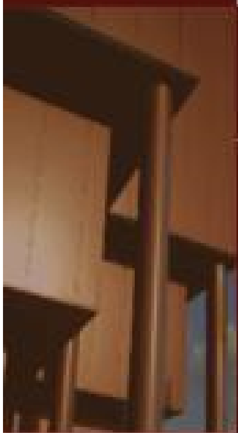
Trabajo Fin de Máster
Máster Universitario en Ingeniería Industrial

USE OF DMAIC METHODOLOGY FOR THE IMPROVEMENT OF MOLD MANAGEMENT IN A TIRE COMPANY

Autor: Aurelio López Madroñal

Tutor: Pedro Luis González Rodríguez



Dep. Organización Industrial y Gestión de Empresas
Escuela Técnica Superior de Ingeniería
Universidad de Sevilla

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El tribunal nombrado para juzgar el Proyecto arriba indicado, compuesto por los siguientes miembros:

Presidente:

Vocales:

Secretario:

Acuerdan otorgarle la calificación de:

Sevilla, 2013

El Secretario del Tribunal

A mi familia

A mis maestros

Agradecimientos

Este trabajo no es más que el resultado de años de esfuerzo, trabajo y sacrificio para conseguir el difícil objetivo de ser ingeniero.

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Aurelio López Madroñal

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Resumen

Bridgestone es una empresa líder mundial en la producción y venta de neumáticos. Bridgestone es una empresa japonesa y tiene presencia en todo el mundo. En Europa, la compañía cuenta con nueve plantas de producción de neumáticos en cinco países diferentes, un centro técnico en Italia y sus oficinas centrales se colocan en Bruselas, Bélgica.

Este TFM se centra en la sede de Bridgestone en el sector de LSCM (Logística y Gestión de la Cadena de Suministro). Este sector es el encargado de gestionar la fase de industrialización de la producción de neumáticos. La industrialización es la etapa en la que varios procedimientos se llevan a cabo con el fin de producir el producto final una vez que el diseño del producto ha sido desarrollado y definido.

El sector LSCM es el encargado de gestionar la adquisición de los recursos de los proveedores, asegurándose de que todas las tareas se realicen a tiempo para alcanzar la fecha en que la producción debe comenzar, se encarga de controlar el inventario, de la planificación táctica para los próximos seis meses para asignar recursos en todas las plantas y establecer el volumen de producción en cada planta, también se encarga de la producción del próximo mes para establecer programas de producción en cada planta, y la gestión de recursos y del transporte de los productos finales.

En particular, este proyecto se centra en el flujo de un recurso clave en cualquier empresa de producción de neumáticos, los moldes. Un molde es una estructura circular de acero que se utiliza para producir un neumático. Un molde se compone de dos partes, sectores y placas de pared lateral. Los moldes se utilizan para dar a un neumático sus características técnicas y sus identificaciones laterales. Un molde en concreto se utilizará junto a un SPEC o especificación concreta, para producir un determinado neumático. El procedimiento es similar a hacer un pastel. La especificación es la receta que contiene los productos que deben ser utilizados y el procedimiento que debe seguirse en la planta. El molde es la estructura que da la forma y las características de la cubierta del neumático. Ambos se utilizan para producir un neumático específico.

Es importante entender que con el fin de producir un neumático en particular; un molde particular debe ser diseñado y fabricado en detalle durante meses. La complejidad del proceso es la razón por la cual el diseño de un molde se hace por compañías específicas que crean dibujos en función de las características del producto final. La fabricación del molde se lleva a cabo en otras empresas que se encargan de ello específicamente.

Bridgestone adquiere los dibujos de los moldes y los moldes en sí de proveedores de dibujos y de proveedores de moldes, respectivamente. Debido a la complejidad de la creación de un molde, un molde supone para Bridgestone entre 25.000 y 100.000 euros cada unidad.

Los moldes se compran teniendo en cuenta el volumen que debe ser producido de un determinado producto y la planta que tiene que producirlo. Por supuesto, otro factor es la disponibilidad de moldes en cada planta. Basándose en estas disponibilidades, los moldes son comprados o incluso transferidos entre las plantas.

Es crucial que el molde requerido esté disponible en cada planta en el momento exacto en el que comienza la producción del producto. El flujo completo de un molde lleva alrededor de seis meses, sin tener en cuenta los ensayos en plantas que pueden aumentar el tiempo de flujo en casi dos años. Es por ello que todos los pasos del procedimiento están estrechamente controlados por el departamento de LSCM. Si el molde no está disponible a tiempo, los neumáticos no pueden ser producidos, y la demanda no será contestada. Además, es importante la compra de la cantidad correcta de moldes debido a sus altos precios.

Con el fin de tener el molde correcto en la planta justo a tiempo, la disponibilidad de los moldes en cada planta está controladas por el equipo táctico en el sector LSCM. Las disponibilidades de moldes son reportadas por cada planta y son visibles en un programa utilizado por el equipo táctico denominado OMP. En OMP, el equipo táctico es capaz de ver cuál es el producto, que llamaremos IPC (Código de Producción Internacional), se tiene que producir en cada planta, y cuyo molde y SPEC se utiliza para producir este producto. Sin embargo, esta conexión entre el IPC y el molde necesario y SPEC es visible cuando las plantas introducen los datos requeridos. Las plantas también introducen los datos de los moldes que han recibido de los proveedores y las disponibilidades de cada tipo de molde. Por lo tanto, OMP muestra las disponibilidades de los moldes de cada planta para producir un determinado IPC, producto.

EL equipo táctico comprueba la disponibilidad del molde en cada planta para producir un cierto IPC y en base a ellos, van a solicitar transferencias de moldes entre plantas o van a solicitar la compra de más moldes. La adquisición y transferencia de moldes es administrado por MPO (Equipo de molde), también en el interior del sector LSCM. Estos procedimientos se realizan seis meses antes de la producción en masa de neumáticos.

Un mes antes de la producción en masa, otro equipo, Equipo de producción, gestiona la fabricación de neumáticos en cada planta. Ellos revisan los IPCs que tienen que ser producidos en cada planta. A continuación, el equipo de producción comprueba la disponibilidad de moldes y SPECs en cada planta. Basándose en estas disponibilidades, establecen el volumen de producir en cada planta en el próximo mes. El equipo de producción también utiliza OMP y por lo tanto trabajar con las disponibilidades de moldes en cada planta que refleja OMP. El equipo de producción no está a cargo de las transferencias o las compras de moldes ya que un mes antes de la producción en masa es demasiado tarde para hacer cualquiera de estas acciones. Si un molde no está disponible un mes antes de la producción en masa para producir un cierto IPC, la producción este producto se retrasará.

Como se puede ver, la disponibilidad del molde en cada planta y la conexión entre el molde y el IPC, o producto, que produce son cruciales.

Sin embargo, el equipo táctico está encontrando problemas al controlar la disponibilidad de molde para algunos productos. En primer lugar, en cada planta diferente codificación se utiliza para informar que molde está disponible en su planta. En segundo lugar, la conexión entre varios IPC y sus moldes no son existentes cuando el equipo táctico hace su planificación. Diferente codificación para nombrar a los moldes da lugar a problemas en la transferencia de moldes entre las plantas ya que el equipo táctico no es capaz de ver si una planta tiene un molde que puede ser utilizado por otra planta debido a la utilización de una codificación diferente entre ellas. Además, si la conexión entre el producto y el molde no está clara, es imposible saber qué molde es necesario para producir un determinado producto.

Si la disponibilidad de moldes, o producto y conexión molde no están claras, existe un riesgo de estimar más o menos la disponibilidad de moldes en una planta. Estos problemas de estimación pueden conducir a comprar más moldes de lo necesario o ser incapaz de producir el volumen requerido de neumáticos. En cualquiera de cada caso, la empresa pierde dinero.

En este TFM, el flujo de molde será estudiado con el fin de encontrar mejoras a los problemas encontrados. La metodología DMAIC será utilizada para definir los procesos y los problemas existentes, para medir estos problemas, para analizar las causas fundamentales que conducen a estos problemas, para proponer mejoras, y para establecer procedimientos de control para el nuevo proceso una vez que se implementen las mejoras. Con el fin de cumplir con todos estos objetivos, este TFM se llevará a cabo en la sede de Bridgestone en Bruselas, Bélgica, en el sector de LSCM como miembro del equipo de molde. Las entrevistas con todos los participantes del flujo de molde se llevarán a cabo en forma de reuniones o llamadas telefónicas directas con el fin de definir el estado actual, los requisitos de los clientes y para resolver los problemas existentes. Los participantes del flujo de moldea los cuales se entrevistará son equipos dentro del equipo LSCM, las personas encargadas de la gestión de molde en todas las plantas de producción de neumáticos, los ingenieros en Roma, y los proveedores tanto de dibujos como de moldes.

Abstract

Bridgestone is a worldwide company leader in tire production and selling. Bridgestone is a Japanese company and it has presence in the entire world. In Europe, the company has nine tire production plants in five different countries, a technical center in Italy and their headquarters are placed in Brussels, Belgium.

This Master thesis is focused in Bridgestone headquarters in the sector of LSCM (Logistics and Supply Chain Management). This sector is in charge of managing the industrialization stage of tire production. Industrialization is the stage where several procedures take place in order to produce the final product once the design of the product has been developed and defined.

LSCM sector is in charge of managing the purchase of resources from suppliers, making sure all tasks are done on time to achieve the date when production must start, controlling inventory, tactical planning for the next six months to allocate resources in all plants and to establish volume of production in each plant, production planning for the next month to establish production schedules in each plant, and managing transportation of resources and final products.

In particular, this project is focused on the flow of a key resource in any tire production company, molds. A mold is a steel circular structure that it is used to produce a tire. A mold is composed of two parts, sectors and sidewall plates. Molds are used to give to a tire its characteristics, pattern and side identifications. A particular mold is used next to a particular SPEC or specification. The procedure is similar to making a cake. The SPEC is the receipt that contains the products that must be used and the procedure that must be followed in plant. The mold is the structure that gives the shape and characteristics to the tire. Both are used to produce a specific tire.

It is important to understand that in order to produce a particular tire; a particular mold must be designed and manufactured in detailed during months. The complexity of the process is the reason why the design of a mold is done by specific companies that create drawings base of the characteristics of the final product. Mold manufacturing is done in other specific companies.

Bridgestone purchases drawings of molds and molds themselves from drawing and mold manufacturing suppliers respectively. Due to the complexity of mold creation, a mold costs to Bridgestone 25000 to 100000 euro.

Molds are purchased taking into account the volume that must be produced of a certain product and the plant that has to produce it. Of course, another factor is the availabilities of molds in each plant. Based on these availabilities, molds are bought or even transferred between plants.

It is crucial that the required mold is available in each plant on time to produce the exact product. The complete flow of a mold takes around six months, without taking into account

trials in plants that can increase flow time into almost two years. That is why all steps in the procedure are closely controlled by LSCM department. If the right mold is not available on time, tires cannot be produced, and demand will not be answered. In addition, it is important to purchase the right amount of molds due to their high prices.

In order to have the right mold on the right plant on time, mold availabilities are controlled by tactical team in LSCM sector. Mold availabilities are reported by each plant and they are visible in a program used by tactical team called OMP. In OMP, tactical team is able to see which product, that we will call IPC (International Production Code), has to be produced in each plant, and which mold and SPEC is used to produce this product. However, this connection between IPC and necessary mold and SPEC is visible when plants input the required data. Plants also input the data of the molds they have received from suppliers and their availabilities. Therefore, OMP shows molds availabilities of each plant to produce a certain IPC, product.

Tactical team checks mold availabilities in each plant to produce a certain IPC and based on them, they will order transfers of molds between plants or they will order the purchase of more molds. The purchase and transfer of molds is managed by MPO (mold team), also inside LSCM sector. These procedures are done six months before mass production of tires.

One month before mass production, another team, Production team, manages tire manufacturing in each plant. They check the IPCs that have to be produced in each plant. Next, production team checks mold and SPEC availabilities in each plant. Based on these availabilities, they establish the volume to produce in each plant in the next month. Production team also uses OMP and therefore they work with mold availabilities in each plant reflected on OMP. Production team is not in charge of transferring or purchasing molds since one month before mass production is too late to do any of these actions. If a mold is not available one month before mass production to produce a certain IPC, this product will be delayed.

As it can be seen, mold availabilities in each plant and the connection between which mold produces which IPC or product are crucial.

However, tactical team is encountering problems when controlling mold availabilities for some products. First, in each plant different coding is used to report which mold is available in their plant. Second, the connection between several IPCs and molds do not exist when tactical team makes its planning. Different coding to name molds lead to problems of transfers of molds between plants since tactical team is not able to see if a plant has a mold that can be used by another plant due to the use of different coding. In addition, if the connection between product and mold is not clear, it is impossible to know which mold is necessary to produce a certain product.

If mold availabilities, or product and mold connection are not clear, there is a risk of over estimating or under estimating availabilities of molds. These estimation problems can lead to purchase more molds than necessary or to be unable to produce the required volume of tires. In any of each case, the company loses money.

In this MT, mold flow will be studied in order to find improvements to encountered problems. A DMAIC methodology will be used to define process and problems, to measure these issues, to analyze root causes that lead to these problems, to propose improvements and to establish control procedures for the new process once improvements are implemented. In order to fulfill all these objectives, this MT will be done in Bridgestone headquarters in Brussels, Belgium, in the sector of LSCM as a member of mold team. Interviews with all participant of mold flow will take place in the form of direct meetings or phone calls in order to define the current state and customer requirements to solve existing problems. Participants of mold flow are teams inside LSCM team, people in charge of mold management in all plants, engineers in Rome, Italy, and suppliers of drawings and molds.

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Acronyms

ADE	Drawing codes
BOSS	Bridgestone Original Scheduling System
BU	Busines Management
CoQA	Corporate Quality
DPO	Drawing Planning Office
FR	Fund Request
FRR	Fund Request Request
IPC	Industrialization Production Code
IPL	Industrialization Planning
LSCM	Logistics and Supply Chain Management
MDR	Mold Drawing Request
MDT	Mold Drawing Transmittal
MP	Mass Production
MPO	Mold Planning Office
MTP	Mid Term Planning
NPA	New Product Approval
OE	Original Equipment
OPP	Operation Production Planning
PB	Proyect Building
PED	Product Engineering Developemnt
PLM	Product Lifecycle Management
PO	Purchase Order
PTD	PSR (Passenger Service Road) Tyre Development Department
SAP	Systems Analysis and Program Development
SGK	Sougou-Keikaku (Total Panning)
SOP	Start Of Production
SOS	Start Of Sales
SPEC	Specification
STP	Strategic and Tactical Planning
TCE	Technical Center Europe

Use of DMAIC methodology for the improvement of mold management in a tire company.

1. Justification and objective of the project.

1.1. Justification of the project

In tire production, mold is a key element. Mold provides the performance and visual characteristics to a tire. Once a product is designed and it is decided to be sold, logistic teams start to work. The stage where the product starts to pass from being just a design to a physical product comes into place. This stage is the industrialization stage. At this stage, all resources are obtained and interactions between suppliers, departments in logistic sector and engineers start.

Drawings of molds have to be created by suppliers, and then produced. This is a very specific process where the smallest detail is crucial. If the mold does not match the requirements, it is not valid.

In addition, the mold has to be clearly identified and controlled. The exact mold has to be at the exact plant to produce a specific tire at the exact moment. A mold is a very expensive element, and with a huge impact in tire production. Therefore, mistakes are highly penalized.

It is important to take into account that this process is more complex than a simple timeline. Many processes, different mold life cycles, are done in parallel, and there are problems in form of time constraints. Thousands of molds interact between each other to produce different type of tires in nine plants in Europe that produce hundreds of thousand tires. In addition to this complexity, it has to be taken into account that molds can be transferred between plants in order to answer to production needs. Due to time constraints, as well as constraints in the different activities, mold flow can produce delays in the time product is ready for sales. This delay means that the target inventory is not matched on time, and thus sales can be lost.

Therefore, the time required in each stage is critical in order to fulfill the demand on time. Time means money for the company. It is crucial that the process is done in a precise way, and in the time that is required. Even though, this (Master Thesis) MT is focused on mold flow, other parts of the production of wheel process will be taken into account. Mold flow is not an isolated process, but part of a bigger process where mold flow interacts with other flows.

All stages are formed by many steps from the idea until the mass production of tires. All these steps require the intervention of many teams, sub-teams and departments that formed a big organization. The process becomes complex and the flow of information becomes very difficult. Information is decentralized, it is not where it is needed and members of different teams need to spend a lot of time to obtain information that they should find easily. Also, there is a lack of visibility of the information and the source of information is not always clear. Thus, the information used is not always reliable. The process has a high complexity that doesn't add value, and a high workload for a low output. As a result of all these problems, products suffer of important delays. In fact, the average delay in products is of around 3 months. These delays mean for the company more than 1 million of Euros per year.

As it can be seen, this lack of organization means an important cost to the company. That is why a good view and understanding of the process is needed, in order to find improvements and fill the gaps of links and information.

1.2. Objective of the project

1.2.1. General objective

This MT was able to be done thanks to the opportunity of working in Bridgestone Europe headquarters in Brussels, Belgium. This work was in the form of an internship. Professor Pedro L. González Rodriguez was contacted before the start of this internship to obtain his guidance and thus, he became the tutor of this MT.

In this MT, the objective is to improve the process and flow of information in the mold production process from the mold creation to the mass production of molds. Bridgestone Europe has realized that there are internal problems of flow of information and organization between the different parts that participate in the mold process. These problems are not only inside Bridgestone headquarters in Brussels but also in other teams inside Bridgestone, and also in plants and suppliers.

1.2.2. Specific objective

In this MT, a DMAIC methodology will be used with the objective of solving this specific objective. DMAIC methodology is divided into five stages: Define, Measure, Analyze, Improve and Control. The objective of all these stages is to focus on customer in order to understand the process, detect problems, measure problems, analyze them and find a solution of this problem of tactical planning of molds.

In order to reach the general objective of this MT, several specific objectives had to be fulfilled.

Specific objective 1: The first specific objective is to understand the problem of the company. In order to fulfill this objective, the company will be described in chapter 2 in terms of its global presence, its goals and its structure. Also, a mold and the process that it follows will be described.

Specific objective 2: Next specific objective is to research on applicable methodologies. This objective is key since it is necessary to use a methodology that will help us solve Bridgestone's problem. This understanding of possible methodologies will be described in chapter 3.

Specific objective 3: The third and final objective will be to put the methodology into action. Specific objective number 3 will be explained in chapters 4 and 5. The division of this specific objective in two chapters will be explained later in point 1.2.3.

1.2.3. Structure of this document

As it has been previously explained, this MT will follow a DMAIC methodology to understand mold process and solve problems that are detected in this flow of information. The goal of this document is to clearly explain the process that has been followed. In order to achieve this goal, it is important to describe the environment where it has been applied, in other words the enterprise. Also, it is needed to understand what a mold is, in order to understand the complexity that resides behind the process. Therefore, the structure of the document is as follows.

The company will be described in the first part of chapter 2. It is important to understand that Bridgestone is a big company with big resources but also big problems derived of its size. Also, the size of the company, the number of plants and the number of employees give an idea of the volume of tires and thus molds Bridgestone works with. At the second part of chapter 2, it will be explained what a mold is, its production process and its importance. This explanation is needed since a mold is a very specific resource only linked to tire production. A mold is a very expensive and complex product. It is important to understand its complexity and how specific it is to produce a tire in order to comprehend the complexity and risk of the process.

Chapter 3 is divided in two parts. First, a state of art will be done where applicable methodologies will be analyzed. This methodology will be compared with other methodologies and the use of DMAIC methodology will be justified. Second, DMAIC methodology will be explained.

Finally, chapters 4 and 5 will includes the five stages of DMAIC methodology: Define, Measure, Analyze, Improve and Control. However, this five stages have been divided into two parts. Chapter 4 will include the first three phases: Define, Measure and Analyze. Chapter 5 will include the next two: Improve and Control. This division is not included in the methodology. However, in the use of the methodology we have encountered two parts. First, the "As is" part where the process and its problems is studied in order to understand it. Second, the "To be" part where once the process is understood, solutions are found and implemented. Chapter 4 will include the "As is" part and chapter 5 the "To be" part.

A conclusion of this MT will be given at the end of this paper at chapter 6. The goal of this chapter is to summarize all steps of the project, to analyze the level of fulfillment of the specific objectives and to explain conclusions.

2. Description of the enterprise and process under study

In the production of tires for wheels, molds are a key element in the manufacturing of tires. Molds provide the tread pattern to the tire, as well as the sidewall design, which allows the wheel to have the required characteristics of the wheel.

However, the production of molds is not a simple process. It requires a good production planning and a precise forecast. Molds are sometimes the bottleneck in wheel production companies for several reasons. The manufacturing of molds requires an important period of time due to its complex process and the precision that is required. In addition, its important weight makes the transportation time very significant and costly.

Furthermore, different and new molds are created to answer to new demands, new technologies and new needs. Molds are designed for trucks, motorbikes, cars, etc. Molds have different sizes, and tread patterns. They can be done to produce tires that have characteristics to be used on road, on mountain, on agriculture, or on construction.

As it can be seen, the mold process is complex and thus its control and administration. From the creation of molds to their use for tire mass production, there are many parts that have to be checked, controlled and administrated. This work is performed by different teams that have to interact together inside any tire company. However, this interaction between teams and the flow of information is not always perfect creating many problems of timing, under or over production, higher costs, lack of control and traceability, delays, and forecasting.

This MT will be applied in Bridgestone, a company leader in the World in wheels selling, being the world's largest manufacturer of tires and other rubber products. It has presence all over the World, having its most important presence in Japan and America. This Corporation and its subsidiaries employ over 140.000 people around the world, operate 178 plants in 25 nations and sell products in more than 150 countries. This project is focused in the Bridgestone Europe NV/SA, European headquarters of the company, in the sector of Logistics, Quality and Supply Chain Management.

2.1. Description of the company: Bridgestone

Now that the tire production has been explained, and the importance of the mold in this process has been pointed out, the company where the MT will be done will be presented.

Bridgestone is a worldwide leader company in its sector, tire selling. One in five vehicles in the world drives on the company's tires. Bridgestone is a Japanese company that has presence in the entire world. However, this project will only focus on the mold process that is administrated in Europe headquarters.

Nowadays, the company has become the world's largest manufacturer of tires and rubber products. The company employs over 140000 people globally, operates 178 plants in 25 nations and markets products in over 150 countries. At world level, it is the company with the highest market share before Michelin and Goodyear *(Bridgestone, 2015).*

Bridgestone also sells other products apart from tires. The company sells chemical and industrial products such as vehicle parts, polyurethane foam and related products, electronic precision parts, industrial related material products, civil engineering and construction materials, equipment and others. Also, sport goods such as golf balls, golf clubs and other equipment are produced by Bridgestone. In addition, the company is related to bicycles, bicycle goods and others.

Bridgestone has presence in Japan, America, where they obtain the biggest percentage of net sales, 47%, and in Europe. In addition, the company is expanding the European sector to include the Middle East, Africa, Turkey and Russia.

The presence of the company in Europe is crucial for its success and growth. In Europe, the company employs more than 12000 people, having 9 manufacturing plants all around Europe, 3 European Logistic centers, and 6 regional sales companies (Bridgestone, 2015).

Figure 1: Map of plants, headquarters and technical center of Bridgestone Europe

In the map above, the placement in Europe of the different organizations of Bridgestone Europe NV/SA is shown. As we can see represented by the red points, the company has 9 plants in Europe, 3 in Spain, 1 in Italy, 1 in France, 1 in Belgium, 2 in Poland, and 1 in Hungary. The Technical Center of Europe (TCE) is in Rome (Italy), represented by a blue dot. The company has three logistic centers: one in Brussels (Belgium), one in Madrid (Spain), and one in Bor (Czech). Finally, the European headquarters are in Belgium, represented by a blue dot. The study of this TFM will take place at the headquarters.

Furthermore, the company has 5 different brands to sell products for passenger cars, 4x4 vehicles, trucks, busses, commercial, construction and Off-the-Road vehicles. Also, they develop tires for tractors and agricultural machinery as well as motorcycles and scooters. Finally, the company develops tires for motor sport and aircraft (Bridgestone Europe, 2014).

Bridgestone aims to achieve the corporate mission of "Serving Society with Superior Quality". According to the MTP (Mid Term Planning), R&D activities are done in order to achieve the objective of establishing a competitive business model and by designing design capabilities that creatively link corporate activities with customers and society.

The tire segment is based on the development philosophy, seeking to create new added value through the core elements, environment and comfort. As part of this initiative, the company has developed value added tires with a new "ologic" technology. In other words, more focus in robotic applications and technologies. This technology has received great acclaim at in Japan and the rest of the world receiving awards such as "Tire Technology of the Year" at the world’s leading "Tire Technology EXPO" and "2016 Environment Minister’s Award for Global Warming Prevention Activity-technology manufactured products category". In 2015, the company was recognized by General Motors as the best supplier of the year, and tire manufacturer of the year by an independent jury of top tire industry in the 2016 Tire Technology International Awards for Innovation and Excellence.

The sales of Bridgestone only in Europe are more 3.5 billion €. Most of its sales come from the aftermarket and it is a major supplier of original equipment to all major car and truck manufacturers, such as: Audi, Ferrari, Toyota, Ford group, VW group, Fiat, Mercedes, MAN, DAF, Iveco, etc.

2.2. Creation of a Tire MOLDS:

Today, the tires of a car are one of the key elements for any car, truck, or motorbike. Tires don’t only provide the connection between the car and the ground, but also, they are responsible of many of the features of the machine, such as speed or safety. Nowadays, tires have to support heavy weights while providing an easy way to stop, start or turn at high speeds, as well as being able to last for years. The components of a tire are shown in the picture below.

