]):
  - *Cyclotron installation (150 days)*: Corresponds to the installation of the cyclotron at the customer's site. This time is not part of the production lead time of the machines, but is also subject to optimization, because this activity depends on the one hand, on the availability of resources, but also on the skills required by these resources (the installation team). The resources needed are not identical from one product to another. It is with the optimalization in view that the design of the machines has been reviewed and standardized to overcome these two difficulties: availability of resources and skills required.

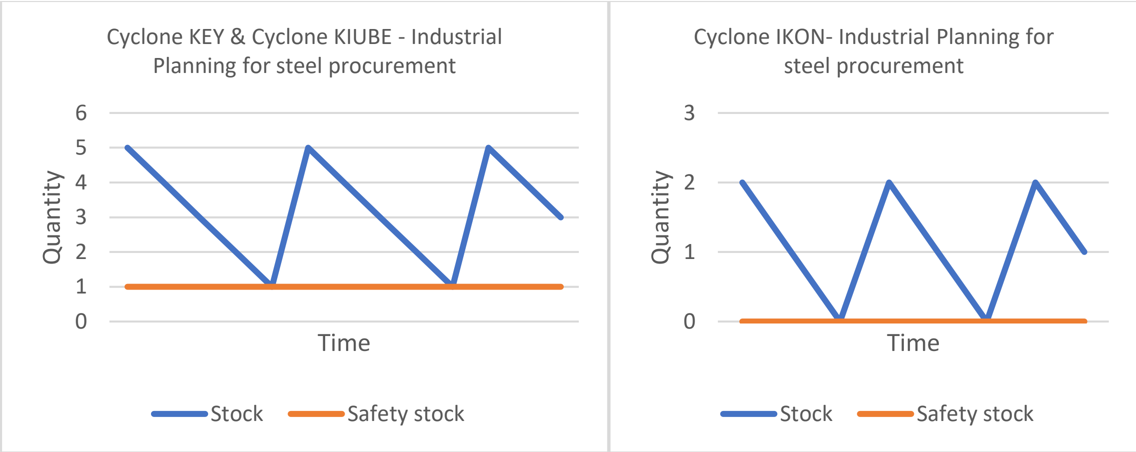
As we can see, a major part of the identified critical paths takes place during the first manufacturing step; magnet assembly. This can be explained by the fact that the "*magnet system*" is the main element of the cyclotron. It is the starting point on which all the other sub-assemblies of the cyclotron will be grafted progressively. It is the critical element without which production cannot begin[34].

The graphs below describe the strategy adopted to meet the industrial and commercial plan. As the "*steel purchasing*" stage is the most critical, it was decided to set up replenishment rules to guarantee the availability of these elements.

[32] This process allows the steel to reach a higher level of quality, but not essential. This treatment of the steel obviously represents an additional source of revenue. Since this step takes approximately 30 days, its impact on lead time is relatively important. The teams are currently studying the possibility of no longer offering this option.

[33] Machine installation time is not included in the "*production lead time*". Nevertheless, actions have also been taken to improve this lead time, which is an important milestone in the overall project completion time and is directly linked to the final invoicing and therefore the possibility of bringing in revenue.

