POLITECNICO DI TORINO

Corso di Laurea Magistrale

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Tesi di Laurea Magistrale

SUPPLY CHAIN RATIONALIZATION AND SAVING STRATEGIES

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Sommario

Introduction

In the following pages there will be an in-depth description of the main activities, concepts and problems encountered during my internship in ABB, more precisely in their Electrification division located in Vittuone, Milan. I was hired as Procurement Specialist in the SCM office to assist Paola Cialini, the manager in charge of handling molded plastic components and metals. I worked side by side with Marco Grassi, the buyer in charge of plastic molded components, responsible for my introduction in the company and my training.

Underneath their supervision I was tasked with several different activities for the Vittuone and Marostica plants, ranging from analyzing offers to dealing with eventual payment problems. Most of these tasks were tied with ongoing external productions, which lack the severe time constraints inherent in new projects; a wider timeframe meant that our efforts to achieve given targets could focus on broader strategies.

The yearly targets set for the SCM office were part of the “Boost Program” which established two thresholds for each KPI: the lower one can be described as merely desirable while the higher one meant that the Business Unit was keeping up with said “Boost Program”. These KPIs will be described in the following pages especially in regard to what was accomplished, and which strategies were implemented.

This internship was an incredibly positive experience and gave me the opportunity to learn many different things which are not studied in the academic world mainly due to their reliance on personal interactions, such as negotiation and supplier relationships; furthermore, it gave me a chance to comprehend the different ways to approach a job and their repercussions.

In practical terms I was tasked with metrics-based and KPI-relevant activities with ongoing evaluations and performance reviews, the responsibility I was entrusted with meant a lot for me: for the first time I had to reach difficult targets on my own (though with the help of my tutors) rather than being entrusted with simple or trivial tasks. The project meant something and was actually critical in order to reach the BOOST Program saving target.

1 ABB Group

1.1 History

ABB is a company which has been characterized, throughout its history, by a high degree of fluidity: “ABB is the product of many acquisitions and mergers, but primarily the 1988 coming together of ASEA and BBC, formerly known as Brown Boveri, two of the proudest and best known names in European electrical engineering history.” (ABB, s.d.).

The parent companies were founded in 1883 and 1891 respectively, they agreed to a merger and created a holding based in Zurich, becoming 50/50 shareholders. In a relatively short amount of time ABB has acquired over sixty companies, most of which were leaders of their respective sectors; this fluidity led ABB to diversify its business in various crosslinked sectors and greatly increase its initial revenue: in 1989 revenues were $17 billion while as of 2019 they were over $27 billion, a 60% growth.

Here are some of the milestones that led ABB to its current position in the global market:

- 1998: launch of the FlexPicker, a robot designed for the picking and packing industry.
- 2000: launch of world’s first high-voltage shore-to ship electric power in Gothenburg port, Sweden.
- 2002: linkage of AC networks across Australia with the world’s longest underground transmission; linkage of Connecticut and Long Island with world’s first HVDC submarine transmission.
- 2004: launch of Extended Automation System, a Distributed Control System which has been installed in thousands of production sites.
- 2005: established a DC link between a gas platform in the North Sea and a location 70 km inland, avoiding annual emissions of 230,000 tons of $C0_2$ and 230 of NO_x.
- 2008: linkage of Norway and Holland’s power networks with the world’s longest submarine HVDC cable.
- 2010: linkage of Xiangjiaba hydropower plant and Shanghai with the most powerful UHVDC cable in existence.
- 2012: development of a hybrid DC breaker suitable for the creation of inter-regional DC grids, “solving a technical challenge […] left unresolved for over a hundred years and perhaps one of the main influencers in the ‘war of currents’.”.
- 2014: unveiling of YuMI, this user-friendly dual arm robot unlocks vast automation potential in industry.
- 2018: ABB becomes the main sponsor of the Formula E Championship, a competition used as trial base to improve and develop new e-mobility technologies.
- 2019: revolution of the low-voltage switchgear, “the safest option for […] maximizing efficiency and reducing costs for digitalized industries.” (ABB, s.d.).

1.2 Divisions

The fluidity and acquisitions that characterized ABB’s history also led to an incredibly varied scope of operations, after the sale of the Power Grids division in 2019 the company re-organized into four global business divisions:

- Electrification: “ABB's Electrification business offers a wide-ranging portfolio of products, digital solutions and services, from substation to socket, enabling safe, smart and sustainable electrification” (ABB, s.d.). I worked in this division, more specifically in the low voltage product line, which encompasses a host of different solution for electrical systems:
  - Cabling.
  - Enclosures.
  - Modular substations.
  - Power protections.
  - Solar inverters.
  - Wiring accessories.
- Industrial Automation: this business is focused on B2B solutions for production control technologies, industry-specific integrated automation, advanced software, measurement and analytics to bring about the 4.0 Industry.
- Motion: the largest supplier of drives and motors in the world, also delivers power transmissions and integrated digital powertrains to the transportation, infrastructure and discrete process industries.
- Robotics and discrete automation: this business provides machine and factory automated solutions; this division was solidified only in 2017 after acquiring B&R and is today the leader in the fast-growing Chinese market [].
- Power grids: this division used to be the global leader in its respective sector and incorporated ABB’s manufacturing network for transformers, circuit breakers, transformers while also offering maintenance services. As early as 2017, shareholders were urging ABB’s CEO Ulrich Spiesshofer to sell this division, but the CEO decided otherwise; however, in 2019, the profit margin of this division reached an all-time low of 10%, down 60 basis points from the previous year and the CEO was forced to sell. After this sudden change of course Spiesshofer resigned as CEO and was replaced by Peter Voser, which remarked “Today's announcement marks the beginning of a new chapter in ABB's history. Building on our technology and global talented employee base we will further strengthen our focus in digital industries, delivering competitive returns for shareholders, including our committed dividend policy. Over the past five years the deliberate execution of ABB’s strategy laid the foundation for our businesses to compete in the fast changing digital industries and deliver profitable growth.” (ABB, s.d.).

1.3 Organizational Model

ABB set up a matrix organizational structure nested within its Business Units, there are two separate chains of command along the functional and projectual lines. This structure often leads to a competition for the same resources since both chains of command may need to leverage the same resources; prioritizing one over the other can lead to adverse results over time, leaving one devoid of power over the other or at least creating this perception within the organization. ABB tried to solve this problem, in the SCM department, by establishing ad-hoc Project Buyers that are in charge of following projects in collaboration with "Functional" Commodity Buyers and reporting to Business Unit category managers. This approach tries to solve the aforementioned problems by creating two different time horizons: projects tend to have much stricter deadlines and each delayed activity -along the Critical Path- delays the whole project. Meanwhile commodity buyers must deal with daily recurring tasks while curating "personal" projects with a higher degree of free demand a farther time horizon.

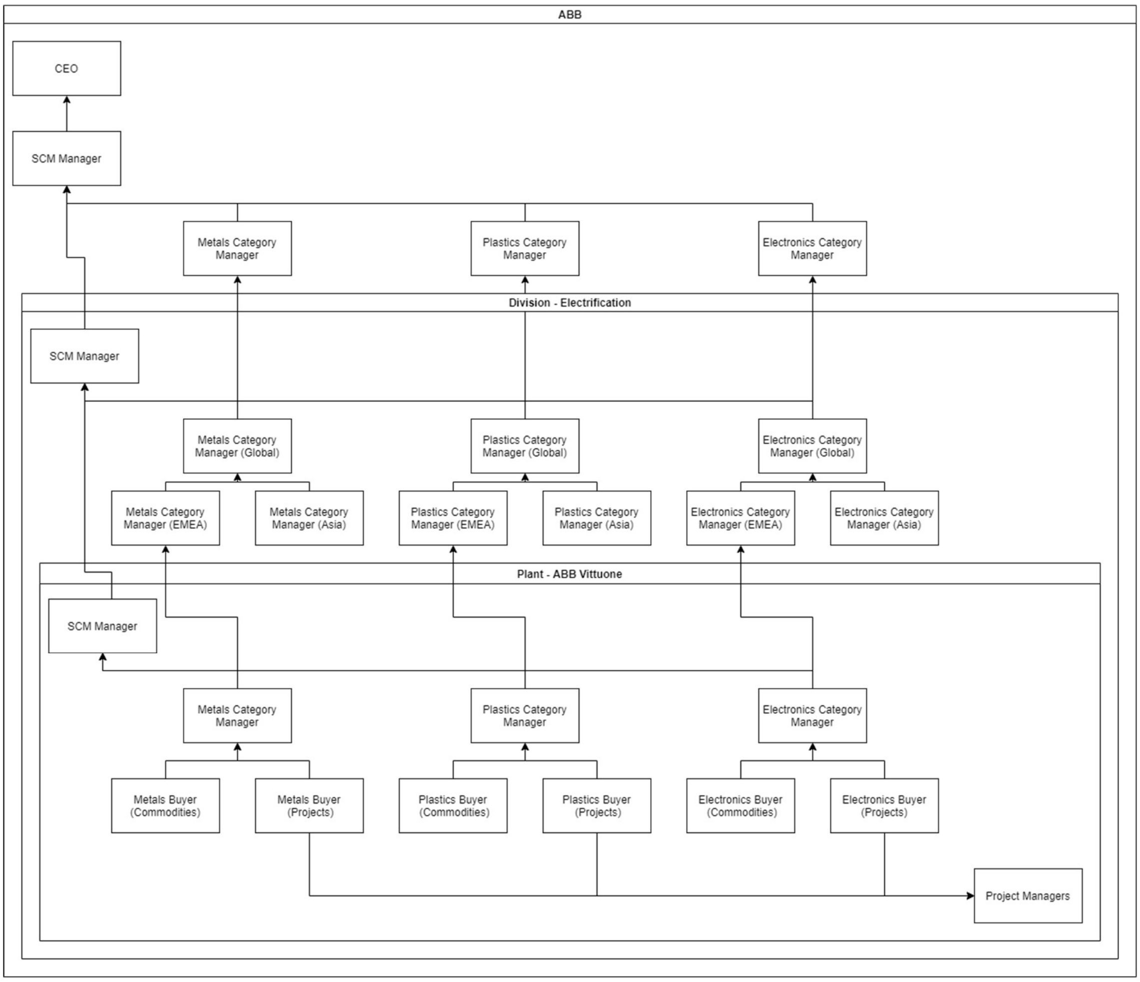

Figure 1.1: Hierarchy and reporting lines within ABB

1.4 Boost Program

The boost program is a set of targets established at the divisional level, business lines and hubs have to work collectively towards those targets in order to achieve them; these targets are measured through many KPIs and have two different thresholds. Most of these targets are strictly financial but are often linked to supply chain performance, the most important are:

- Days Payable Outstanding (DPO), the average time -in days- the company takes to pay its suppliers, vendors and other companies. At the SCM level, pursuing this target meant achieving more favorable payment terms with the biggest suppliers; payment terms are usually negotiated and written directly in the contract stipulated at the beginning of the supplier-client relationship. Coincidentally, most contracts were about to expire when I arrived in the SCM Office, which gave us the chance to re-negotiate more favorable terms.
  - Italian suppliers usually work with 120 days End-Of-Month (EOM) terms, meaning that an invoice dated 10/06/2019 would be paid on 31/10/2019.
  - Chinese suppliers and more generally speaking non-EU suppliers usually work with 90 days EOM terms.
  - Swiss and Deutsche suppliers try to force -often successfully- 60 days terms, meaning that the same invoice dated 10/06/2019 would be paid on 09/08/2019.

  The various terms are weighted by supplier expenditure both at the national, hub and divisional level, they are however compared mostly by country due to regional differences in common payment practices.

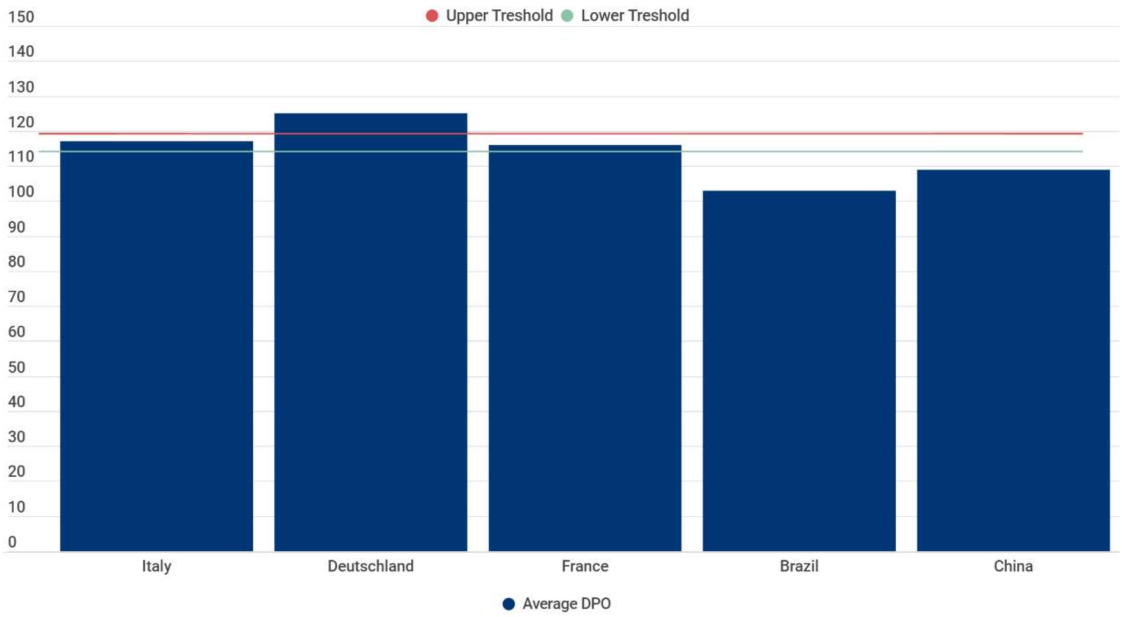

Figure 1.2: DPO Boost Report

- Year-On-Year Savings, the difference between last year and this year expenditures for the same given items. They can be achieved through commercial discounts, investments, renegotiations and process improvements such as centering, decreasing defectives, widening specification boundaries, decreasing logistic costs by optimizing shipments etc. This metric is usually tracked at the hub level and is set up with the same double threshold method:

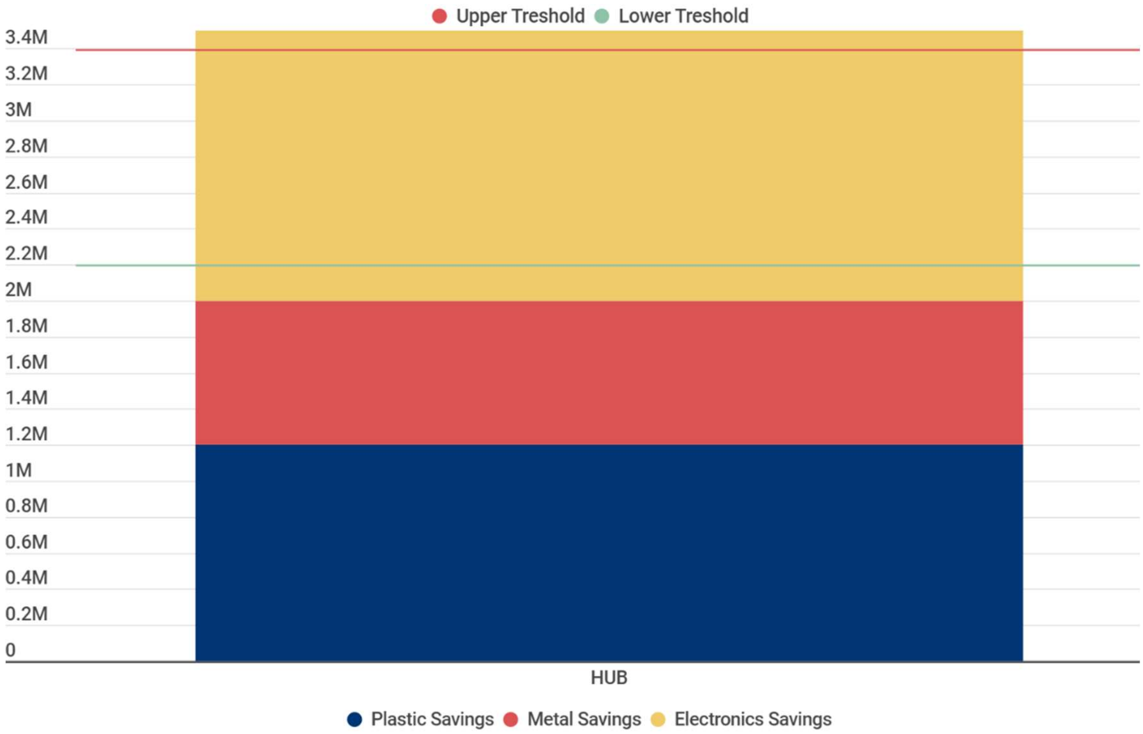

Figure 1.3: Savings Breakdown by Category

- Order Fill Rate, the percentage of total orders which are fulfilled on the first try; failure to do so is usually due to
    - High percentage of defectives, leading to rejection by the quality department.
    - Missing SKUs, leading by partial acceptance by the logistic department.
    - Missing documentation, leading to acceptance under reserve as long as the supplier pledges to provided missing documents within a specified timeframe.
    - Wrong materials or components delivered and subsequently rejected.
    - Late deliveries, while early ones are accepted on condition that they are invoiced as if delivered on time.
- Inventory Accuracy, the difference between MRP stock quantities and actual physical inventories where a high discrepancy -meaning a ratio well over or under 1- can lead to backorders and increase overall costs; it is expressed as

$$\frac{MRP\ Inventory\ Count}{Physical\ Inventory\ Count}$$

- On-Time Deliveries (OTD), the percentage of deliveries which are dispatched, received and cleared on schedule. This KPI is probably the most important as far as logistic operations are concerned, it is used as clear indicator of the quality of suppliers' operations. It is tracked on a monthly basis for each supplier and then weighted for each suppliers' expenditure.