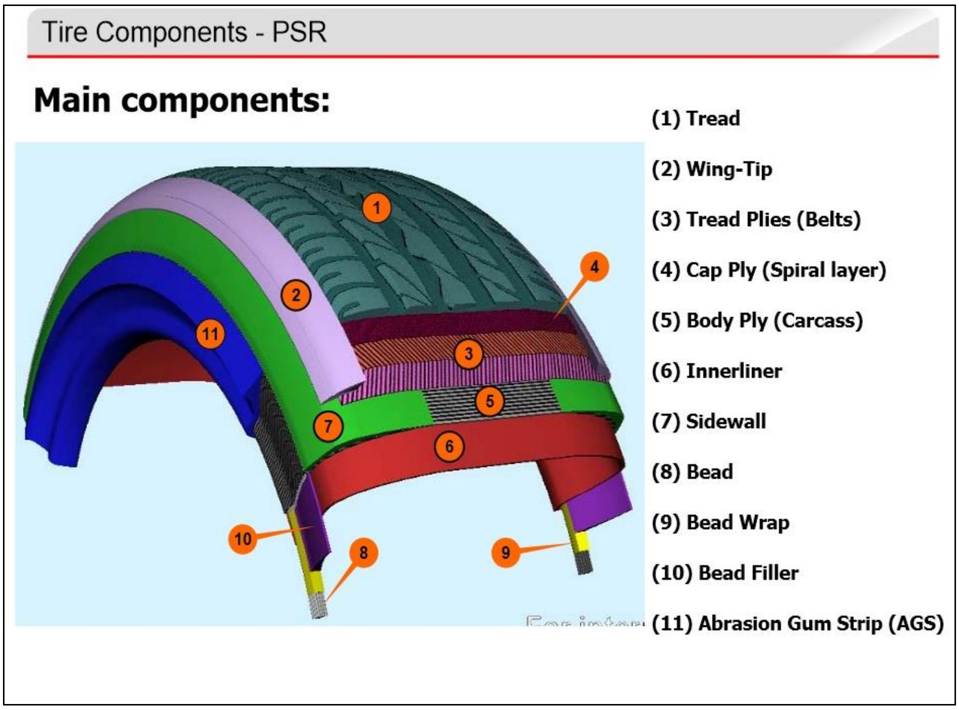

Figure 2: Components of a tire

As we can see in figure 9, tread is the external thick layer of the tire. Treads are made of rubber and it has a trend pattern molded into it. Trend pattern is used to optimize traction and wear. The tire must rip the road even when it is wet or dry because the tire is responsible of controlling the traction forces with the ground. Rubber compounds are chosen to provide specific characteristics such as fuel economy, speed, wet traction and resistance. Different components of the rubber are chosen to provide resilience, resistance, and be able to bear heat and wet.

Next, cap is the top layer and it is used for long to ease even wear. Base is the layer below and it is used to avoid heat damages the tire. Another part is the tread piles or belts. Belts are layers of steel cables and rubber. Usually, there are three or four layers of belts. Belts are used to hold the tire flat against the floor, and thus, improve the traction of the wheel with the floor. Also, steel belts are used to resist penetration by nails or other elements of the floor.

The body ply is a group of around 200 radio tires that go around the whole tire, forming also part of the sidewall. Sidewall is the part of the tire that does most of the flexing as it rolls in order to absorb most of the hits coming from the floor while driving. Sidewalls transmit steer, driving and breaking forces from the wheel to the tread as well as forces from the road to the suspension system. However, sidewalls are more expose to the environment. Therefore, special materials are used to bear heat, humidity, UV radiation, etc.

Finally, bead is the edge of the tire, where the tire makes contact with the wheel creating a seal between tire and wheel.

Once, the main parts of the tire have been described. The process of creation of a tire is going to be explained. First of all, the different rubber compounds that give the desire and particular properties are mixed into layers using Banbury mixers (Industrial mixer). Then, rubber is heat into heated rolls called mills in order to create sheets. The sheet of rubber could return into the Banbury mixer depending on chemical engineers' specifications.

Next, multiple wires of steel are aligned and bump into rubber. Wires are mixed with rubber in a machine called Calender (Calandria). Powerful heated rollers press rubber on to and between the cores. After these different steps, a sheet of rubber reinforced with steel is obtained. These sheets will be cut in the sizes they are required to obtain the belts of the tire. After, the Innerliner, another sheet of rubber without steel, is also made using a Calender. Finally, Beads are obtained by combining thick wires with rubber and bend into rings. Many rubber components such as sidewalls or treads are made by extrusion.

Once all these parts are manufactured, they will be assembled by a tire builder with a tire assembling machine. The process that takes place in the assembling machine is shown in the picture below.

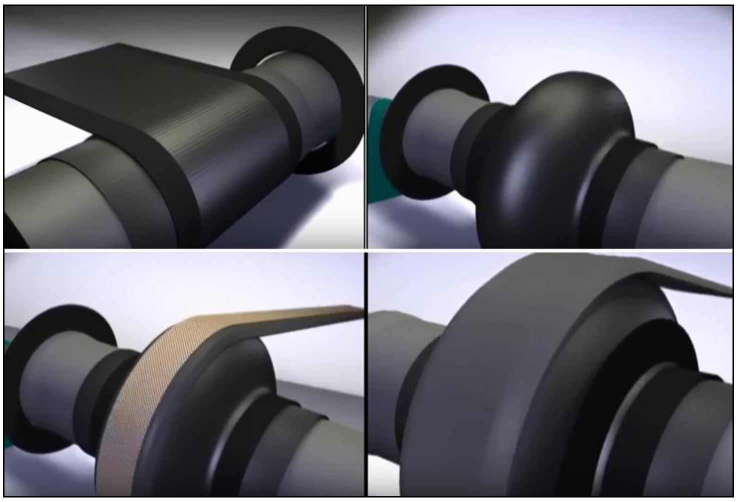

Figure 3: Assembling process of a tire in an assembling machine

As we can see in the top left part of the picture, parts are laid out on the surface of a tire assembling machine and match end to end. Second, when the different parts are laid together, a bladder inside the assembling machine is inflated. Third, belts are put into place on top of the different parts in order to protect the surface. Fourth, the tread is attached to form tire.

When these four steps are completed, bladders at each side of the tire are inflated in order to push components in the characteristic tire shape. The sidewalls and Body ply ends are folded around the beads, and press firmly against the sides of the tire.

At the end of all these steps, the tire is not yet cured and thus components are still soft. All components are pressed together using special rollers. As a result, a green tire is obtained. A green tire has the shape of a tire but it is not yet cured, it doesn't have the tread pattern or the sidewall design, as we can see in figure 4.

Figure 4: Green tire after assembling

Next, the curing will be done using big heated molds. Molds are incredibly precise and expensive. A mold costs between 25000 to 60000 euro depending on its size, characteristics, exclusiveness, quality, etc. In order to obtain this precision, drawings of the molds are done by engineers. In these drawings, technical and legal characteristics are introduced, in order to make the mold. One mold is formed by nine parts that weights around 20 kilos, and two sidewalls. The picture below portrays the different parts of a mold and the tread pattern that makes on the green tire, as well as an example of a mold drawing. Different molds are needed for every tire size, and tread pattern. Many parts of the process are done by hand, taking around three to three months and a half to make a complete mold.

Figure 5: Drawing of a mold and sectors of a mold for tire manufacturing

The manufacturing of a mold takes around three to three months and a half. It is a complex process that is usually performed by plants that only manufacture this product. That is why

Bridgestone Europe NV/SA orders and buys molds to external suppliers. Before arriving to the final mold that has been shown in Figure 5, there are several steps. First, the mold is made in wood, where the tread pattern is made. Second, a silicon product is poured on top of the wood mold, obtaining the pattern when it solidifies. Next, a plaster is used in order to obtain the next mold in the process. Again pattern is obtained. Finally, steel is used to obtain the final mold structure. Once steel solidifies, the plaster mold is broken in order to have the needed pattern on the steel mold.

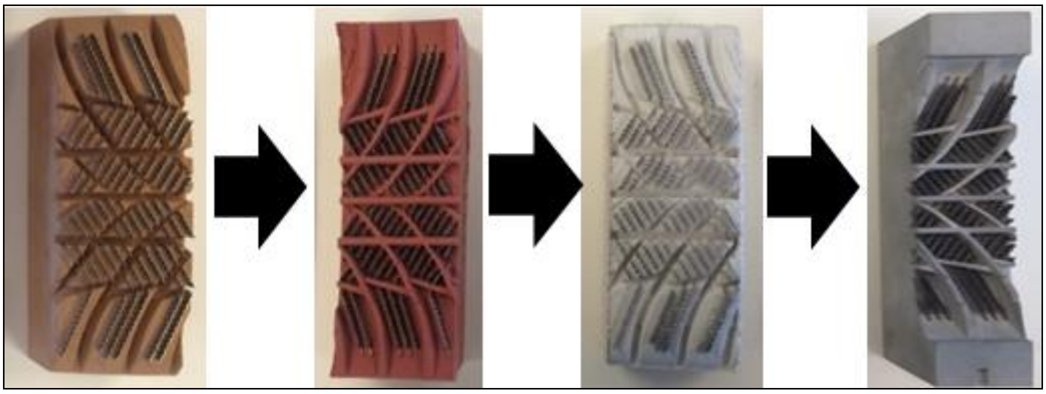

Figure 6: Four steps in creation of a mold. Wood, silicon, plaster and steel.

After the steel mold is obtained, a cleaning process is done. Next, small holes are done in the different parts of the mold so that steam can come out when using the mold to cure the tire. Curing of the tire will be explained later. Technicians must check manually that all the parts of the mold are correct. Also, the tread pattern and sidewall logos are checked and done manually. When mold is ready, it is used to vulcanize the tire.

Rubber is vulcanized or cured in heated molds in order to combine all elements. Molds provide the trend pattern on the rubber, as well as the sidewall design that contain label, homologation, brand or type of tire. The green tire is placed inside the heated mold and a bladder is inflated inside in order to press the tire against the mold as it is shown in the picture below.

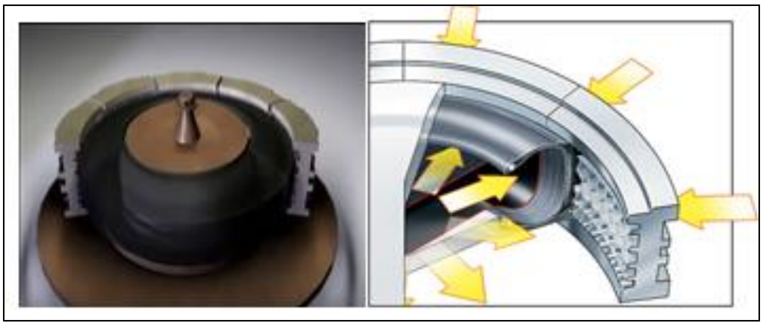

Figure 7: Inflation of a green tire against mold to create pattern and sides

In this process, the tread pattern is inscribed on the tire, as well as the sidewall labeling. The result is shown in the following picture. Finally, the tire is complete and it has the characteristics that are required by wheel. On the left, the tread pattern can be seen; this will provide characteristics such as fuel consumption, speed, or safety characteristics. The sidewall, right side, contains labeling that shows brand, homologation, or name of the tire.

Figure 8: Final tire with pattern and inscription on each side

3. Methodology

In order to deal with the improvement of the process, a methodology of work is going to be used. It is common to fall into the tentative of using an in-house methodology to improve process. The use of an unestablished methodology can result in an inefficient methodology, not identifying important factors, and to obtain poor results.

The use of a methodology is very beneficial for a company. Useful benefit can be found through the integration, collaboration and communication of supply change members with respect to quality and customer satisfaction see Matsui (2013).

3.1. State of the art

A search on scientific articles has led us to the use of a six sigma methodology. Six sigma is a business strategy that seeks to identify and eliminate causes of errors or defects in business processes by focusing on outputs that are critical to customers, see Antony (2004). Ang Boom Sing (2015) stated that "Six Sigma is a business strategy that helps organizations to improve organizational efficiencies and customer satisfaction; it decreases operating costs and increases profits. Numerous practitioner studies claim that Six Sigma improves organizational performance."

Lean methodologies share the same philosophy of Six sigma. However, Lean is focused on eliminating waste and it has as key objective lead time. Six sigma also follows the objective of improving the processes but in a wider and not predefined sense. In addition, Six sigma is better structured see Pérez-López (2014).

In addition, although originally, it was focused on manufacturing, Six Sigma is widely accepted in both services and transactional services, see Antony (2004).

It is proved that Six sigma methology and specially DMAIC methodology improves quality and performance by using, increasing and transferring knowledge, see Boom Sing (2015). Results support the notion that knowledge-creation practices influence the success of process improvement projects. Specifically, the inclusion of softer, people-oriented practices for capturing tacit knowledge, see Anand (2010*).* Also, knowledge creation has direct positive impact on customer, internal business process, employee learning and growth and indirect positive impact on financial, see Boon Sing (2015).

In six sigma there are various methodologies but there are three key methodoloies.The principle sub methodologies of Six Sigma are DMAIC and DFSS. The two of them are going to be compared (Process improvement approach, 2016).

Now that the importance of Six sigma has been stated as well as its most important methodologies, these two methodologies are going to be described and compared in order to make the best decision choosing between them.

DMAIC

DMAIC refers to a data-driven quality strategy for improving processes, and is an integral part of the company's Six Sigma Quality Initiative (American Society For Quality, 2012). DMAIC is an acronym for five interconnected phases: Define Measure, Analyze, Improve, and Control. From the set of Six Sigma methodologies, it is the most applicable methodology to the manufacturing or production side of a product or service, DMAIC includes these project stages:

- Define - address the identification of specific processes to be examined.
- Measure - record data and use metrics to track effectiveness and evaluate efficiencies.
- Analyze - utilize critical thinking skills to review data and clarify goals.
- Improve - create changes in business processes geared toward improvement and better alignment with corporate goals.
- Control - build a system of checks and adjustments for ongoing improvement in production processes.

DMAIC is a cyclic process. Once the last phase is finished, the entire process starts again.

DMAIC is a useful methodology to reach the goals of this MT. It has a period of recording data of the process and analyzing to improve the process. In addition, it has parts of improvement and control which again go align with the objective of this MT. *(Bisk Education, 2016).*

DMAIC is used in a wide range of fields such as a information, technology, manufacturing, health, etc. It has been use in many fields with successful results such in information management, see Chung (2010), in automotive company, see Pugna (2016), design of heat exchangers, see Srinivasan (2014), paint line in manufacturing industry, see Srinivasan 2014, etc. This flexibility makes DMAIC a good option as methodology.

DFSS:

DFSS stands for Design For Six Sigma. DFSS is a data-driven quality strategy for designing or redesigning a product or service from the ground up. *(Process improvement approach, 2016)*. This means that this methodology is used to start creating a new process that adapts to Six sigma methodology.

Normally DFSS is implemented by companies to suit their business, industry and culture; other times they will implement the version of DFSS used by the consulting company assisting in the deployment. "Because of this, DFSS is more of an approach than a defined methodology" (iSixSigma, 2016).

DFSS focuses on giving a high quality of a product or service. This is the reason why the customers´expectations and needs must be completely understood before a design can be implemented.

The most important DFSS methodology is DMADV. DMADV is going to be explained below.

DMADV

DMADV is the complementary set of Six Sigma processes that is most applicable to examining and improving the customer relations side of a company. DMADV includes these project stages:

Define - address customer needs in relation to a product or service

Measure - involve the use of electronic data collection to measure customer needs, response to product, or review of services

Analyze - utilize metrics to evaluate areas where product or service can be better aligned to customer goals and needs

Design - overlap the improvement of business processes that streamline corporate goals to best meet client and customer needs

Verify - build a system of tests and models to check that customer specifications are being met through on-going improvements

Again, DMADV is a cyclic methodology.

DMADV is not a methodology applicable to this MT. It is focused on the development of a product in order to satisfy customer's needs. It is not oriented in the optimization of the process but in the final product (Bisk Education, 2016). Therefore, it is not aligned with the goal of this TFM and this project.

Conclusions of state of art:

In this state of art, based on a deep research on scientific articles, it has been concluded that Six Sigma is the best approach to complete this project. Six Sigma focuses on customer needs with the objective of optimizing the process, covering all aspects with a very well structured methodology. Finally, Six Sigma is able to optimize processes through the use and spread of knowledge.

Six Sigma experts conclude that there are two types of key methodologies inside Six Sigma. These two types are DMAIC and DFSS. And inside DFSS, the most important methodology is DMADV.

Comparing these two types, DMAIC methodology is the best methodology for this project. The reasons for this conclusions are various. First, DMAIC is a very versatile methodology that can be used to optimize a process. Second, DMADV is mainly focused on creating new processes from scratch and introduce a Six Sigma approach. Finally, DMAIC methodology is in line with this project since it can be used into an already existing process. DMAIC can give very optimal results and be very beneficial with the use and transmission of knowledge.

3.2. DMAIC Methodology

DMAIC refers to a data-driven quality strategy for improving processes, and is an integral part of the company's Six Sigma Quality Initiative. DMAIC is a structured problem-solving method. DMAIC is an acronym for five interconnected phases: Define, Measure, Analyze, Improve, and Control. From the set of Six Sigma methodologies, it is the most applicable methodology to the manufacturing or production side of a product or service. Sometimes, project leaders or sponsors don't feel a formal approach is necessary, but most problem-solving efforts benefit from a disciplined method (American Society for Quality, 2015). DMAIC includes these project stages:

- Define - address the identification of specific processes to be examined.
- Measure - record data and use metrics to track effectiveness and evaluate efficiencies.
- Analyze - utilize critical thinking skills to review data and clarify goals.
- Improve - create changes in business processes geared toward improvement and better alignment with corporate goals.
- Control - build a system of checks and adjustments for ongoing improvement in production processes.

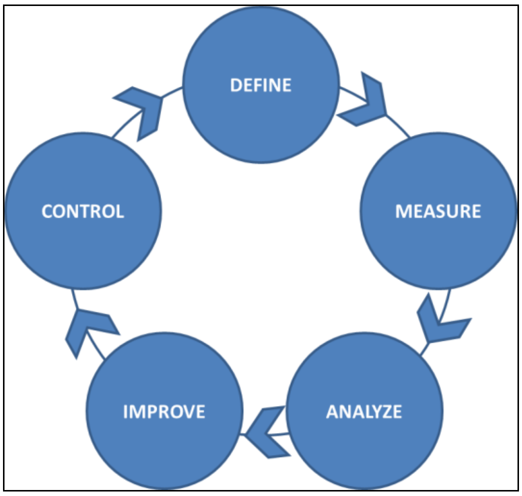

Figure 9: Five phases of DMAIC methodology. Define, Measure, Analyze, Improve and Control

DMAIC is a cyclic process where each phase builds on the previous one, with the goal of implementing long-term solutions to problems (GOLEANSIXSIGMA, 2015).

If a current process wants to be improved and the problem is complex or the risks are high, DMAIC should be the method used. Its discipline discourages a team from skipping crucial steps and increases the chances of a successful project, making DMAIC a process most projects should follow (GE´s DMAIC Approach, 2014).

There are two approaches to implementing DMAIC. The first is the team approach in which individuals who are skilled in the tools and method, such as quality or process improvement experts, lead a team. The team members work on the project part-time while caring for their everyday responsibilities. The quality or process improvement expert might be assigned to several projects. These are long-duration projects taking months to complete.

The second tactic involves the kaizen event method, an intense progression through the DMAIC process typically done in about a week. Prep work is completed by the quality or process improvement expert, and is centered on define and measure phases. The rest of the phases are done by a team of individuals who have been pulled from their regular duties for the duration of the kaizen event.

In most cases, the changes are piloted during the event, and full-scale implementation is completed after the event. It is crucial the impact of these changes—whether they are wanted or not—are monitored. The advantage of this approach is the ability to make rapid change (American Society For Quality, 2012).

The tools used in the **define** phase lay the foundation for the project. The team accurately and succinctly defines the problem, identifies customers and their requirements, and determines skills and areas that need representation on the project team. Individuals who must be part of the core team or be ad-hoc members are identified, and project measures, financials and a communication plan are established. *(Bisk Education, 2016)*

The define phase is usually the longest one and it contains several steps to fulfill:

1. Define the current state of the process
2. Interpret the Voice of the customer using the VOC translation matrix
3. Do the Customer Value Checklist
4. Create the project charter

The **measure** phase is when the true process is identified and documented. Process steps, and corresponding inputs and outputs are identified. Measurement systems are identified or developed, and validated and improved as required. Baseline performance is established with trustworthy data.

Before making the necessary measurements it is necessary to make a data collection plan in order to avoid over collection of unnecessary data.

In the **analyze** phase, the critical inputs are identified. Inputs that have a strong relationship with the outputs and root causes are determined. These critical inputs are the drivers of performance.

In the analysis, a root cause diagram or fishbone diagram is used to detect root causes and from these root causes find solutions.

In the **improve** phase, potential solutions are identified and evaluated, and the process is optimized. The critical inputs that must be controlled to maintain performance that reliably satisfies the customer are determined. Process capability and project financials are estimated.

A Stakeholder diagram and an Impact-effort matrix are two steps necessary to develop the improve phase.

The **control** phase establishes mistake-proof, long-term measurement and reaction plans. The team develops standard operating procedures and establishes process capability. Project financials are updated, verified and reported. Control plans are established with reaction plans, ownership and control is transitioned to the process owner, and lessons are documented. The team documents opportunities to spread the outcomes to other areas in the organization.

Control phase is divided in three parts:

1. Process control plan
2. Monitoring plan
3. Response plan

DMAIC methodology builds on learning from previous phases to arrive at permanent solutions for difficult problems. Define will tell the team what to measure. Measure will tell the team what to analyze. Analyze will tell the team what to improve. And improve will tell the team what to control. *(GOLEANSIXSIGMA, 2015)*

4. As is

4.1. DEFINE

As it has been explained before, in order to start sales on the established date, a stockpile must be built. This stock pile will be achieved only if the date of start of production is matched. There are many processes that are done in order to have everything ready on that date. One critical process is the mold flow. The criticality of molds in tire production has been explained before. In order to make sure mold is in plant on time, there are many teams working along the mold flow.

However, in order to make sure this process is done precisely and on time, a planning has to be done. If the planning fails, all the mold flow is reckless. Several issues have been detected by the logistic sector in Bridgestone when running the tactical planning of molds.

In order to understand this problem, a DMAIC methodology will be followed. In the first step of this methodology, Define, the issue will be stated as well as its importance and impact. In addition, the current mold flow must be understood. It is crucial to understand the complete process, not only the pieces of it that can lead to a suboptimal result. To achieve this understanding, meeting with all teams in the mold flow will be interview in order to define the current, the inputs and outputs. The objective is to interpret the voice of the customer in order to understand its requirements and the problems they have to face.

At the end of the definition phase, the problem will be defined, customers and their requirements will be established, and measures will be identified.

4.1.1. Current State of entire mold flow

In order to understand the current state, several interviews have taken place. The objective is to understand the entire flow, teams´ tasks, and their requirements in order to establish the current state. It is needed to have a clear view of the entire enterprise in order to identify all teams participating in the mold flow.

In Europe, Bridgestone is formed by different sectors that are in charge of fulfilling different objectives. These sectors are Technical Center in Europe sector, Manufacturing sector, Logistic, Supply, and Chain Management sector, Business Unit sector, and Human Resources. The organigram of Bridgestone is shown in the figure below.

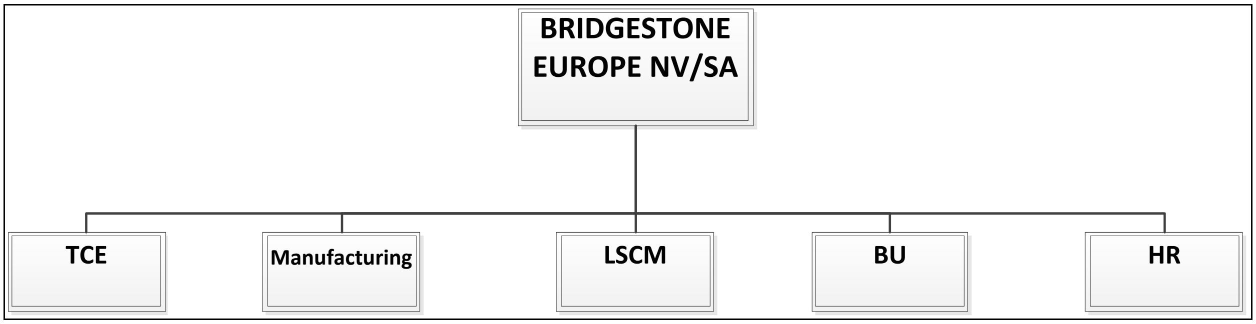

Figure 10: Bridgestone structure divided into sectors.

This organigram shows the division of Bridgestone Europe NV/SA in sectors. *(Bridgestone, 2016)*. First TCE (Technical Center in Europe) sector is where the engineers are. They know the technical factors of the tire, molds and drawings. They are in charge of designing the final product and it is where the knowledge of technical data relies. Then, the manufacturing sector is where production of tire is done. This sector also has a role in the mold flow since it is the destination point of molds. Manufacturing sector uses the molds for mass production of tires, and the demand they need and the information they provide is critical in the mold process. Next, LSCM (Logistic, Supply, and Chain Management) sector has as objective to ensure the correct flow of the process at its first levels, starting from suppliers, passing by production at the plant, until deployment to customers. LSCM is also in charge of developing the manufacturing plans. This sector is key in the mold flow. They are in charge of the entire mold flow making sure it goes to a good end by interacting with other sector. Finally, the sector BU (Business Unit) has an important influence since they are the ones who establish the volume of tires that has to be manufactured and sold based on demand. Therefore, they have influence in all other sectors and usually they are the trigger of the different processes.