[34] See *Annex 3 – Cyclotron sub systems*



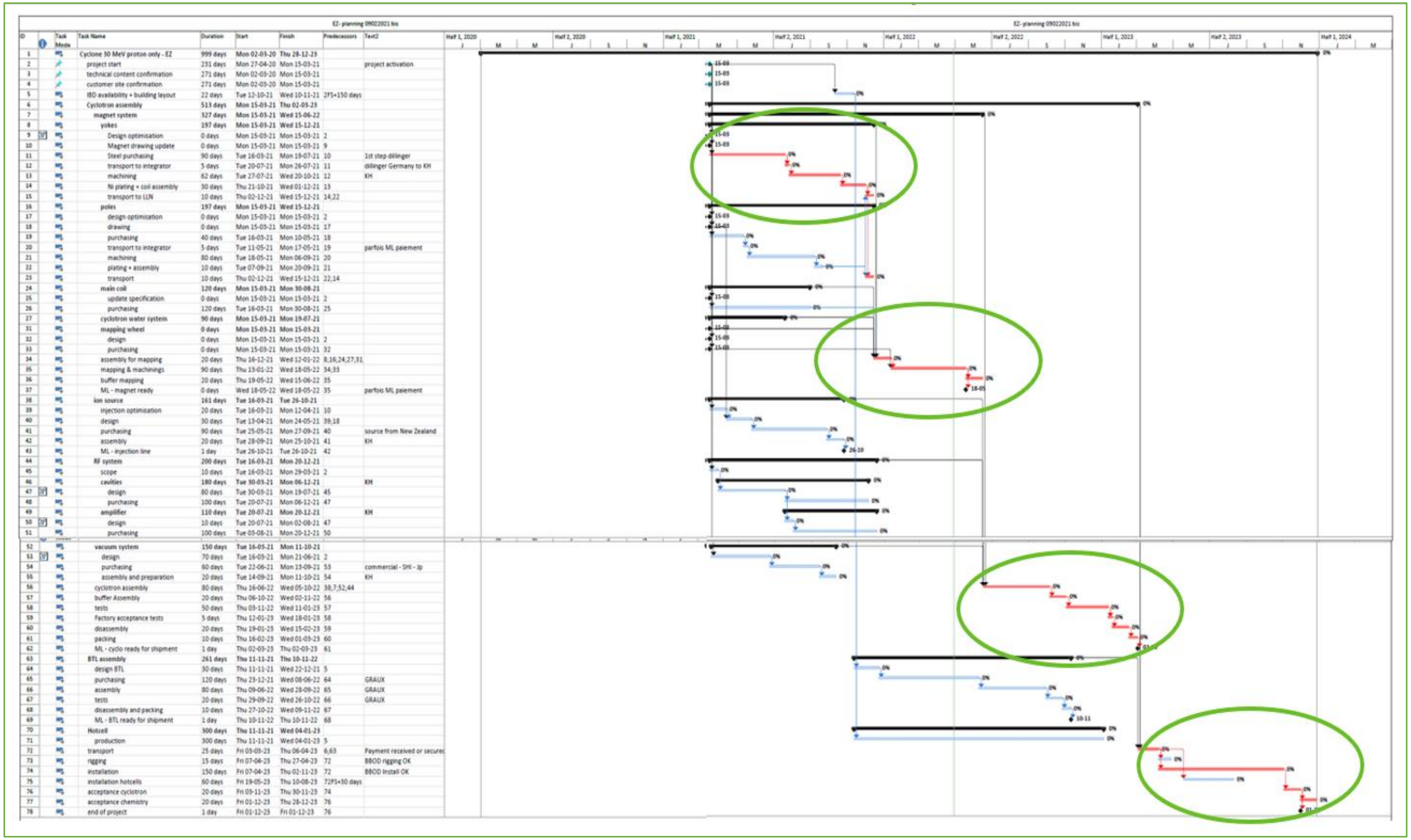
Steel purchasing strategy

- Cyclone KEY & Cyclone KIUBE:

The steel is purchased by quantities of four. When there is only one steel left in the safety stock, a new order of four steels is placed. The idea is to always have several steels (fully machined and mapped) in advance on the shelf to cover the needs. When one steel is reached, four new steels are ordered (reordering quantity). It is important to have a "*safety stock*" because the planning foresees the continuous production of fourteen machines per year (commercial production), regardless of the variation in demand.

- Cyclone IKON:

The purchase of steel would be done in pairs and with the same purpose as for the Cyclone KEY and Cyclone KIUBE; to be able to benefit from an advance steel on the next order. However, since this machine is manufactured in "*project*" mode with small quantities, the "*safety stock*" is non-existent, since the demand foresees the sale of one machine per year on average for the next three years. This leaves more time to anticipate supplies.



Gantt chart – production planning of Cyclone IKON[35]: critical paths in red. The bottlenecks are highlighted in green.