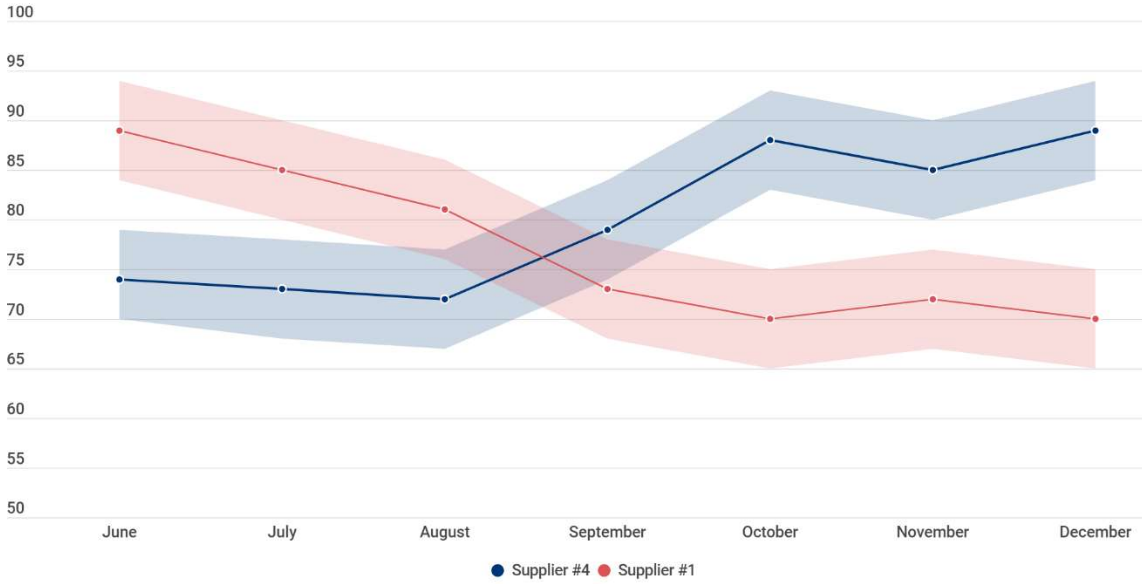

Figure 1.4: OTD% Comparison

2 Working Environment & Processes

2.1 SCM Office

The Supply Chain Management office houses the many category managers and buyers in charge of sourcing the many raw materials, components and Work In Progress or semi-finished goods. The roles within the office are divided by type of material handled within the following categories:

- Plastic Components: These molded goods are produced by smaller external suppliers located throughout Europe operating within a subcontracting agreement. SCM provides them with the required molds which are then mounted by the suppliers on their presses.
- Metal Components: These goods are bought both from smaller and larger suppliers operating within a global supply chain. Both raw reels and semi-finished cast-died materials are ordered by the buyer according to the processes in which they are needed.
- Electronic Components: This printed circuit boards are designed ad-hoc by ABB and commissioned to Chinese suppliers which hold a monopoly over these goods due to their control over rare-earth elements.
- Brand Labelling: These products are produced outside ABB's premises and are labelled as ABB's own products only after quality inspections. The level of overseeing over these products is lower and therefore there is a much higher liability linked to eventual failures and misfunctions. Each category has an assigned manager in charge of overseeing the respective buyer while working on higher level projects. The only exception to this structure is the CapEX buyer, in charge of capital expenditures and reporting directly to the SCM Manager, to which every category manager also reports.

2.2 Supply Chain Structure

While the SCM office is located in Vittuone, suppliers are located throughout Europe with the highest concentration in northern Italy and ongoing production and quality operations are carried out in Santa Palomba near Rome. Most components are to be delivered under DAP (Delivered At Place) Incoterms at Santa Palomba's warehouses, meaning that the supplier is in charge of all packing and delivery costs and the risks tied to transportation shift to the buyer only once the destination has been reached.

However, in order to optimize delivery volumes across major suppliers, ABB put in place a shuttle service that crosses the north-eastern regions of Italy and collects the weekly supplies owed as per previous agreements; this operation is carried out under EXW (Ex Works) Incoterms: the buyer is charged with risks and costs of all operations such as packing and loading, even if carried out by the suppliers.

This service was established after carefully evaluating yearly delivery costs and potential savings tied to extreme optimization of truckloads and distance travelled and was possible only because of long-term collaborations and certainty of joint future paths.

Goods coming from outside Europe are shipped under different incoterms depending either on the category of the goods, the country of origin and the agreement in place with the supplier; they can be roughly split into the following groups:

- FCA: under the Free Carrier agreement the seller is in charge of delivering the goods, cleared for export, at a given destination; the buyer is in charge of unloading the goods and loading them onto its carrier. These terms are mostly used for deliveries coming from outside the EU: Chinese molds and electronic components, north-African semi-finished goods and rare-earths elements.
- DDP: Delivery Duty Paid terms are very risky for the supplier since they place all obligations on him, the risks shift to the buyer only upon unloading the goods. This agreement is harder to negotiate and is mostly used with deliveries from eastern Europe.

In recent times ABB acquired a plant located in Marostica, which is responsible for in-house production of smaller job-shop batches. This plant's supply chain is also handled by the SCM office in Vittuone, with a different approach:

- There are no mass productions, but rather smaller projects with different customers all over the world with a focus on Australia.
- The most used raw materials such as common plastic compounds and metals are kept in Vendor Managed Inventories while others are ordered as required.

Payments are handled by another office except for those invoices that are disputed by ABB's accounting. When an invoice is wrong or not exhaustive it is automatically sent to a software solution which ties SAP to ABB's payroll systems, this software is handled in a centralized Polish office, in charge of collaborating with local buyers and category managers in order to solve any problem.

This process is clearly cumbersome due to the necessity of locating information spread across several offices, documents and colleagues; a slower approach in such a vital aspect of a company can lead to many problems with far reaching consequences such as:

- Buyers and category managers are burdened with other time-consuming tasks with no value added.
- The backlog of unresolved invoices tends to grow over time if not solved quickly, leading to a volume which can hardly be tackled by a single person.
- Suppliers can be damaged by a slower cashflow, losing competitive advantage over competitors as a result of slower operations.
- Suppliers' relations can degrade over time with extreme consequences such as threatening legal actions or blocking shipments.

This approach to handling payments was established not long before my arrival and as such is a work in progress, with its inherent flaws and solvable problems; it has, however, raised due questions and concerns from the SCM Office.

2.3 Injection Molding Process

Injection molding is a manufacturing process that can be performed with various materials such as metals (die-casting), glasses, elastomers and especially thermosetting and thermoplastic polymers. Due to its versatility this process is today the most common method to mass manufacture a large variety of plastic components; for the purposes of this paper I will only discuss thermoplastic polymers since they are the only category employed by ABB's Vittuone Business Unit. This process in conducted in-house by the suppliers and requires an injection press, consisting of the following equipment:

- Material Hopper: Used to store the bulk of plastic pellets before they are processed.
- Screw Plunger: This helical reciprocating screw is used to feed the plastic pellets in the heating unit and then drive the flowing material inside the mold. It maintains constant speed for the first part of the process and then, once the material is being feed into the mold, it provides constant pressure by adjusting its speed.
- Heating Unit: This cylindrical chamber provides the heat that, combined with the shearing action of the screw, weakens the Wan-der-Waals forces of the polymer in order to reduce its viscosity. This place is also where, eventually, the masterbatch or dye is added. The flowing material is gathered at the front of the screw into a volume called "shot" which is equivalent to the part volume plus a percentage to offset linear shrinkage (dependent on material used and easily calculated).
- Clamping Unit: The majority of this units have an hydraulic driving system and provide the pressure to hold the mold in place, hold the two parts against each other and eject, through specific pins, the components from the mold once they are complete.

Once the components are ejected, it is often required that the final components are separated from the sprue; this can either be done manually for complex geometries or automatically for simpler parts. The sprue can then be grinded and reused for following batches, mixed with non-grinded material in a 1:4 ratio; according to Supply chain rationalization directives, ABB Vittuone does not use grinded material for its products.

Injection molding leads to inevitable minor defects such as gate marks, parting lines, ejector pin marks; for internal components with larger clearances these defects do not cause any problem while for external aesthetics and tight clearances it is required further processing such as deburring.

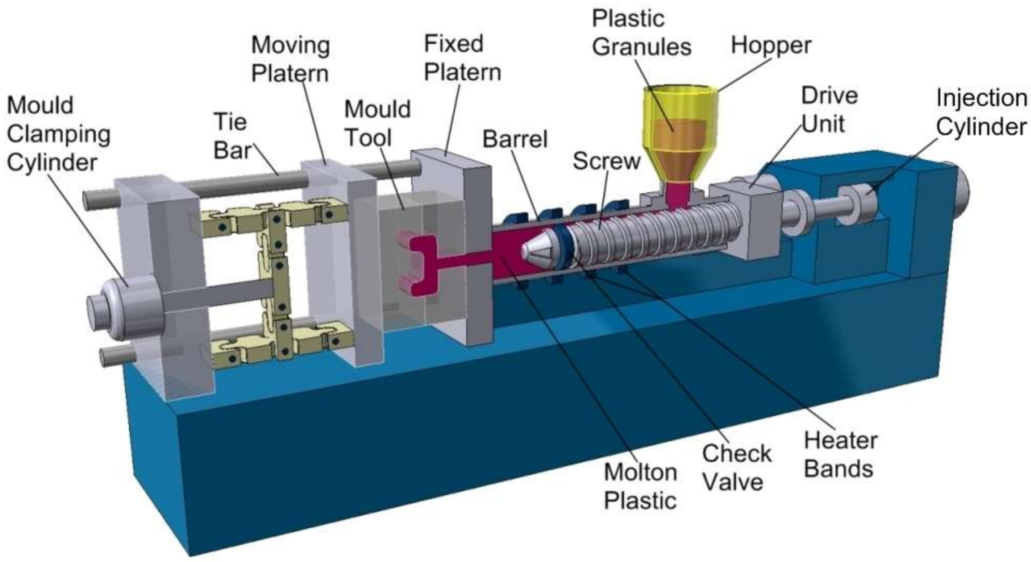

Figure 2.1: Injection Molding Schematics

2.3.1 Molds

Plastic components are designed by ABB and produced by external suppliers, which operate their own fleet of presses, with the process of injection molding. The molds needed for production are manufactured either by the final supplier itself or by specialized suppliers which do not use the molds after building them.

- Italian suppliers are often preferred to realize high quality molds to achieve more complex geometries, smaller parting lines, more cavities and lower tolerances. These molds are clearly more expensive since they are realized with hard alloys which are difficult to process, often requiring electric discharge machining (EDM), rectification, precision machining in a country with higher labor costs. Their prices range from the tens of thousands to the hundreds.
- Chinese suppliers are the standard choice for heavy duty molds which are employed for simpler geometries, smaller parts and aim to achieve higher volumes and longer production lives. They are often used to build cheaper “trial molds” with aluminum alloys and with much shorter lives which are then used to test some part designs.

The lead times -shipping included- for these molds ranges from two or three months for the aluminum trial molds to upward of six months for more complex and higher quality molds.

Chinese suppliers conduct massive operations and are able to fulfill hundreds of orders at the same time due to their structure. Italian suppliers on the other hand belong to the PMI category, which is the most widespread in our country, due to their limited size they can fulfill one or two mold orders a year. Once the molds are delivered, they are tested with pre-series and, when needed, adapted to the press available within the supplier fleet. Most if not all maintenance operations are conducted in-house in the tooling department of the supplier to keep the Mean

Time to Repair at a minimum by avoiding shipping operations which could potentially further damage the molds

The mold also determines the injection type used to manufacture the components, often related to the intended material:

- Traditional injection: the molten flow is injected through a sprue, is channeled in the runners and then fills the cavities entering their gate. The volume of the sprue and the runners is comprised in the shot, all this excess material must be removed and therefore might be a significant source of cost in the case of techno polymers.
- Hot-chamber injection: this approach is used to minimize excess material and avoid gate marks by injecting the molten flow directly into the cavity through a spot nozzle. This technology also allows to place the injection point in the optimal place. The disadvantages of this approach are mainly tied to increased cost of the mold, complexity of the equipment and maintenance.

2.3.2 Raw Materials

The physical and technical requirements defined during the design phase are met by employing different polymers according to the desired specifics. This job is carried out by the engineering team, which tests several candidate materials in order to understand which one satisfies the requirements without exceeding them excessively (causing extra costs) while also providing a security margin.

Materials with better technical specifications are often far more difficult to work with, throughout the molding process, due to several criticalities:

- Higher melting point.
- Increased mold wear rate.
- Higher feed pressure.
- Increased screw wear rate.
- Creation of toxic gasses within the mold.
- Increased linear shrinkage rate.

The advantages tied to employing these materials are often related to the following main specifications:

- Increased tensile strength.
- Increased dimensional stability at higher temperatures.
- Higher heat deflection temperature.
- Improved flammability rating.
- Improved electrical resistivity.

Suppliers are in charge of buying both the raw materials and the masters (which are dyes mixed with the polymer in order to achieve different final colors), by taking on this financial burden they relieve pressure on ABB's cashflow. However, the price at which suppliers buy the raw materials is negotiated by divisional category managers in order to leverage ABB's size of operations and order quantities.

Each supplier is provided with a pricelist for the various classes of materials negotiated based on the yearly order quantities of the whole division; if each supplier were to source the raw materials by itself it would lead to far higher prices due to their reduced volumes. On the other hand, as of summer 2019, dyes and masters were sourced directly by the component supplier; this aspect will be further explained in the relevant section.

During my time in the SCM office it was made clear that a collective negotiation conducted by divisional category managers would lead to significant savings. A project of such magnitude would clearly require a common effort a various level of the organization.

The materials which are most commonly employed, and therefore have been thoroughly tested according to ABB's quality standard in compliance with the industry's legislations and requirements are:

- Polymers:
  - Nylon 6 and Nylon 66
  - Polypropylene and Expanded Polypropylene
  - Polyphthalamide
- Technopolymers:
  - Polycarbonates
  - Polyphenylene Sulfide
  - Polyether Ether Ketone
  - Polyoxymethylene
  - Polybutylene Terephthalate
  - Polyetherimide

All these materials are available in different versions, with different additives such as glass fiber.