This TFM will be realized in the sector of LSCM. Inside LSCM sector, there are 3 different teams. Operational planning team (OP), Strategic and Tactical Planning team (STP), and Product Lifecycle Management (PLM). Each team has different objectives that have to be achieved by realizing different tasks step by step. The tasks are done by different departments in each team. The organigram of LSCM sector is provided below.

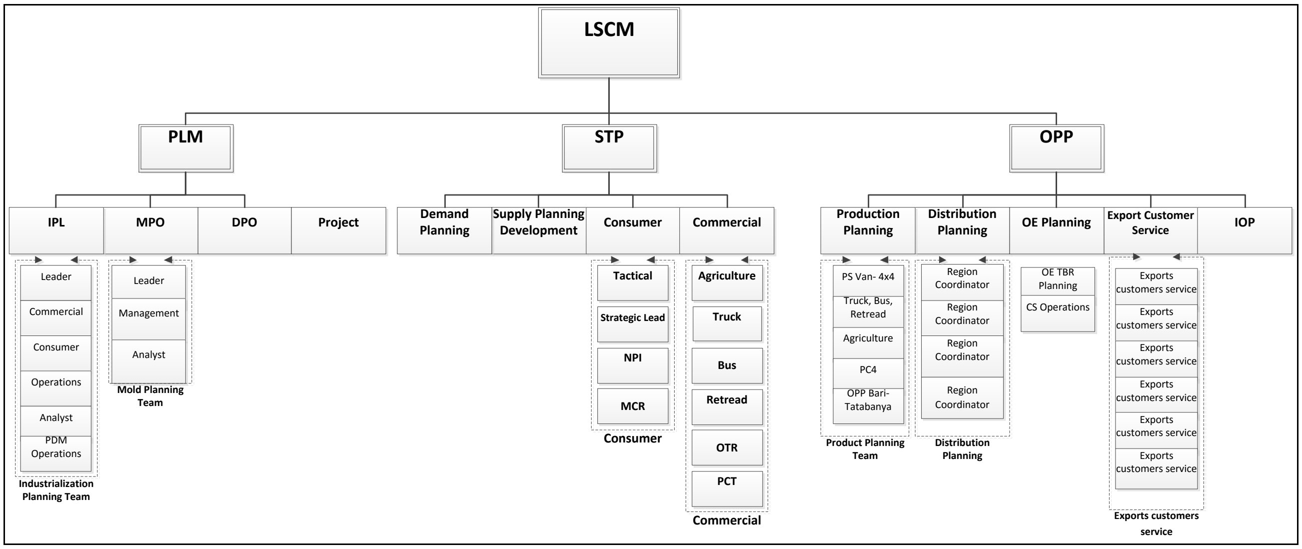

Figure 11: LSCM sector divided into teams and departments

As we can see, LSCM is formed by many subgroups that will be called departments. Each department has different tasks to fulfill the objective of each team and departments are formed by one to several members. Departments interact between each other receiving and providing information. As a result, teams work between each other providing key information to each other.

Now, that the structure of Bridgestone Europe has been described, all teams that interact in the mold flow can be identified.

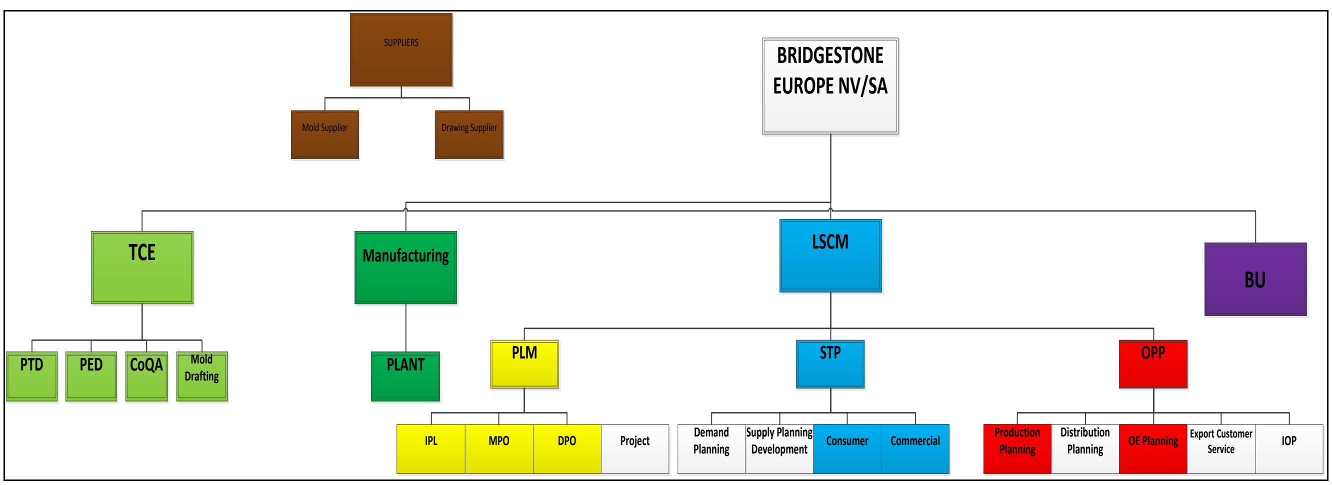

Figure 12: Sectors, teams and departments that take part in the mold process

As it can be seen, four different sectors intervene in the mold flow, R&D, Manufacturing, LSCM and BU. First, BU is in charge of finances, sales, and volume related to tire production. In TCE (Technical Center in Europe) in Rome, is in charge of developing the technologic and approve many parts of the process since it is formed by engineers. Teams inside TCE that interact in the mold flow are PTD (PSR (Passenger Service radial (tire category)) Tire Development Department), PED (Process Engineering Development), CoQA (Corporate Quality Assurance) and Mold Drafting. Second, plants will manufacture the tires once they receive the molds. Finally, LSCM is in charge of the industrialization, and production process. They are in charge of organizing, planning and making sure that the process is done. Three teams in LSCM interact between them to manage this process, PLM (Product Lifecycle Management), STP (Strategic and Tactical Planning) and OPP (Operational Planning). As it can be seen, the departments that take part of this process is IPL (Industrialization Planning), MPO (Mold Purchasing Order), DPO (Drawing Planning Office), Consumer, Commercial, OE (Original Equipment) and Production Planning. In addition, in the mold flow there are two types of suppliers that take part in the process. Drawing mold supplier and mold manufacturing supplier. The different departments, teams and sectors will be described below. *(Bridgestone Europe NV/SA, 2016)*

List of interviewers:

Once all members interacting has been established, the following list of interviewers has been developed.

- BU
- TCE
- Plant
- Suppliers
- IPL
- MPO
- DPO
- STP
- OPP
- OE

4.1.1.1. DESCRIPTION OF DATABASES:

In order to comprehend the tasks performed by all departments that are going to be described next, it is necessary to understand the different databases that are used in the mold process. Databases are the tool used to exchange information between departments in separate parts of the mold process. In the mold flow, there are three databases that are used by different teams and each one of them is oriented to a specific task in the mold process.

All databases are property of Bridgestone. Each department, team or sector is in charge of creating and maintaining them. Indeed, almost all databases are available for all members.

First of all, **Mold database** is, as its name says, the database that contains mold information. Mold database is based on industrialization stage. In this database, information for each mold is reflected. Each individual mold has a serial number, an IPC that reflects the type of mold, the plant that requested the mold, the FR related to the mold, the mold group that the IPC belongs to, the prize of the mold, how many have been ordered, etc. This database is useful to give knowledge about molds that it is necessary at other parts of the process.

Second, **BOSS database** is where plants include their information. BOSS stands for Bridgestone Original Scheduling System. BOSS exists with the purpose of connecting plants with headquarters in Brussels. Plants introduce information about their process and headquarters will use it at other steps of the process. The information that is introduced by the plant in BOSS is serial number, drawing number of the mold drawings, date of reception of the mold, status of the mold (Either if it is broken, available, etc), size and pattern of the mold, the manufacturer from where the mold has been received, etc. The problem with BOSS is that it doesn't provide how many molds are available for production. It is here where OMP comes into action.

Third, **OMS** is a database used mainly by MPO in order to keep truck of molds. OMS is used as a database where MPO, DPO, tire manufacturing plant, and mold manufacturing plant (suppliers) share data. This data is used by MPO to keep truck of molds and make sure that the process is done correctly. There is six data that is introduced into OMS and will be explained late. First, FR and MDR data is included. Second, PO from plant. Third, MDT for drawing preparation data. Fourth, Full MDT data. Fifth, manufacturing state of the mold and when it will be ready. And finally, information about mold arrival. MPO needs to know the dates of each process to determine that the flow is going correctly and mold will arrive in plant on time. Also, the mold arrival has to be recorded in order to record and map that molds are in destination and no more molds are needed.

Fourth, **SAP** (System Analysis and Program development) is a ERP (Enterprise Resource Planning) used in many companies. One feature of SAP, is that it provides workers in a company with the ability to interact with a common corporate database in different applications. SAP allows the capability to manage financial, asset and cost accounting, production operations and materials, personnel, plant, and archived documents. In the Bridgestone, SAP is where the product data is stored. First, IPCs are created in SAP where information about its technical characteristics, the financial aspects and the regulations it has to follow is included. Second, information about the relationship of successor-predecessor is present in SAP. Successor-predecessor is data of two IPCs where one replaces the other. In other words, a IPC that is becoming obsolete can be substitute by another IPC. This information is in SAP.

Fifth, **DPO database** is a database only used by DPO department. In this file, it is recorded information about the drawings orders with dates and the steps in which they are. DPO has the suppliers that will do it, the number of mold, the type, the destination and the four types of drawings. Inside DPO database, data of the process is saved. This data is MDR, MDT for drawing preparation, Full MDT, four types of drawings, and their codes (ADE codes). This database can only be access by DPO department. However, it is shared with MPO in OMS. MPO uses information from DPO database in order to make, follow, and report the mold flow.

Sixth, **SGK** stands for Sougou-Keikaku, which in Japanese stands for Total Planning. SGK is basically the industrialization planning. As it has been explained, industrialization stage is before production and it is preceded by plan, design and development. SGK database is maintained by IPL. Inside this database, information of the source can be found such as the supplier that provides the molds. Also, the code of the product is present, the engineer that manages this product, technical information about the product, and mass production dates.

Seventh, **Sourcing** is a database that gives information about source and mass production. It is maintained by IPL which obtains information from PTD and the plant. Also, STP provides information about the source. In Sourcing database, the source of the mold, the status of the product, if the product is qualified or not for mass production and the stop date of the product can be found.

Finally, **OMP is a planning tool** with a database that it is used in two different steps of the process. OMP is focused on production. This tool is used by two teams, STP and OPP in order to obtain a view of the process for the next six months and to determine the production of the next month respectively. Both teams use data coming from BOSS and Mold database that is introduced into OMP. Constraints are introduced and a prediction is obtained.

As it will be presented later on the TFM, problems arise due to these different databases. The alignment between the three of them is not always perfect which creates problems with data availability and data accuracy.

Another important tool used for the flow of information is **Share Point**. Share Point is a platform of the company used to share internal data. Excels are extracted from the different databases explained above and they are share in Share Point. Share Point is a tool that creates a connection between data bases in some basis. However, it cannot ensure that data is shared or complete. Also, it doesn’t ensure that data is fulfilled correctly and completely by each responsible team.

4.1.1.2. *DESCRIPTION OF THE DIFFERENT TEAMS INVOLVED IN THE MOLD PROCESS*

Once meetings were held, some objectives were able to be fulfilled. Now the description of each team and thus each department will be explained.

First, it is important to understand some terms of the mold flow that will be used in along these descriptions.

NPA: NPA stands for New Product Approval. It is a code used to name a final tire just after the development stage and before production stage. In other words, it is the code to name a product before it is made. It can be seen as the code of the idea of the product.

SPEC: The composition and the procedure that has to be followed in order to make the tire is called SPEC. In other words, it is the recipe of the tire that goings inside the mold to be "cook". There is a difference between final SPEC and Guide SPEC. Final SPEC is obtained after several trials from the Guide SPEC. Trials are done in the plant.

IPC: It is the code used to name one type of tire. An IPC has a one to one connection with a final SPEC inside a plant. However, an IPC can be done with different final SPECs depending on the plant. IPC differentiates from NPA in that IPC is the code used to name a product for industrialization, production and sales while NPA is used before the product is created.

ADE: ADE is the number given to the drawing of a mold. In reality a mold has four drawings as it will be explained later, but the ADE number used is the ADE for tread drawing.

Mold Group: It is a mold that can be used to make more than one IPC. IPCs can share the same tread pattern or sidewall. A better explanation of mold group will be given later in the description of the process.

The process of interviews was to have separated interviews with each department in order to understand its internal flow, and the interactions they have with other departments. These interviews had different objectives. First objective was to understand the goals or purposes of each department. Second, to understand which are their starting points and ending points in the flow, their sources of information, and their area of action. Third, to have a clear view of the process or steps they have to follow, taking into consideration the documents they require. Fourth, to see the interactions each department has with other departments. Fifth, to obtain feedback about the difficulties they have to face in order to attain the final goal, propose improvements in the process.

During each interview, reports of all sectors, teams and departments were made. In these reports, the description of each one of them has done. This step is crucial in order to able to make the mapping of the mold flow linking them to each other.

BU

BU (Business Team) sector is one of the main sectors in Bridgestone Europe. It is in charge of financial, production and sales issues. Although BU is not directly link to mold flow, it greatly affects teams interacting in mold flow through the decisions taken inside their sector.

First of all, BU has a big role in the definition of MTP (Mid Term Plan) where volume of tires that will be produced and the date they have to be ready are decided. Volume and date is decided based on the demand. However, the technology must also be taken into account of course. Bridgestone cannot produce a tire that it is not attainable by them from the technological point of view. In the MTP, the different tires that are going to be produced are decided, and the necessary amount of them.

Second, BU is the one that approves operations in economic terms. For example, in the mold flow, MPO must get the approval of the expenses done when buying molds. In other words, budget must be approved by BU.

Finally, Business Unit is in charge of giving green light to IPL, who at the same time passes to the rest of the teams. Green light is the approval given by BU to pass from Development stage to Industrialization stage. This approval is based on the possibility of starting the process in financial terms.

TCE

TCE (Technical Center in Europe) is in Rome, Italy, and basically they are the engineers of the company. They have the knowledge about the technical factors related to tires, molds and processes. TCE is the one that has the final word in terms of technical approvals. In the mold flow, they are in charge of approving drawings and molds after trials. In addition, they have the word to give SPECs to plants in order to make the final tire. Finally, they provide technical information through the entire process to the different teams in order to have a good flow of information. This information is established by TCE and that is why they can provide it.

Inside TCE, there are several teams that take part in the mold flow. They are in charge of several steps in the process. These teams are Mold drafting, PTD (PSR Tire Development Department), PED (Process Engineering Development), and CoQA (Corporate Quality

Assurance). They are in charge of the SPEC process, the approval of the drawing process, the approval of the SPEC, and of the technical factors.

PLANT

In the manufacturing sector of Bridgestone Europe NV/SA, we have the different plants that develop the tire. As we have seen, there are nine plants in Europe. Three plants are in Spain: Burgos, Bilbao and Puerto San Miguel; one in Italy: Bari; one in France: Bethune; one in Belgium: Lanklaar; two in Poland: Stargard and Poznan; and one in Hungary: Tatabanya.

In the mold flow, they are the ending point of molds. Plants are the actor of the mold flow that use them in order to build the final tire from green tires as it has been explained in the description of the manufacturing of molds.

Also, plants are in charge of creating the PO (Purchasing Order) once they receive a FR (Fund Request) from MPO. This process will be explained later. But basically, this process is an authorization of MPO to the plant to order molds to a supplier.

In addition, plants are in charge of registering the arrival of molds once they arrive. They have to make the connection between mold and IPC (the type of tire that they are going to produce). This connection is not always clear because they receive various molds for different IPCs and they have to make sure that they have the necessary mold for the production of each IPC.

Finally, plants are in charge of make the different trials that assure that the final product, the tire fulfills the requirements. First, they will check that mold and SPEC are correct. Next, they will do several trials in order to obtain the right SPEC they are going to use. Finally, they will make sure that the final product fulfills specifications. At the end of the process, a qualification of the product is obtained and plant will receive an authorization to start mass production.

SUPPLIERS

Bridgestone is a company that produces tires. However, like all companies, they need suppliers of certain products to produce their final product that they sell to customers. One of this needed products are molds. Bridgestone buys molds to suppliers. However, in the process of molds, as it will be explained later in detail, drawings of molds are needed. Therefore, in the mold flow two different suppliers are going to be considered.

First, mold drawing suppliers will provide Bridgestone with the drawings necessary to produce a mold. As it will be explained later, the drawing of a mold consists of four different drawings: Cavity, Tread, Stamping and Mold construction drawing. Each one of them must be approved separately by the engineers in Rome, except for mold construction drawing that is approved by a section of Mecamold, a Belgium supplier in Liege of both drawings and molds. Bridgestone Europe has four different drawing suppliers, in Belgium, in Italy, and in China. Not all of them can do the four drawings. Therefore, suppliers must be chosen in order to optimize the process. Drawing suppliers are chosen by DPO.

Second, mold manufacturing suppliers will use the drawings to manufacture molds. Again, there are different mold suppliers in Belgium and China. However, their capacity and lead times vary to one another. It is job of MPO to choose mold manufacturing suppliers in terms of capacity, prize, time that are needed and volume in order to optimize the mold flow.

LSCM:

PLM:

PLM (Product Lifecycle Management) team is the principal department in the mold flow. It is formed by IPL, DPO and MPO. They are responsible of making sure the product is produced. They assign suppliers and follow the process step by step. PLM interacts with all sectors both in mold and tire production process.

IPL Department

Industrialization planning department (IPL) is in charge of the synchronization of all tasks from the start of the industrialization stage, until the start of MP (Mass Production). The time scope of this department is long to medium term. They work with the MTP (Mid Term Plan) which is the 5-year plan of the company.

Every year, the MTP is decided. Teams that take part in the development of mold flow and MTP creation at the same time are Business Unit (BU) sector, IPL and STP. In the MTP, it is decided what to do, what to sale and when to do it is decided, in other words, the date, volume, and number of sizes for the next five years. However, BU has to contact TCE to make sure that this idea is possible, for example if the technology is available. This is the start of the Development process that takes around 2 years. BU also contacts STP to make the MTP where decisions such as volume of tires and dates where they have to be ready to sale are established. IPL will do the Industrialization plan based on MTP requirements.

Once volume and date is decided, STP (Strategic and Tactical Planning) decide the plants where the production of tires is going to be done and the volume of each plant. In other words, they decide where mass production of tires is going to take place and how much is going to be produce by each plant in order to fulfill the total demand established by BU. This decision by STP is done taking into consideration constraints such as capacity, volume, transportation, technology availability, etc. STP takes also part in the mold process and this will be explained later.

Now, the volume of mass production of tires for each plant is known, as well as the date for when they have to be ready for the SOS (Start of Sales). Industrialization planning is defined. If both volume and date are not met, a problem of lack of available stock can happen. Therefore, IPL must make sure that mass production starts at SOP (Start of Production). IPL is responsible for Mass Production startup. In order to achieve this goal date, they must make sure that molds that are used to make the tires are available in each plant.

At this point, IPL has to contact MPO to make sure molds will be ready for SOP. MPO's tasks will be explained later, but basically they make sure that the process of mold creation is done from the moment they receive green light from IPL, until mold arrives to the plant that will manufacture tires.

Therefore, IPL must follow and make sure that the mold process is done from the moment they receive green light from BU until mass production. Basically, they are given a date by BU to have ready a stock for the SOS, and taking into consideration the different processes that take part until the SOP, they make sure that the different departments do their part to have the molds ready on time.

Parallel to the mold process, they follow that the SPEC, which is the recipe, materials and the process to make the tire, reaches the plant. Once SPEC and mold reaches the tire manufacturing plant, different trials take place. In these trials, they check the mold and the SPEC, and they start planning the project. This planning receives the name of PB (Project Building). At this stage, plant checks that everything is fine and they try different SPECs making different tests. At the end, qualification tests are done in order to approve that the tire fulfills specifications and it is ready for mass production. Until this point, IPL follows the process and makes sure that everything is done.

In addition to these tasks, IPL is also in contact with STP and BU in other ways. STP checks mass production with a shorter view, and tells IPL that they have to anticipate mass production, and thus molds. BU also checks the mass production but gives a more global view, while STP is more specific to each month.

MPO DEPARTMENT

In the Mold Purchasing Order department (MPO) the objective is to make sure that the molds requested by different departments or teams are manufactured. MPO is in charge of assigning the requested molds to different manufacturer suppliers depending on capacity, demand, lead time and urgency. MPO works as a bridge between final plants and the manufacturer suppliers.

They receive purchasing orders from different departments, and they develop the required documents to make the order feasible. Also, MPO department is in charge of choosing the transportation mode, the manufacturer supplier of the demanded product, and to determine the prize of the operation. Furthermore, they will control the lead time of the molds and the dates the purchasing order reaches its destination.

In order to be able to achieve these tasks, they maintain a close connection with manufacturer suppliers. This relation enables both parts to communicate and to establish or modify the production planning and thus, achieve the dates when molds are needed in each destination. MPO checks manufacturer schedules and calculates the capacity of the manufacturer suppliers to be able to assign the manufacturing to different suppliers. Finally, MPO takes care of transfers of molds between receiving plants. Transfers can be requested by STP most of the times, and sometimes by IPL as well.

The first step is the confirmation to start. MPO receives initializations of molds Fund Request (FR). The request comes from different teams inside the company through Share Point. These requesting teams will receive the name of clients. There are three different clients that initiate the FR. IPL department, STP team and OE (Original Equipment) department.

IPL usually request new products. They have the forecast of Original Equipment, which are the wheels that go with the car when it is initially sold. Also, they have Repetition Equipment forecasts that are the wheels that are sold at the shops.

OE department sees if the demand of cars has increased, and thus the demand of wheels. They will request more molds to MPO if the available molds in the plant are not enough to fulfill the demand. MPO will check if they actually need these molds by looking at plant availabilities of different molds.

Finally, STP has a view of forecast for the next 6 months. They have a better view of the future, and they demand MPO for more molds, new molds, or transactions. In fact, STP uses information, coming from MPO and the plant, about mold availabilities of the different receiving plants in order to make its forecast.

The requests received the name of FRR (Fund Request Requested). Each client can demand different types of products that have different lead times. In the initialization of fund request several data is given to the MPO department. This data contains the date they make the request, the due date of the request, the destination plant, the type of item, the activity that must be done, if drawings of the molds must be done. The type of item can be a complete mold, only a sector of the mold, Sidewall plate etc. The activity can be to ask for a new item, a modification or a transfer between plants.

Once the initialization of fund request is received, the MPO department checks if the request in terms of number of molds needed is correct. In order to check if the request is correct, the number of needed molds, and the number of the available molds by the clients is used to determine the number of molds needed. If they are the same, the request is right.

The next step is to make the FR and the Mold Drawing Request (MDR). In order to create these requests, two documents must be filled in, Fund Request (FR) document and Mold Drawing Request (MPR) document. A member of the MPO team must take into consideration several factors. First, seasoning is important since winter and summer have different lead times. Second, depending on the type of product requested by the client, the company selects a supplier. Each supplier is able to provide different types of products. Third, the transport mode must be taken into account. The transport mode is chosen considering first lead time more than cost. Fourth, the destination plants that are taken affect the process since they have an impact on lead time, of course. Finally, manufacturing will affect this process since the manufacturing time of molds is important. These factors will provide to the MPO department with the date when the molds will reach the client, even if the date is later than the requested date.

When both documents are ready, they are issue by the MPO department in Share Point. Here, the documents will wait for the approval from the client which is the tire production plant that will receive the tires, the MPO manager and TCE (Technical Center in Europe), that are the engineers in Rome. Both parts will receive a notification when the documents are uploaded in Share Point. If there is any mistake in any of the documents, a notification will be given to the same member of the MPO team that developed these documents. This member is the only one that can modify them. Once both documents are approved, they are forwarded to the plant that will manufacture the molds by email. Also, MPO makes sure that the drawings are at their destination checking with DPO.

At this point, the manufacturing of molds starts. MPO checks with all suppliers and molds that there are not delays and the manufacturing schedule is follow by the manufacturer supplier as planned. When molds are ready, they are delivered from the manufacturer supplier to the receiving plant. At the moment, the delivery is responsibility of the receiving plant. MPO chooses the transportation mode in order to answer to the demand on schedule. However, there are some problems in this step since the receiving plant doesn’t understand the priorities and the transportation is sometimes inefficient. Finally, the MPO department will receive a notification from the receiving plant where they will specify the date when they received the molds from the manufacturer supplier. However, receiver plants sometimes don't inform MPO that the molds have arrive or they do not register the arrival of the molds until SPEC arrives. This creates confusion because MPO is not able to have a registration that the mold is where it has to be. This issue can lead to a demand molds to a supplier when the molds are already in the final plant since STP can see that these plant need more molds.

Another problem identified in the process done by MPO, but that affects the entire mold process, is a lack of standardization of the mold groups and IPCs (International Product Code) belonging to each mold group. This problem will be explained in detail later in the problem identification section.