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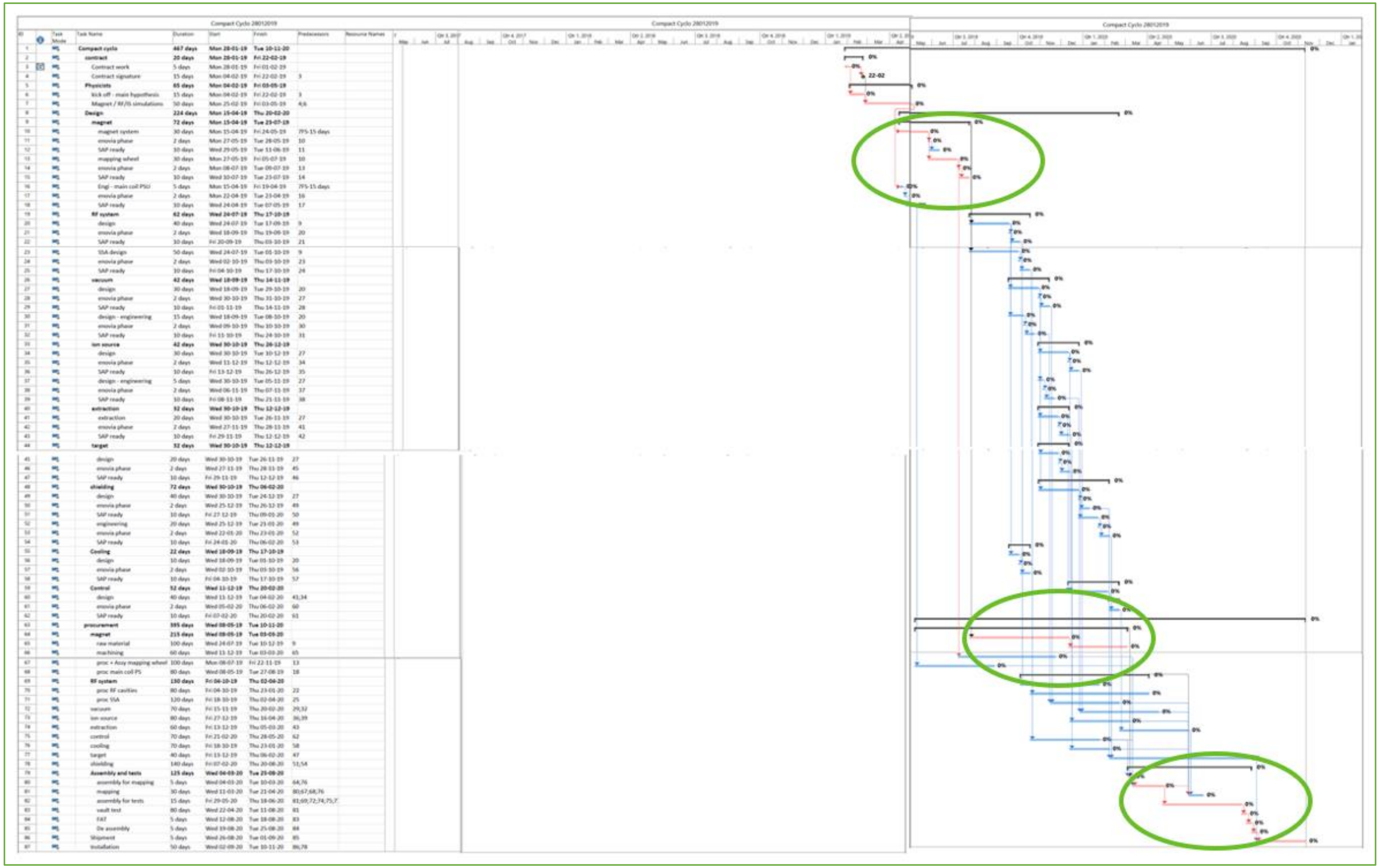
[35] See *Annex 4 – Planning IKON*

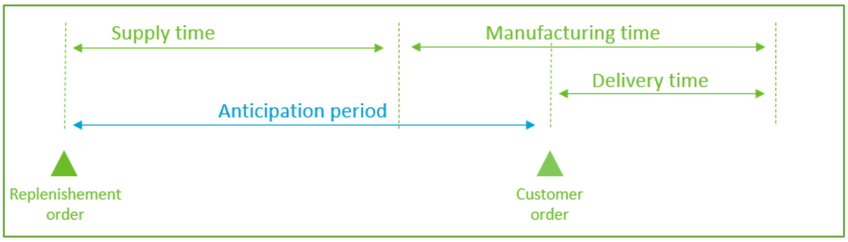


Gantt chart – production planning of Cyclone KEY[36] & Cyclone KIUBE: critical paths in red. The bottlenecks are highlighted in green.