2.3.3 Maintenance

Molds are significant investments, therefore it is of utmost importance that their productive lives are prolonged through preventive, routine and extraordinary maintenance. In the following lines I will present the most common operations carried out by the suppliers according to their recollections. The bulk of preventive and routine maintenance operations is carried out without taking the mold off of the injection press, this is especially advantageous since setup times represent a significant source of cost. Frequent cleaning operations are simple yet very important, the mold's cavities can develop a thin film of material that needs to be rinsed out in order to avoid dimensional defects. The screw and heating unit may also fill with specks of burnt material or dirt that can damage the equipment in the long run, therefore cleaning is both a routine and preventive operation. It can be carried out either by manually scraping excess material off of the mold or by loading purging compounds in the hopper. Operations that require the mold off of the press are much more critical, they often cannot be postponed and negatively impact costs, production capacity and planning:

- Repairs: ejection pins, sleeves, strippers are only some of the more fragile mold components that can breakdown; dents and local shavings of metal can be present within the cavities. Suppliers are equipped to perform most of these repairs, except for extremely extensive and serious damages.
- Replacement: although infrequently, the helical reciprocating screw must be changed due to dullness caused by the shear forces applied to both the raw material and the screw; this wear has far-reaching consequences such as increased energy consumption, decreased quality due to uneven pressure, increased cycle time. The wear rate is tied to the type of polymer used, the percentage of glass fiber and grinded material within the flow, its melting point and abrasiveness. These screws could potentially be repaired if the correct precautions and measures are put in place, this subject will be analyzed further in the relative section.
- Cooldown: running a mold for days without breaks can put lots of stress on it eventually leading to a premature "burnout". This notion was often presented as common knowledge by both the suppliers and the engineering team, highlighting the need for a "cooldown" period for the mold. During this time the mold is inevitably taken off of the press and replaced so that the supplier can optimize its production schedule, this practice doubles the number of setups needed and will be further analyzed in order to understand if there is an optimal approach to this problem.

2.4 VMI Invoices Handling

The plant located in Marostica has in-house production for many plastic components and, to spread raw materials costs over a longer period of time and improve cash flow, uses Vendor Managed Inventories for its plastic compounds which are stored in-house and payed upon withdrawal.

Each withdrawal's information is coded and stored in SAP where the supplier can consult it and then invoice accordingly, associating an invoice line to each withdrawal ID to trace costs transparently; this process, however, has not been established with all suppliers, mostly due to technological deficiencies and a lack of integration of the supply chain. In these cases, the process to work out invoicing details is far more complicated:

- The amount of raw material withdrawn in Marostica (in each weekly or monthly tranche) is communicated to the supplier by Marostica's workers.

- The invoice is billed and sent to ABB, it is scanned and digitalized if not already in a digital format. Often a single time period is not associated with a single invoice, mostly due to asynchronies in communications and the fear of a single error in invoicing blocking large sum of money owed to the supplier; therefore the total amount withdrawn is often split into several invoices, if one is wrong the other are still paid in time.
- Due to the missing withdrawal IDs, the invoices are automatically disputed and enters ABB's Basware flow, a software solution that links SAP and payroll systems.
- The commodity buyer enters its Basware profile and finds all disputed invoices and the disputes' reasons, in case of VMI invoices, missing withdrawal IDs to match the declaration of the supplier.
- The buyer has to trace each withdrawal to the relevant invoice line, matching quantities. Due to the fragmentation of invoices, this task is incredibly time consuming and approached tentatively due to a lack of a clear methodology to solve this problem.

I tried to develop a new method of approaching this problem in a easier and faster way, which is discussed in the relevant section #6.

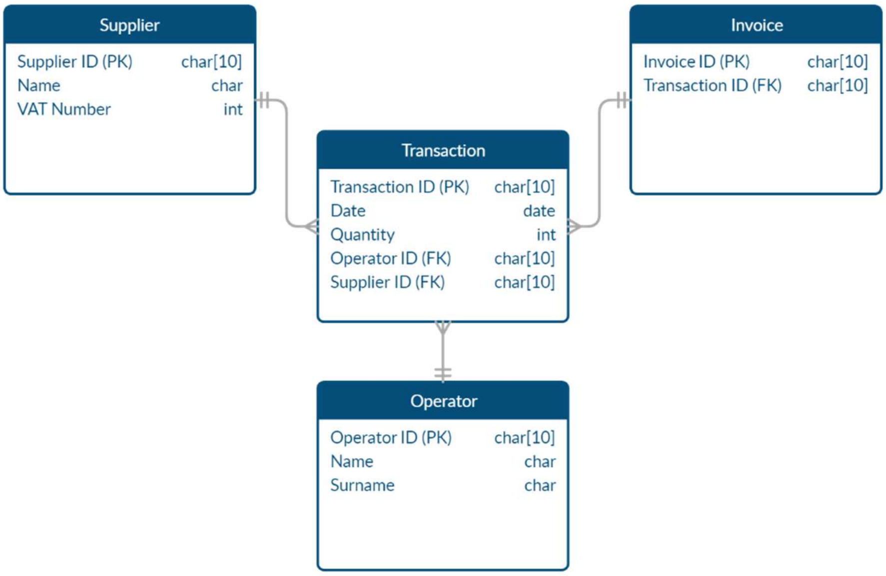

Figure 2.2: Relational representation of Invoice elements and data

3 Internship Recurring Activities

3.1 Request for Quotations

As a buyer, RfQs are some of the most recurring activities: they consist of inquiries with established and potential suppliers for production prices of a given set of components at a set yearly volume. Due to ABB' internal regulations each RfQ must include at least three different suppliers to ensure a wider sample and range of opportunities, this number is often exceeded due to the dimension of the tenders.

These inquiries can be part of market surveys, as part of benchmarks or to allocate a production package to the supplier who brings forward the best offer.

The latter has a clearer goal, it's the beginning of a process that accounts for potential savings and has long-term consequences as far as SCM goes; it can be carried out in two main cases:

1. Once a project concerning a new product is near completion, the project buyer -who is the main figure up to this point- consults with the commodity buyer in order to establish which are the best candidates among the established supplier base. In this case it is often preferable awarding the whole product line to a single supplier to simplify its handling, achieve a homogenous quality level and troubleshoot the setup of the production line only once.
2. As part of a saving strategy, the commodity buyer may decide to re-allocate components -either related or unrelated- to profit off of further market developments based on the last benchmarks or simply to rationalize a supply chain that has drifted toward a suboptimal situation. This case study will be analyzed in section #4.

The choice of the potential best suppliers is usually driven by the following factors:

- Difficulty: in case the components are geometrically complex, require particular treatments, are made up of techno polymers or require an extremely low level of defects it is often preferred relying on big Italian suppliers.
- Volume: yearly volume orders in the millions can hardly be fulfilled by one small supplier without risking delays, excessive volumes are one of the main culprits of an unbalanced supply chain and can lead to a degradation of the supplier KPIs as a direct result of the SCM office's errors.
- Position: if a production line is expected to be troublesome, requiring constant fixes or consultancy from ABB's engineers, it is often preferable to award the production package to a close supplier which can be audited easily and often.
- Margins: low value-added mass productions of trivial components are more likely to be delocalized to Eastern Europe while high value-added ones can be sustained in a HCC (High Cost Country) such as Italy.

These factors must be evaluated while keeping in mind the overall SCM strategy at a Business Unit, and sometimes Division, level:

- Growth: if a certain supplier shows great promises of future success, ABB may be interested in helping it grow in order to establish an early collaboration from which it will benefit in the future. The cost of this relationship development might be more forgiving negotiations and thus slightly higher margins.
- Leverage: buyers and managers must carefully evaluate their leverage against the various suppliers. If a supplier's business is largely tied to ABB then it is easier to negotiate favorable conditions due to their dependence, and further increase ABB's percentage of overall business. This type of shrewd strategy prioritizes short term returns and savings, however, it can prove to be a double-edged sword in the long run; it may alienate other current suppliers and scare away potential ones, most importantly it may cause financial struggles for the supplier and damage ABB's own interests. "The bottom line on leverage is that it is a tool that more often than not creates antagonistic relationships. This is okay when you're in a wrestling match or, as in the case with commodities, you don't rely on the supplier for anything other than the parts you buy and you have other comparable sources available. But when you have costs that go beyond piece-price, leverage is a strategy that often doesn't produce the optimal result" (Staff, s.d.).
- The same concept can be easily traced to the supplier's side and the leverage that it can exert on ABB's operations; a supplier that is in charge of a large percentage of ABB's supplies whereas ABB is only a small part of its total business. In this case it is far more difficult to drive hard bargains and reduce costs unless the supply is for very trivial components, at the same time such a large supplier may not be interested at all in low value-added productions. When dealing with large multi-division companies this problem is compounded by the simultaneity of operations of different and unrelated SCM offices; if a supplier has already established a business relationship with another division, with set prices and margins, it is far more difficult -if not impossible- for another SCM office negotiating better conditions, furthermore the supplier can take advantage of the inter-divisional competition for the same resources to inflate its prices.
- Exposure: it is important to keep track of the financial situation of established supplier in order to properly risk manage the allocation of the company resources and the sources of our supplies; reducing exposure to catastrophic events such as supplier bankruptcy, crowding out or other critical events is incredibly important and the due diligence required can be greatly reduced with proper SCM tools such as supplier performance reports.

3.1.1 Plastic Components Cost Breakdown

Once the suitors of the RfQ have been decided, the buyer is in charge of preparing a mock cost breakdown in which all useful information concerning the components are conveyed in a quick and clear manner. This breakdown is different for each category of materials, and it would be impossible for me to describe each one; I will focus on the plastic components cost breakdown and briefly talk about the major differences from the metal components one.

It must be highlighted that the plastic cost breakdown is standardized across the whole division in order to evaluate each cost item with the same objective metrics.

The suppliers will receive the cost breakdown alongside an e-mail that explains the scope of the quotation requested, the due date of the request, the technical drawings of the components, quality documents such as the SCP (Scheda Controllo Particolari) and, sometimes, the notice of a sample dispatched to them.

The information provided by the buyer are grouped into five categories, each one sums up the costs of the related items:

- **General Information**
    - Part Number: ABB's unique code to identify the component.
    - Part Description.
    - Drawing Number: ABB's unique code to identify the component's technical drawing.
    - Technology: the type of process used to create the part, for Vittuone's Hub this field can only be "Thermoplastic Injection".
    - Supplier Name.
    - Supplier Country.
    - Supplier City.
    - MOQ: Minimum Order Quantity, the least number of pieces that are profitable to produce at a given price point.
    - Lead Time.
    - Annual Quantity: the needed annual volume forecasted by ABB.
- **Material Costs**
    - Trade Name of Raw Material.
    - Raw Material Producer: ABB's divisional supplier for the given raw material.
    - Lot Size (kg): the MOQ for the raw material.
    - Raw Material Price (€/kg): the price point negotiated by ABB's divisional category manager.
    - Density.
    - Gross Weight (g): the component weight, including the sprue and runner.
    - Net Weight (g): the shear component weight.
    - Recycling (%): the percentage of re-grinded material used in the molding process, within ABB's hub this practice is not used thus this field is always zero.

    - Material Markup (%): surcharge applied by the supplier and related to the handling of raw materials, from buying to stocking.
    - Customs (%): surcharge applied by the supplier in relation to customs clearances costs and practices.
- **Production Costs**
    - Clamping Force (tons): the tonnage of the press needed to mold the components.
    - Cycle Time (s).
    - Number of Cavities: the number of components produced with each shot in the specified cycle time.
    - Variable Cost* (€/h): this field is used to report the hourly cost of the operator.
    - Fixed Cost* (€/h): this field includes many cost items which are discussed in section #5.2.
- **Others**
    - Others 1: Masterbatch (€/pcs).
    - Others 2: Thermal Treatments (€/pcs).
    - Others 3: Deburring (€/pcs).
- **Logistic Costs**
    - Packing Cost (€/box): this field includes costs such as labor force, boxes, labels and plastic wrappings.
    - Quantity per Box.
    - Packing Cost (€/pcs).
    - Shipping Cost (€/pcs): this field is not filled by supplier working under Ex Works Incoterms.
- **Total Cost**

This cost breakdown is incredibly extensive and detailed, mirroring the complex SCM strategy behind the production of molded plastic components and attempting to account for -and isolate- every possible source of cost in order to enable targeted cost-reducing actions in a highly integrated supply chain.

3.2 Relevant Formulas

$$Material\ Cost = \frac{Raw\ Material\ Price}{1000} * Net\ Weight * (1 + Recycling\ \% \ + Material\ markup + Customs\ \%)$$

$$if\ 1 - \frac{Net\ Weight}{Gross\ Weight} < Recycling\ \%$$

$$Material\ Cost = \frac{Raw\ Material\ Price}{1000} * Net\ Weight * (1 + Recycling\ \% \ + Material\ markup + Customs\ \%) * (1 - Recycling\ \%)$$

$$if\ 1 - \frac{Net\ Weight}{Gross\ Weight} > Recycling\ \%$$

$$Production\ Cost = \frac{Fixed\ Cost + Variable\ Cost}{3600} * \frac{Cycle\ Time}{N°\ of\ Cavities}$$

$$Logistic\ Cost = \frac{Packing\ Cost}{Quantity\ per\ box} + Shipping\ Cost$$

3.3 Metals Cost Breakdown

On the other hand, the cost breakdown for metal components is provided by the supplier itself and is far simpler, with fewer fields that sum up information that is explicated in detail for plastic components:

- Part Number: ABB's unique code to identify the component.
- Raw Material.
- Raw Material Cost (€/kg): unlike plastics, this cost is not negotiated at a divisional level but established on a monthly or semiannual basis according to the material's price on the futures market. This approach is more fitting for high volatility material's prices such as gold, silver, copper, zinc etc.
- Processing (€/pcs): the fixed piece cost of manufacturing a component with a given method.
- Extra (€/pcs): any post-processing operation such plating, quenching or tempering, these may be either fixed or variable depending on the techniques used.

3.4 Offers Evaluation

The suppliers must fill out the cost breakdown with their respective forecasted costs and notify the buyer of potential meaningful sources of variability within their forecasts, they are often encouraged to critique the specifics established by ABB during the design process in order to find and fix potential mistakes or suboptimal choices.

The offers are not evaluated by slavishly comparing each cost field, that approach would not be useful in properly addressing the pros and cons of the various; however, since there is not a proper standard process, it is up to the buyer how to approach this task and the weight given to the different factors.

It must be understood that a significant trade-off of control is accepted, leaving such discretion to the buyer is an important sign of trust at a company level and can be rewarded by their personal insights.

This process can be automatized by employing ad-hoc solutions such as Easy Procurement and SAP Ariba, which enable the buyer to shorten this process by having each supplier enter their offers directly on a dedicated webpage which than populates the linked database.

3.4.1 Negotiations

This phase is entirely discretional and can be approached and conducted in a multitude of ways, most of which I would not be able to properly describe. All the factors taken into account when choosing the potential suitors of the manufacturing package are extremely relevant during the negotiation phase and can be leveraged by each side to profit off of the other. The adversarial component implicit in this phase can be avoided or dampened if the respective part's objectives are tame or expected as part of a continuous relationship.

Further insights into this phase are available at the relative section detailing my operations within ABB's SCM Office.

3.5 Allotment

When the negotiations come to an end and the final offers are ready, it is time to award the manufacturing package to the supplier who brought forward the best one. This process can involve the buyer, the buyer and the category manager or buyer, category manager and SCM manager depending on the scope and financial impact of the choice; the same factor influences the timing and deadlines of decisions and operation.

Once the package has been awarded, a host of processes are set in motion in order to set-up the production line:

- The molds must be dispatched to the supplier, either from China or Italy, in several tranches to avoid overburdening its tooling department.
- Once the molds have reached him, the supplier must inspect them and eventually adapt them to the presses available within the fleet.
- The supplier produces trial pre-series that are evaluated by his and ABB's quality departments, if any non-conformity is found ABB's engineering team and the supplier collaborate to troubleshoot and fix the sources of the problems. This step is repeated until the required quality level is achieved and the production line is activated.
- The planning department communicates the weekly and monthly volumes for the following trimester. ABB pledges to pay and pick up all components forecasted in this trimester -even in case of reduced demand, market crashes or other catastrophic events- in order to grant a high degree of security for the supplier and ease its production planning.

3.6 Benchmarking

Benchmarking is the process through which the buyers and category managers can keep track of the market in which they operate, gaining deeper insights by comparing business practices, cost structures, organizational models and technologies employed across all their suppliers. This process is not discrete but rather continuous, ongoing at different levels within the organization: each level feeds off of the lower levels aggregate data to create a bigger picture, the higher the level the larger the scope.

Amidst normal benchmarking operations I was asked to work under Andrea Leone, Global Plastic Category Manager for the Electrification Division in order to create a report concerning cost discrepancies among Business Lines which work with the same suppliers and mostly in the same geographical area. In order to bring this task to completion I sifted through the pricelists of the twenty most important suppliers to compare their production costs for presses within the same tonnage range and comparable materials; besides the internal comparison, I carried out a comparison with foreign suppliers located in Eastern Europe and Asia which is not publicly available and has been omitted.