DPO DEPARTMENT:

The objective of DPO (Drawing Planning Office) is to make sure that the drawing process is correct and fulfilled. The task of DPO department is to assign the mold drawings to different drawing suppliers depending on capacity and schedule. Also, they have to make sure that the process flows correctly and steps are done by one. Finally, DPO is in charge of making the schedule of workload of drawings for their different suppliers.

DPO process starts when documents FR and MDR are sent by the MPO team. TCE receive the documents and they have to develop other two documents. MDR1 and MDR2. MDR1 is a technical document which is done by PTD (Product Engineering Development), and MDR2 is a legislation document which is done by CoQA (Corporate Quality and Labeling). They are consolidated by PTD.

Once these documents are ready, PTD sends a MDT (Mold Drawing Transmittal) for drawing preparation to DPO. DPO has to choose among four different drawing suppliers who will make the drawings. Drawings are divided in four steps, cavity, tread, stamping, and mold manufacturing. Some of the company's four suppliers have the skill to draw the four parts, others, only some of them. DPO will choose among these suppliers depending on their skills, workload, and due dates.

When the four parts are done, they are sent to TCE to be approved. The four parts are approved separately and one after the other, in the priority that have been listed above. DPO has to make sure that the drawings reach TCE and that TCE approves the drawings in order to make sure that the mold process continues and they are on time on their destination. DPO department will contact TCE to confirm that the process is done.

Finally, when documents are approved Full MDT is ready. Full MDT is sent to the manufacturer supplier. The manufacture supplier and the drawing supplier can be the same or different.

Normally if the drawings are assigned to a supplier that is also a manufacturer supplier, this will be assigned to do the manufacturing. However, in some cases they can change even if they are able to supply both drawing and manufacturing. MPO department, as has been explained above, is the one that determines the manufacturing supplier.

STP (Strategic and Tactical Department): Commercial and Consumer

As it has been explained before, STP is in charge of deciding the volume assigned to each tire manufacturing plant. However, STP also has an important part in the mold process. Contrary to IPL that has a long term view of the mold process, view of the next one to five years; STP has a closer view, six months.

STP analyzes the different data from the past and the future coming from different sources and obtains a view of the mold process for the next six months. In order to do this task, STP uses an optimization program that uses different data to obtain a scenario for the next 6 months. The process is the following.

STP introduces mold data, which is number of molds, when molds will arrive to each plant, transfers, mold groups that is obtained from MPO and plants. Also structural data is introduced, such as machine constraints or individual mold constraints. Furthermore, product data is taken into consideration where sizes, activity, attributes and other features are included. Product data is provided by IPL. Finally, demand is used, provided by BU, inventory, calculated by STP, and supply that is obtained from other STP departments and OPP.

Once all the data is introduced, the program creates different simulation to obtain scenarios. This is done to obtain bottlenecks, needs, supply and the issues that can be found in the next six months.

At this point STP informs MPO, IPL and OE about the different issues that can happen in the next six months. The demand of molds can vary in different plants depending on their availability and constraints. Therefore, more molds have to be produce, or transfers of molds between plants can be needed. Now, of course, the different departments have to act to answer to this demand following their different steps.

In fact, the process done by STP regarding the molds can be view as a cycle. Every month, STP uses data from MPO, Plant, IPL and OE to introduce in its optimization program. A view of the next 6 months is obtained about the necessities of each plant. Next, MPO, IPL and OE get this information in form of demand from STP, so they have to start their different processes. Finally, once the different processes are finished, the data is given to STP to start the cycle again.

However, some problems are found in this flow of information. Every month, at the moment STP has to introduce data coming from the different departments, there is missing data. This problem will be explained later, next to the other problems identified in the mold process.

OPP:

OPP team (Operation Production Planning) is in charge of the last stage in the process. They are in charge of the Production stage. Their objective is to plan the tire production of every plan for each week. As it can be seen, this stage is a critical stage where no errors are allowed if demand wants to be matched.

In order to plan the production, every month they predict the tire production for next month based on different information. They use information coming from BU, MPO, IPL, plants, and product. OPP team uses an optimizer or planning tool based on penalty to determine the tire production. Constraints are included in this program every month. There are two type of constraints, soft constraints, they can be unmatched if they are impossible to fulfilled, or hard constraints, which are constraints that are mandatory to respect. Soft constraints are demand, inventory, minimum inventory, target inventory, or maximum inventory. Hard constraints are usually more technical constraints such as which machines in the plant can produce the tire, inflation procedure, or the type of tire that has to be done. Also, mold availability of a plant is considered as a hard constraint.

It can be seen that many of the constraints are obtained by information coming from other teams that participate in previous stages of the process. In fact, as it has been explained, production of each plant is established by STP. STP makes predictions every month for the next six months of the production and availabilities. This information will be used by OPP to determine the demand of the next month. However, OPP time constraint is limited, if there is a failure, they cannot do anything since the previous process takes much more than one month. Therefore, if for example molds are not available at a plant when needed, the tire production of next month will be in shortage.

The only thing that OPP can change in the previous process is to order mold transfers to MPO base on STP predictions for the next 6 months. However, a transfer of molds usually takes around two months. Therefore, transfers are usually done for the start of production of 3 months later.

Also, MPO, DPO, and IPL work to make sure molds arrive on the plant on time. The process that these teams follow, industrialization, is managed to try to be squeezed in order to meet the SOP (Start Of Production) date. The time of tire production is fixed.

All teams work together with the purpose of answering to this final team. The company is as good as the production team is. However, even at this stage, there are problems of flow of information. The information that OPP uses is sometimes not correct, either because is not updated or it is wrong from the beginning. But at this stage, it is too late for any changes. Problems identified will be explained later in the paper.

OE Department

OE stands for Original Equipment. As its name says, OE is in charge of original equipment. Original equipment is tires that come with the car when it is sold. Therefore, this type of tires is sold directly to car manufacturers to include them into cars when they are produced. Original equipment tires are different than replacement tires that are sold directly to end user.

Original equipment department has a key role in Bridgestone. In 2016, 10.5 million tires were sold, which means almost 1 million per month. As it can be seen this means a real important income for Bridgestone.

The job of OE is to make sure to keep in line production and demand. When molds are ordered at the beginning, they are done based on demand forecast. However, demand can change. For example, a car can be very popular and the production can increase. In cases demand increases five times than initially expected.

In order to make sure that demand is answered, OE makes sure that production fulfilled. As it has been explained in this process, in order to make sure production is done, molds have to be in plant on time, and sometimes more molds are needed. OE keeps truck of production and if more molds are needed, they request them to MPO.

They check in monthly basis the official forecast of the next four months, and OE compares with the current forecast to see if there are in line. If they are not in line, they check with IPL if they can anticipate molds. Molds can be anticipated by changing the preferences in production or by changing the transport mode. Also, OE can demand more molds when the demand increases. They need the approval of BU in order to spend more money in molds. OE checks forecasts for all the sizes even if they are active or new.

In the attached Visio map, the complete mold process is presented. Horizontally, the map is divided in swim lines into departments that interact in the process. Vertically, the process is divided into the time stage of the process.

4.1.1.3. *New mold order-Step by step process:*

Planning stage

1. Once in a year, **MTP** (Mid Term Plan) is created by all teams. In the MTP, it is decided the date, volume, and number of sizes for the next five years.

2. During the **planning period**, BU establishes the volume of production of each tire and the date they have to be finished. The goal date receives the name of SOS (Start of Sales). The objective is to create stock (Volume) at SOS (Date) in order to sell the tires.

3. Next, STP determines the **volume of tires** that each plant belonging to Bridgestone will produce in the coming year.

4. Using the volume allocation determined by STP in step 3 as an income, IPL makes the **industrialization planning.**

Planning period is finished with Gate 1; it is the start of Design stage. During each gate, there is a process of decision. If there is a positive decision, it continuous to next stage, if not, it must come back to the previous stage.

Design stage

The product is design by BU in economic terms. At the end of design stage, Gate 2 is passed.

Development stage

During the development stage, the design gets into shape by TCE with the participation of BU. At the end of development stage, Gate 3 is passed.

Industrialization stage

5. BU gives **green light** to IPL to start the process. Gate 3 is passed. IPL passes green light to MPO to start the production of mold process. It is the end of the Development stage and the start of the Industrialization stage.

6. **Confirmation to Start:** It is the initiation of a fund request. FRR (Fund Request Requested) is sent to MPO. It can be sent by IPL, only when it is a new product, it can be sent by SPT and by OE directly when it is not a new product.

7. **FDR** (Final Design Review) is sent by **PTD** (PSR Tyre Development Department) when a new design is finished.

8. FDR is the **start of SPEC industrialization** process. SPEC process is parallel to the mold process, until both arrive into plant. The arrival into plant is a later step.

9. Once FRR is received by MPO, MPO sends a **FR** (Fund Request) next to a **MDR** (Mold Drawing Request) to **Mold Drafting** team inside TCE, the engineers in Rome, Italy. MPO introduces data of FR and MDR into OMS.

10. At the same time, the FR is sent to the receiving plant that creates a **PO** (Purchase Order) that it is share with the manufacturing of mold supplier. Basically the FR is the approval that has to be sent to the plant so that they can spend money. When they have the approval, they can send the PO to the supplier in order to make the order. Plant introduces PO data into SAP.

11. Once Mold Drafting receives both FR and MDR, two documents are needed, a technical document (**MDR tech1**) that is done by PTD and a legislation document (**MDR tech2**) (MDR2 is done by CoQA (Corporate Quality and Labeling). They are done one after the other.

12. PTD assemble both documents and creates **MDT for Drawing preparation**. MDT (Mold Drawing Transmittal). At this step, ADE numbers of Cavity, Tread, Stamping and Manufacture are given.

13. MDT for Drawing preparation in sent to **DPO**. Once DPO receives the MDT for Drawing preparation, it can start working. DPO chooses, depending on different constraints, between 4 **drawing suppliers** (Mecamold, Himile, Palma, GDTech). DPO makes sure it is send to one of these external suppliers. DPO introduces the MDT for drawing preparation into DPO database.

14. The MDT for Drawing preparation is sent to a **Mold Drawing Supplier**.

15. The **drawings** are done by one of the drawing suppliers listed in the previous step. The first drawing is the cavity drawing.

16. Once drawings are done, they must be **approved in 4 steps by TCE**. Steps: 1. Cavity 2. Tread 3. Stamping 4. Mold Construction. The first approval, cavity, is done by PTD.

17. When cavity is approved, **tread and stamping drawings** start to be done by mold drawing supplier.

18. Then, they have to be approved. **Tread** is directly approved in one step by PTD. PTD also gives the approval of **Stamping** drawing. However, after Stamping approval, there is a second one to be done.

19. The **second approval** is done by **PED** (Process Engineering Development), another team inside TCE.

20. Once stamping and tread drawings are approved, **mold construction drawing** is done.

21. Mold construction is approved by a team inside **Mecamold.** Mecamold acts as a mold and drawing supplier. However, it also has a department that is in charge of approving mold construction drawings.

22. Once all steps are approved by TCE, PTD receives an e-mail with the approvals and the drawings. They create the **Full MDT**.

23. Full MDT arrives to **DPO** at the same time than mold manufacturer supplier with an e-mail. DPO introduces Full MDT data into DPO Database, that is then included into OMS.

24. The Full MDT is sent to the **mold manufacturer supplier** that will manufacture the molds using the drawings (Full MDT). MPO team chooses the manufacturer supplier. Also, some drawing suppliers (Mecamold and Himile) are also manufacture suppliers. Normally if these suppliers are assigned to do the drawing, they will do the manufacturing as well. However, it can happen that the manufacturer supplier is different than the drawing supplier, even if they can do both parts of the process.

25. Full MDT is also shared with the **tire production plant**.

26. Once, Full MDT is sent to the manufacture supplier, **MFG** (Mold Manufacturing) starts. MPO makes the planning of mold manufacturing depending on the required dates.

27. Once the MFG is finished (**mold is finished**), **Mold Shipment** is done. The manufacture plant is responsible of the delivery. MPO chooses the transportation mode depending on the delivery dates and priorities.

28. The receiving **plant receives the molds**. Plant registers arrival of molds into E-mail.

29. The plant receives **SPEC** from PTD. SPEC process is in parallel to mold process. It starts when green light is received at the beginning of industrialization stage. SPEC is sent by PTD to the plant. Both mold and SPEC must be in plant two weeks before start of trials. Normally the arrival of SPEC and molds is around the same time.

30. The **plant informs** MPO that they have received the molds once molds and SPEC are in plant. They cannot do it before both SPEC and mold are in plant. This is because they have to make sure that the mold is the right one for the IPC that is done with the received SPEC. In order to make the match between mold and IPC, they use the ADE number of the tread drawing that comes with the mold and the SPEC. MPO registers the arrival of the mold into OMS.

31. Once a new mold and SPEC arrive into plant, several **trials** are done in order to check that molds and SPEC are correct, and that the tire fulfills specifications in order to start mass production. It is a complex process and its time vary depending on the result of the trials and if they have to be repeated.

32. PTD receives information of all the trials. If the trials are passed, in other words, if the product is qualified, PTD sends final SPEC to plant. Plant receives complete SPEC information.

33. PTD gives connection between final SPEC and NPA to plant. Connection between final SPEC and IPC can be done. Plant introduces SPEC information and IPC-Final SPEC connection into BOSS database.

34. At the same time of two previous processes, PTD send confirmation to IPL that final SPEC has been obtained. IPL only receives partial SPEC information from PTD since SPEC is secret information.

35. PTD gives connection between final SPEC and NPA to IPL. Connection between final SPEC and IPC can be done. IPL introduces IPC-Final SPEC connection into SAP database.

36. Once final SPEC is confirmed, there is a **Technical Release to Mass Production**. In other words, an approval is obtained that technically mass production can start. However, even if the approval is obtained, production can start later.

37. **Mass Production data** is inserted by IPL into SGK database.

38. OPP obtains **dates of mass production** from SGK database and introduces them into Sourcing database.

39. Using this data, OPP determines the **production of tires for the next month**.

It is the end of industrialization stage.

<u>Production stage</u>

40. Before production starts, it must be approved. **Gate 4** must be passed.

41. Tire production will start at **SOP** when molds have passed the trials and more molds of this type arrive around 4 to 6 months later than the first one used for trials.

Once the entire process has been understood, we can interpret the voice of the customer and determine their requirements. In order to follow established this, a Customer value checklist has been developed as wells as a Voice of the customer translation matrix.

4.1.1.4. Simplification of the current state

In order to have a clear view of the complete tire process and the mold process, a simplification of both processes will be presented below.

First, it is important to understand the complete process including the mold process. The process of tire production is divided into several stages before the tires that are manufactured using them are sold: plan, design, development, industrialization and production. As we can see in the timeline below, the process starts with an idea. A planning, design, and a development process are undertaken where the product takes shape, the plan of industrialization and production are done, and the sale plan is developed. Next, industrialization starts until SOP (Start of Operations) takes place. It is in the industrialization stage where the mold flow takes place. The final stage is production of tires that finishes with SOS (Start of Sales). During the production stage, as it has been explained before, the mold is used in order to make tread pattern and sidewalls of the tire.

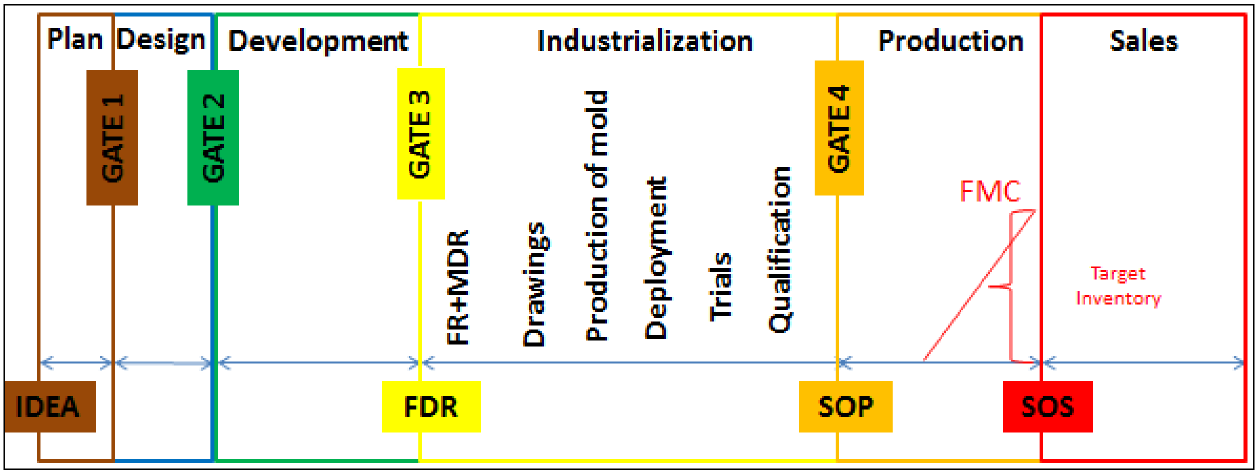

Figure 13: Complete tire production process divided in six stages. Plan, Design, Development, Industrialization, Production and Sales.

In the picture above, we can see the timeline followed in the production of wheels. The first stage is development. From the decision on sales made by the BU (Business Unit), a production plan is developed. An idea comes into place taking into consideration the market, but the technology available must be checked with the Technical Center in Europe (TCE). The plan, design and development process can take around 2 years. Next, in the industrialization stage, molds are developed following several steps such as drawings, mold production or trials. At the end of this stage, plants have the mold and have tested it, and then they can start the production of wheels. Finally, production must be finished at a certain point in order to be able to answer the inventory specified in the FMC (Forecast Monthly Coverage) and be able to start sales.

However, this process is more complex than a simple timeline. Many processes, different mold life cycles, are done in parallel, and there are problems in form of time constraints. As it is shown in the picture below, five processes take place where hundreds of molds interact. Due to time constraints, as well as constraints in the different activities, can produce delays in the time product is ready for sales. This means that the target inventory is not matched on time. This is reflected in the figure below.

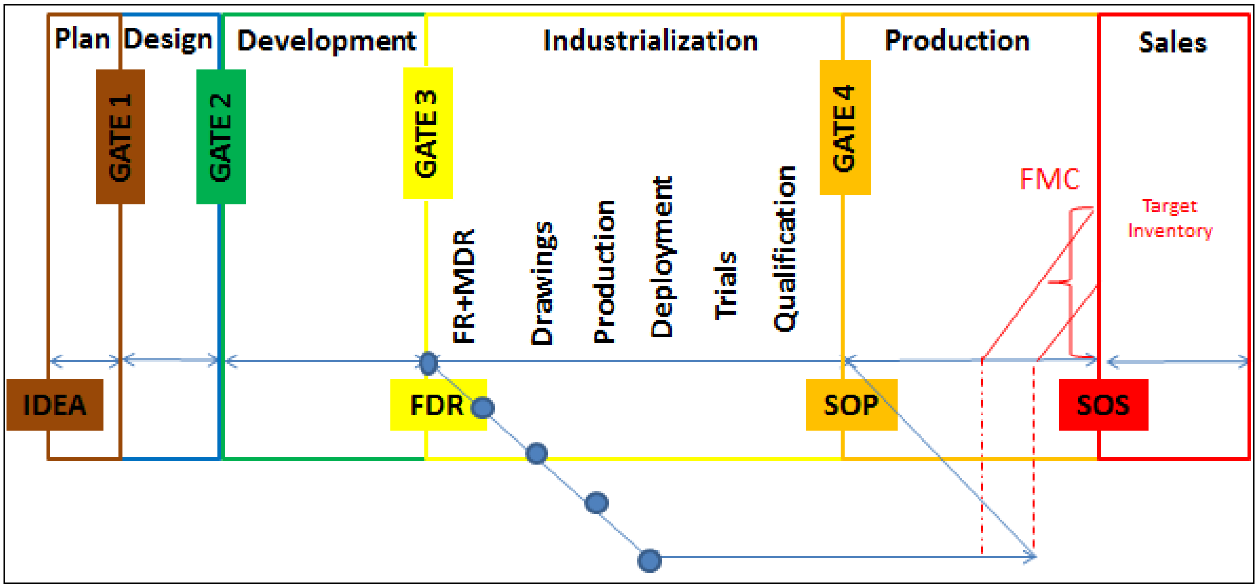

Figure 14: Complete tire production process with lines in parallel.

Therefore, the time require in each stage is critical in order to fulfill the demand on time. Time means money for the company. It is crucial that the process is done in a precise way, and in the time required. Even though, this TFM is focused on mold flow, other parts of the production of wheel process will be taken into account. Mold flow is not an isolated process, but part of a bigger process where mold flow interacts with other flows.

All stages are formed by many steps from the idea until the mass production of tires. All these steps require the intervention of many teams, sub-teams and departments that formed a big organization. The process becomes complex and the flow of information becomes very difficult. Information is decentralized, it is not where is needed and members of different teams need to spend a lot of time to obtain information that they should find easily. Also, there is a lack of visibility of the information and the source of information is not always clear. Thus, the information used is not always reliable. The process has a high complexity that doesn't add value, and a high workload for a low output. As a result of all these problems, products suffer of important delays. In fact, the average delay in products is of around 3 months. These delays mean for the company more than 1 million of Euros per year.

As it can be seen, this lack of organization means an important cost to the company. That is why a good view and understanding of the process is needed, in order to find improvements and fill the gaps of links and information.

Now that the complete process is presented, it can be understood that the mold process takes place mainly in the industrialization stage until mass production of tires. If we have a closer view of the mold flow, it is as presented below.

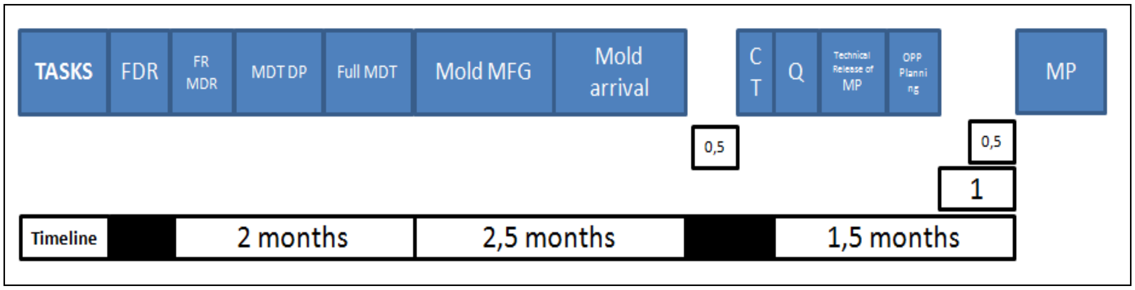

Figure 15: Mold process

The figure above shows the tasks of the mold flow, from FDR until mass production. Also, it reflects the timeline of these tasks. In this timeline, there are two black gaps. These two gaps will be explained later on this MT.

Again, in order to have a clear view of the mold process, the task will be briefly explained. First, FDR (Final Drawing Review) is the green light received in order to start the industrialization stag from BU to LSCM. Next, FR (Fund Request) and MDR (Mold Drawing Request) are sent by mold team to plants and TCE, engineers in Rome, respectively. FR is sent to plants as an order to purchase molds from suppliers. This is done because money to purchase molds is assigned to plants. MDR is simply a request to start the drawing process. Next, MDT DP (Mold Drawing Transmittal) is a document given by TCE to drawing suppliers in order to start the drawing process. MDT DP contains a coding assigned by TCE for the drawings that are going to be done. Fourth, Full MDT is a document containing all finished drawings with drawing codes assigned. Now that the drawings are done, they are sent to mold suppliers and the mold manufacturing takes place. Once manufacturing is finished, molds are sent to plants where mold is used for trials, CT and once all trials are finished, Qualification is obtained. Later on, a technical release of mass production is given as an order to start production of a certain product using its respective molds. Finally, Production team makes production planning of mass production for the following month.

4.1.2. Interpret the Voice of the Customer: VOB/VOC: (Gemba checklist; VOC Translation Matrix)

Now that we have understood the current state of the entire mold flow, we have to interpret the voice of the customer in order to detect problems in the flow, and obtain requirements from the customer to fix the existing issues.

4.1.2.1. Customer Value Checklist

In the customer value checklist, several questions are established in order to understand the process. In this case, MPO is the team working on this project. Therefore, questions will be answered from its point of view.