[36] See *Annex 5 – Planning KEY & KIUBE (Cyclone KEY & Cyclone KIUBE have the same standard production planning. This planning above, is including the "design phase".)*

4. ANALYSIS AND RESULTS

As we have seen, being proactive can be defined as the ability to anticipate operations in order to meet a demand by taking the initiative. In the supply chain domain, this can be translated into the ability to acquire the necessary means, with the aim of responding to the industrial and commercial plan.



Flow management

This proactivity can take place upstream (suppliers) and downstream (production).

- Upstream (suppliers): *Supply time*

We have identified four critical suppliers (see Chapter 3 - IBA Supply Chain Structure and Production Process) in the entire cyclotron manufacturing process. One stands out as requiring special attention: Karl Hugo. This supplier is responsible for a large part of the production of the machines (steel machining, assembly of the machines (Cyclone KEY, Cyclone KIUBE and Cyclone IKON), assembly of the subsystems, storage, and testing (Cyclone IKON)). An analysis has been carried out and has shown that IBA's subcontracting to Karl Hugo generates more or less 60% of their turnover. IBA is therefore an important customer for this supplier. IBA's negotiating power[37] is relatively strong because of the volumes ordered from Karl Hugo, and so a special relationship can be established.

- - Downstream (production): *Manufacturing time*

We have identified, thanks to sales forecasts (forecasting), the needs to be provisioned to meet the industrial and commercial plan. The standardization of the products allows us to launch certain production orders[38] before the reception of the orders, and this, with the aim of creating stock which will allow to gain time of production in the total lead time of manufacture.

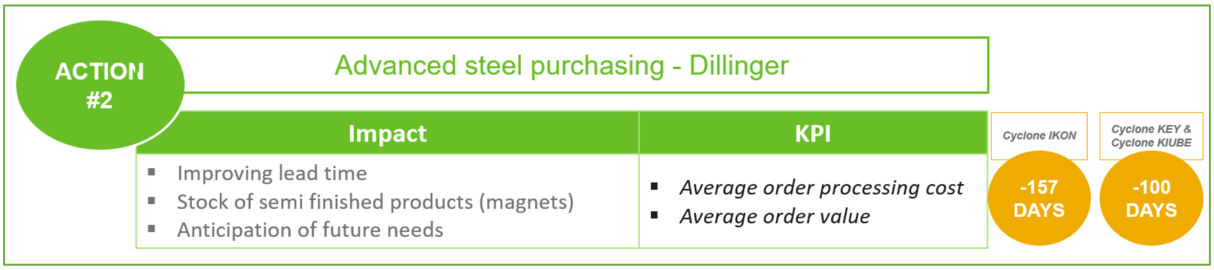
[37] The volumes ordered from other critical suppliers do not represent a significant part of the overall turnover of these companies. The negotiation weight is therefore not significant in order to establish a "*privileged*" relationship with these suppliers.

[38] Late differentiation is a production technique that aims to delay the customization of products in the manufacturing cycle as long as possible, downstream of the supply chain. This process allows to align production constraints (standardization and economy of scale) and commercial constraints (customization and market demand (shorter delivery times)). Thanks to this technique, it is possible to reduce lead times thanks to the anticipation of production needs and the creation of a stock of "*semi-finished*" products which will allow to react quickly when an order enters the system and thus to save time.

a. What actions should be taken to meet market demand?