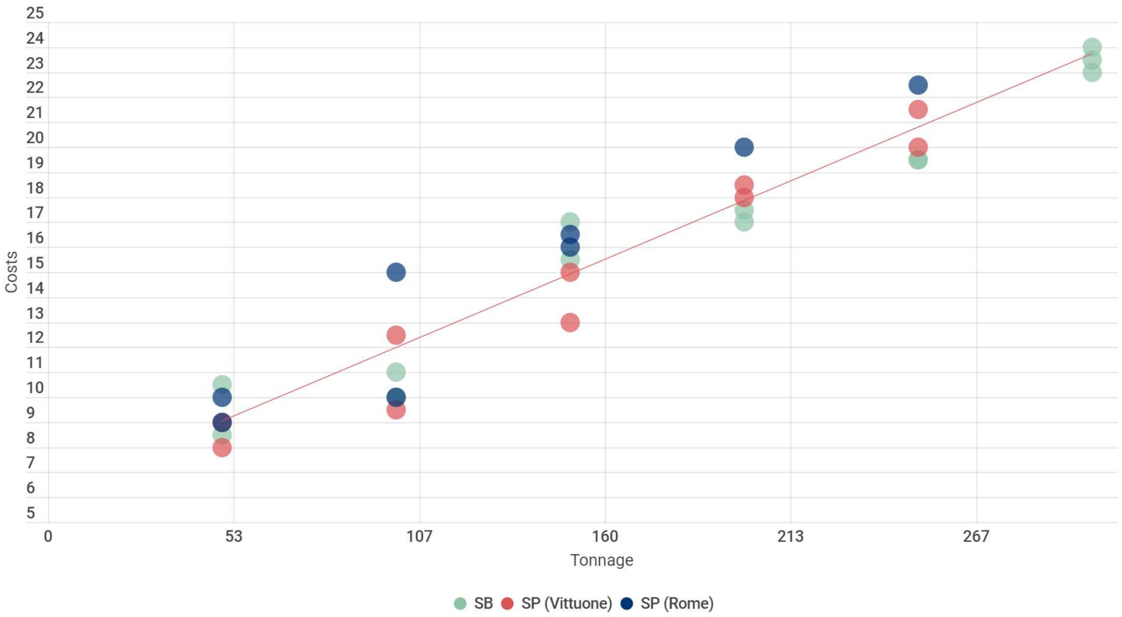

Figure 3.1: Cost comparison across SCM offices

The most significant discrepancies were found among the suppliers located in central Italy, mostly in Lazio, which supply both the plants of Frosinone (SB) and Santa Palomba (SP) but at incredibly different price points, with some extremely disturbing outliers.

Once I had aggregated all data for these suppliers, I weighted each fixed cost per ton against total expenditure and then compared the weighted average with the aggregate data provided by the Global Category Manager for the Smart Business product line.

The findings of these benchmarking were shocking, though somewhat expected, and spurred the Global Category Manager to apply immediate pressure on Santa Palomba's SCM detachment in order to nip this situation in the bud and to understand the causes behind such outliers.

After a few calls and meetings between Vittuone and Santa Palomba's plastic buyers overseen by the Global figure, these outliers were analyzed one-by-one and mostly understood with some notable egregious exceptions:

- Some savings were perhaps achieved by awarding other overpriced productions, effectively cancelling each other out.
- While smaller MOQ with lower annual volumes call for increased costs, some of the smaller productions were still overpriced when compared both to Northern Italy suppliers and SB suppliers located in Lazio.
- Materials usually very cheap to process were being priced like technopolymers by at least two different suppliers.

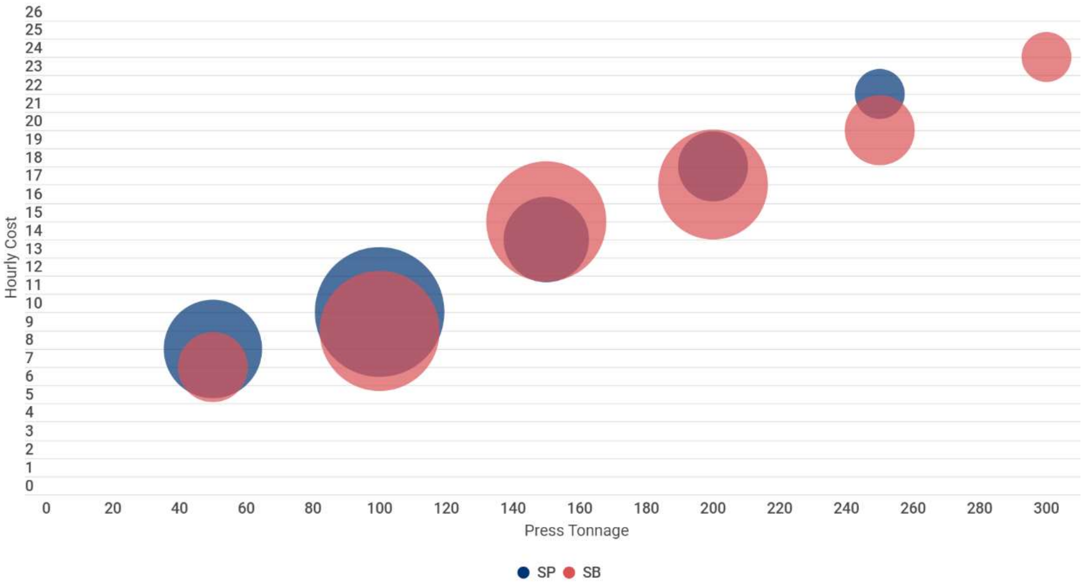

Figure 3.2: Product Line cost comparison (size of bubble represents number of suppliers benchmarked)

3.7 SAP Management & Auditing

After some time -due to technical and bureaucratic delays- in the SCM Office I was given my personal SAP access, to help the plastic buyer handling the various recurring tasks such as:

- Fixing delta prices in VMI and normal invoices.
- Adjusting prices according to new incoming pricelist and quotations.
- Ordering molds and pre-series.
- Benchmarking.
- Checking shipments and the relative documents.
- Checking quality processes such as shipment acceptance, rejection and pre-series clearance.
- Checking components' details and/or enabling them for ordering.
- Updating Inforecords and Source Lists.

Each SAP task is associated with a unique alphanumerical code made up of four characters, the first two letters identify the module while the final digits specify the action:

Number	Action
01	Create
02	Change
03	View

Table 3.1: SAP Codes

SAP is highly hierarchized and, as such, not every module can be accessed by every user. Below a list of the most used modules during my internship and the respective codes:

T-code Beginning	Module
M	Materials Management
ME	Purchasing
ME1	Purchase Requisition
ME2	Purchase Order
MM	Material Master
MK	Material Vendor Master
MR	MM Invoice Verification
VF	Billing

Table 3.2: SAP Transactions

For auditing purposes, it is extremely important that all information kept on SAP is consistent, transparent and traceable: in this particular case, an external audit was being carried out on behalf of New York Stock Exchange (NYSE) to verify that ABB was complying with all the rules imposed by NYSE to allow a company being quoted on its market.

The rules which I had to ensure were being enforced were the following:

1. Purchasing has to be broken down into more steps which are carried out by different figures within the company, this measure is applied to avoid malpractices, unjustified spending and scams and is enforced in the following way:
   a) Position #1 (this can be a host of different positions) issues a Request for Purchase (RfP), which is categorized in SAP and automatically sent to the relevant buyer.
   b) The relevant buyer either signs the order and sends it to the supplier or, if the requested commodity is not usually bought, sends various requests for quotations and the chooses the best offer.
   c) Once the commodity is delivered, a third person is in charge of signing the bill of delivery and entering into SAP the bill code to identify the material entrance in the company environment.
   d) The buyer forwards the bill to the accounting department to start the payment process.

   This process is designed to easily trace the movement of goods and money without any secrecy to avoid, per example, that the same person can request, order, receive and pay or attest the reception to enable payment of fictitious goods as a way of transferring money to accomplices in a fraud.

2. Dual power of attorney, which establishes a clear “chain of command” for purchasing operations, each purchase document has to be signed by at least two persons with one being the superior of the other and with highest hierarchical level being established by investment size:
    a) For expenditure up to €10,000 both the RfP issuer and the buyer sign the purchase order.
    b) For expenditure up to €50,000 both the buyer and the category manager sign the purchase order.
    c) For expenditure up to €150,000 both the category manager and the SCM manager sign the purchase order.
    d) For expenditure up to €500,000 both the SCM manager and the HUB manager sign the purchase order.
3. Traceability and consistency, each price change, source change discount or variation related to the SCM office has to be motivated by an official communication between the supplier and the relevant buyer or category manager.

3.7.1 Inforecords – ME11

Inforecords are timed data entries which specify materials’ price, lead time and MOQ. Each Inforecord is tied to a supplier and allows for more price entries, according to the timed validity and the associated MOQ. The individual Inforecords can also be associated with a collective pricelist, this additional step ensures that each price is tied to a specific supplier communication; to smooth over the auditing process, I had to double check each supplier’s Inforecords and collect hundreds of pricelists that had not been updated regularly (they usually require an update each six month), each pricelist was checked again and compared to the previous version to figure out the total savings or extra costs. Once the pricelists were checked and compared, most had to be entered in the MRP and approved by the relevant category manager and SCM manager, this endeavor took over three weeks of discontinuous work.

3.7.2 Source List – ME01

A source list is a list of approved suppliers for a single SKU, it usually marks which supplier is the preferred source and, in case multiple preferred sources exist, shows the percentage of supplies coming from each over the total yearly requirement.

These lists must be updated very frequently and quickly to avoid generating orders to dismissed or deprecated suppliers, such errors inevitably set off a chain reaction which damages economically the SCM Office and takes effort to repair.

3.7.3 Purchase Order – ME21N

A purchase order can only be created once a Request for Purchase has been issued, to limit the "power" and autonomy exerted by the buyers: for commonly bought commodities these RfP are usually issued by the Planning Department according to the rolling forecasts and the supplier's current Master Production Schedule; they can also be issued by Project Managers (pre-trials), Quality Specialists (to re-order rejected batches) and internal auditors for various reasons, these orders usually skip ahead -when possible- of the MPS due to their urgency and are far more expensive (except for rejected batches).

A purchase order can be considered "closed" or "fulfilled" only when all related goods are delivered and cleared, since orders can contain hosts of unrelated goods that are often delivered in separate tranches this can create a sort of "tracking error" in the following KPIs:

- Order Fulfillment Cycle Time, the average time span between order issue and order closure, this KPI is greatly affected when a large order is kept open because a single order line -often relatively insignificant economically speaking- has not been fulfilled.
- Buyer Past Due Orders, this metric track how many unfulfilled and past due orders are associated to a single buyer at a given moment in time and is supposed to reflect the buyer's ability to process anomalies in orders and solve any arising problem.

3.7.4 SAP Structure

All these structures are tied within the MRP to allow for an easier and consistent handling of data, most importantly it double checks that each data is consistent over time: for auditing purposes, understanding the structure which verifies information is extremely important because it serves as roadmap towards its proper maintenance.

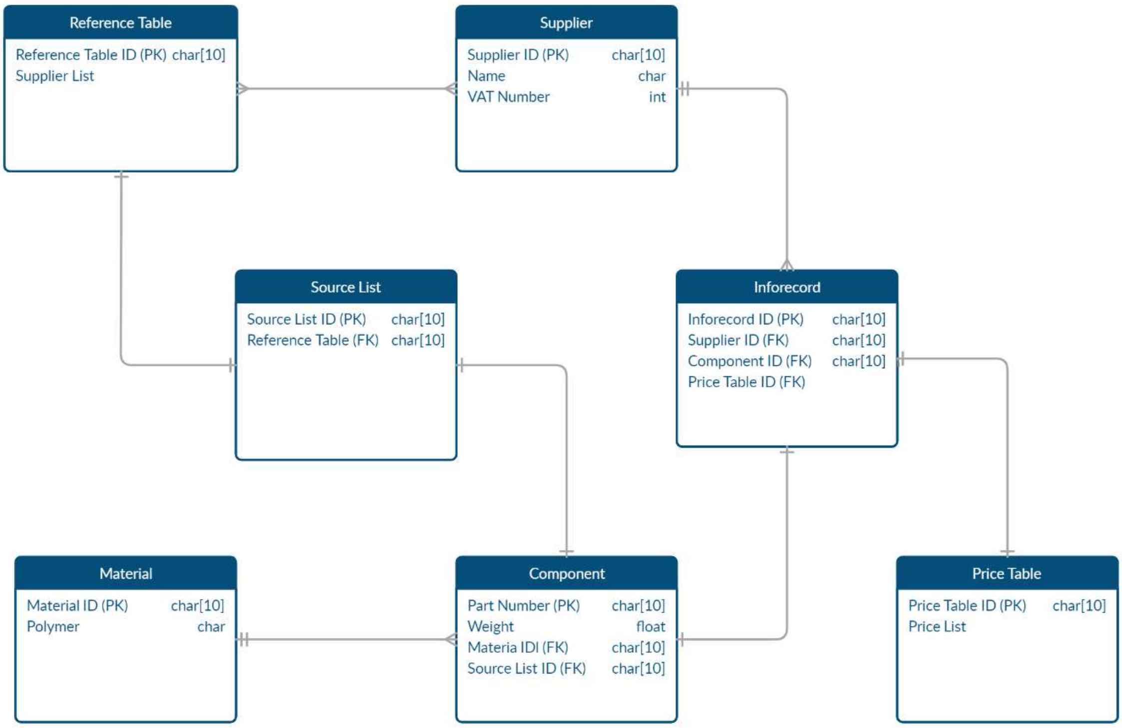

Figure 3.3: MRP Structure

Supplier List:

Supplier	Percentage	Preferred Source	Deprecated
Supplier #1	35%		
Supplier #2	0%		X
Supplier #3	65%	✓	

Table 3.3: Supplier Table

Price List:

Price	MOQ	Period Start	Period End
€3,20	1000	10/06/2019	31/10/2019
€2,85	10000	10/06/2019	31/10/2019

Table 3.4: Price Table

4 Main Project

4.1 Baseline

This stand-alone project was developed by my tutor, Marco Grassi, in order to reach the annual savings targets as specified in the Boost Program. He designed a rationalization strategy in order to create a production hub in charge of nylon (PA6 and PA66) molded parts; at the beginning these parts were scattered across three suppliers, all faced with their own challenges in the near future.

I combed through the pricelists of these suppliers and gathered all the part numbers and relevant cost breakdowns in order to better understand the scope of the task at hand, the production volumes and the combined supplier revenues tied to this type of components.

I identified and evaluated over eighty unique parts which accounted -yearly- for over 9,000,000 pieces and over €825,000 in direct costs; these parts were tied to around fifty molds, which sparked the first controversy and critical point when discussing with the engineering team: these assets (so called “cespiti”) are not codified on SAP nor are they in any way registered or handled digitally, therefore it is impossible to know where they actually are and their current state without personally contacting each supplier and inquire about the molds’ whereabouts.

This problem caused a lot of delays during the beginning phases of the process and was gradually solved by the engineering team which had to recover each mold code by combing through many documents in what was an incredibly time consuming and non-value-added process. Going forward it would be pretty easy to prevent any situation like this by simply recording each mold within SAP and linking it to the component and eventual supplier.

Once this information had been gathered, the planning department was informed of the future development of the supply chain and was urged to stock up and plan ahead of the foreseeable future to account for a period of loss production.

To facilitate both this task and the setup of the production lines, it was established that the molds would be moved in three separate tranches spanning over six months.

The final step of this beginning phase was deciding which suppliers were the best candidates to undertake such an important manufacturing package while also granting ABB the required yearly savings.

4.2 Components and Supply Chain

Besides the clear common denominator of the raw material, the tender's manufacturing package comprised a heterogeneous mix of components regarding geometries and dimensions, colors, applications and position within the final product.

However, within the package itself, an important subset can be identified due to its relative weight: ten molds associated with simple half-covers were responsible for more than two thirds of the entire manufacturing volume. This production lines are quite different from "standard" ones, since the molded parts are then transferred to a third-party -in charge of a significant step of the process- and then reacquired by ABB. These half-covers are coupled together to house a magnetic core which is then used in different industrial applications, the most common one being in Residual Current Circuit Breakers (RCCB) and transformers in Energy Meters. These components belong in a complex value chain, exiting and reentering ABB's supply chain, they proved to be incredibly difficult to trace since we could not directly ask to the suppliers without arising suspects among them. The magnetic cores are not manufactured by ABB but from a French and a Deutsche multinational which provide magnetic cores for many different companies, therefore the various housings are funneled to collecting centers located strategically throughout Europe and then moved to Asia where they are assembled.