#	Question	Work area
1	What are our core processes?	**Mold management** **Mold group creation** **Mold Drawing management**
2	What is the primary "thing" we deliver to our customers?	**Mold management -->** Authorization to buy molds, budget, transactions, control of mold transportation, mold usage, mold status **Mold group creation -->** *Mold group* **Mold Drawing management -->** final MDT, ADE number
3	What are our key sub-processes?	**Mold management-->**FR,MDR,PO, manufacturing, transportation, arrival in plant, mold damage **Mold group creation-->** Check IPC, Check existing mold group, Check size and pattern, Creation of mold group **Mold Drawing management-->** CAV/STA/TRE, Construction drawing, MDT prep, final MDT, ADE number
4	Who are our key customers of these processes?	**Mold Management-->** *FR : Plant* *MDR : Plant/PTD* *Mold Status : STP, OPP,IPL* *PO : Mold supplier* *Manufacturing:STP,OPP,IPL* Transportation:STP,OPP,IPL Arrival in plant:STP,OPP,IPL *Mold damage:STP,OPP,IPL* ***Mold group creation-->****STP* **Mold Drawing management -->** *CAV / STA / TRE / Mold draw : PTD, PED, CoQA, mold supplier* *MDT-prep : DPO* *Final MDT : DPO, mold supplier, MPO,Plant*
5	What is important to customers of this process?	**Mold Management-->** FR issued on time, prioritation of molds, *visibility on demand, respecting committed timing,visibility of availabilities, state of the mold in the process.* **Mold group creation -->** Connection between a sector and all IPCs that can be produced with this sector. **Mold Drawing management-->** *visibility on demand, clear indication of priority, respecting committed timing, mix of activities, ADE number*
6	How do we measure what is important to our customers?	**Mold Management -->** S&OP meetings, Production startup on time and scheduled **Mold group creation -->** Production accuracy, midterm planning, **Mold Drawing management-->** Mold availability accuracy
7	Are we tracking what's important to our customers?	Yes, but not for mold group creation
8	If so, how well are our core processes performing against customer requirements?	KPIs are not in line between internal groups. Mold group there are not KPIs
9	Are our assumptions about what	NO, KPIs are not in line

	customers want correct?	
12	Which processes and measures have strategic significance?	**Mold management -->**Process that goes from FR and Mold in plant, CAPEX **Mold Group creation -->** Mold group existence to map molds **Mold Drawing -->** Drawing management
13	Which processes are most painful for the customer?	**Mold Management-->** late FR resulting in possibly idle/lost capacity, last minute changes, rework, no clear availabilities in plants, no able to see at which state the mold is. **Mold group creation -->** Missing mold groups, no clear connection with plants' mold group, heavy workload, difficult to map molds by STP, no clear connection between molds and IPCs **Mold Drawing -->** late FDR or FR resulting in possibly idle/lost capacity, last minute changes, rework
14	Which processes have expensive re-work?	**Mold Management-->**Mold inventory management, rework of molds **Mold Group creation -->**Workload **Mold drawing -->** *Rework*

Table 1: Customer Value Checklist

4.1.2.2. Voice of the customer translation matrix

In the following table, customer comments were gathered in order to understand them. Next, customer requirements were extracted from these comments. Third, drivers to answer these requirements as well as the Critical To Quality actions that have to be done have been identified. Finally, measures have been pointed. These measures will be used to evaluate the effectiveness and efficiency of the current state. For these measures to be obtained, several requirements have been identified.

Customer Comment	Gathering More Understanding	Customer Requirement	DRIVERS	CTQ	MEASURES	REQUIREMENTS
Increase accuracy of planning.	When a mold group is not properly assigned, STP has to create "dummy" mold groups which means an under or overestimation of availabilities	Database with mold groups, IPCs, availabilities and plants.	Mold group defined based on trustful information. Full information available for Tactical Run.	100% of mold groups defined at the beginning and aligned with all teams. 100% of mold groups based on experts' knowledge.	% of SGK mold groups created. %of OMP mold groups created. % of volume assigned to these molds. Number of mold groups missing when running tactical run.	Total number of mold groups. Total supply. Total volume linked to mold groups. Total volume linked to SGK mold groups.
Planning is done on guesses. Assumptions are done when creating a mold group	When a mold group is not properly assigned, STP has to create "dummy" mold groups which means an under or overestimation of availabilities	Trustful information of mold groups.	Mold group defined based on trustful information.	100% of mold groups defined by the beginning and aligned with all teams.	% of SGK mold groups created. %of OMP mold groups created. % of volume assigned to these molds. Number of mold groups missing when running tactical run.	Total number of mold groups. Total demand. Total volume linked to mold groups. Total volume linked to SGK mold groups
Choose one way to create mold groups. (Use a sector base mold database.)	Lack of alignment between mold groups created by plant and MPO	Trustful information of mold groups.	Mold group defined based on trustful information.	100% of mold groups defined by the beginning and aligned with all teams.	Alignment with plant mold groups	Mold groups created by the plant. Plant mold group creation procedure
For all new IPCs (Rhawk), STP does not know number of molds from MPO. STP has to create mold groups.	When a mold group is not properly assigned, STP has to create "dummy" mold groups which means an under or overestimation of availabilities	Increase accuracy of tactical run.	Full information available for Tactical Run. Mold group defined based on trustful information.	100% of mold groups defined by the beginning and aligned with all teams.	% of SGK mold groups created. %of OMP mold groups created. % of volume assigned to these molds. Number of mold groups missing when running tactical run.	Total number of mold groups. Total demand. Total volume linked to mold groups. Total volume linked to SGK mold groups

Table 2: Voice of the customer translation matrix

From Customer Value checklist, the interpretation is that mold group creation is the most painful process for MPO customers. Customers in this process are STP, IPL, and OPP. The input is mold group and the output is the production planning.

Next, VOC of the customer translation matrix reflects that an increase of planning accuracy is needed. In order to achieve this increase, tactical run done by STP must be accurately performed. Tactical run requires trustful information as well as a proper database connecting IPCs and molds. Customer requirements can be summarized in three requirements: Database with mold groups, IPCs, availabilities and plants, Trustful information of mold groups and Increase accuracy of tactical run.

4.1.3. Create the Project Charter:

Now that we have understood the current state, and we have interpreted the voice of the customer, we are able to build the project charter.

<table>
<tr><th>Project Title</th><th colspan="4">Mold group study to increase precision in mold availabilities.</th></tr>
<tr><td>Problem Statement</td><td colspan="4">STP is encountering problems to allocate molds in plants and to connect molds to their respective IPC to produce. This is the reason why MPO has to align with STP in order to increase vision of the business and have an end to end view.

Integration between MPO and STP is needed in order to increase vision of the business and have an end to end view. The results of LSCM are as good as the effectiveness of production. Therefore, it is key to create an accurate production planning.
In order to fulfill the production planning, molds have to be available on time in each plant. Tactical Run of molds is created by STP team in order to allocate efficiently molds at the places where they are necessary.</td></tr>
<tr><td>Project Objective</td><td colspan="4">The goal is to increase accuracy of production planning in order to satisfy customer demand and produce on time for the start of sales.</td></tr>
<tr><td>Project Metrics</td><td>Name</td><td>Equation</td><td>Baseline</td><td>Target</td></tr>
<tr><td>Primary Metric</td><td>Satisfy Demand</td><td>F=Y(X1,X2)

F1=Satisfy Demand
Y=Production accuracy
X1=Accurate mold availabilities
X2=Forecast accuracy</td><td></td><td></td></tr>
<tr><td>Benefit Description</td><td colspan="4">Increase accuracy of tactical planning of molds.
Alignment between teams participating in mold flow.
Increase understanding of tasks of teams participating in mold flow.
Reduce workload
Reduce risk in mold purchase and tire underproduction</td></tr>
</table>

Table 3: Project Charter

Creating the project charter allows to state the issue, the project objectives, metrics that have to be taken into account and to describe the benefits of this project. The project charter allows to settle all the factors to clearly complete the definition phase.

Problem statement:

Based on tactical planning of molds, production planning accuracy is not based on accurate data. When STP makes the tactical run, mold groups are used to see mold availabilities to produce a certain IPC. However, several mold groups are created based on guesses. This means that the volume related to IPCs that belong to these mold groups have risk of not being planned accurately.

In addition, not all the molds are mapped in plant when they arrive. This lack of mapping means that when OPP makes its production planning for next month, there are several molds that are not accurately mapped in OMP. As a result, there is a risk in the production of the volume of tires linked to these not mapped molds.

Goal: The goal is to increase accuracy of production planning in order to satisfy customer demand and produce on time for the start of sales.

How is this project aligned with business initiatives or goals?

Production planning is the first step to satisfy customers; therefore, it must be accurate and efficient to answer customers' demand

Why do this project now?

Integration between MPO and STP is needed in order to increase vision of the business and have an end to end view. The results of LSCM are as good as the effectiveness of production. Therefore, it is key to create an accurate production planning.

In order to fulfill the production planning, molds have to be available on time in each plant. Tactical Run of molds is created by STP team in order to allocate efficiently molds at the places where they are necessary. However, STP is encountering problems to allocate molds in plants and to connect molds to their respective IPC to produce. This is the reason why MPO has to align with STP in order to increase vision of the business and have an end to end view.

What is the impact of doing this project?

The impact of doing this project is to increase tactical run accuracy and as result, increase production planning accuracy. Understanding mold group issue and finding a way to improve the current situation STP will be able to have a proper link between IPC and molds. This we will improve production planning accuracy, as well as reducing workload, and we will have a better use of production capacity and mold purchase.

What are the expected required resources and the eventual financial benefit?

The required resource of this project is time and support from teams involved in mold flow. Time is needed to obtain knowledge from participants in the flow, to understand the current flow, identify difficulties, understand database, and understand inputs and outputs.

The financial benefit of this project is sales, reduction of back order, mold purchase, reduction of workload.

Does this project have sufficient support?

This project is well supported by all teams interacting in the mold flow as well as the support of plants.

Once we have understood the current state of the entire mold flow, we have interpreted the voice of the customer and we have built the project charter, we have stated the problem.

STP (Tactical team) is encountering problems to allocate molds in plants and to connect molds to their respective IPC to produce. STP is using a mold group in order to match IPCs to molds.

The issue is that these mold groups are not accurate and therefore they don't show precisely the availabilities of molds in each plant.

In order to further understand problems faced by tactical team, it is necessary to define the tactical procedure that is done to determine mold availabilities in plants.

4.1.4. Current State: Mold availabilities.

As it has been explained in the current state of entire mold flow, STP makes tactical planning for the next six months. Tactical planning is done using OMP database. Tactical planning is based on mold availabilities for IPCs to be produced in next 6 months. Mold availabilities are checked using mold group. When using mold group, there are two possible cases. Mold groups created by the plant on BOSS database that feeds OMP. However, the other case is that plants have not created the mold group in BOSS and therefore it does not exist in OMP. In this case, this not created mold groups are called "Dummy" mold groups.

Both plant created and Dummy mold groups are used in the tactical planning. However, the issue is that dummy mold groups are created based on assumptions. MPO provides a database that links IPCs and mold groups, but it is based on assumptions as well. The result is that the tactical planning is not entirely accurate. This lack of accuracy is an important issue since, as it has been explained before, a unique mold costs 7000 to 60000 euro.

In addition, this problem is also detected when making the production planning. OPP makes production planning for the next month. In order to plan production for IPCs, SPEC and molds availabilities are needed in OMP. OMP is used by both Tactical and Production team. OMP for production planning is using mold availabilities in plants. This information is fed by BOSS. Therefore, if a mold group or a SPEC is missing, it will be reflected on OMP as dummy. Three cases are seen in OMP for an IPC to produce in the next month: Mold group defined+ SPEC defined, mold group defined + Dummy SPEC, and Dummy mold group + Dummy SPEC. The last two cases don't reflect the real availabilities in the plant. However, the three cases are used to plan production in next month.

The problem of using Dummy mold groups or Dummy Spec is that the availabilities of molds are not clearly defined, and this can lead to an over or under estimation of molds in plants. This problem in estimation can lead to not answering the demand on time.

Now, that the issue has been explained two key questions are raised. What is a mold group? And, what is a SPEC? In order to answer these questions, all teams using mold group and SPEC were questioned.

4.1.4.1. *What is mold group?*

The teams using mold group are MPO, Tactical team and plants. Plants considered in this study are Burgos in Spain, Bethune in France, Poznan in Poland and Bari in Italy. These plants have been study since they are the ones that the tactical team is considering in its tactical planning.

As we can see in the table below, MPO maintains a mold database. This mold database contains four-character code mold groups that connect all IPCs that share the same size and pattern, in other words, IPCs that share the same sector. The purpose of this database is only to provide Tactical team some way to connect IPCs when their mold group is missing.

Second, tactical team has two types of mold groups, plant created mold groups and dummy mold groups. Plant created mold groups are of two types. First, ADE number mold groups and a four-character code mold groups. Dummy mold groups are those created by Tactical team based on MPO database following size and pattern, or mold groups created without any information, entirely assumptions.

Third, plant mold group is a code used by the plant in order to link all molds that have the same ADE number. In order words, it is a way to track molds that are the same. All four plants use ADE number of mold construction drawing. However, Poznan reflects mold group as a four-character code. This four-character code is a production code that is created only in Poznan. Even if Poznan uses a four character to code to reflect mold group in BOSS that later feeds OMP, their mold group are based on ADE number of mold construction drawing. However, Poznan is using the four-character code is used because they are lacking all ADE numbers.

	Mold group	Purpose
MPO	4 digit number (Sequential without any meaning)	Link IPCs that share the same size and pattern
Tactical	Plant created: • ADE number/Plant • Four character code/Plant • Tatabanya code Dummy: • SGK/Plant • MTPnumber/plant • IPC_MGDummy • MoldDummy/plant • OMP+IPCnumber/plant	Match IPCs that share the same size, pattern and plant. (Dummy molds)
Bethune	ADE number (MFR1)	• It is used as a reference of the mold. It links sector, sidewall and container. • Only information we are using for mold identification in specification. (MFR1)
Burgos	ADE number (MES2)	• Utilizamos el plano ADE (código molde - plano constructivo de molde) para identificar los moldes asignado a los distintos códigos BOSS. Se utiliza tanto en especificaciones, como en tooling y en especificaciones de grabado. (MES2)
Bari	ADE number (MIT1)	• We use ADE to exactly know type of mold to mount. In fact ADE is reported in plant spec to allow mold shop guys to keep the right mold. Size and pattern are not enough: there could be 2 molds with same size and pattern, but different ADE. (MIT1)
Poznan	Four character code (MPL1)	• Mold group in the plant helps local ticket validations and also scheduling in case of shared sector sets. (MPL1)

Table 4: Mold group definition and purpose in mold team, tactical team and plants.

Now that all mold groups have been defined, we can conclude that a mold group is the connection between all IPCs that can be done by a mold. However, a mold is formed by sidewalls and sectors. Therefore, we have to establish all the possible connections between sidewalls and sectors. The following table represents these connections.

IPC	Sidewall Plate	Sector
A	1	I
B	2	II
C	3	III
D	4	IV
E	5	V
F	6	VI

Table 5: Connection between IPCs, sectors and sidewall plates with mold groups

As it can be seen represented by four different color lines, there are four types of mold groups. First, blue, a sidewall and a sector that can produce only one IPC. This is the simplest case. Second, red, one sector that can be used to produced several IPCs when changing sidewall plate. Third, green, one sector and one sidewall plate that can be used to produce several IPCs. Fourth, two sectors and two sidewall plates to produce the same IPC. This case is very rare, and it is only in case of Tatabanya, that it is not taken into account.

Therefore, at this point, we can conclude several points. A mold group is used to identify molds that are the same in a plant, a mold is the combination of sidewall and sector, a mold group is used to link IPCs that can be produced with the same sector and sidewall plate, or same sector and different sidewall plate. Finally, plants are using ADE number of mold construction drawing as this mold group.

So, now it is important to understand what is a ADE number. As it has been explained in DPO team explanation in the current state of entire mold flow, there are four ADE numbers. ADE number of sector, ADE number of sidewall, ADE number of cavity and ADE number of mold construction drawing. They are done by drawing suppliers and they are used by mold suppliers to produce the mold.

ADE numbers are ready at MDT for Drawing Preparation, before drawings are done, and they are provided to plant at Full MDT, when drawing are done, and they also come with the mold.

ADE of mold construction number reflects the combination of the other three. If there is a change in one of them, it will be reflected in mold construction drawing. Therefore, ADE of mold construction drawing is the combination of sidewalls and sectors. If the sidewall or the sector changes, the mold construction drawing changes. This is the reason why plants use this number; it combines both parts of the mold.

Also, ADE numbers are common in all plants. In other words, it does not matter in which plant the mold is; it will have the same ADE number. However, some plants, like Poznan, are reflecting a mold group that is not based on this ADE number. Therefore, it is not possible to identify common molds available in plants. This creates an issue when making transfers because more molds than needed can be purchased instead of transferring between plants.

Poznan plant was contacted in order to understand why they are not using ADE number as mold group. The reason is that they are missing data of ADE numbers and they are cannot fill their database with ADE numbers.

Now that we understand what a mold group is, it is time to answer what spec is.

4.1.4.2. What is SPEC?

SPEC is the acronym of Specification. SPEC is the composition and the procedure that has to be followed in order to make the tire. In other words, it is the recipe of the tire that goings inside the mold to be "cook". There is a difference between final SPEC and Guide SPEC. Guide SPEC is provided by TCE when mold arrives into plant. However, several Guide SPECs are provided by TCE since it is not defined which one should be used. From these guide SPECs, Final SPEC is obtained after several trials from the Guide SPEC. Trials are done in the plant. Guide SPEC sheet contains all ADE numbers as well.

Once all trials are done and a SPEC is obtained, TCE provide a Final SPEC number to the plant two weeks before Mass Production. The difference in coding between a Guide SPEC and a Final SPEC is reflected in the table below.

Guide Spec number	Final Spec number
A0001-E	Rejected
A0002-E	Rejected
A0003-E	A0003

Table 6: Comparison between Guide SPEC number and Final SPEC number

As it can be seen, when a Guide Spec is obtained, the Final SPEC number is the same as its previous Guide SPEC but with the removal of “-E”.

Once, the plant has the Final SPEC number, they are able to make the math between IPC and mold. Final SPEC is given as a sheet where all specifications in the procedure are given, as well as the Final SPEC number, and the ADE numbers.

Also, Final SPEC number is given to LSCM team that is able to match it with a given IPC. This IPC is given to the plant.

Therefore, plant connects IPC and mold (ADE number) through Final SPEC. Once they have this connection, they can make the link in BOSS database, and it will be reflected in OMP. The process is shown in the figure below.

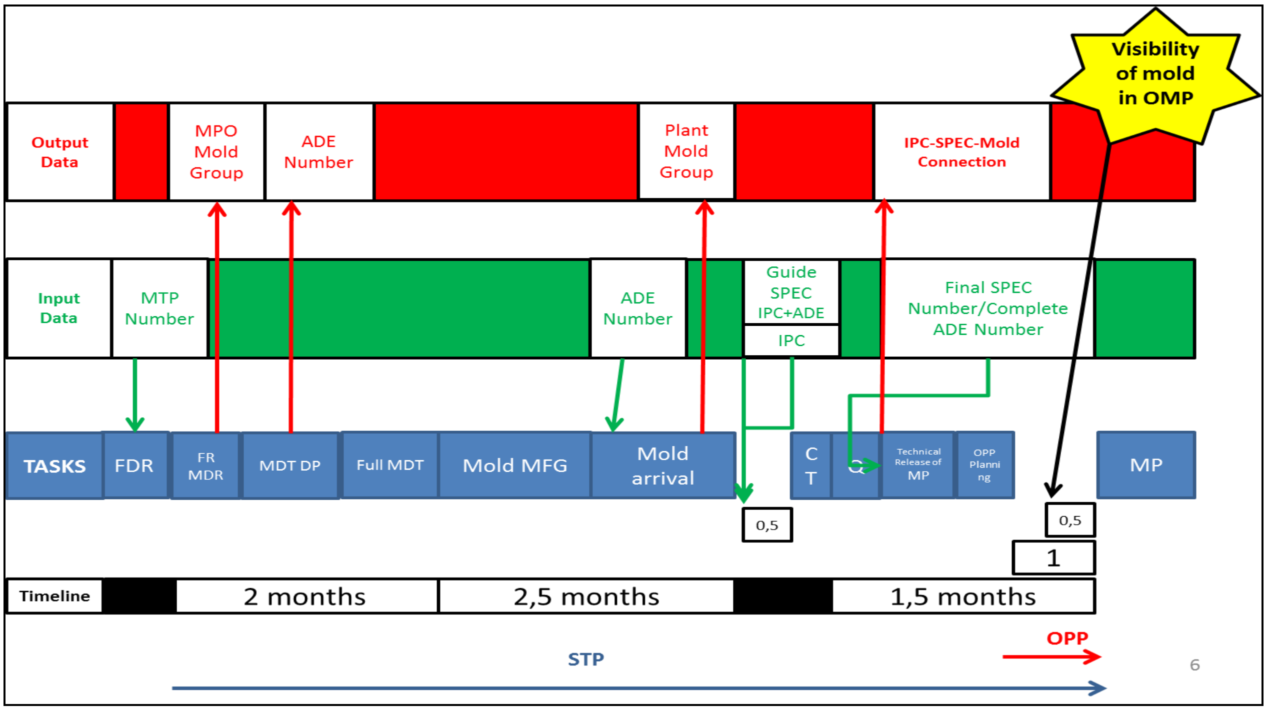

Figure 16: Current state of mold flow with Data related

The figure shows the tasks that are done from the green light for FR (Fund Request) until Mass production. The blue arrow represents the six-month view of tactical team, and the red arrow the one-month view of production team.

Timeline contains two black gaps. These two black gaps correspond to new molds. As it has been explained, there is a difference between new and repeat molds. New molds are those that are created first at the launch of a new product. Repeat molds are done months later in order to be ready to start mass production once the new mold has passed all trials. The process of the new mold is different since drawings have to be done for it, while repeat molds don't have to follow this process since they have the same drawings as the new mold. Also, the new mold has to pass all the trials while repeat molds only have to pass several trials. The first black gap on the left is in black because the time for the FDR to be done varies between months to years depending on when green light is given to launch a project. The second one is because the time for trials can vary between six months to two years.

Next we can see the input and the output data of each process. MTP number is given at FDR. MTP number is the same as IPC number but in development stage. At the FR, MPO mold group is created and at the MDT DP ADE numbers are created. When the new mold arrives into plant, ADE number arrives with it, plant creates mold group in BOSS, but it is not reflected to OMP since it is not linked to any IPC. Two weeks before, Guide SPEC is given by TCE to plant with an IPC. Once trials are done, Final SPEC number is given and plants are able to connect IPC to mold through Final SPEC number. At the end visibility in OMP of IPC-Mold connection is two weeks before Mass Production.

Making the connection at this time shows why both tactical and production team work with dummy molds and dummy SPECs when making their respective planning. The issue of using dummy molds and dummy specs in both tactical and production planning has been explained before.

Now that the current state for mold availabilities has been obtained, we can state conclusions in the Define Stage.

4.1.5. Conclusions of Define Stage:

1. Accuracy problems in tactical run for molds. Problem of mapping molds by tactical team. Tactical run implies making the forecast of production for the next six months. Therefore, we need to know the number of molds ordered for a particular size.

2. Overestimation of availabilities when making production planning.

3. Plants use mold group (ADE number) to identify molds.

4. Mold group is not standardized among plants at first sight. But they are all base on ADE mold construction number. (Except Tatabanya) This creates issues when using mold group by tactical team and to identify availabilities in plants.

5. Mold group used by BSEU is different than plants and it should be in line with them.

6. ADE mold construction drawing takes into account sectors and sidewall plates.

7. Poznan reflects production code for mold group although it is based on mold group. Same mold ADE number we can have more than one production code assigned. This is because for one ADE number we can have several stamping specifications and each specification refers to one production code.

8. Modifications in ADE number are not always straight forward. It is necessary to contact the engineer.

9. Final Spec number is key to link IPCs and molds and thus have visibility in OMP. Boss is not working with IPCs.

As we can see, accuracy problems in tactical planning and production planning are linked to mold group and the late connection that is done between IPC and mold due to Final SPEC number.

Therefore, the uncertainty of the planning relies on the dummy molds.

Therefore, the next step in the DMAIC methodology, Measure, the accuracy of the planning will be measured in order to understand its efficiency. In addition, in this phase, it is critical to identify the sources of data that are needed to be analyzed in the third phase of DMAIC methodology, Analyze.

4.2. MEASURE

At the Measure phase, the impact of the problem stated in the Define phase will be measured. It is important to quantify the issue in order to see the relevance of the problem. The measure phase will provide us with the critical inputs that cause the problem to later analyze in the Analyze phase. Also, it is necessary to measure the impact of the problem in order to see if it is worth it to apply improvements later on.

However, it is important to first create a data collection plan. A data collection plan helps to have a clear view of what it is necessary to measure, where to obtain the data and thus, to waste time researching on data that is not useful. Also, identifying measures is helpful for future control of the process.

The following data collection plan was developed.

Measure	Data Type	Operational Definition	Stratification Factors	Sampling Notes
Additionnal orders done		Overpurchase molds		Not straight forward
Not created mold groups	OMP data	Dummy mold groups	1-4 months/5-6 months	Done
Molds that are needed but have to be ordered (Therefore, they have not been mapped)	OMP data	Molds to be ordered	1-4 months/5-6 months	Not visible in OMP
Molds that have been mapped wrongly	OMP data	Wrongly mapped molds	1-4 months/5-6 months	Not visible in OMP
Molds that belong to a wrong forecast and have not been mapped	OMP data	Wrong forecast molds	1-4 months/5-6 months	Not visible in OMP
Molds that have arrived into plant and have not been mapped	OMP data	Molds with past MP date	1-4 months	Done
Molds that have not arrived into plant and have not been mapped	OMP data	Molds with future MP date	1-4 months	Done

Table 7: Data collection plan

The desire measure to obtain was the number of molds that were purchased but were not necessary. However, this measure is not able to obtain, since it is not reflected in any data. Therefore, it was decided to measure the number of dummy molds used in tactical planning for the next six months. Next, it was decided to measure wrongly mapped molds, molds that should have been assigned another mold group. However, this measurement was not able to be obtained since the data does not reflect molds that have been mapped wrongly. Also, it was required molds with a wrong forecast. In other words, molds that were bought based on forecast but at the end they were not needed. This data is not reflected on logistics database. Finally, it was decided to measure molds that are dummies but divide them into molds with a mass production date in the past and mass production date in the future.

In order to measure the number of dummy molds used in the tactical planning of the next six months, OMP database was used and the volume of tires assigned to these dummy molds was obtained. At the end the percentage of volume assigned to dummy molds for each month was obtained.