Action 1: Downstream – Karl Hugo –

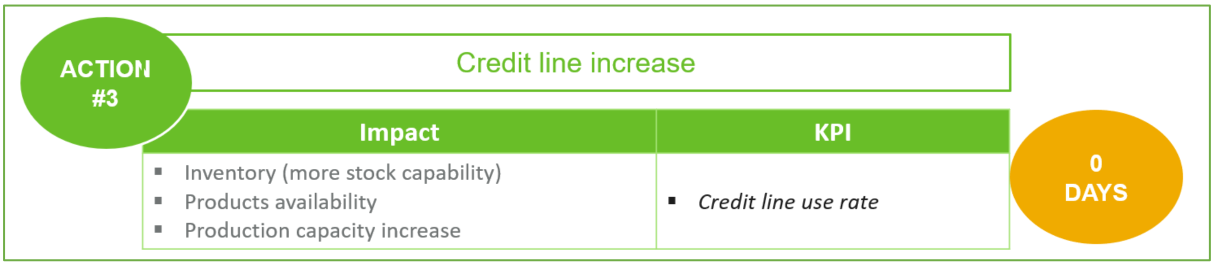
- Establishing a partnership relationship with Karl Hugo:
  - In this type of relationship, the customer (IBA) and the supplier (Karl Hugo) must study together the points and actions for improvement from which each can benefit.
  - Establish cross-functional working groups involving the different departments of each company (finance, production, sales, IT, etc.).
  - Collaborative processes [39] (e.g., ongoing information exchange, both formal and informal).
  - Long-term contracts.



Action #2: Downstream – Dillinger

- Anticipation of raw material purchases:
  - Grouped purchases according to the forecast.
  - Ordering of steel in volume necessary for future productions:
    - Buy steel for 4 machines (Cyclone KEY and Cyclone KIUBE)
    - Buy steel for 2 machines (Cyclone IKON)

[39] For example, the relationship with Karl Hugo and its management is special. Because of its geographical location, contacts are easier and more regular than with other suppliers. Karl Hugo's management and IBA RPS are in regular and continuous contact, exchanging relevant information in a transparent manner so that Karl Hugo can anticipate its needs in relation to the forecast communicated by IBA, and so that IBA can keep its commitments to its customers. Some members of Karl Hugo regularly take part in "*workshops*" and "*team building*" organized by IBA. This type of relationship enables the supplier to gain a better understanding of the products (to increase production efficiency and make economies of scale) and to get to know the people involved better (better circulation of information). It is not uncommon for informal exchanges about product updates or forecast variations to be communicated informally to Karl Hugo, through email exchanges or during meals between managers. This creates a certain trust between IBA and Karl Hugo because everything is done transparently on both sides, we consider each other as partners, where each is essential to the other. Karl Hugo plays its role as a partner to the full and has agreed to make new investments in its machining equipment to be able to meet the growing demand of IBA RPS.

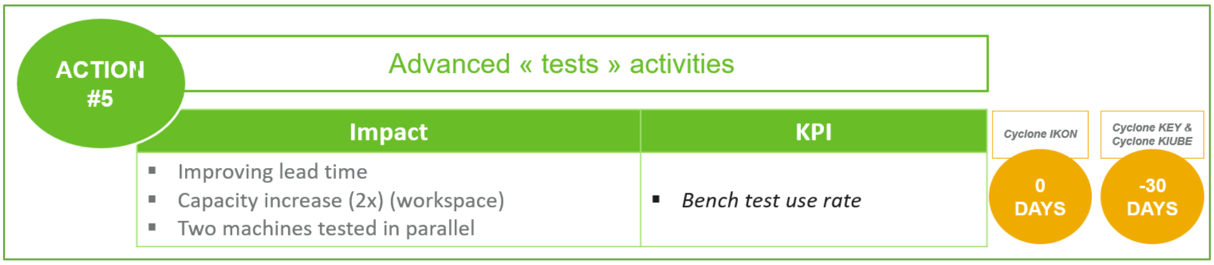


Action 3: Downstream – Credit line

- Increase in credit line per product:
  - Provision of financial means to create a stock (7 million € credit line starting from 2022 (work in progress (stock)) against 5.5 million € before.