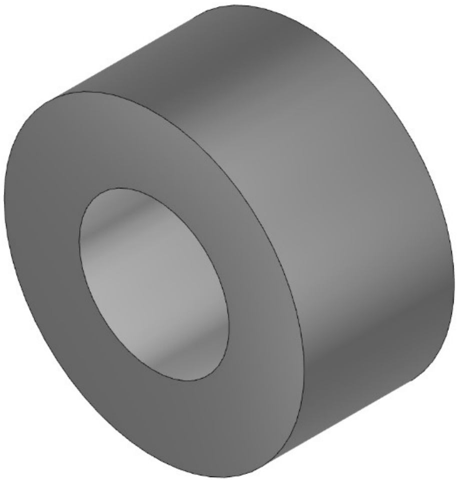

Figure 4.1: Isometric view of half-cover (front)

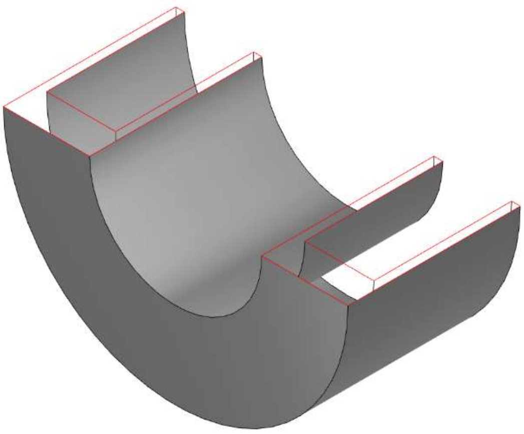

Figure 4.2: Isometric view of half-cover (section)

The covers are color coded and divided into two categories, upper and lower cover. The color of the upper part is used by ABB to trace which third parties assembled the core, while the color of the lower half is used to identify the voltage of the core inside; these system is especially useful in case of misfunctions and breakdowns to quickly understand which party is liable without opening or breaking the shell since the cores are extremely brittle and potentially toxic when broken down.

After various inquiries with middlemen in charge of the collecting operations, we were able to gain more insights in the path undertook by these components and the Incoterms under which each supplier was currently working with the third party. This research also led to a better understanding of the different logistic costs charged by each supplier, since their terms with the third parties were negotiated individually.

We finally managed to reconstruct the movements of the components, shown above and described below:

- Two out of the three initial suppliers shipped, under FCA Incoterms, over a third of the total volume of components to Amiens (France), where the components exited ABB's supply chain and could not be traced any further; the best we could gather is that they were shipped by boat to China, assembled in Asia and then re-shipped to Europe.
- The other two thirds of the production were sent to Deutschland, collected by Vacuumschmelze and then shipped to Malaysia for assembly. Components were sent, under FCA Incoterms, either to Hamburg's port or to Frankfurt's airport based on the deadlines for arrival in Malaysia.

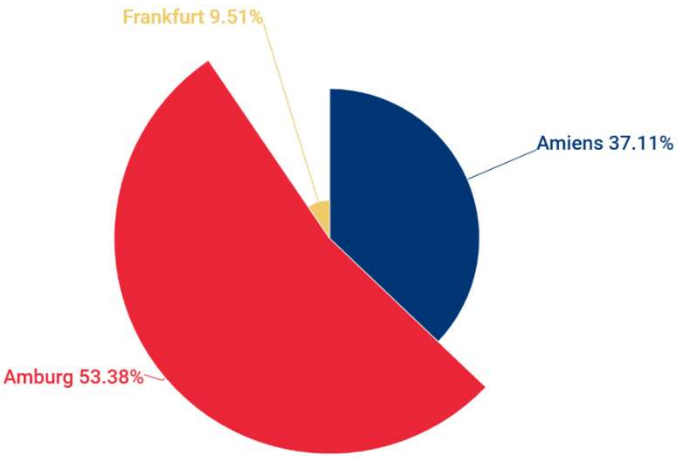

Figure 4.3: Collecting centers by volume %

- The last supplier, which corresponds to Supplier #1 described below, oversaw shipping the components directly to Malaysia under DDP Incoterms thus incurring in much higher costs. Since production was still ongoing, we strongly advised the supplier to renegotiate its agreement with the company in charge of assembly due to the burden of supplying under DDP all the way from Italy to SEA (South East Asia) regions. He later restructured its supply chain and joined the collecting system established by Vacuumschmelze.

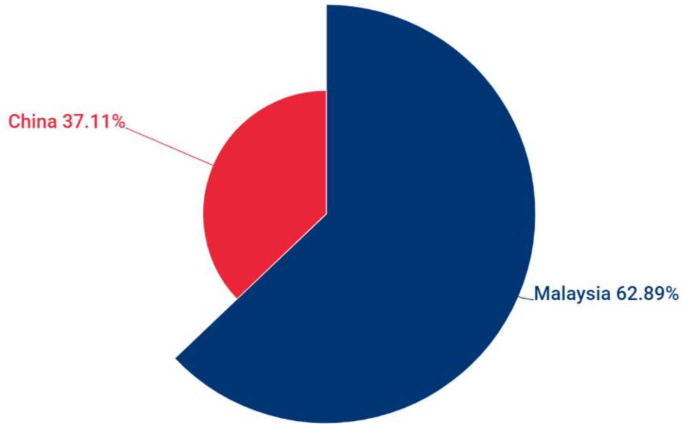

Figure 4.4: Country of destination by volume %

4.3 Supplier SWOTs

4.3.1 Supplier #1

This supplier had already been producing nylon components for a few years, in fact some of the components we intended to re-allocate were currently being manufactured here. These components are quite easy to manufacture due to their size and simple geometry; however, the supplier's track record with past, more complex geometries, granted they could achieve the desired quality levels while potentially offering a discount on the current prices to offset the huge increase in yearly volumes.

Figure 4.5: Supplier #1 SWOT

It was decided to include him in the tender due to the aforementioned reason and the following circumstances:

- Seeing as this supplier had been struggling for a while, it was a chance to allow him to regain some financial stability. If the supplier were to win the tender it would further leverage ABB, which would account for more than 90% of total revenues. Such an unbalanced relationship would prove to be beneficial for ABB, while the supplier would have had to use the newfound revenues to try and expand and attract other customers and other sources of income.
- This supplier was already accustomed with the intricacies of some of these components' supply chain, mostly associated to the various destinations of these components: these intricacies would prove to be a significant hurdle later down the road and which are explained in-depth in section #4.2.

The first quotations offered by the supplier accounted for the second most expensive offer, totaling around €780,000; nonetheless they were invited for a second round of inquiries and negotiations.

4.3.2 Supplier #2

This supplier was, at the time of the tender, in charge of some of the most valuable and massive production lines and other minor ones; nonetheless, its relationship with the SCM office had been strenuous for a while: agreements were often too difficult to reach and were sometimes unachievable.

To compound these issues, the products tied to the valuable production lines were closing in on the EOL (End of Life): this would represent the best possible moment for ABB to enact an exit strategy and completely exclude this vendor from its supply chain.

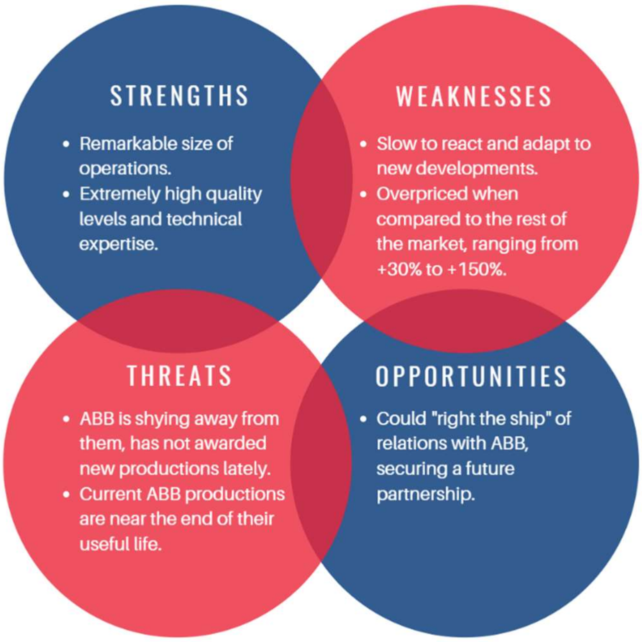

Figure 4.6: Supplier #2 SWOT

The supplier itself can clearly anticipate this future development by evaluating two simple signals:

- Current worn-out molds are not being replaced nor are they being re-worked, with high probability the related components are about to be obsolete.
- During the last two-year period they have been awarded fewer and fewer molds, none during the last 10 months.

The root causes of these disagreements can be found both within ABB and the supplier, with apparently no will to repair the underlying business relationship from both sides:

- ABB complains about the supplier slow response to its request, the inability to meet its demand or adapt to its business decisions despite continuously flaunting their complex management structure and business capabilities.
- The supplier is mostly involved in the automotive industry, which usually grants higher margins and more stable demand, easing production planning. They deem their structure worthy of higher compensation due to their capability in regards of quality, volumes, management which are fairly rewarded in the automotive industry but are not as appreciated by ABB.

This supplier brought forward the most expensive offer, totaling at over €900,000 and exceeding even the current costs. They were not invited to the negotiation phase seeing as it was impossible to reconcile their needs and ABB’s requests.

4.3.3 Supplier #3

This smaller supplier has been working with ABB for less than two years and is not in charge of productions as massive as this current tender.

However, this supplier recently set up a complex manufacturing line using advanced technologies, perhaps exceeding the SCM and engineering offices' expectations. While some doubts lingered about its ability to actually accommodate such a large manufacturing package, it was decided to include it in the tender.

Figure 4.7: Supplier #3 SWOT

Perhaps this decision was mostly a strategic one rather than the reflection of the supplier's possibilities to win the tender: by including a smaller and ambitious new supplier eager to win such a significant tender the SCM office was sure to drive down costs across the board by using it as a positive benchmark.

As expected, this supplier brought forward the cheapest offer at around €710,000 and was invited to the negotiation phase; its offer was so far better than any other to the point that to me, an inexperienced observer, the tender's winner was a foregone conclusion.

4.3.4 Supplier #4

Perhaps the BU's favorite supplier both due to their privileged geographical position, close to Vittuone, and their ability to provide quality components across the board -as far as geometries and materials go- and at a great price point.

They were currently supplying some of the components that Supplier #1 was also producing at a comparable cost, thus they were included in the tender with the same target: driving down current costs by reallocating only part of the manufacturing package.

Figure 4.8: Supplier #1 SWOT

During recent years this supplier has won a lot of massive manufacturing packages but, thanks to a cautious strategy, managed not to be too dependent on ABB diversifying its clientele and avoiding too much leverage on either side. Nonetheless, during the last year most KPIs of decreased dramatically due to increased demand by ABB on many different components; the supplier was unable to meet this unexpected and unanticipated surge in demand and obviously does not want to be held accountable for ABB's own errors.

The KPIs which were mostly affected by this crisis were:

- On-Time Deliveries (OTD): sharp decrease in the percentage of all deliveries that reach ABB right on time, fell to 10% lower than the minimum threshold.
- Non-conformities: increase in the percentage of deliveries which showed defective components, unsorted parts, non-colored or non-deburred pieces.
- Defect rate: increased defective components as a percentage of all components delivered.

This supplier brought forward an average offer, totaling around €750,000, while also suggesting some minor adjustments to improve and ease the production of some components.

4.4 Offers Comparison

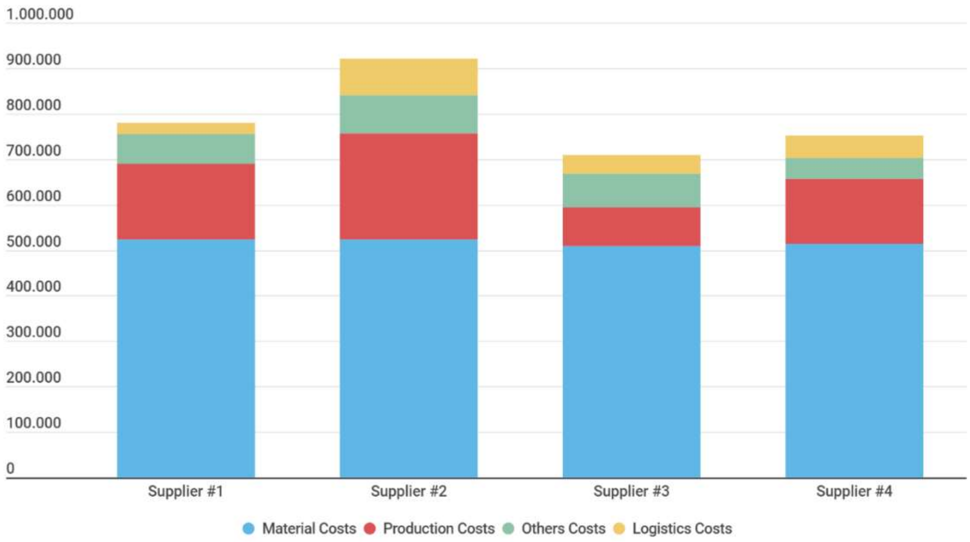

Figure 4.9: Cost breakdown of first offers

It is immediately obvious by looking at this cost comparison breakdown where the potential profit of the suppliers lies, with some due shrewdness; Production Costs are often labelled as "Transformation Revenue" for the supplier, but this label willfully ignores the possibility for suppliers of disguising their sources of revenues:

- When comparing Supplier #3 to the others, it was self-evident for the buyer how Supplier #3 had shifted some of its cost to the "Others" entry to undermine the other suppliers' hourly fixed cost. This was clear to me only after I analyzed the historical data concerning the various productions of each supplier.
- On the other hand Supplier #1 might be inflating its material costs to keep logistics cost as low as possible.

4.5 Negotiation

4.5.1 First Round

We decided to exclude Supplier #2 from this step due to the perceived irreconcilability of our views, which was made clear both throughout my experience and before. After evaluating all offers, we set up a series of individual meeting with each supplier in order to discuss any possible doubt or improvement proposed. Simultaneously, we gave the suppliers the chance of comparing their offer to the others (without disclosing any sensitive data) in order to better gauge their own performance and to understand where they can improve. We showed a breakdown of cost by component, without insight in the cost structure.

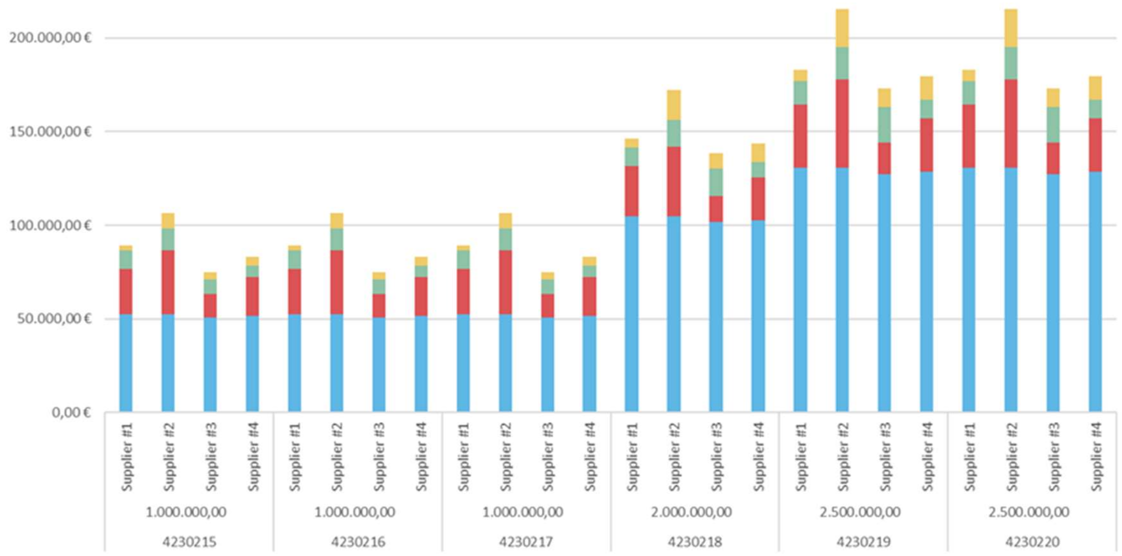

Figure 4.10: Cost comparison for each component

We received a mostly positive feedback from our supplier, with the exception of Supplier #1 which repeatedly lamented the "unlikely" costs reported by the other suppliers: he feared that we were comparing its offer with foreign competitors to undercut its pricing and did not accept our explanations in the first instance, but only after some convincing. All suppliers were invited to the second and final round of negotiation due to their will to collaborate with us and the shared perspective that each one could bring forward a better offer given the feedback received and more time to work out the various details to further optimize their cost structure.