Month	% of supply linked to Dummy molds
July	4,72
August	4,66
September	4,43
October	5,04
November	13,91
December	15,35

Table 8: Percentage of supply linked to dummy molds per month

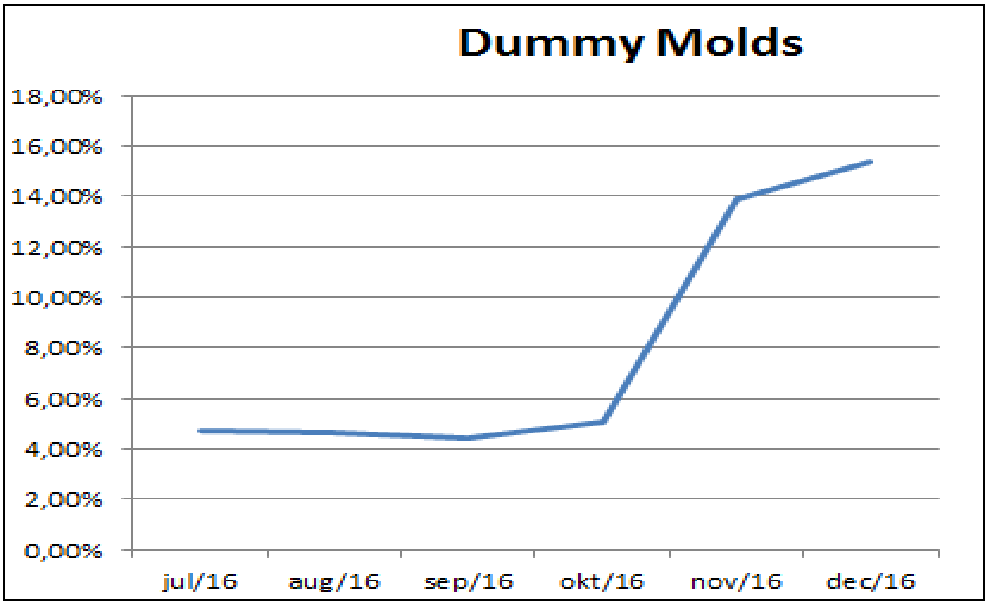

Figure 17: Percentage of supply linked to dummy molds per month

The chart above shows the percentage in each month of supply linked to dummy molds. As it can be seen, the percentage for the next four months is around 4 to 5 percentage. For November and December, the percentage increases around 13 to 15 percentage.

The reason of this increase is due to the fact that in the next four months new products are being used, therefore new molds are created, but the link is not done yet. These molds have not passed the trials, therefore the connection between IPC and mold has not been done since Final SPEC number has not been given yet to the plant.

In conclusion, this measurement provides two views of the impact. First, 15% of the supply for the next six month belongs to dummy molds that have not been well defined by the plant. This lack of definition means that tactical planning can under or overestimate availabilities in plants since molds are not defined. It can be discovered that a new mold belonged to an existing mold group instead of a new one created by tactical team. Also, it can happen that it was assumed that this new mold was belonging to an existing mold group. Then, when repeat molds arrive into plant based on availabilities of the plant; it can happen that since they belonged to an already existing mold group, there is shortage of production due to the fact that not enough molds were sent.

The second impact is reflected on the percentage of supply related to dummies for the next four months. These are molds that are repeated molds and will arrive to plant soon but the connection for the new mold has not been done yet. For this second part, there is not enough time to send new molds on time, especially for the next month. This affects as we know to the production planning. Production team works with dummy molds and production plan can be done based on availabilities that are not real.

In order to further investigate, these four months, and to see the real impact in the short term, a separation of the next month was done. In this case, the next month was considered October. Next month was separated between molds that have a mass production date in the past and molds that have a mass production date in the future. A mold with a mass production date in the past means that the mold is already producing tires and a mass production in the future means that it has not started yet to produce tires. The results obtained were the following.

	October 2016
MP Date Past	1.78%
MP Date in the Future	0.94%

Table 9: Percentage of supply of October linked to dummy molds with MP date in past and future

As it can be seen in the table above, 1.78% of supply is linked to dummy molds with a mass production date in the past and 0.94% of supply to dummy molds with a mass production date in the future. This percentage doesn't seem very significant. Therefore, this percentage was transformed into number of molds.

	October 2016	Number of molds
MP Date Past	1.78%	20
MP Date in the Future	0.94%	10

Table 10: Percentage of supply and number of molds of October linked to dummy molds with MP date in past and future

The number of molds that are linked to dummy molds are 20 and 10 respectively for mass production date in the past and in the future. These results mean that in the next month, the availabilities of 30 molds are based on assumptions. Therefore, 30 molds could have been over or under purchased. As it has been explained, the cost of a mold is around 7000 to 60000 euro. Therefore, the price is significant for only one month.

In order to avoid these risks, many countermeasures are taken. For example, production team contacts the plant before making production planning or MPO team checks mold by mold with engineers in order to see how to group molds. However, two types of risks exist.

For those molds with a mass production date in the past, it is assumed that these molds are already mapped by the plant. Therefore, they are not mapped in the system. Since they are not mapped, it is assumed that 0 or 2 molds are present in the plant. This assumption creates the risk of buying more molds than needed for a certain plant or to overestimate the number of molds that are in the plant.

The second risk is related to both molds with mass production date in the past and future. This risk is reflected in production planning. Production team will make the initial production plan which creates production ticket based on molds that are dummies. But as we have seen dummy molds contain assumptions. Next, a commitment with customer is done based on production ticket. However, there is a risk of making wrong assumptions and therefore having a wrong plan due to different capacity than assumed. If the plan is wrong, final production plan will differ from initial production plan. As a result, mass production date can be delayed and there is a risk of not answering the demand.

A real example is the following:

There are three IPCs that belong to a mold group: 9652, 9653 and 9658. For this mold group we have six molds. Then, for another IPC, 9659, we have a dummy mold group which has 6 molds as well. Production team makes production plan based on these availabilities. Plant receives the production plan, but plant is able to check all ADE numbers in plant, which defines a mold group, and it is able to see that in reality 9659 actually belong to the same mold group as the previous three IPCs. In addition, there are only 6 molds in total and not 12 for each. In other words, there has been and overestimation of mold availabilities. The problem in this case is that mold group has not been identified due to lack of link done through Final Spec number.

4.2.1. Conclusions in the measure phase:

The Measure phase has shown us that dummy molds are creating a significant risk in both tactical and production planning. Availabilities of molds in plants can be overestimated or underestimated. These estimations can lead to a waste a significant expenditure in molds that are not needed in reality. Also, it can lead to have a shortage of production and not answer the demand of customers.

However, these measurements do not reflect another issue that was explained in the Define phase. Plants use of mold group is not aligned. This means that even if plant has created a mold group for a mold and the entire process is correct, we can miss connection between molds in different plants. As it has been explained, Poznan uses a four character code while the rest of plants use ADE number to reflect mold group in OMP. Even if molds in these two types of plants are the same, it will not be reflected on OMP. This means that instead of being able to transfer molds and be able to avoid buying new ones, more molds will be bought.

To conclude, measurement raises the questions that will be answer in the analysis phase.

- Why are plants not creating mold groups for molds that are already in plant?
- How can all molds be properly mapped?
- Why is OMP not able to map molds earlier in the process?
- How can visibility of molds be increased?
- How can the risk of overestimating or underestimating availabilities of molds be decreased when doing tactical and production planning?

4.3. ANALYZE

In the **analyze** phase, critical inputs will be identified. These inputs are those that have a strong relationship with the outputs. These critical inputs are the drivers of performance. Next, root causes are determined.

In order to determine root causes, first process and data must be analyzed.

In order to determine root causes, we have analyzed both process and data. The next step that was followed was to use brainstorming in order to obtain root causes. A fishbone diagram was developed in order to follow a structure brainstorming until root causes. The obtained fishbone diagram is presented below.

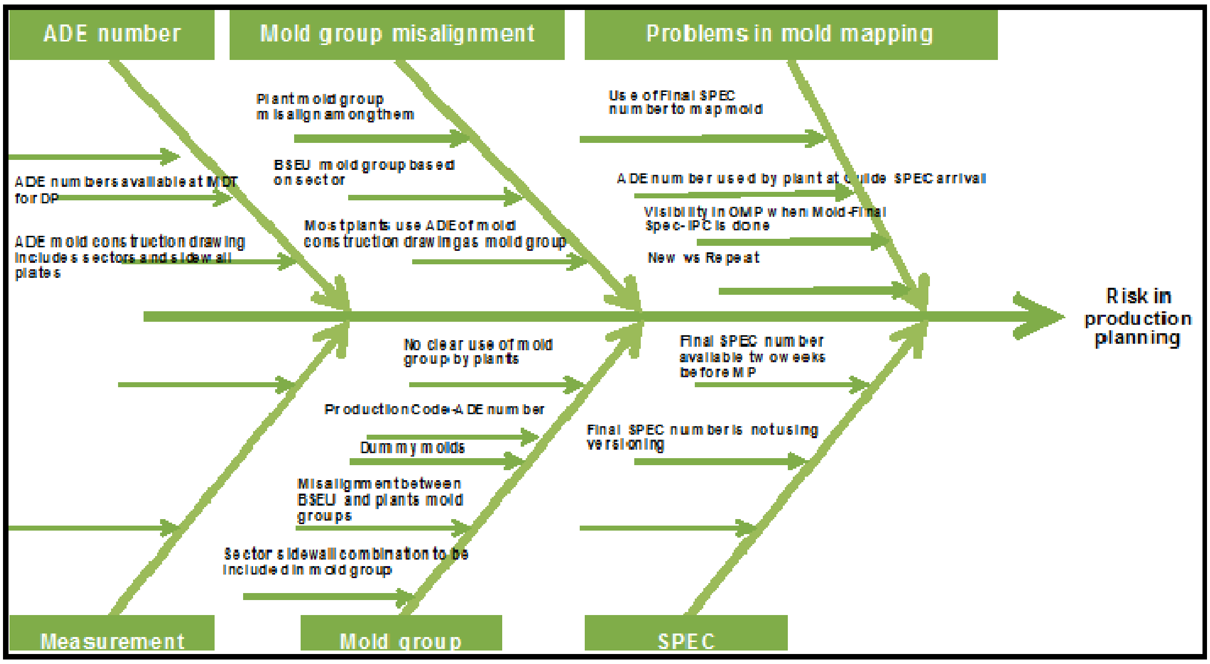

Figure 18: Fishbone diagram to analyze root causes that lead to risks in production planning

As it can be seen from the fishbone diagram, there are four critical inputs that lead to risk in production planning. These are, mold group misalignment, problems in mold mapping, mold group, and SPEC.

First, problems in mold mapping are due to the use of Final SPEC number to map molds, use of ADE numbers to map molds, visibility of mold in OMP when making the link of Mold-Final SPEC-IPC, and the difference in timing between new and repeat molds.

Second, SPEC critical input is related to the fact that Final SPEC number is available two weeks before mass production and Final SPEC number is not using versioning of Guide SPEC number.

Third, mold group misalignment is due to the fact that plants' mold groups are misaligned among them, LSCM mold group is based on sector, and plants' mold group use ADE number of mold construction drawing to create their mold groups.

In the case of Poznan, the plant is using production code instead of using ADE number of mold construction drawing. The reason for this is that they are missing data of ADE numbers. ADE numbers are provided by TCE at Full MDT. Therefore, data from ADE numbers should be provided by TCE.

Fourth, mold group importance comes from the fact that it has to include sector and sidewall plates, there is misalignment between plants and LSCM, Poznan uses production code to reflect mold group in OMP, and this is all reflected through dummies.

Fifth, ADE number of mold construction drawing includes sectors and sidewall plates which is exactly what is necessary to define a mold group. Also, ADE numbers are available for all teams at MDT for drawing preparation as it was explained in the definition phase.

Now, that we have reached root causes, we can answer to the questions raised in measure phase. Mold groups are not created by the plant because they are lacking Final SPEC number and therefore they are not making the proper connection between IPC and mold. This is also the answer why molds are not mapped in OMP earlier.

Mold can be properly mapped if several factors are done. First, plants should be aligned when creating mold group. This will allow an accurate mapping of molds between them. Also, tactical team will be able to do a more accurate planning.

Also, even if plants have not created mold groups, tactical team will be able to create dummy molds in a precise way if they would use ADE number of mold construction drawing. This will align LSCM with plants from the beginning.

Finally, in order to increase visibility in OMP of molds and to increase accuracy, the next step would be to create the link between IPC-Final SPEC-Molds earlier in the process.

4.3.1. Conclusions in Analysis phase:

In this phase, several root causes have been detected using a fishbone diagram. A misalignment among plants using mold groups has been detected as a root cause. Also, the use of Final SPEC number, ADE number and IPC to create visibility in OMP leads to problems in planning. ADE number of mold construction drawing includes all drawings as can be used as a mold group. Finally, Final SPEC number, ADE numbers and IPC should be given earlier in the process.

5. To be

5.1. IMPROVEMENT

In the Analysis phase, three root causes have been pointed out. Mold group misalignment between plants, mold group misalignment between plants and LSCM and late visibility in OMP. Therefore, improvements are suggested based on the analysis.

5.1.1. Mold group alignment between plants

The first step in the improvement stage is to align mold group among all plants. In other words, to use a mold group in all plants that use the same coding and it is based on the same information. A mold group in a plant, as it was understood from the interviews in the plants, should link all molds that have the same sector and sidewall plates.

However, at the definition stage, it was presented that plants are defining mold groups in different ways. This lack of standardization in mold group among plants has several effects as explained. First, tactical team is having problems to understand and thus map molds. Second, there is no connection between plant's mold groups, which can lead to purchasing unnecessary molds.

Therefore, in the analysis phase, it was found as a root cause that has to be solved the lack of standardization among plants. In order to solve these problems of standardization, the improvement that is proposed is to make plants use ADE number of mold construction drawing as mold group. ADE number of mold construction is the selected ADE since it includes both sectors and sidewall plates. Therefore, it will reflect the entire mold.

	Mold group
Bethune	ADE number (MFR1)
Burgos	ADE number (MES2)
Bari	ADE number (MIT1)
Poznan	ADE number (MPL1)

Table 11: Mold group alignment between plants using ADE number as mold group

The table above presents mold groups used by plants team after improvement is introduced. It shows how all plant will be aligned by using common coding. This common coding will increase understanding of mold group by tactical team, visibility of molds in plants, and it will connect molds between plants.

As it was explained in the definition phase, it is only Poznan which is not using ADE number of mold construction drawing as mold group. Instead, they are using production code. The current state is that they are not using ADE numbers because they are missing some ADE numbers.

The analysis done concluded that in order for Poznan to use ADE numbers, it is TCE who should provide these ADE numbers. Once all ADE numbers are provided to Poznan, all plants will be able to have a common coding for mold group.

However, in order to introduce this improvement, it is needed to check the feasibility of the improvement. To check this feasibility, a stakeholder analysis of all teams that would be involved in this improvement is done. The stakeholder analysis will provide a view of the support of teams and the impact they would suffer.

Stakeholder	View of Improvement Effort			Impact Level		
	Supportive	Neutral	Resistant	Direct	Influence	Affected
Bethune						
Bari						
Burgos						
Poznan						
TCE						

Table 12: Stakeholder analysis of mold group alignment between plants

As we can see from the stakeholder analysis, all plants are supportive in using ADE mold construction number as mold group. In fact, except for Poznan, all of them were already using them. In the case of Poznan, the plant was already implementing ADE numbers but it lacked ADE number data. TCE was contacted to check if they could provide this data. That is the reason why they are considered as an Influence stakeholder. TCE is supportive on this issue and it has no problem to provide this data to Poznan.

Now that we have built the stakeholder analysis for this improvement, we can build an impact effort matrix. This type of matrix reflects the impact that the improvement has, and the effort it is required.

	Hard	Easy
High Impact		
Low Impact		TCE will provide data to Poznan The majority of plants are already using ADE number Same visibility of molds in OMP. Same risk of buying unnecessary molds

Table 13: Impact-Effort matrix of mold group alignment between plants

As it can be seen, it is an improvement easy to implement since most plants are already using ADE mold construction number and mold group and the stakeholder analysis all teams are supportive. At the other hand, the impact of this project is low since it the visibility of molds in OMP is the same and it doesn't decrease the use of dummy molds, and thus it does not decrease the risk of buying unnecessary molds. However, although this step has a low impact, it is necessary to introduce further improvements as it will be explained later.

5.1.2. Use of ADE number of mold construction drawing by tactical team when creating dummy mold groups.

The second step in the improvement phase is to align LSCM use of mold groups with plants. In the Define phase, it was explained that tactical team had problems understanding mold groups in plants. Also, there are mold groups missing in the system that lead to the use of dummy mold groups to make the planning. As it has been explained in the Measure phase, the use of dummies means a risk to Bridgestone in terms of overestimation or underestimation of mold availabilities that can lead to purchase molds that are not necessary or to be unable to answer to demand.

The problem of dummies is that they are not in line with reality. They should be defined using trustful information. As it has been explained and as plants do, ADE number of mold construction drawing is the trustful information to define a mold group. Therefore, tactical team should use ADE numbers as mold groups.

In fact, tactical team will be using dummy mold groups, but using ADE number of mold construction drawing would mean that these ADE numbers are based on trustful information. Therefore, dummy mold groups will be the same as plant created mold groups. In conclusion, it can be stated that tactical team is eliminating the risk of working with dummy mold groups.

However, in order to use avoid the use of dummy mold groups on time for the tactical planning; ADE numbers must be available for tactical team. As it has been pointed out in the fishbone diagram, all ADE numbers are available at MDT for drawing preparation for DPO team. MDT for drawing preparation is 6 months before mass production. Therefore, DPO team can provide drawing numbers linked to IPCs to tactical team in order to make their tactical planning.

In addition, MPO's mold group will be erased, since it is no longer needed to make the match between IPCs. As a result, workload will decrease for MPO team as well as tactical team.

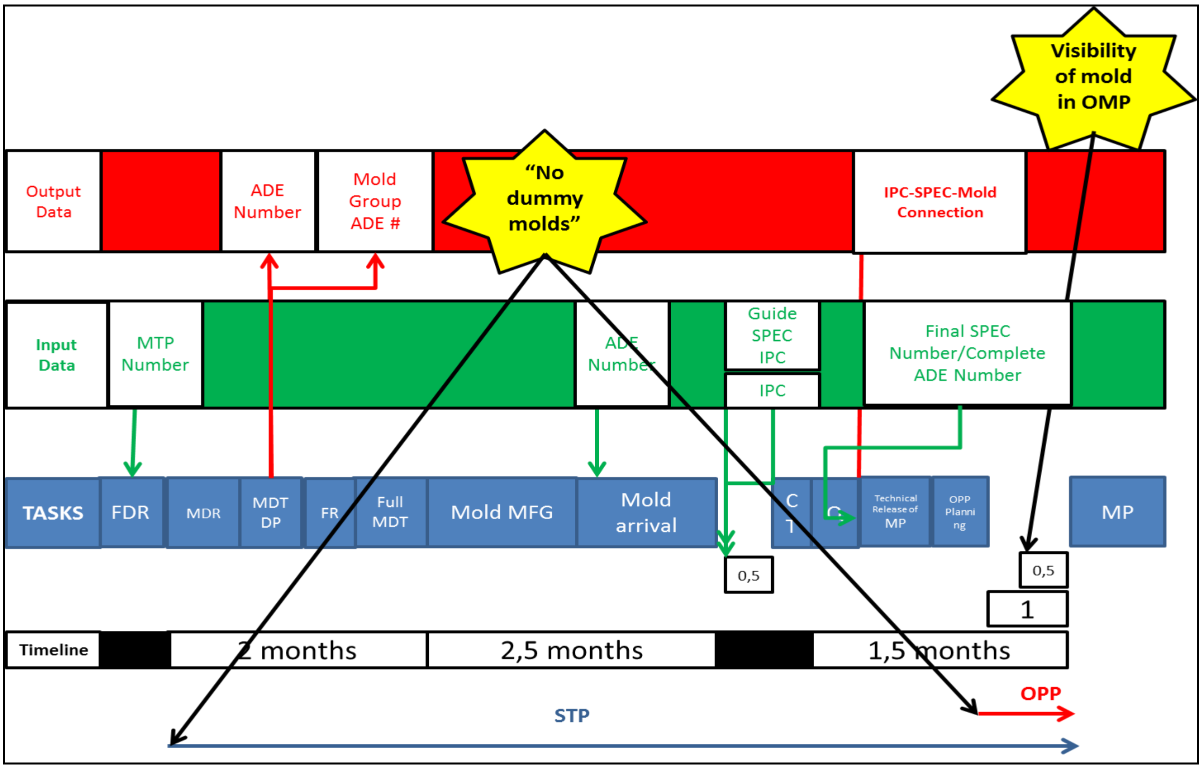

Figure 19: Mold flow when using ADE number as mold group

The figure above is a simplification of the process as it should be once the improvement is introduced. The process is exactly the same as the current one except for several differences. First, MPO mold group is not created. At MDT of DP ADE numbers are generated and sent to Tactical team to create mold groups. Once mold arrives into plant and all trials are passed which means the reception of Final SPEC, plant will make the connection of IPC and mold through Final SPEC number as currently. Visibility in OMP will remain the same, however, tactical and production team will work with dummy molds but that are based on trustful information.

Now, the stakeholder analysis is done to see the feasibility of the project.

Stakeholder	View of Improvement Effort			Impact Level		
	Supportive	Neutral	Resistant	Direct	Influence	Affected
Tactical						
Production						
DPO						

Table 14: Stakeholder analysis of use of ADE number by tactical team

As we can see in the stakeholder analysis, the teams that interact in the second improvement ADE numbers to tactical team, which means only, resending the same e-mail they receive from TCE. Then, tactical team will use ADE numbers to create mold groups. Finally, production team will be only affected since they have to work with mold groups but they are not creating them. Tactical team is supportive since their creation of mold groups will be better and thus its planning will be more accurate. Production team is neutral since they don't have to create mold groups but their planning will be improved. Finally, drawing team is supportive. Their additional task will be only to resend ADE numbers to tactical which means a low workload for them and no change in tasks.

	Hard	Easy
High Impact		ADE numbers provided by DPO at MDT DP Tactical team creating mold groups using ADE numbers. Decrease the risk of using untruthful mold groups It doesn't change visibility of mold in OMP
Low Impact		

Table 15: Impact-Effort matrix of using ADE number as mold group by tactical team

The impact effort matrix of the figure above shows that the impact of this improvement is high since it reduces the risk of using dummy mold groups although it doesn't change the visibility of mold in OMP. Also, the introduction of this improvement is easy since it only requires the sending of ADE number from DPO team to tactical team which means that DPO team only has to send an e-mail.

5.1.3. Use of versioning of Guide SPEC number in order to make connection between molds and IPCs earlier in the process.

The third step in improvement phase is related to increase the visibility of molds in OMP. The fact that affects the visibility of OMP is the connection between IPC and mold group. This connection is made through Final SPEC number two weeks before mass production as it has been shown in Define phase. Since IPC and mold group, ADE number, are given before, the bottleneck of this connection is the Final SPEC number. Therefore, the way to make connection earlier and thus the visibility in OMP is to provide the Final SPEC number earlier.

Currently, Guide SPEC is given two weeks before CT, and Final SPEC number is provided after qualification. In the define phase, it was presented how Guide SPEC and Final SPEC are linked. This link can be seen in table 6.

As we can see, the problem related to the way Guide SPEC and Final SPEC are linked is that with this coding they are not able to be properly linked and thus to work with it efficiently. Therefore, the solution to Guide SPEC and Final SPEC coding is the use of versioning.

Versioning is simply a way to code that can be done in several ways. One way, which is already used by Bridgestone for ADE numbers, is to have a base number to which you add a "-" when you do a versioning next to a number. This number will grow every time a change is done from the basic one.

For example: 23456 could be our base number, and 23456-1, 23456-2, and 23456-3 three versions of the base number.

Versioning enables to track and manage information as it evolves. You can look at earlier versions and recover them, if necessary. Also, it allows linking all versions together.

Therefore, the idea is to use versioning in SPEC numbers. The Final SPEC number will be the base number and the Guide SPEC numbers will be the different versions.

Guide Spec number	Final Spec number
A000E-1	Rejected
A000E-2	Rejected
A000E-3	A000E

Table 16: Use of versioning in Guide SPEC numbers to link it to Final SPEC number

The above table shows the use of versioning in SPEC numbers. Guide SPEC numbers will be versions of the Final SPEC number. It does not matter which one is chosen, the Final SPEC number will have a common base number.

The benefits of using versioning in SPEC numbers are two. First, all Guide SPEC numbers will be easily connected to Final SPEC number. Second, Final SPEC number could be used earlier in the process.

This second benefit is crucial for the vision of molds in OMP. As we have seen, Guide SPEC number is provided two weeks before CT. This fact next to the use of versioning means that Final SPEC number is available two weeks before CT, and thus the connection between IPC and mold. As a result, the visibility of molds in OMP is available at this moment.