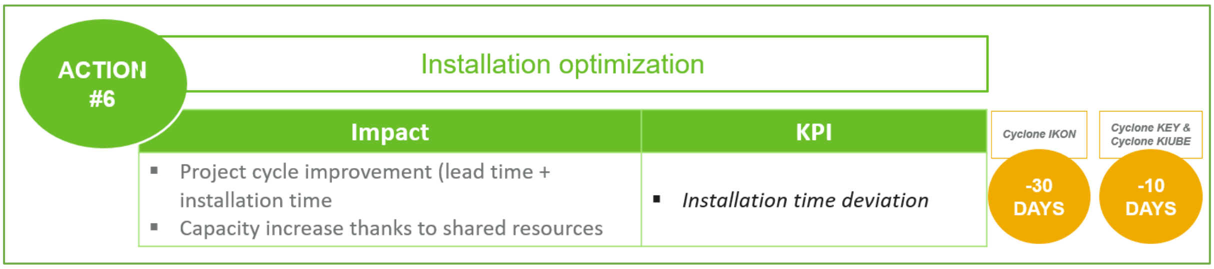
Action 4: Downstream - Mapping activities

- Anticipating the mapping activities of the ordered steel:
  - Purchasing steel in advance allows us to have this raw material available and therefore it is possible to machine and map the steel in advance before a customer order arrives.
  - Having semi-finished products in stock.



Action 5: Downstream - Testing activities

- Increasing the capacity of tests that can be performed in the factory:
  - Implementation of an additional test area for the Cyclone KEY and Cyclone KIUBE (increased capacity).



(**Action 6**: Downstream - Installation activities [40])

- Installers trainings:
  - Decrease the time required per installation by training multiple people to be effective on all the products.
  - Increase internal resources (increase capacity).

b. What are the expected results?

The objective of this work was to highlight the different actions that can improve the standard lead times of products. Some actions have a direct impact and result on the lead time and other actions prepare the ground to propose optimized lead times.

The sum of the actions taken allows us to have a projection of future lead times. Nevertheless, these results must be qualified, because these new "*optimized lead times*" are not considered when the first machine goes into production. Since the critical point is the purchase of the steel, we cannot anticipate the first machines of each product. The actions explained above can therefore only be fully effective when the second machine of each product line is put into production[41].

Below are the theoretical gains realized according to the actions taken.

Cyclone KEY	Cyclone KIUBE	Cyclone IKON
-160 days (5,2 months)	-160 days (5,2 months)	-257 days (8,4 months)

Lead time improvement

Following this series of actions, it would be theoretically possible to propose the following lead times:

Cyclone KEY	Cyclone KIUBE	Cyclone IKON
6 to 9 months	6 to 9 months	16 to 18 months

Theoretical new lead time (optimized lead time)

We can see that it is possible to offer optimized lead times that meet market demand. It is necessary to consider some unforeseen events that may occur during the production phase. Therefore, it is more reasonable to indicate a window of availability, rather than a fixed and firm deadline. I have also included KPI[42] (Key performance Indicators) to follow up those actions.

[40] Installation activities are not part of the "*production lead time*" as represented in this case study. It happens that some machines are delivered on site and then stored for a certain period before being installed.
[41] As a reminder, the industrialization plan foresees the start of production by two for the Cyclone IKON and by four for the Cyclone KEY and Cyclone KIUBE.
[42] See *Annex 7 – KPI description*

5. CONCLUSIONS

a. What to remember?

Improving the lead time of complex products to be manufactured is not an easy task. Many parameters come into play when defining the industrialization strategy and production processes to achieve this goal: capacity, purchasing, R&D, finance, resources, suppliers, sales forecasts, etc.

Nevertheless, this challenge can help to strengthen the organization and create added value when it is achieved. As a company, being able to offer product availability times faster than the competition will provide a definite competitive advantage. Especially when operating in a niche market like IBA.

Through this work, the goal was to answer the main question:

"How to respond to market demands for improved delivery times? "

To answer this question, two axes have been explored: *proactivity* and *bottleneck resolution*.