I offhandedly pitched the idea of showing a comparison of the different offers, more as a question rather than an actual path, it was fully embraced by my tutor and with hindsight it can be said that it allowed a far more transparent discussion with the suppliers, which perceived it as a chance to trim the edges of their respective offers rather than a race to the bottom.

4.5.2 Second Round

The second round of negotiation was conducted mostly by our office, it was established that to reach our yearly goals we would have to realize fifty thousand euros more in cost reductions: we decided to include the winner of the tender in the shuttle scheme which already ran through the main northern Italian suppliers.

Furthermore, my tutor decided to impose a seven percent discount over the cheapest offer as the most desirable target; the supplier which came the closest to such offer would be awarded the tender. Personally, I did not expect the suppliers to accept such a bold target, especially considering their past complaints and the already strained relationships with some of them; however, I was astounded when all the suppliers met the target imposed by our office achieving up to 15,62% cost reduction over the original offer.

The inner workings of negotiations at the company level were truly obscure before this experience however I did gain more clarity:

- The buyer must have an insight over the inner workings of the supplier and its operations, this insight is mostly left unspoken unless it is needed to gain further discounts or disprove some of the misconception brought forward by the supplier to justify unwarranted costs.
- KPI monitoring can be used as a tool during negotiations, either threatening to enforce the strict thresholds established in the past but not respected or by granting laxer regulations. I would personally argue that using these tools, intended for monitoring and benchmark purposes, in such a way can prove to be detrimental in the long run seeing as the organization risks losing the pulse of the supplier's true performance and how it stacks up to the competition. It is however incredibly hard to argue against increased savings even if it comes at the cost of worse metrics due to the extremely different time-horizons involved.
- There are several various psychological components involved in the negotiation phases, during the various talks that I witnessed it was repeatedly made clear the importance of making suppliers understand when they are seriously being considered for a tender in order to spur them to optimize their offers to the maximum.

I often noticed defeatist undertones in the suppliers' speeches and arguments, a sort of flaunting ABB's crushing terms imposed on them in order to persuade the buyers to accept their current offer without enforcing further discounts. At first, I tended to believe their version or at least accept this as their true perception of the situation, I was told on several occasions to distrust the suppliers and their rendition of the "truth"; I did need, however, to experience this process myself: when all three suppliers complied with our request without any complaint nor grievance, after lamenting comparisons with foreign competitors to undercut their costs and repeatedly threatening to leave the bargaining table, I realized the true weight behind their words during negotiations.

4.6 Awarding the Tender

Once the final offers came in both the buyer and the category manager were somewhat taken aback, to figure out who would win the tender it was agreed to involve the SCM Manager Maurizio Marega in the decision process: due to the volume and the financial significance of the tender, this was deemed to be the safest way.

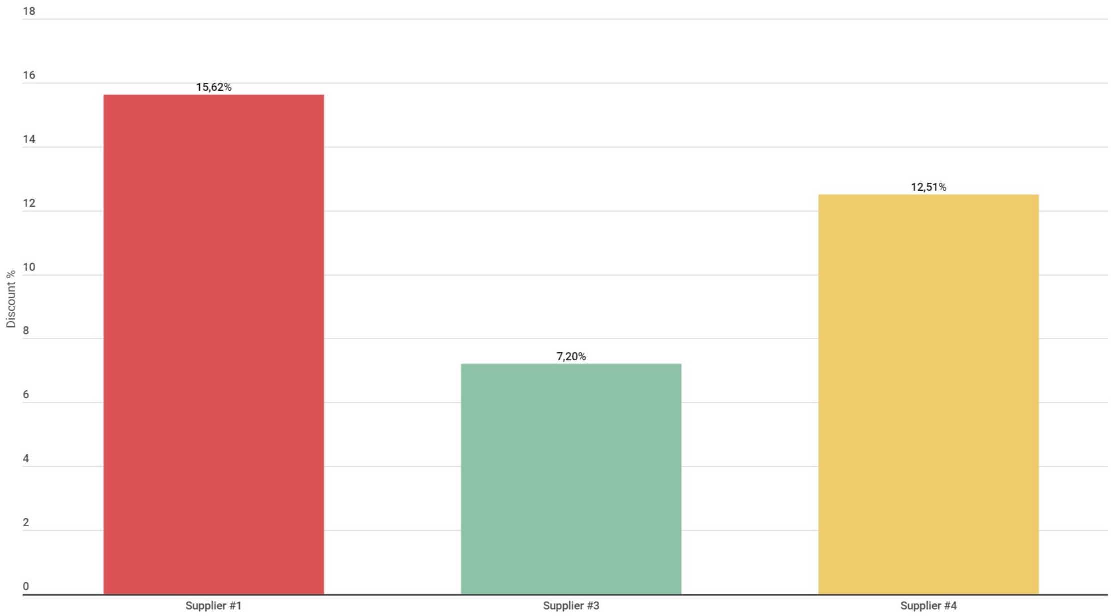

Figure 4.11: Discount % applied by each supplier

The main considerations made concerning the suppliers were:

- Supplier #1 willingness to debase its cost structure to win the tender clarified in our mind the seriousness of their crisis, we understood the gravitas of their financial instability and the SCM Manager devised a possible future exit plan. This final offer probably hurt their chances more than it benefitted them, since it outed its distress and undermined their past and current productions costs inviting further scrutiny in its, perhaps fake, cost structure.
- Supplier #3 received a mostly positive feedback because it identified each reason behind their 7% discount within the cost breakdown rather than justifying it with a blanket "Commercial Discount" statement. It was deemed, however, too inexperienced to handle such a large package. It was clear how this supplier would be a favorite in the future, especially after such a positive showing of competence.
- Supplier #4 acted as expected, granting a large discount in the beginning anticipating growing volumes in the following years and to try to force ABB to further rely on them while undertaking a manufacturing commitment which does not require extreme quality level nor advanced setups or strict and short lead times. Almost simultaneously a new CEO was appointed and showed great promise and competence when discussing future developments and strategies, reconfirming the joint paths of the two companies.

After consulting with the SCM Manager it was decided that the manufacturing package would be awarded to Supplier #4 on the basis of their track record and reliability both on quality levels and lead times, sort of admitting ABB's responsibilities in their recent performance downturn. It was decided that the molds would be moved in three tranches, the first one of which would be re-assigned in during the month of March 2020 due to the necessity of creating large enough safety stocks in during the last trimester of 2019.

A two-month period in-between each relocation tranche was agreed upon with Supplier #4 to allow a smooth and correct setup of each production line without overloading the supplier as mistakenly done in the recent past. The two months would not include shipping the molds but rather start at the time of receiving and accepting, after a quick inspection concerning their conditions, each batch.

The planning department placing such voluminous orders, in a period of the year in which traditionally companies try to reduce their stocks at the bare minimum, would obviously send a strong signal to the current suppliers, therefore it was decided to warn them ahead of time of the incoming relocation of said molds. During this step of the process it was important to renew ABB's commitment toward the replaced molders, where possible at least, while also explaining the reasoning behind this decision.

Concerning Supplier #1, it was decided that the molds currently entrusted to him would be included in the last batch that would be relocated allowing them to create a safety stock at a slower pace thus being able to focus on other perhaps higher margin productions with other clients to try and solve their financial problems. It is important to state that, were they in a more dire situation with a higher short-term danger of bankruptcy or foreclosure, their molds would actually be placed in the very first batch trying avoid the possibility of a possible failure impacting ABB's operations leaving it with no safety stock.

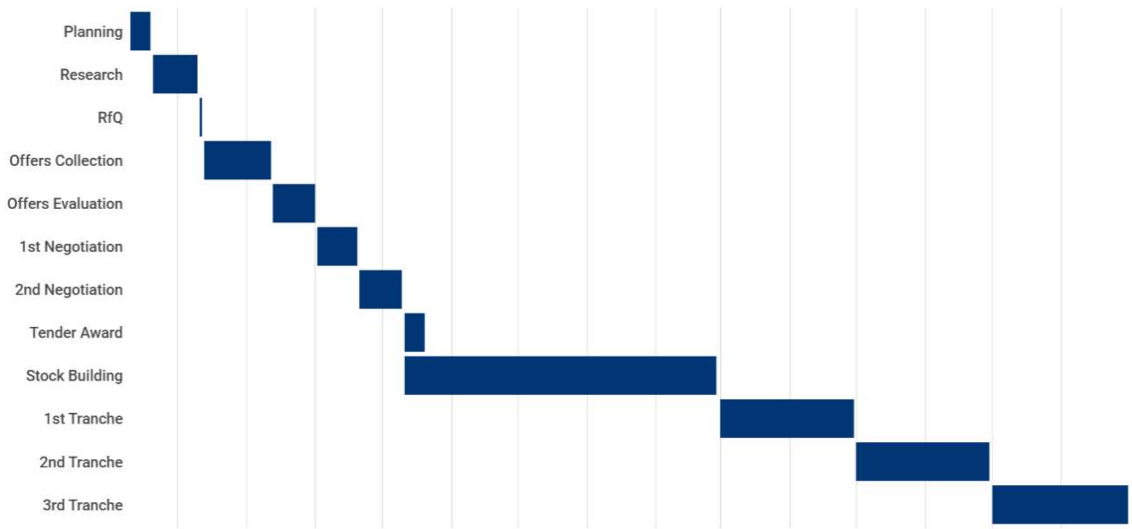

Figure 4.12: GANTT Chart of Main Project

4.7 Suggested Improvements

4.7.1 Color Coding

The main improvement suggested by the winning supplier was to rethink the color-coding system for these components in order to reduce costs, a problem which originates with the design department not being in touch with the reality of the manufacturing process: the colors chosen to represent each third party assembler and voltage were tied to perhaps the most expensive masterbatches which are also very difficult to work with especially under the constraints specified by the design department. To properly explain the problem, a deeper understanding of colorimetry it is needed: the simplest way to judge the difference between two colors is by using the concept of Euclidean distance to evaluate the tridimensional distance of two hues in the defined color space such as RGB:

$$distance = \sqrt{(R_2 - R_1) + (G_2 - G_1) + (B_2 - B_1)}$$

However, the distance between two hues fails to account for perhaps the most important factor which makes color a quality component which is among the most difficult to evaluate objectively: each individual perceives the same wavelength and the difference between two or more differently. This is still a debated topic among experts of colorimetry: "[…] women were more adept at distinguishing between subtle gradations than were men. This sensitivity was most evident in the middle of the color spectrum. With hues that were mainly yellow or green, women were able to distinguish tiny differences between colors that looked identical to men." (Lewis, 2015). This concept is aptly expressed by the MacAdam diagram, which identifies those hues who are deemed to be perceptually uniform, defined by the MacAdam ellipse:

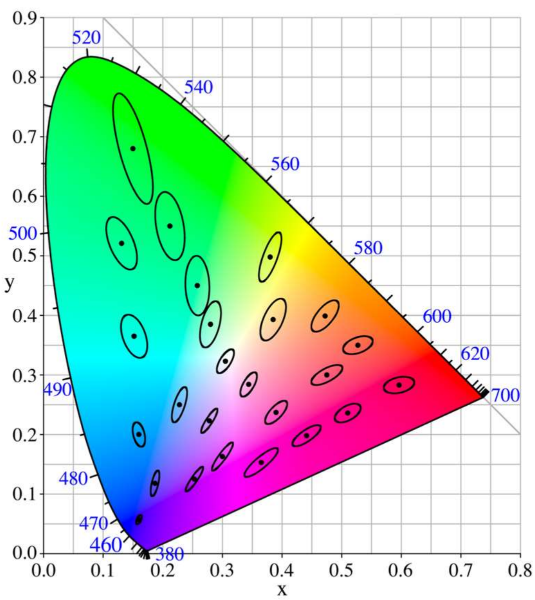

Figure 4.13: MacAdam's Diagram

To avoid subjectivity related to the perception of color by the operator in charge of conducting a quality inspection, color is usually evaluated by means of a colorimeter or spectrophotometer, which generate the exact fingerprint of an object's color.

In most manufacturing process -and molding in particular- with many moving parts and variables it is important to choose an appropriate color tolerance to avoid either pursuing an unachievable -and extremely expensive- target or approving components which will be rejected by the customer. The tolerance is usually defined using the distance metric ΔE^*_{ab} which has been refined and redefined during the years to account for perceptual non-uniformities in different areas of the color space, the latest and most complete definition of ΔE^*_{ab} is far more complex than the Euclidean distance due to the need to correctly evaluate and correct for neutral colors, lightness, chroma and saturation:

$$\Delta E^*_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}}$$

$$\Delta L' = L^*_2 - L^*_1$$

$$\bar{L} = \frac{L^*_1 + L^*_2}{2} \quad \bar{C} = \frac{C^*_1 + C^*_2}{2}$$

$$a'_1 = a^*_1 + \frac{a^*_1}{2}\left(1 - \sqrt{\frac{\bar{C}^7}{\bar{C}^7 + 25^7}}\right) \quad a'_2 = a^*_2 + \frac{a^*_2}{2}\left(1 - \sqrt{\frac{\bar{C}^7}{\bar{C}^7 + 25^7}}\right)$$

$$\Delta h' = \begin{cases} h'_2 - h'_1 & |h'_1 - h'_2| \le 180^\circ \\ h'_2 - h'_1 + 360^\circ & |h'_1 - h'_2| > 180^\circ, h'_2 \le h'_1 \\ h'_2 - h'_1 - 360^\circ & |h'_1 - h'_2| > 180^\circ, h'_2 > h'_1 \end{cases}$$

$$\Delta H' = 2\sqrt{C'_1 C'_2}\sin(\Delta h'/2), \quad \bar{H}' = \begin{cases} (h'_1 + h'_2 + 360^\circ)/2 & |h'_1 - h'_2| > 180^\circ \\ (h'_1 + h'_2)/2 & |h'_1 - h'_2| \le 180^\circ \end{cases}$$

$$T = 1 - 0.17\cos(\bar{H}' - 30^\circ) + 0.24\cos(2\bar{H}') + 0.32\cos(3\bar{H}' + 6^\circ) - 0.20\cos(4\bar{H}' - 63^\circ)$$

$$S_L = 1 + \frac{0.015\left(\bar{L} - 50\right)^2}{\sqrt{20 + \left(\bar{L} - 50\right)^2}} \quad S_C = 1 + 0.045\bar{C}' \quad S_H = 1 + 0.015\bar{C}'T$$

$$R_T = -2\sqrt{\frac{\bar{C}'^7}{\bar{C}'^7 + 25^7}}\sin\left[60^\circ \cdot \exp\left(-\left[\frac{\bar{H}' - 275^\circ}{25^\circ}\right]^2\right)\right]$$

Figure 4.14: Delta E Improved Equation

The resulting ΔE^*_{ab} value is then compared to a reference table

Delta E	Perception
<=1.0	Not perceptible by human eyes.
1 - 2	Perceptible through close observation.
2 - 10	Perceptible at a glance.
11 - 49	Colors are more similar than opposite
100	Colors are exact opposite

Table 4.1: Delta E Reference Table

This latest CIEDE2000 formula does create however a discontinuity when comparing hues which are located 180° apart from each other as noted by Sharma, Wu and Dalal in their analysis paper:

"Because the CIEDE2000 formula is applicable primarily for small color differences, both samples will typically be close together. Therefore, the only situation under which they may lie in opposite quadrants is for the case of colors close to gray. These have a low value of chroma and therefore the magnitude of the discontinuity will be small in practical applications. As illustrated in the previous section, if the samples are under ΔE^*_{ab} units apart, the discontinuity in CIEDE2000 color-difference is under 0.2734, which is small in comparison to color differences encountered in a number of applications, but not negligible. If the samples are 1 ΔE^*_{ab} unit apart, the discontinuity magnitude is smaller than 0.0119, which is negligible in most practical situations. Because of their small magnitude, the discontinuities in the CIEDE2000 color-difference computation may not be a major concern in most industrial applications, where other sources of experimental variation are much larger." (Sharma, Wu, & Edul, 2004).

On the technical drawing provided by ABB's design department, a specific color code is stated as the production target alongside the maximum acceptable delta E which, for the half-covers, was 2; such a high accuracy for an internal component means increased costs with no real purpose nor value added to the final product, which is added to the already higher than usual masterbatch cost due to the hard to replicate colors chosen to code information:

- Red, the most expensive masterbatch due to the organic pigments used and the relative difficulty to obtain uniform coloring was used to color upper covers destined to Vacuumschmelze.
- Yellow, the second most expensive color to reproduce consistently, was used for covers destined to France.
- Lower halves were colored either in orange, green, brown and purple to distinguish between various voltages, all very particular and higher than average cost masterbatches with the exception of brown.