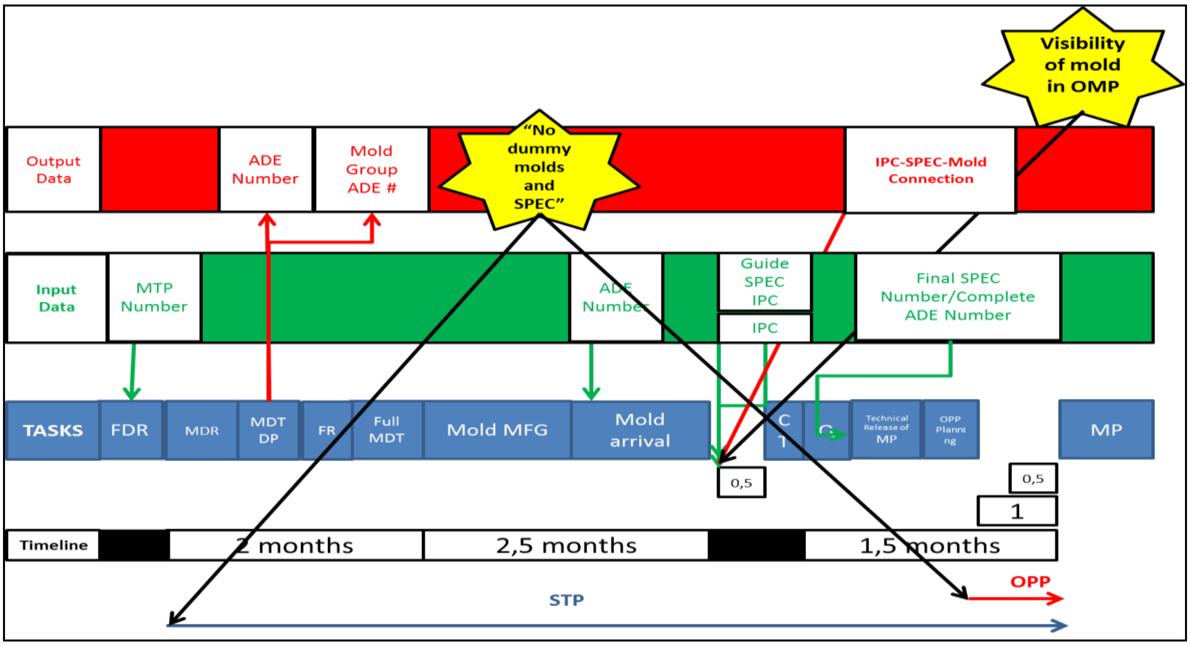

Figure 20: Mold flow after use of versioning in Guide SPEC number

The figure above represents the process that has been explained. This new way of using versioning means, as the figure represents, that the visibility of mold in OMP is two weeks before CT. Also, added to the fact that tactical and production team are not working with molds base on untruthful information, it also means that they will be able to see to which SPEC number is connected earlier in the process.

Now, we have to see how feasible this improvement is. First, TCE must change coding of SPEC numbers. Second, plants have to be informed to make the connection earlier in the process. Finally, tactical and production teams will need a way to make sure that SPEC and mold are not actually available to produce.

The stakeholder analysis of this improvement is shown below.

Stakeholder	View of Improvement Effort			Impact Level		
	Supportive	Neutral	Resistant	Direct	Influence	Affected
Tactical	■					■
Production	■					■
Bethune		■		■		
Bari		■		■		
Poznan		■		■		
Burgos		■		■		
TCE	■				■	

Table 17: Stakeholder analysis of using versioning of Guide SPEC number

As we can see in the figure above, all plants have a direct influence since they are creating the link of IPCs and molds. Tactical and production team are affected since they will see this connection earlier in the process. TCE is Influence since they are the team that creates versioning of SPEC numbers.

For production and tactical team, it is clear that they are supportive since they are benefited by an earlier vision in OMP. On the other hand, plants are considered as neutral. It is true that they have to create the link earlier. However, the task will be the same. They are receiving the same information but just earlier and again, it is Final SPEC number the one that makes the connection equally as the current state. Finally, TCE is the one that has to make the versioning change in one of its tasks. However, they understood the necessity of the versioning and they have no issue creating versioning.

	Hard	Easy
High Impact	Versioning of SPEC numbers IPC-SPEC-Mold connection earlier Earlier visibility of mold in OMP	
Low Impact		

Table 18:Impact-Effort matrix of using versioning of Guide SPEC number

The impact-effort matrix shown in the figure above shows that this improvement has a high impact but a hard effort. The impact is clear because it increases the visibility of molds in OMP. This means that mold availabilities are more precise and it reduces the risk of over purchase of molds or problems of answering the demand.

On the other hand, the effort is considered hard for two reasons. First, TCE has to start using versioning. Second and most important, old specs will not use the same coding. This means that TCE has to invest workload on changing past SPEC numbers. However, it is important to take into account that the Final SPEC number is already defined for the majority of IPCs. Therefore, it is not necessary to change already defined Final SPEC numbers. This means that the workload will not be as big.

5.1.4. Provide Final SPEC number earlier in the process in order to make connection between molds and IPCS from the beginning.

The final step in our improvement phase is to have the IPC-Final SPEC-Mold connection from the beginning of the process. As it has been stated, the connection of these three elements is critical to reduce the risk in mold planning. Also, it is clear that the three of them are necessary.

As we know, IPC is created at the beginning of the process. Afterwards, molds are defined by ADE numbers which are given at MDT for drawing preparation. This means that ADE numbers are done even before the actual drawings are done. Later on, drawings are done and provided to mold supplier. Finally, we know that a Guide SPEC is provided two weeks before CT with a number and afterwards the Final SPEC number is given. However, we can already consider from the previous improvement that Final SPEC number is available two weeks before CT. As we can see, Final SPEC number is still the bottleneck of the connection.

Therefore, the next improvement is to provide Final SPEC number earlier in the process. Similarly to drawings, the Final SPEC number can be given before the actual SPEC containing all the receipt is created and given. It will be just the coding what will be generated.

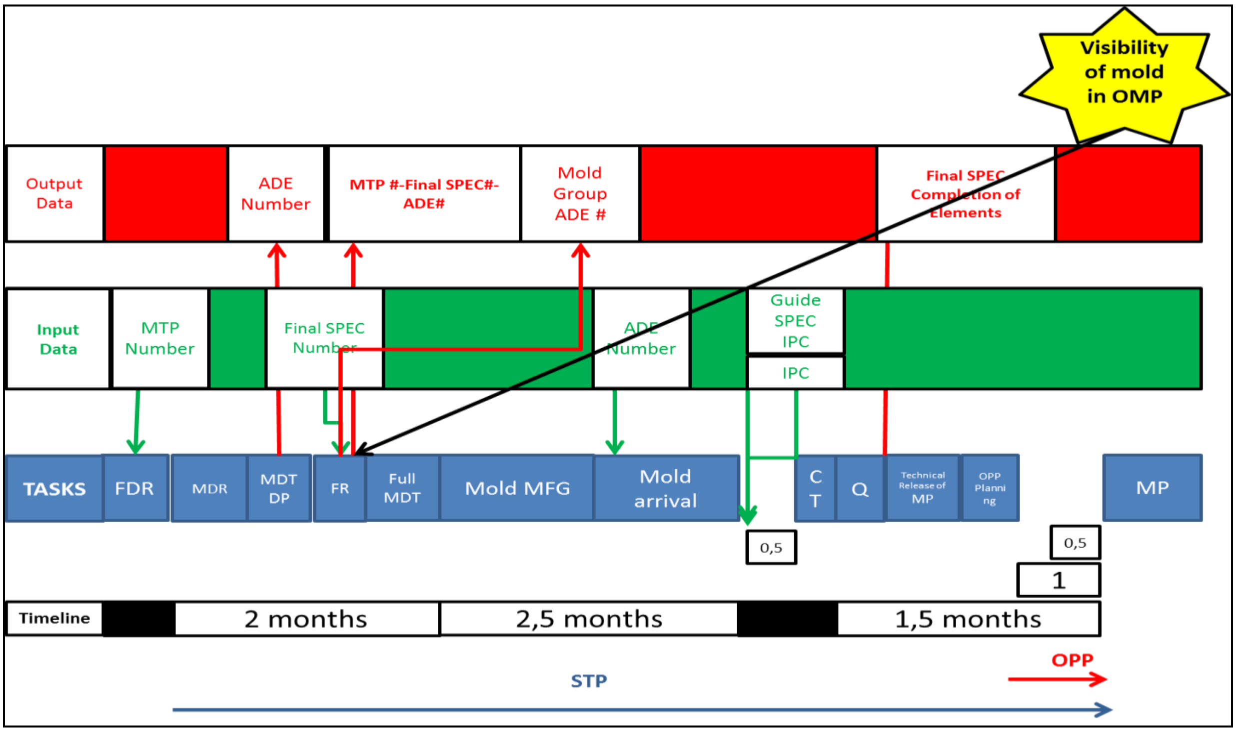

Figure 21: Mold flow after providing Final SPEC number earlier in the process

As it can be seen from the figure above, another change is needed in the process. As it can be seen just after green light is given with FDR, the task that will start the process is MDR, the request for drawings. Currently, MDR and FR are sent at the same time to TCE and plant respectively. MDR is the starting point of drawings and FR is given to plant to send a PO, purchase order, to a mold supplier. However, it is not until the drawings are done that mold supplier can start making the mold. In any case, MDT for drawing preparation is only one week after MDR. Therefore, it is not a problem if FR is issued right after MDT DP since all drawing have to be done and accepted.

The idea of issuing MDR before is the following. First, IPC is already created. Second, MDR is currently sent to TCE which is also in charge of SPEC even if two different departments are in charge of drawings and SPEC. TCE will receive MDR and it will generate all ADE numbers without the actual drawings are done, the same as the current process. However, with this new improvement, TCE will also generate the Final SPEC number, without creating the actual SPEC, only the coding. Therefore, MDT for DP will be sent to LSCM. At this stage, IPC, ADE numbers and Final SPEC numbers are created and available. Next, MPO team will send FR to plant with all this information and it will be able to make the link of the three of them. As a result, the visibility of mold in OMP will be at FR as it is shown in the figure above.

However, there is an issue to take into account. Tactical and production teams will be able to see in OMP a mold but it will not be able to differentiate between a mold that is actually in the plant and a mold that is still in the process.

This issue is easily solved. Currently, BOSS system, which is the database used by plant that feeds OMP has the option of indicating that a mold is arriving by assigning a future delivery date. Therefore, production and tactical team will be able to differentiate from a mold that is in the plant from a mold that is still on its way. In addition, it will allow both tactical and production team to see what will be the future availabilities of molds of each plant directly in OMP. This will reduce the workload for MPO, tactical and production since they will not have to check between each other when the mold will arrive.

Now, it is time to see which teams are involved in this fourth improvement.

Stakeholder	View of Improvement Effort			Impact Level		
	Supportive	Neutral	Resistant	Direct	Influence	Affected
Tactical						
Production						
Bethune						
Bari						
Poznan						
Burgos						
TCE						
MPO						

Table 19: Stakeholder analysis of providing Final SPEC number earlier in the process

As it is shown in the stakeholder analysis table, tactical team, production team, plants, TCE and MPO are needed in this improvement. Tactical and production are affected since they will just see the results in OMP. They are both supportive since they are benefited by an earlier view of the mold in OMP. Plants as well as TCE and MPO teams are direct stakeholders. Plants have to create the link as in the previous process. This is the same reason why they are supportive. It does not increase their workload. Plants only have to change expected delivery date by mold in plant once the mold arrives into the plant. This work is already done by the plant. MPO is supportive since their tasks don’t change. It is only the order that changes and it only means to send another documents later one. The case of TCE is different. TCE’s view is divided. Drawing department in TCE will not change its tasks while SPEC department will. This generates some problems of alignment between them. However, it is just a minor shift of workload. Instead of providing the Final SPEC number later on, TCE would do it earlier.

Once more, we make the impact-effort matrix for this improvement.

	Hard	Easy
High Impact	Versioning of SPEC numbers IPC-SPEC-Mold connection earlier Earlier visibility of mold in OMP Provide Final SPEC number at MDTDP Alignment in TCE Shift of MDR and FR tasks Introduce delivery date in BOSS	
Low Impact		

Table 20: Impact-Effort matrix of providing Final SPEC number earlier in the process

The impact-effort matrix above shows that the impact of the process is high but it requires a hard effort. First, the impact is high since it will provide a much earlier and precise vision in OMP. However, added to the SPEC number versioning and the need of plants of making the connection earlier, there are other added efforts. MPO will have to shift their tasks. This does not mean a big change for MPO since it only requires sending documents at two stages of the process. Plants will have to include delivery dates in BOSS. This change does not require a big workload since plant only has to add the date once they receive FR and change it once they receive the mold. Finally, the biggest workload and especially resistant will come from the alignment between TCE departments in order to issue Final SPEC number at MDT for DP.

5.1.5. Conclusions in Improvement phase:

At this phase, it can be concluded that an introduction of improvements step by step will be the most effective way to implement improvements. First, a common use of mold group as ADE number of mold construction drawing is a crucial but easy to implement improvement. Second, tactical team can easily use ADE number of mold construction drawing as mold group with a very effective result. Third, using versioning in Final SPEC number will allow to connect IPC and mold earlier in the process without altering the flow of tasks and having high results. Finally, once all these improvements are implemented, providing Final SPEC number earlier in the process reaches the level of excellence the process requires. It is true that it is the most complex improvement, but the previous improvements will allow this final one to be easier to implement.

5.2. CONTROL

Now that we have stated improvements, based on our analysis, to solve problems detected and measured in define and measure phase respectively, the next phase is Control. In control phase, standard operations procedures are built. Also, process control plans are built to define ownership. Next, monitoring plans are defined to measure the process with the new improvements. Finally, response plans are created to answer to possible difficulties faced with the new improvements.

5.2.1. Mold group alignment between plants

In the improvement phase, the first step in improvement required the participation of all the plants and TCE. The objective is to standardize mold group in all plants by using ADE number of mold construction drawing. ADE numbers are generated by TCE at MDT for drawing preparation as it was discussed in Define phase.

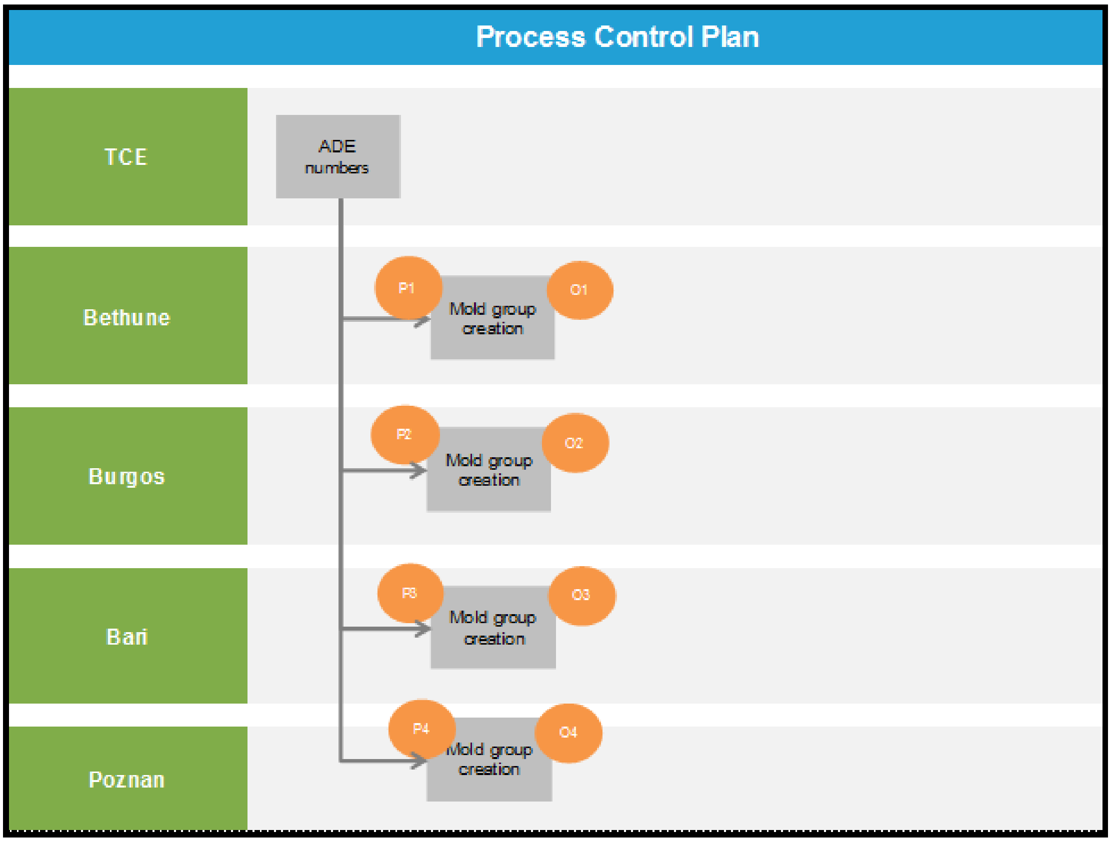

Figure 22: Process control plan of mold group alignment between plants

The figure above shows the process control plan of the first improvement. The process is simple; TCE will provide all plants with all ADE numbers to create mold groups. Also, there are two types of measurements. Input measurements represented by the letter P and output measurements represented by the letter O.

For this first improvement, input and output measurements are the same for all the processes since they all are the same process but in different plants. Input measurement is to measure the number of ADE numbers that the plant is missing.

$$Available\ ADE\ numbers\ _i = \frac{Availabe\ ADE\ numbers\ in\ plant\ i}{Total\ number\ of\ ADE\ numbers\ needed\ in\ plant\ i};\ \forall\, i = 1, \dots, 4$$

Equation 1: ADE numbers available in each plant

This measurement is straight forward for the plant to check if they have all ADE numbers needed to completed mold groups. If they don't have it, they can directly report to TCE to obtain ADE numbers that are missing.

Next, output measurements are again the same for all the processes.

$$ADE\ mold\ groups_i = \frac{Mold\ group\ created\ using\ ADE\ number\ in\ plant\ i}{Total\ number\ of\ mold\ groups\ in\ plant\ i};\ \forall\, i = 1, \dots, 4$$

Equation 2: Mold groups created using ADE numbers in each plant

The measurement shown in the equation above shows the ratio of mold groups created using ADE numbers in comparison with the total number of mold groups created by the plant. This measurement will allow plants, and production and tactical teams to check if they are working with mold groups that are using coding different than ADE numbers.

Next step in the Control phase is to create a monitoring plan.

Monitoring Plan					
Measure	**Input, Process or Output?**	**Trigger Measures (Control Limits/Specs)**	**Method of Measurement**	**Checking Frequency**	**Who is Responsible**
Available ADE numbers	Input	Missing ADE numbers	BOSS maintenance	Daily	Plant
ADE mold groups	Output	Mold group with different coding than ADE number	BOSS maintenance	Daily	Plant

Table 21: Monitoring plan for mold group alignment between plants

The monitoring plan shows that is the plant which is responsible of both input measurements. Plants should check daily their databases while maintaining BOSS system that feeds OMP. Once they detected missing ADE numbers in BOSS or mold groups with different coding than ADE number, they have to contact TCE to obtain missing ADE numbers

Final step in Control plan is to create response plans in order to create contingency plans in case performance drops. Response plan is divided into four parts. First, damage control which describes potential contingency plans for this failure. Second, process adjustment which describes changes that could be made to prevent the problem. Third, effective assessment, which describes the benchmark that the process must achieve to be considered effective. Fourth, continuous improvement, potential ideas for future process adjustments.

Response Plan			
Damage Control	**Process Adjustment**	**Effectiveness Assessment**	**Continuous Improvement**
Contact TCE or DPO to obtain missing ADE numbers	Provide plants with IPC-SPEC-Mold connection from the beginning	All ADEs available by each plant	Provide IPC-Final SPEC number-ADE numbers connection at start of process
Contact TCE or DPO to obtain missing ADE numbers	Provide plants with IPC-SPEC-Mold connection from the beginning	All mold groups created by plant using ADE number	Provide IPC-Final SPEC number-ADE numbers connection at start of process

Table 22: Response plan to mold group alignment between plant

The figure above shows that in case ADE numbers are missing or there are mold groups created using a different coding than ADE numbers, plants should contact TCE or DPO team to obtain missing ADE numbers. The objective is to have all mold groups created using ADE numbers and thus all plants should have all ADE numbers available. Finally, further improvements should be to provide plant with IPC-SPEC-Mold connection from the beginning. This will avoid problems of missing ADE numbers. In order to make this improvement feasible, IPC, final SPEC number and all ADE numbers should be available at the beginning of the process.

5.2.2. Use of ADE number of mold construction drawing by tactical team when creating dummy mold groups.

In the second improvement, three teams are participating. Tactical team, DPO (Drawing department in LSCM) and Production team. The flow is represented in the Process control plan below.

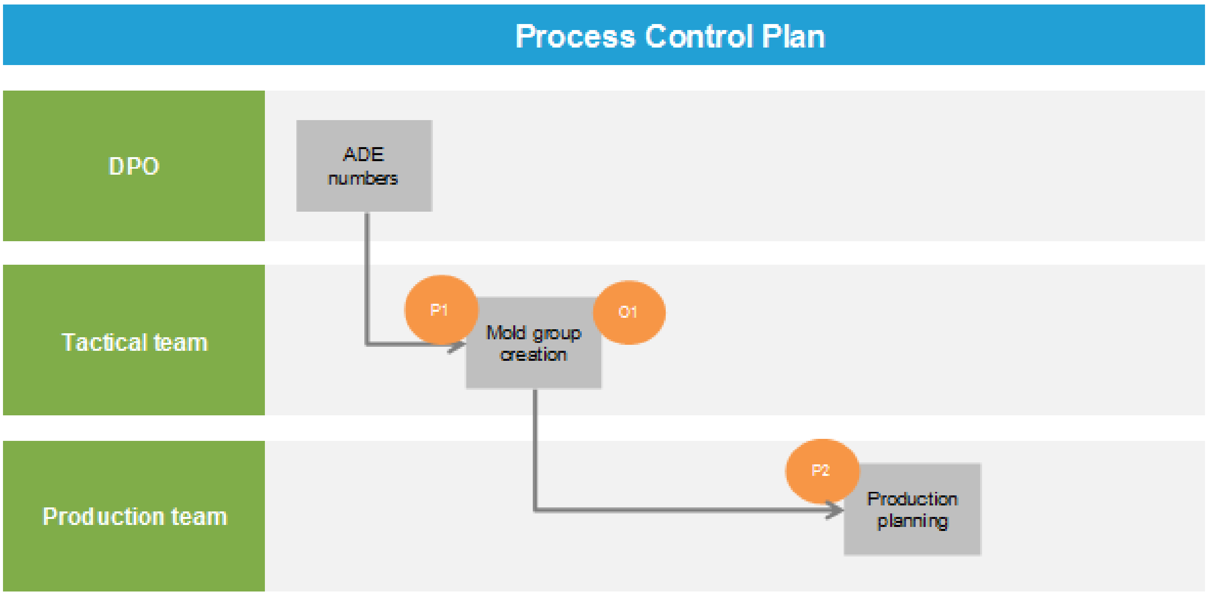

Figure 23: Process control plan of use of ADE number as mold group by tactical team

Process control plan shows that DPO provides Tactical team with ADE numbers. Next, when making their tactical planning, tactical team will create mold groups for those that don't have a mold group created by the plant. As explained, they will use ADE number to create mold groups and base dummy molds on truthful information. Finally, when tactical team finishes with their tactical planning, and update mold groups that they created, production team will work with these mold groups. Once they start working with these molds all mold groups should be defined using ADE numbers, including the dummy ones. If dummy molds are detected using different coding that ADE number, this should be detected by production team.

Again, in this process control plan we have input and output measures. For tactical team, input and output measures are the following.

$$Available\ ADE\ numbers\ = \frac{Availabe\ ADE\ numbers\ by\ Tactical\ team}{Total\ number\ of\ ADE\ numbers\ available\ by\ DPO}$$

Equation 3: ADE numbers available by tactical team

$$ADE\ mold\ groups = \frac{Mold\ group\ created\ using\ ADE\ number\ in\ tactical\ planning}{Total\ number\ of\ mold\ groups\ in\ tactical\ planning}$$

Equation 4: Mold groups created by tactical team using ADE numbers

First measure, input, defines the ratio of ADE numbers available by tactical team against ADE numbers available by DPO, which is the total number available by LSCM. This will allow tactical team to track if they are missing ADE numbers. Second, output measure, it represents the ratio of mold groups used by tactical team in their tactical planning that are created using ADE numbers, against total number of mold groups that tactical planning uses. This ratio will allow tactical team to detect mold groups that are not using ADE numbers and start tracking them.

Finally, the input measure that production team will use is the same as the output measure used by tactical team, but in this case when doing production planning. This measure will allow to double check that all molds are created using ADE numbers. This measure is necessary since it will allow to give a measure of how much risk is taken at a late stage as it is production planning. This measure is represented by the ratio below.

$$ADE\ mold\ groups = \frac{Mold\ group\ created\ using\ ADE\ number\ in\ production\ planning}{Total\ number\ of\ mold\ groups\ in\ production\ planning}$$

Equation 5: Mold groups created using ADE numbers that are used by production team

Next step is the creation of monitoring plan. The table below represents the three measures that have been explained above. As it has been explained, tactical and production team will be responsible of this measurements while doing their tactical and production planning respectively. Tactical team will check monthly since tactical planning is done every month for the next six months. However, production team will check weekly since production planning provides the production for the next month for each week. This fact added to the criticality of the time period regarding the risk regarding mold groups based on untruthful information makes a weekly control of mold groups that are going to be used in their production planning.