The "*proactivity*" in the supply chain must be a constant state of mind within the different departments of the company. This state of mind must enable the exchange of information, in quantity and quality, between the company and the different actors involved (customers, suppliers, employees...) to implement strategies aimed at bringing value. As we have seen, anticipation is the key factor of proactivity. Knowing how to anticipate needs is crucial in production planning. This is possible thanks to a good estimation of sales forecasts. This will allow to establish a supply and production plan adapted to the demand. In this case study, we have seen that the supplier Karl Hugo is a key player in the supply chain. A very particular attention is brought to him because he is considered as an essential partner.

"Bottleneck resolution" is the other axis explored to answer the question. In a manufacturing process, some steps are critical and have an obvious impact on production operations. Knowing how to identify these steps, understanding their causes to offer alternatives is a solution that can increase productivity and thus take part in the creation of value by respecting the schedule. In this case study, the main bottleneck is located at the steel supply level. Implementing a purchasing strategy aimed at anticipating present and future needs is a way to respect the production plan. This is possible thanks to the allocation of financial resources with the aim of creating stock and thus reducing lead time.

It is important to remember that *customer satisfaction* is a primary objective that contributes to the overall health of the company. The entire process is not only the reason for the implementation of these different actions, but also the ultimate goal of these actions.

Establishing good collaborative relationships with its key suppliers means creating a continuous commitment, which will lead to the implementation of improvement processes between the partners. Continuous monitoring of its supply chain structure and awareness of potential problems are key factors in a company's success in a complex industrial environment such as the one in which IBA operates.

b. Impact of COVID-19 on the supply chain

I would conclude this work by mentioning the current crisis due to the COVID-19 pandemic, which is affecting business operations at every levels. When this optimization exercise was undertaken, the global environment was relatively stable and had little impact on the entire supply chain. With the COVID-19 crisis, we have been put to the test both internally (IBA) and externally (suppliers). Working conditions have been considerably disrupted and this has created multiple problems (transport, availability of resources, travel bans, working conditions, team organization, illness, etc.).

As I write these last lines, the Russia/Ukraine conflict is underway. Once again, we find ourselves in a situation of instability that is just as disturbing as the COVID-19 crisis. In an industrial sector in which IBA operates, certain resources are becoming increasingly difficult to obtain. Added to this is the volatility of materials and components, which leads to significant price increases.

The hypotheses of my work take place in a stable and controlled environment, which is not currently the case.

Proactivity makes sense in this kind of economic context. All actors must analyze and consider these disruptions in their planning, to reduce the uncertainty they cause. Being able to reduce this uncertainty by adapting to the current situation is a determining factor in an increasingly demanding and constraining competitive environment.

I would therefore like to end by quoting Charles Darwin's famous quote:

"It is not the strongest of the species that survives,

not the most intelligent that survives.

It is the one that is the most adaptable to change. "

As a company and as human beings, we must adapt to this new reality and integrate it into our lives, while finding the best compromises to keep a certain level of quality, reliability, and service.

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7. List of annexes

Annex 1 - IBA Corporate Brochure

Annex 2 - IBA RPS in a nutshell

Annex 3 - Cyclotron sub systems

Annex 4 - Planning IKON

Annex 5 - Planning KEY & KIUBE

Annex 6 - Bottlenecks illustration

Annex 7 - KPI description

“How can we meet the market demands for improved delivery times?”

This is the main question around which this work is based. In a complex and increasingly demanding industrial environment, companies must outperform themselves to satisfy customers. IBA is confronted with market demands that challenge its supply chain structure and production processes. What solutions and actions can we put in place to offer shorter lead times for the manufacture of our products (cyclotrons)?

"Comment répondre aux exigences du marché en matière d'amélioration des délais de livraison ?".

Telle est la question principale autour de laquelle s'articule ce travail. Dans un environnement industriel complexe et de plus en plus exigeant, les entreprises doivent se surpasser pour satisfaire les clients. IBA est confrontée à des demandes du marché qui remettent en cause la structure de sa supply chain et ses processus de production. Quelles solutions et actions pouvons-nous mettre en place pour offrir des délais plus courts pour la fabrication de nos produits (cyclotrons) ?

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