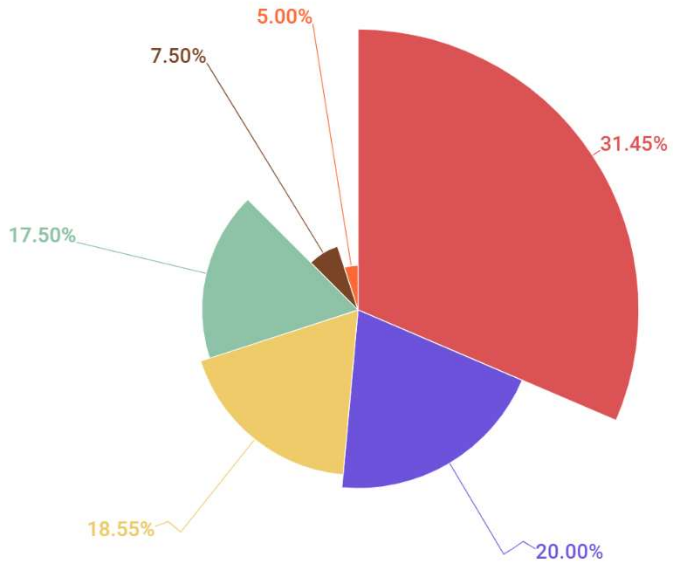

Figure 4.15: Baseline Masterbatch Breakdown

After some counseling with Supplier #4 it was decided that the color scheme would change as follows:

- Red to grey, the natural color of the polymer compound used for the components, cutting cost of masterbatches to zero.
- Yellow to blue, one of the easiest and least expensive masterbatches which was also easily sourced and at a discount by the supplier.
- Lower halves would be changed to black, brown, white and light blue which are quite easy to manufacture and very cheap as far as masterbatches go.

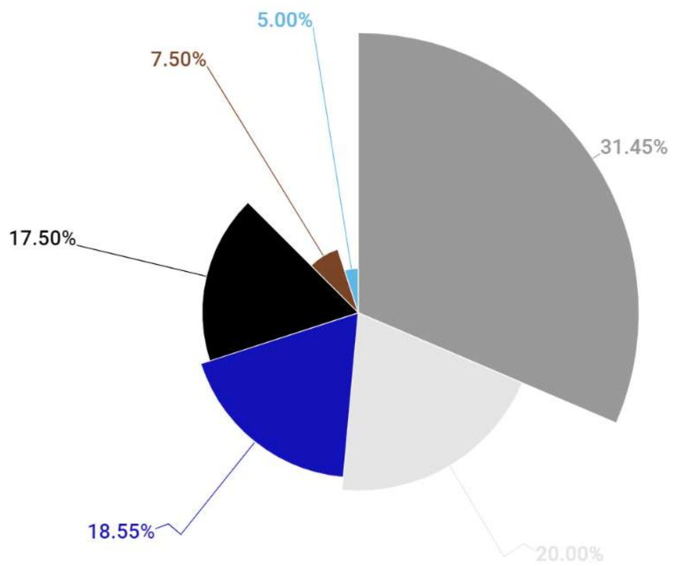

Figure 4.16: Improved Masterbatch Breakdown

To further increase future savings it was established that a higher Delta E tolerance had to be approved to allow supplier to utilize what is improperly called "primetta" which are the very first and last components produced with a new masterbatch: the resulting parts are often imperfect presenting small defects such as color inhomogeneity, flow lines or marks and color streaks. The reduced number of defectives components, the reduced amount of masterbatch per shot and the re-centering of the process all mean decreased direct and indirect -such as maintenance and cleaning- costs.

Before this changes, the manufacturing process could have been hypothetically centered in $\Delta E^*_{ab} = 1$ and had a significant upper specification lever in $\Delta E^*_{ab} = 2$, the reasoning behind this centering would be:

- $|USL - \mu| > |LSL - \mu|$ would mean incurring in progressively higher costs as μ approaches Delta E = 0.
- $|USL - \mu| < |LSL - \mu|$ would mean increasing the percentage of discarded defectives as μ approaches 2.

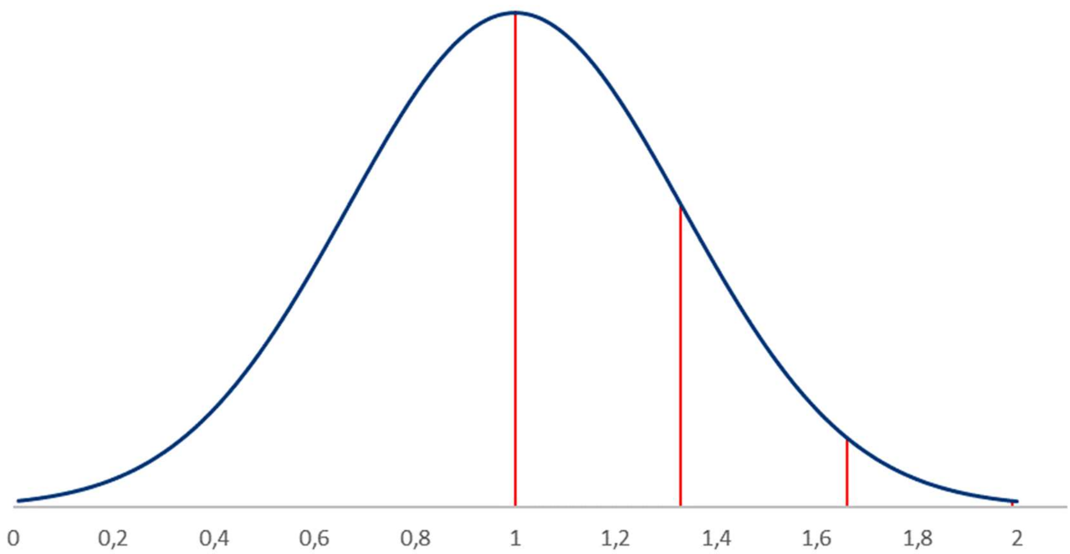

Figure 4.17: Three Sigma Delta E Curve

We can calculate the process capability of said manufacturing operation as follows:

$$\hat{C}_p = \frac{USL - LSL}{6\hat{\sigma}}$$

$$\hat{C}_p = \frac{2 - 0}{6 * 0{,}33} \cong 1$$

Which can then be compared to the relevant reference table to find out that it would be deemed below every admissible threshold, at least according to Montgomery and Douglas.

Situation	Recommended minimum process capability for two-sided specifications
Existing process	1,33
New process	1,50
Critical parameter for existing process	1,50
Critical parameter for new process	1,67
Six Sigma quality process	2

Table 4.2: Centering Reference Table

However, since there is only an upper bound on Delta E, to achieve equivalent quality on a single end of the bell curve would mean a slight shift of μ to the right; another possibility would be having a uniformly distributed process with negative skew.

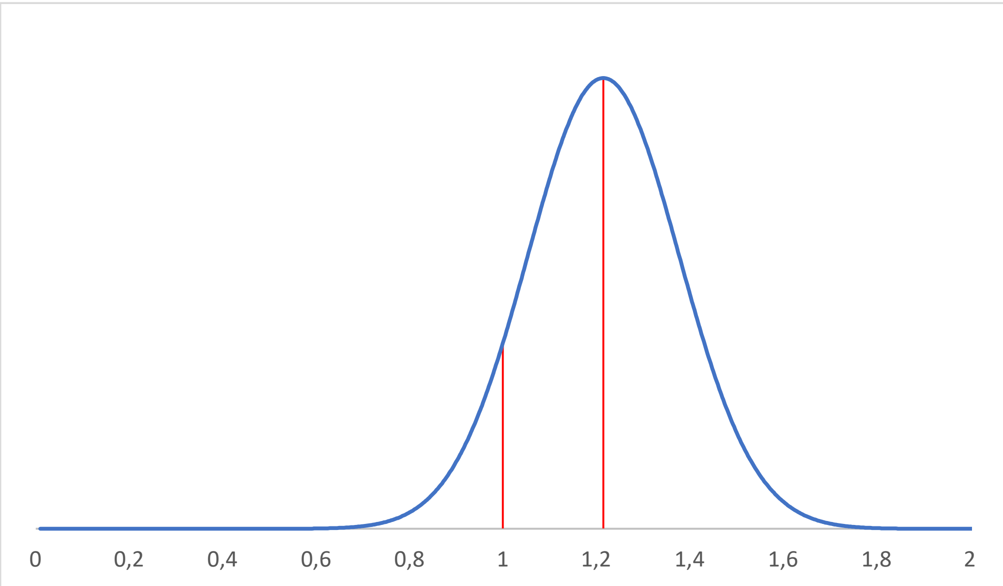

Figure 4.18: Skewed Normal Distribution

In the chart shown above μ is 1 while the mode equals 1,215 it should be taken as an example rather than a description of reality since skewness can differ greatly for what is depicted here.

It must be noted that $\hat{C}_p$ as a parameter is only as good as the specification given during the design phase, as such a more illustrative description would be that of Taguchi's loss function which considers consumer's feedback on a specific quality of the product and its perceived shortcomings.

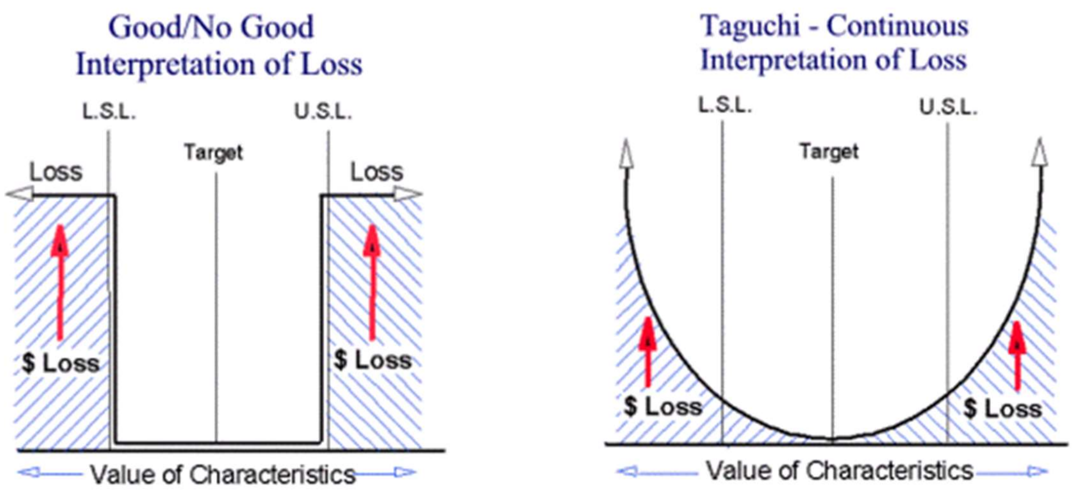

Figure 4.19: Traditional/Taguchi Quality Lost Function

The traditional interpretation of loss would perhaps be flawed in judging a continuous and fluid quality such as color and color discrepancy, while Taguchi's view seems to reflect more closely the subjectivity of the final customer with its flexibility, of course since only the upper specification limit is relevant for Delta E the function would not be symmetrical but rather only the right side would be considered.

These interior components however are judged on this parameter only from other workers which are the actual target "clients" for this particular quality: their interest on color discrepancy is low as long as the actual color is still distinguishable from the others. To adjust accordingly, the new average Delta E proposed was 6 as calculated by looking to the reference table of the parameter and centering on the following perception class which is "Perceptible at a glance".

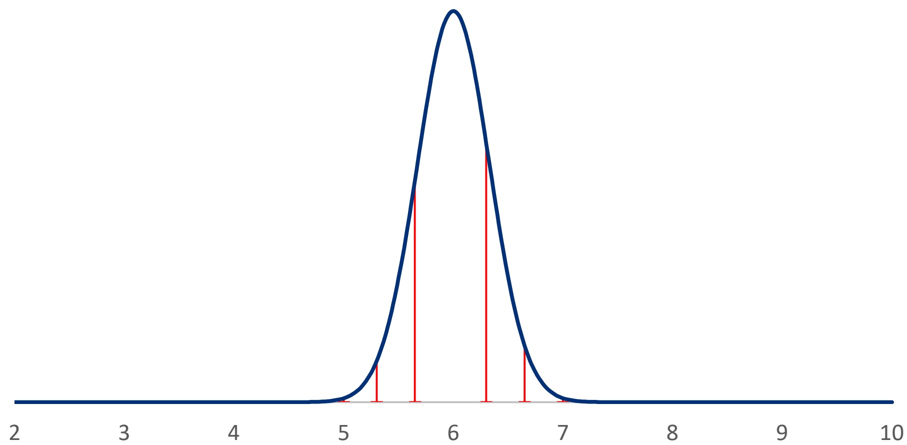

Figure 4.20: New Centering of Manufacturing Process

Now we can re-calculate the process capability to assess the effect of the changes:

$$\hat{C}_p = \frac{10 - 2}{6 * 0,33} \cong 4$$

According to Booker, Raines and Swift any index capability over 2.5 would mean an overzealous precision which can be extremely expensive, especially at the level highlighted in the formula above. The introduction of primettes and lower quality masterbatches would subsequently increase variance both within and across production batches thus lowering the process capability and creating two scenarios.

1. If the increase is limited to a doubling of the standard deviation, a six-sigma process capability is achieved at a lower cost:

$$\hat{C}_p = \frac{10 - 2}{6 * 0,66} \cong 2$$

2. It the increase is more significant the process maintains the same capability index:

$$\hat{C}_p = \frac{10 - 2}{6 * 1,25} \cong 1$$

Rethinking this centering before the reallocation would have meant a cost-benefit analysis for each color, and possibly press, by each supplier to understand whether it would be more beneficial to reduce the number of defectives by re-centering to the left or decrease costs by re-centering to the right. This effort could have taken up to a year for each supplier, possibly costing more than what would later be saved, a disastrous outcome.

4.7.2 Mold Renewal

Once the tender was awarded, the molds were inspected on-site by the engineering team in order to assess their working capabilities, maintenance condition and general wear and tear; this was mostly done as a routine check but, by chance, it coincided with an important SCM event in Santa Palomba's plant: the Supplier Innovation Day.

This event was organized with three purposes:

1. Showing the plant to the most important suppliers in order to allow them to better understand the technologies employed and the production lines capabilities, an improved understanding of these assets was deemed a fundamental step towards a better supply chain integration.
2. Suppliers and relative buyers and category managers would meet in groups and discuss ongoing and arising problems, each one would then be analyzed in order to come up with innovative solutions.

3. Suppliers would then critique the productions entrusted to them, coming up with possible improvements and suggesting new approaches that would optimize their process capabilities.

During the event, Supplier #4 suggested -based on the evaluation carried out by the engineering team- that the molds associated with the tender were renewed due to a perceived excessive wear that would have sabotaged their efforts to achieve the required quality level. The supplier boldly suggested that over half the molds were in dire need to be replaced or at least reworked, which clearly sparked a heated debate for three reasons:

1. The engineering team deemed that, at most, only four molds were at the end of their productive lives and needed to be replaced while two needed minimum reworking and were around 555-75% functional.
2. Supplier #4 is one of the main Italian tooling suppliers and, as such, would directly benefit by a massive mold tender, especially since retooling is usually assigned to the supplier which is currently responsible of production, where possible.
3. Such an extensive retooling would delay the mold reassignment process and possibly invalidate the savings obtained through rationalization and negotiation.

Supplier #4 bias and interests were immediately evident and had to be addressed personally by the category manager, which agreed to only retool the molds greenlit by ABB's engineering team.

Before going ahead with this operation, a discussion had to be put in place concerning the new molds capabilities and, in particular, the number of cavities and injection technology employed, which are the two most significant factors in determining the final cost of the mold besides the mold's material.

Furthermore, a proposal was put in place by the supplier to provide different payment options to the SCM Office in order to meet the cashflow related demands of the BOOST Program, molds could be paid:

1. As 100% CAPEX with half payment upfront and the other half on confirmation of the mold functionality and setup of the production line.
2. Half upfront and the other half spread out over *N* molded components as additional cost until completely repaid.
3. Completely spread out over *2N* molded components at an advantageous interest rate.

To analyze these different proposals, I used three of the most commonly used methods to evaluate investments and then reported to the category manager in order to make an informed decision.