Monitoring Plan					
Measure	**Input, Process or Output?**	**Trigger Measures (Control Limits/Specs)**	**Method of Measurement**	**Checking Frequency**	**Who is Responsible**
Available ADE numbers	Input	Missing ADE numbers	Tactical planning	Monthly	Tactical team
ADE mold groups	Output	Mold group with different coding than ADE number	Tactical planning	Monthly	Tactical team
ADE mold groups	Input	Mold group with different coding than ADE number	Tactical planning	Weekly	Production team

Table 23: Monitoring plan of tactical team using ADE numbers as mold groups

Response Plan			
Damage Control	**Process Adjustment**	**Effectiveness Assessment**	**Continuous Improvement**
Contact TCE, DPO or plants to obtain missing ADE numbers	Provide plants with IPC-SPEC-Mold connection from the beginning	All ADEs available by tactical team	Provide IPC-Final SPEC number-ADE numbers connection at start of process
Contact TCE, DPO or plants to obtain missing ADE numbers	Provide plants with IPC-SPEC-Mold connection from the beginning	All mold groups created by plant using ADE number	Provide IPC-Final SPEC number-ADE numbers connection at start of process
Contact TCE, DPO or plants to obtain missing ADE numbers	Provide plants with IPC-SPEC-Mold connection from the beginning	All mold groups created by plant using ADE number	Provide IPC-Final SPEC number-ADE numbers connection at start of process

Table 24: Response plan to using ADE numbers as mold group by tactical team

Response plan shows that to damage possible problems, tactical and production team should contact TCE, DPO or plant to obtain ADE numbers to the IPCs that have a mold group with a different coding. Also, in the case of plants, tactical and production teams can contact them to obtain directly the mold group they assigned to this IPC. The objective again is to have all ADE numbers available by tactical team and thus create all mold groups based on this coding. Again, having the connection of IPC-SPEC-Mold from the beginning will decrease risk and workload.

5.2.3. Use of versioning of Guide SPEC number in order to make connection between molds and IPCs earlier in the process.

For the third step in improvements, process control plan shows that SPEC number should be given by TCE to all plants using versioning. Once they receive SPEC numbers, Plants will make the link between molds and IPCs. Tactical team will be able to check if the mold has been done by checking if mold groups are dummy. This same input will be seen by production team which will be able to see if molds are dummy even if tactical team is creating mold groups based on ADE numbers.

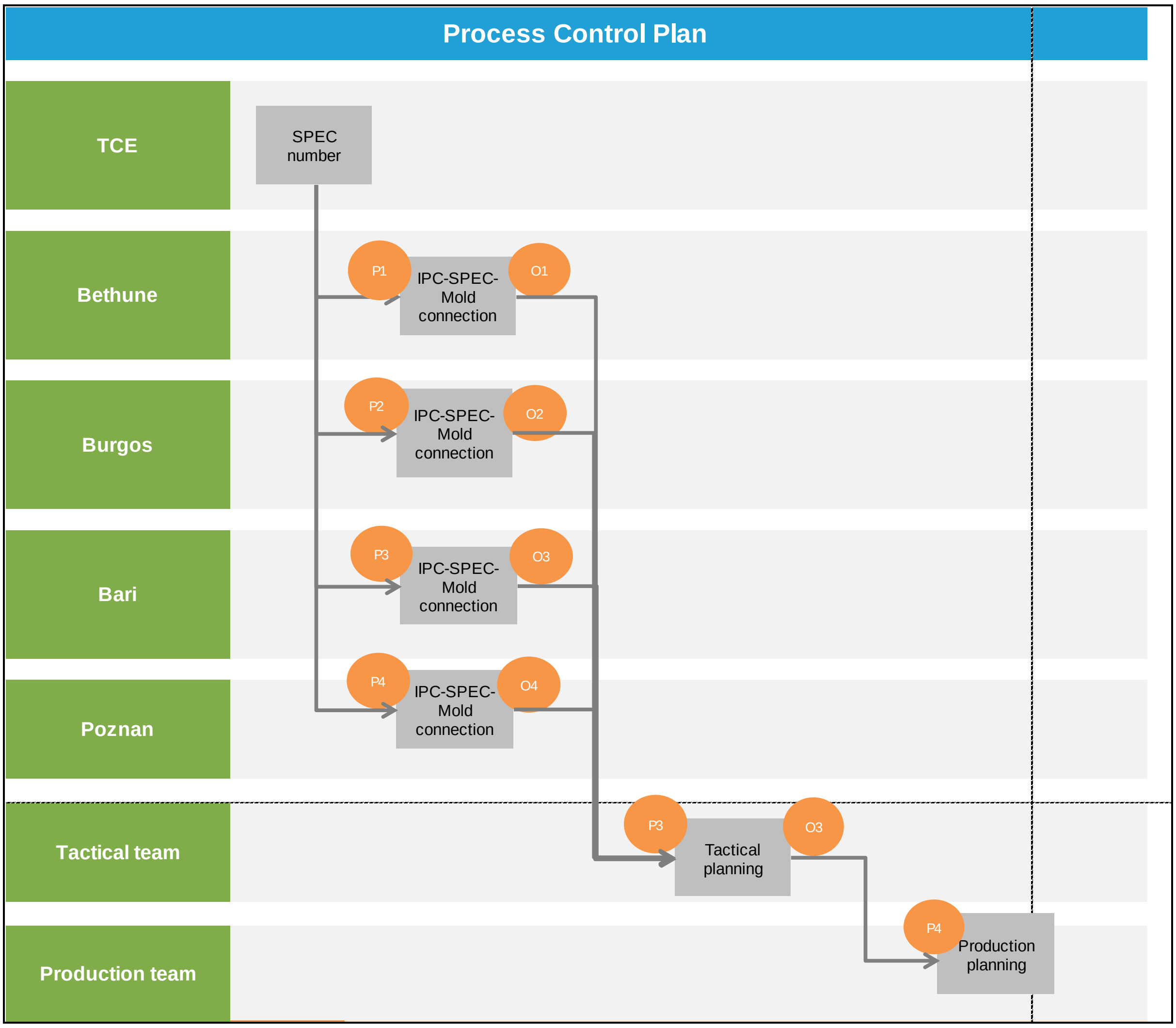

Figure 24: Process control plan of using versioning of Guide SPEC number

Input measurement shown for all plants is the one shown in the formula below. It represent the ratio of available SPEC numbers in each plant compared to all those that each plant needs. This measurement will make the plant be able to check if they are missing SPEC numbers once CT, time when SPEC numbers are delivered, arrives.

$$Available\ SPEC\ numbers_{\ i} = \frac{Availabe\ SPEC\ numbers\ in\ plant\ i}{Total\ number\ of\ SPEC\ numbers\ needed\ in\ plant\ i};\ \forall\ i = 1, \ldots, 4$$

Equation 6: Availability of SPEC numbers in each plant

$$Created\ connections\ by\ plant_i = \frac{Connections\ created\ by\ plant\ i}{Total\ number\ of\ connections\ in\ plant\ i};\ \forall\ i = 1, \ldots, 4$$

Equation 7: Connections created in each plant

The equation above shows the actual number of connections done by each of all the connections that have to be done by each plant. The total number of connections is measured obtaining the total number of IPCs that are going to be produced by the plant and are missing a mold group.

In the case of tactical team, there are two measurements, one input and one output.

$$Visibility\ of\ molds\ in\ OMP\ = \frac{Mold\ groups\ created\ by\ plant\ in\ tactical\ planning}{Total\ number\ of\ mold\ groups\ in\ tactical\ planning}$$

Equation 8: Visibility of molds in OMP

$$Dummy\ mold\ groups\ tactical = \frac{Mold\ group\ created\ by\ tactical\ team\ in\ tactical\ planning}{Total\ number\ of\ mold\ groups\ in\ tactical\ planning}$$

Equation 9: Dummy mold groups used by tactical team

Input measurement, visibility of molds in OMP, reflects the number of molds groups that are used in tactical planning that are created by the plant out of all the molds that should have been created by the plant. This will provide the number of IPCs that are missing a link with a mold. The output of tactical team will be to create dummy mold groups. Dummy mold groups are those that are created by tactical team. At this point, tactical team will create mold groups based on ADE numbers, as it was explained in the second step of improvements. However, the percentage of dummy mold groups will provide visibility of those IPCs that are missing SPEC number, molds that have not yet arrived into plant or maybe molds that have some problems with SPEC versioning.

The input of production team will be the same as the output of tactical team but only looking at molds use in production planning.

$$Dummy\ mold\ groups\ production = \frac{Mold\ group\ created\ by\ tactical\ team\ in\ production\ plan}{Total\ number\ of\ mold\ groups\ in\ production\ plan}$$

Equation 10: Dummy mold groups used by production team

This measurement will allow production team to detect IPCs that are missing a mold group and act in order to understand and solve this issue. Maybe the SPEC is not there yet and they have to push plants to ask TCE for the SPEC.

Monitoring plan above shows that plants are in charge of checking two weeks before CT that all SPECS are available and that they make all connections in BOSS to feed OMP. Tactical team will check monthly if there are IPCs that are missing a mold group and they will measure the number of dummy mold groups they are creating even if they are created based on truthful information. This last measurement next to the measurement by production team of dummy mold groups will allow to see if there are missing SPECs, if the mold has arrived or if the SPEC is not using versioning.

Monitoring Plan					
Measure	**Input, Process or Output?**	**Trigger Measures (Control Limits/Specs)**	**Method of Measurement**	**Checking Frequency**	**Who is Responsible**
Available SPEC numbers	Input	Missing SPEC numbers	BOSS maintenance	Two weeks before CT	Plant
Connections created by plant	Output	IPCs missing a mold group	BOSS maintenance	Two weeks before CT	Plant
Visibility of molds in OMP	Input	Missing IPC and mold connection	Tactical planning	Monthly	Tactical team
Dummy mold groups tactical	Output	Mold group created by tactical team in tactical planning	Tactical planning	Monthly	Tactical team
Dummy mold groups production	Input	Mold group created by tactical team in production planning	Tactical planning	Weekly	Production team

Table 25: Monitoring plan of using versioning of Guide SPEC number

Response Plan			
Damage Control	**Process Adjustment**	**Effectiveness Assessment**	**Continuous Improvement**
Contact TCE to obtain missing SPEC numbers	Provide plants with IPC-SPEC-Mold connection from the beginning	All SPECs available at CT	Provide IPC-Final SPEC number-ADE numbers connection at start of process
Contact TCE to obtain missing SPEC numbers	Provide plants with IPC-SPEC-Mold connection from the beginning	All SPECSs available at CT	Provide IPC-Final SPEC number-ADE numbers connection at start of process
Contact plant to ask why they are missing IPC mold connection. Check with MPO if mold has arrived into plant	Provide plants with IPC-SPEC-Mold connection from the beginning	All mold groups created by plant at CT	Provide IPC-Final SPEC number-ADE numbers connection at start of process
Contact plant to ask why they are missing IPC mold connection. Check with MPO if mold has arrived into plant	Provide plants with IPC-SPEC-Mold connection from the beginning	All mold groups created by plant at CT	Provide IPC-Final SPEC number-ADE numbers connection at start of process
Contact plant to ask why they are missing IPC mold connection. Check with MPO if mold has arrived into plant	Provide plants with IPC-SPEC-Mold connection from the beginning	All mold groups created by plant at CT	Provide IPC-Final SPEC number-ADE numbers connection at start of process

Table 26: Response plan to use of versioning of Guide SPEC number

Response plan shows that plants should contact TCE to ask for SPEC numbers in case they are missing SPECs or they are not creating IPC mold connections. Tactical and production team should check with MPO to check if mold is already in plant. This will allow both teams to know if the lack of connection is because the mold is not there or if it is related to SPEC. If it is related to SPEC, both teams should contact plants in order to push TCE to obtain SPEC numbers. For all cases, giving a connection of IPC, SPEC and mold from the beginning will solve the problem of missing connections, having dummy mold groups and thus having risk in planning.

5.2.4. Provide Final SPEC number earlier in the process in order to make connection between molds and IPCS from the beginning.

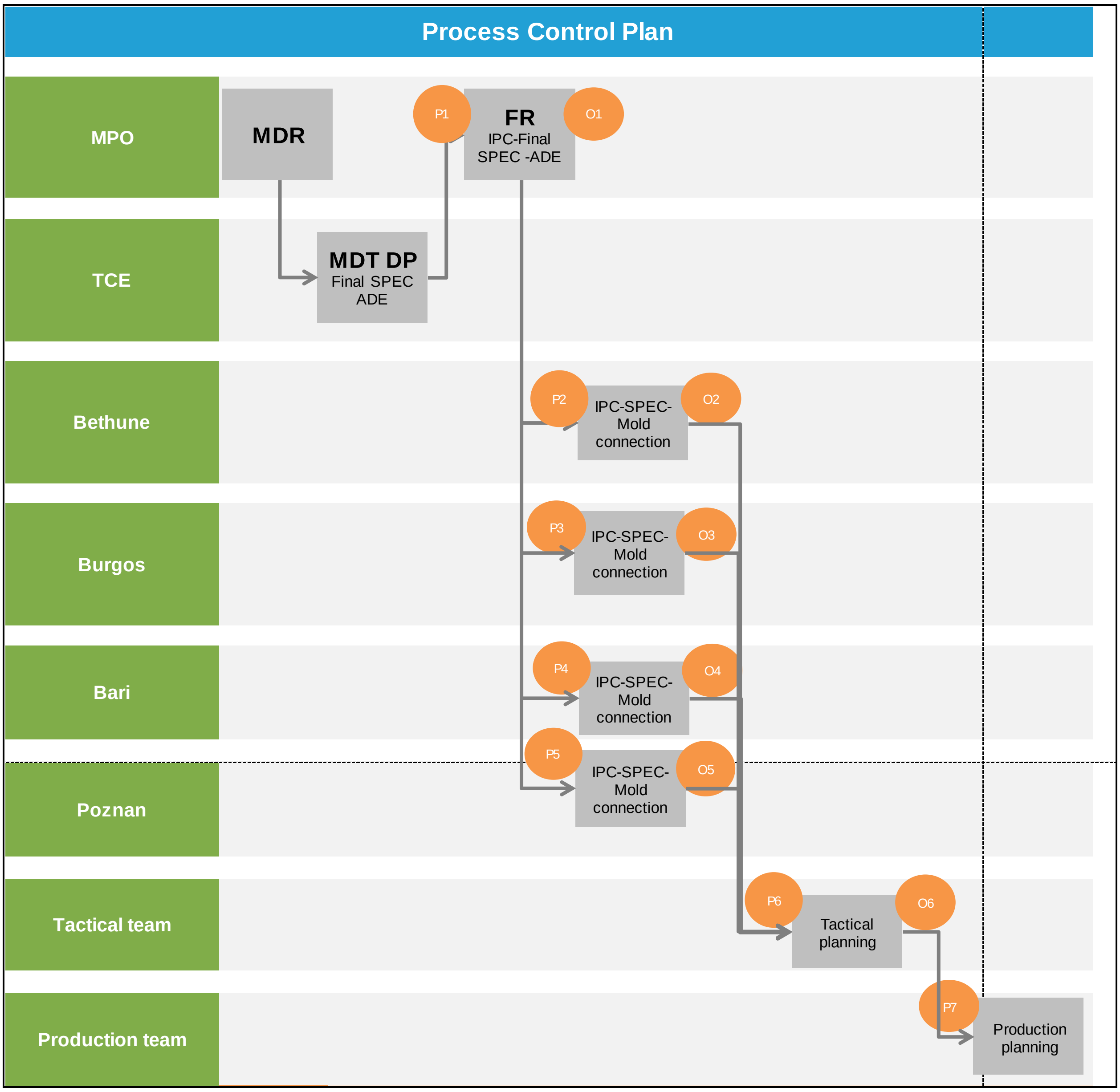

Figure 25: Process control plan of providing final SPEC number earlier in the process

The process control plan of the fourth improvement shows that MPO team will issue MDR (Drawing request), then TCE will provide one week later Final SPEC number and ADE numbers. Just after MPO will issue FR (Fund Request) with IPC, ADE numbers and Final SPEC numbers to plants. At this moment plants will be able to make mold groups and link them to IPCS, thus mold will be visible in OMP. Plants will put the arrival date of the mold in BOSS to show it in OMP. Finally, tactical team and production team will work with IPCs with assigned mold groups, all of them visible in OMP, and knowing the arrival date of the mold and SPEC to start producing.

Similarly to the previous improvement, plants, tactical and production team have similar measurements. Tactical and production team will measure the visibility of molds in OMP, and dummy molds that they are using in their respective planning. Again, even if the mold groups are based on ADE numbers. Plant will control the number of connections created based on the coding they receive from MPO. The only difference is that now, they will keep track of the ratio of entire coding available, IPC, Final SPEC number and ADE numbers.

$$Available\ \ coding\ _i = \frac{Availabe\ coding\ \ in\ plant\ i}{Total\ number\ of\ \ coding\ needed\ in\ plant\ i};\ \forall\, i = 1, \ldots, 4$$

Equation 11: Available coding numbers in each plant

$$Created\ connections\ by\ plant_i = \frac{Connections\ created\ by\ plant\ i}{Total\ number\ of\ connections\ in\ plant\ i};\ \forall\, i = 1, \ldots, 4$$

Equation 12: Connections created by each plant

$$Visibility\ of\ molds\ in\ OMP\ = \frac{Mold\ groups\ created\ by\ plant\ in\ tactical\ planning}{Total\ number\ of\ mold\ groups\ in\ tactical\ planning}$$

Equation 13: Visibility of molds in OMP

$$Dummy\ mold\ groups\ tactical = \frac{Mold\ group\ created\ by\ tactical\ team\ in\ tactical\ planning}{Total\ number\ of\ mold\ groups\ in\ tactical\ planning}$$

Equation 14: Dummy mold groups created by tactical team

$$Dummy\ mold\ groups\ production = \frac{Mold\ group\ created\ by\ tactical\ team\ in\ production\ plan}{Total\ number\ of\ mold\ groups\ in\ production\ plan}$$

Equation 15: Dummy mold groups used by production team

The new measurement come will be used by MPO.

$$Issued\ FR\ = \frac{Total\ number\ of\ FR\ issued\ by\ MPO}{Total\ number\ of\ FDR\ received}$$

Equation 16: Percentage of issued FRs by MPO team

$$Available\ coding\ in\ FR\ = \frac{Number\ of\ FR\ with\ coding}{Total\ number\ of\ issued\ FR}$$

Equation 17: Coding available in FRs

First, MPO will make sure that they have sent all FR that they were supposed to send comparing the number the number of issued FR against the total number of FDR received. They can check FDR received in share point. Second, MPO, which saves FRs, can be able to check if there are FRs missing coding. This will allow MPO to see if all information was available from TCE once they sent a FR. It seems obvious that FR should contain all coding since they come after MDT for drawing preparation that should contain all coding. However, there can be problems with ADE numbers and SPEC numbers since they are managed by two different departments. Also, sometimes it could happen that in order to save time in industrialization some actions are done by decisions of IPL (Industrialization team).

The monitoring plan below shows that MPO has to check daily that coding is not missing in FRs and that they are issuing all FR requests. Next, plants will check every time that they receive a FR that all coding is available and they have to measure that they are creating all links on time.

Monitoring Plan					
Measure	Input, Process or Output?	Trigger Measures (Control Limits/Specs)	Method of Measurement	Checking Frequency	Who is Responsible
Available coding in FR	Input	Missing IPC, Final SPEC number of ADE numbers in MDT DP	FR issuing	Daily	MPO
Issued FR	Output	FDR without FR	FR issuing	Daily	MPO
Available coding	Input	Missing SPEC numbers	BOSS maintenance	FR reception	Plant
Connections created by plant	Output	IPCs missing a mold group	BOSS maintenance	FR reception	Plant
Visibility of molds in OMP	Input	Missing IPC and mold connection	Tactical planning	Monthly	Tactical team
Dummy mold groups tactical	Output	Mold group created by tactical team in tactical planning	Tactical planning	Monthly	Tactical team
Dummy mold groups production	Input	Mold group created by tactical team in production planning	Tactical planning	Weekly	Production team

Table 27: Monitoring plan of providing final SPEC number earlier in the process

Response Plan			
Damage Control	**Process Adjustment**	**Effectiveness Assessment**	**Continuous Improvement**
Contact TCE for missing coding	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP
Check FDR to compare with sent FRs and send FRs.	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP
Contact MPO or TCE to obtain missing coding numbers	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP	All connections done at FR reception	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP
Contact MPO or TCE to obtain missing coding numbers	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP	All connections done at FR reception	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP
Contact plant to ask why they are missing IPC mold connection. Check with MPO if mold has arrived into plant	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP	All mold groups created by plant at FR reception	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP
Contact plant to ask why they are missing IPC mold connection. Check with MPO if mold has arrived into plant	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP	All mold groups created by plant at FR reception	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP
Contact plant to ask why they are missing IPC mold connection. Check with MPO if mold has arrived into plant	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP	All mold groups created by plant at FR reception	Create IPC, SPEC, Mold connection at LSCM for all plants and reflect it in OMP

Table 28: Response plan to providing SPEC number earlier in the process

Response plan shows that MPO has to contact TCE when coding is missing. Plant should check with TCE or MPO for missing coding. Again tactical and production team will check with plants for missing mold groups and with MPO for arrival of the mold

5.2.5. Conclusions in Control phase:

Similarly to improvement phase, control phase grows smoothly. All plants become bigger and bigger with the new improvements becoming more complex. However, the first parts of control phase allow that the final parts of control phase are not as hard to implement.

6. Conclusions

In this MT, a DMAIC methodology has been followed in order to define, measure, analyze, improve and control the mold process management in the logistic team inside the headquarters of Bridgestone Europe.

It can be concluded that the general objective of improving the process and flow of information in the mold production process from the mold creation to the mass production of molds has been achieved.

In detailed, we can conclude that the two first specific objectives have been achieved, and the third one has been partially achieved.

In chapter 2, specific objective 1 has been completely reached. The problem of the company has been completely understood including its goals, structure, and everything related to mold process and its flow of information.

Furthermore, chapter 3 has focused on the study of applicable methodologies that could be used to solve Bridgestone's problem. A deep research on both scientific and practical works has been done with the conclusion that a Six Sigma methodology, and in particular DMAIC methodology, was the best option to solve Bridgestone´s problem.

Finally, specific objective 3, to put the methodology into action, has been partially achieved. In this project, the methodology has been divided into two parts, "As is" and "To be".

First, "As is" part has been developed in Chapter 4, and it included the first three phases of DMAIC methodology; Define, Measure, and Analyze:

During the first stage, Define, mold process has been defined, as well as problems detected in the flow. Interviews with all members interacting in the mold flow have taken place. The objective of these interviews was to define the current state of mold flow. During these meetings, the voice of the customer was taken into account in order to detect problems in the flow and to listen to their requirements. Once all meeting took place, the entire mold flow was mapped. As a result, a problem in mold tactical planning was detected. Tactical team was experiencing problems of lack of precision in their planning due to lack of information and visibility of availabilities of molds. Customers required a more precise tactical planning, better vision of mold availabilities, and trustful information to define the connection between an IPC and the mold that produces it.

Next, problems in tactical planning were measured during Measure stage. The objective at this stage was to quantify the issue of lack of precision in tactical planning. In order to measure this precision, the percentage of supply linked products no properly linked to molds was measured. This measurement showed that 15% of supply in the next six months was not properly defined. This 15% reflected that tactical planning was based on guesses of which mold was needed in reality and guesses in availabilities. In addition, around 5% of supply in the next month was also not properly defined. This 5% meant around 30 molds per month or a volume of 70000 tires. The risks of this lack of precision in tactical planning were two. First, if tactical planning is not precise, availabilities of molds in plants could be under or over estimated. As a result, more molds than needed could be bought. This over purchase of molds is very significant due to the high price of a mold. Also, if a mold is not available on time, volume of production is at risk and thus commitment with customers. Second, if the connection between a product and its mold is not properly defined, again availabilities of molds are wrong. Again, volume of tire production is at risk.

Final phase of “As is” part, Analysis phase was conducted in order to detect root causes that led to problems in tactical planning. In order to detect root causes, a fishbone diagram was developed. Fishbone diagram reflected several root causes. First, plants were defining molds in different ways among them. Some were using certain drawing mold numbers, other plants were using different drawing numbers, and other plants were using production codes. This lack of alignment was leading to problems in achieving precise mold availabilities in plants. Next, lack visibility of molds and IPC mold connection in OMP, was due to the use of Final SPEC number as a connection between IPC and mold. The use of Final SPEC number to make this connection was creating problems due to two factors. First, versioning was not used for SPEC numbers and second, Final SPEC number was given too late in the process.

We can conclude that “As is” part has been successfully achieved.

Second, “To be” part has been partially achieved:

During Improvement phase, solutions to root causes were established taking into account the effort of these improvements and analysis of stakeholders. First improvement was to use a common in all plants way to define mold by using drawing numbers. The right drawing number is mold construction number since it includes both sectors and sidewall plates of a mold. In order to achieve this improvement, all plants should define molds using this drawing code. Second, tactical team will use drawing numbers in their tactical planning to define molds even if plant has not defined molds yet. This improvement will finish with the lack of trustful information in tactical planning. Third, versioning will be used to define SPEC numbers. Versioning will help with traceability of SPECs, and it will provide a better visibility of molds in OMP. The final step of improvements is to provide Final SPEC number at the beginning of the process. This earlier availability of the final SPEC number next to IPC and mold codes will provide a better control and precision of both tactical and production planning.

Finally, at Control phase, process control plans were defined next to monitoring and response plans. At this stage, the new flow is defined in order to establish ownership of the new tasks. In addition, KPIs were defined to control the new process. These KPIs will allow to properly monitor the new process and to establish response plans in case some issues are encountered.

“To be” is concluded that is partially achieved due to the fact that improvements were not implemented due to the fact that the internship with Bridgestone ended. This is the reason why, an implementation schedule was not developed and included in this MT.

To conclude, the general objective of this MT has been reached by achieving specific objectives 1 and 2, and partially achieving specific objective 3. In addition, DMAIC methodology has clear benefits on mold process. First, the understanding in mold process has increased by all members of mold process by transferring knowledge. Second, all root causes to problems have been detected, leading to a clear and controlled step by step improvement process. Finally, in economic terms, the implementation of DMAIC methodology will have clear benefits. As it was described in Measure phase, the risk of buying more molds than necessary or losing volume of tires will be extremely reduced. This risk means around 400,000 euros for Bridgestone every month. Finally, workload will be significantly reduced in terms of data analysis, databases maintenance, and rework.

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