I was explicitly requested to apply the payback method to evaluate the second and third payment proposals by creating different possible scenarios:

	Mold #1		Mold #2		Mold #3		Mold #4	
Initial Investment	40.000,00 €	60.000,00 €	40.000,00 €	60.000,00 €	70.000,00 €	100.000,00 €	60.000,00 €	90.000,00 €
N° of Cavities	4	8	4	8	8	12	4	8
Yearly Volume	1.000.000,00	1.000.000,00	1.500.000,00	1.500.000,00	3.000.000,00	3.000.000,00	2.000.000,00	2.000.000,00
Monthly Volume AVG	83.333,33	83.333,33	125.000,00	125.000,00	250.000,00	250.000,00	166.666,67	166.666,67
N1	1.000.000,00	1.000.000,00	1.000.000,00	1.000.000,00	2.000.000,00	2.000.000,00	1.000.000,00	1.000.000,00
N2	2.500.000,00	2.500.000,00	2.500.000,00	2.500.000,00	3.500.000,00	3.500.000,00	2.500.000,00	2.500.000,00
Payback Time 1 (months)	12,00	12,00	8,00	8,00	8,00	8,00	6,00	6,00
Payback Time 2 (months)	30,00	30,00	20,00	20,00	14,00	14,00	15,00	15,00

Figure 4.21: Payback Scenarios

The final extra cost would be significant even for longer payback periods and higher volumes and, due to how the savings KPI is measured, would undermine -in the short term- most savings obtained thus preventing the HUB from reaching its BOOST saving target.

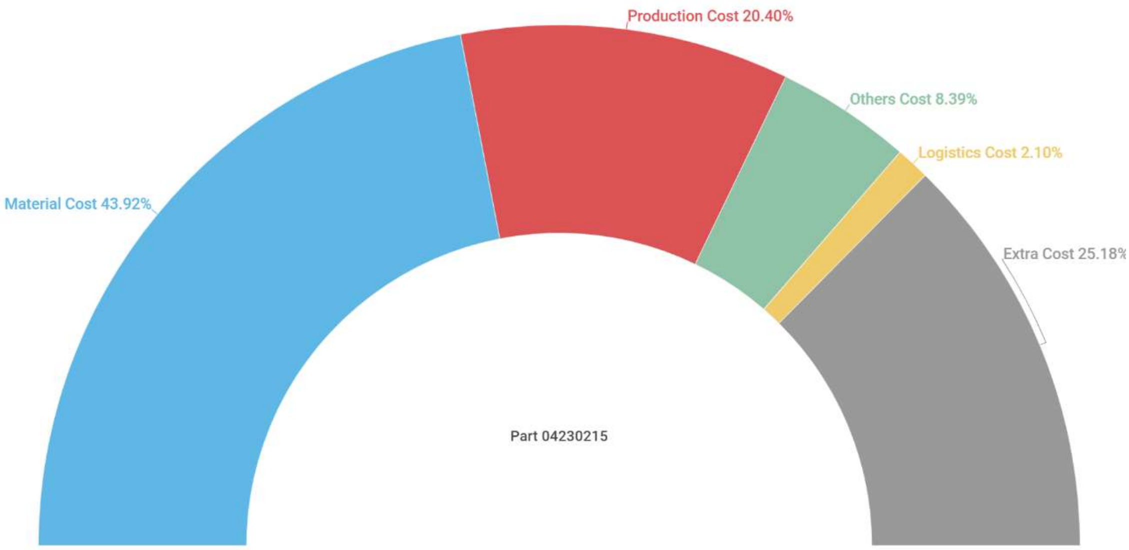

Figure 4.22: Extra Cost impact over single component

To evaluate the first option, I decided to apply the Net Present Value (NPV) to the CAPEX value because NPV is arguably considered the best method to rate capital investment proposals. To apply this method, I assumed the future cashflow to be equal to the year-on-year savings on each component; according to standard practice, the cash inflows time periods should equal the amortization time-span allotted for molds and other capital expenditures which is usually ten years but, due to the unpredictability of long-term production terms I decided to shorten it to five years.

Mold #1 & #2					
Time Period	1	2	3	4	5
Savings Year on Year (CF)	12.152,78 €	12.152,78 €	12.152,78 €	12.152,78 €	12.152,78 €

Investment	40.000,00 €
Discount Rate	12%
NPV	43.808,04 €
Adjusted ROI %	8,69%
Benefit/Cost Ratio	110%

Figure 4.23: Investment NPV Evaluation N°1

Mold #3					
Time Period	1	2	3	4	5
Savings Year on Year (CF)	13.368,06 €	13.368,06 €	13.368,06 €	13.368,06 €	13.368,06 €

Investment	70.000,00 €
Discount Rate	12%
NPV	48.188,85 €
Adjusted ROI %	-45,26%
Benefit/Cost Ratio	69%

Figure 4.24: Investment NPV Evaluation N°2

Mold #4					
Time Period	1	2	3	4	5
Savings Year on Year (CF)	16.710,07 €	16.710,07 €	16.710,07 €	16.710,07 €	16.710,07 €

Investment	60.000,00 €
Discount Rate	12%
NPV	60.236,06 €
Adjusted ROI %	0,39%
Benefit/Cost Ratio	100%

Figure 4.25: Investment Evaluation N°3

The evaluation above highlights how the total CAPEX payment option is viable for all molds with the exception of Mold #3, yet can also be used to point out how the return on investment - adjusted for the cost of capital or the expected rate of return- is minimal and perhaps other investments could be more profitable.

By looking at these analyses with the buyer and category manager, the following decisions were taken:

- Mold #3 would be paid half upfront and the other half would be deferred and paid over the fourteen months following the mold completion.
- The other molds would be paid as 100% CAPEX to maximize savings in the short term, ensuring that the BOOST Program target were reached.
- The option to repay the molds only as extra cost was immediately discarded, because of the SCM Office internal policy which forbids from agreeing to loans except for particular cases.

4.7.3 Improvement Evaluation

To evaluate the impact of coloring over the total material cost the cost breakdown had to be adapted ad hoc for this project and later submitted to the global category manager for approval, which was not given on the account that it would mostly be unutilized due to the low amount of supplier which actually use masterbatches. Nonetheless this change allowed us to prepare a report which described the projected savings related to this new color-coding system, which would have had to be approved by the design department after an accurate evaluation.

The original cost breakdown is structured as follows:

Material Costs										
Trade Name of Raw Material	Raw Material Producer	Lot Size (kg)	Raw Material Price (€/kg)	Density (g)	Gross Weight (g)	Net weight (g)	Recycling (%)	Material markup (%)	Customs (%)	Material Costs (€/pcs)
PA66	Lati	1.000	€ 3,56		14,0	12	0%	5%		€ 0,05233

Figure 4.26: Material Costs Breakdown

Others				
Others 1 (€/pcs)	Others 2 (€/pcs)	Others 3 (€/pcs)	Others description	Others (€/pcs)
€ 0,02000				€ 0,02000

Figure 4.27: Others Costs Breakdown

And was adapted to reflect the improvements:

Material Costs													
Trade Name of Raw Material	Raw Material Producer	Lot Size (kg)	Raw Material Price (€/kg)	Master Color	Master Price (€/kg)	Master %	Density (g)	Gross Weight (g)	Net weight (g)	Recycling (%)	Material markup (%)	Customs (%)	Material Costs (€/pcs)
PA66	Lati	1.000	€ 3,44	Blue	€ 4,00	3%		14,0	12	0%	5%		€ 0,06737

Figure 4.28; Improved Material Costs Breakdown

This new approach gives the buyer and the category manager the chance to keep track other cost items which are made explicit rather than remaining submerged, this leaves less discretion to the supplier when justifying costs while also allowing for an optimized management of masterbatches and potentially enabling a collective bargaining of these materials at the divisional level.

4.8 Contract Re-Negotiation

During my time in the SCM Office I was asked to help rewrite the contract which is then used as the base when negotiating with the various suppliers, in particular I was tasked with the English translation of the contract and the addition of few critical paragraphs.

These new paragraphs were agreed upon during the monthly City Block reunion, in which all members of the SCM office can discuss their problems and confront with the SCM Manager and, sometimes, with the HUB Manager.

During the first reunion in which I took part, the need to renew the standard contract was argued by the SCM Manager, which also urged the buyers and category managers to do so as soon as possible since many different contracts were about to expire.

The first improvement discussed was that of adding a paragraph to explain to supplier the need to subscribe a civil liability insurance policy, especially for those who are in charge of their own quality inspections: safety equipment such as mid and low voltage circuit breakers can fail because of a trivial component and cause economic damage in the order of hundred thousands euros, ABB reserves the right to ask compensation to the supplier in charge of the component(s) which are at fault and cause the failure of the equipment.

Without an insurance policy, paying court fees and eventual compensations to the injured party or parties could potentially bankrupt the supplier, even the bigger ones.

The second improvement was spurred by the recent increase of suppliers with deteriorating OTD%, thus it was decided that the new contract had to be more punitive for those suppliers. After discussing this problem with the plastic buyer and category manager I started writing this paragraph and came up with a solution to this problem:

- A fee has to be paid for each late delivery; the fee increases progressively as the number of days overdue increases.

$$Late\ Fee = Performance\ Modifier * Total\ Delivery\ Value * Days\ Overdue$$

- Suppliers which are below the required threshold for OTD% pay increasingly higher fees based on the difference between their performance and the threshold by increasing the "Performance Modifier":
  - 0,01 or 1% for suppliers whose OTD% is above 95%.
  - 0,02 or 2% for suppliers whose OTD% between 85% and 95%.
  - 0,05 or 5% for suppliers whose OTD% between 75% and 85%.
  - 0,07 or 7% for suppliers whose OTD% between 65% and 75%.

If the OTD% falls below 65%, the company can reserve the right to rescind the contract unilaterally without paying any fee.

5 Criticalities

5.1 Maintenance Costs Tracking

While negotiating the biggest production set with one of ABB main suppliers, it was made clear to us that the maintenance cost of the hydraulic presses was merely estimated by the supplier. The component which is most subject to wear and tear is an infinite screw which feeds the plastic pellets into the mold; however, the wear rate ranges from minimal (with materials such as polypropylene) to severe (with high tech plastics such as polyaryletherketone) due to:

- The coarseness or roughness of the different compounds.
- The temperature at which each polymer is processed.
- The genesis of gasses such as hydrogen chloride.
- The presence of additives such as glass fiber and their percentage.
- Metal-to-metal contact between the barrel liner and the screw flights (Gordon, 2010).

The life span of these screws is varied and, since they are employed with different materials, it is difficult to evaluate ex-post which production batches caused the most wear especially due to the non-linearity of the wear rate.

In the world of Industry 4.0, there is no space for unaccounted costs, furthermore suppliers estimating these costs without an objective basis can use it as a way to justify overpriced rates. At best this strategy leads to more difficult negotiations, where every objection to more expensive production costs is quickly dismissed; at worse this strategy means that even the supplier does not have the pulse of its internal costs which can result in either overpriced items or unexpected losses. To avoid this trap, it would be beneficial a standardized approach to maintenance where each component used for repairs is treated as any other SKU and -where possible- wear rates are monitored throughout the production cycle.

A paper on injection molding wrote by A. Schroeder and H. J. Lemke completed in 1983, reflecting on process control, cited the lack of in-depth control over the process as one of the main problems of the process which requires a different approach: "While the sequence of production steps in injection moulding, as material feeding, plastification, injection, cooling, is controlled automatically, process supervision and machine monitoring is normally done by operators. This task is often difficult because of non-visible parts of processing or short cycle times. Today, the programmed sequence of machine function is supervised by the control system itself, thus a shut-down can be given if a certain step cannot be finished or executed. However, process variables are often used merely for limit comparison. In very few cases, machine monitoring is supported by means of displaying on a CRT the course of significant process variables." (Schroeder & Lemke, 1983).

The solution proposed at the time was that of employing an experimental modeling of the process by monitoring the following control parameters and their trend over time:

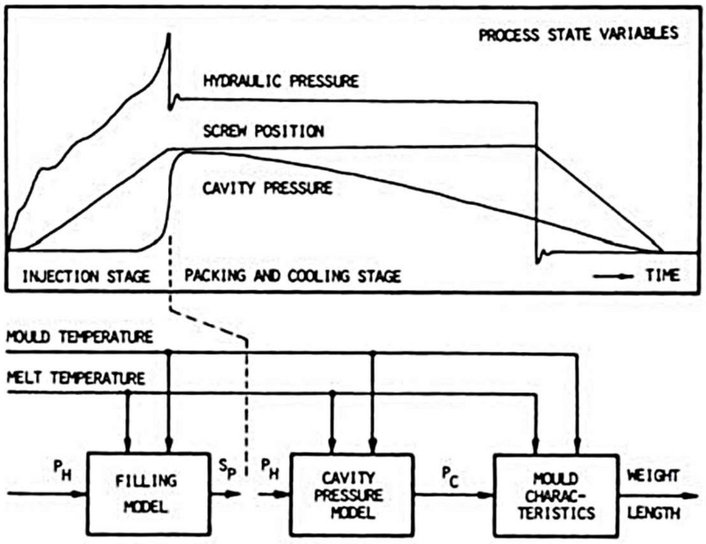

Figure 5.1: Typical course of process variables (one production cycle)

This can approach can be done with older presses which do not have newer control technologies or for those suppliers who cannot afford significant investments to achieve the "[…] Estimation of specific mathematical models from process data is used to compute variables which are not directly measurable and to indicate variations in processing conditions or machine malfunctions." (Schroeder & Lemke, 1983).

To establish a clear baseline for comparison sake with the model it is important that the supplier possesses sufficient knowledge (i.e. an extensive database) by conducting "Preparatory investigations […] with a feedback controlled injection molding machine" (Schroeder & Lemke, 1983).

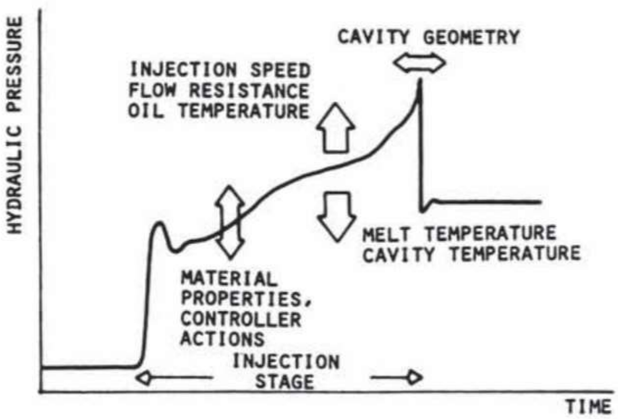

Figure 5.2: Pressure over time (single shot)

Once the baseline has been established, a "[…] disturbance and failure detection […] algorithm must be used for feature extraction to separate certain classes of malfunction" (Schroeder & Lemke, 1983). At the time these scholars concluded that "the running of the production machines is normally not supported by computer application. However, technology has changed and nowadays offers computing power even in small-sized equipment. […] First experiments on process supervision of injection molding, via modelling and graphics display, have been encouraging. To transfer this basic investigations into industrial practice, a more universal relationship is needed, which is independent of the cavity and machine type. Moreover experience must be gained how operators can interpret and evaluate computed process information like NLC's." (Schroeder & Lemke, 1983).

The last phrase rings especially true since, in most injection molding operations, workers are outnumbered by presses at a 1:8 ratio which poses the challenge of being able to interpret and monitor all feedbacks at once.

Today, process control systems are far more advanced than they were forty years ago and yet, among ABB's main Italian suppliers only a selected few employed such technologies to their maximum extent: some lack the theoretical and practical know-how to deploys such measures while others lack the capital to invest and others are missing both. To overcome these problems an innovative approach is needed, such as that of using ultrasonic sensors to monitor barrel and screw wear in polymer extrusion processes (Jen, Sun, & Kobayashi, 2004).

5.2 Fixed and Variable Costs

Studying the cost breakdown and its structure, I noticed an improper distinction between fixed and variable costs or rather a misinterpretation -among different suppliers- based on standard practice and sometimes cultural differences that poses a problem when comparing pricelists across different HUBs or countries.

According to the cost breakdown fixed costs field description, the supplier is supposed to consider fixed costs the following items:

- Setups.
- Quality.
- Tooling.
- Electricity.
- Production Site.
- Routine Press Maintenance.
- Routine Mold Maintenance.
- Depreciation.
- Profits.

In and of itself this list can already be considered flawed because of fundamental differences between the personal interpretation used to compile the cost breakdown and the practical world:

1. Maintenance of both presses and molds should actually be considered a variable cost according to most if not all definitions of what constitutes a variable overhead, I will cite only one for the sake of brevity: "Variable overheads are the costs that are constant when calculated per unit but become variable when totaled to the volume of the output. All costs like repairs and maintenance, indirect labor, etc., are variable overhead costs." (International Financial Reporting, s.d.).
2. Quality should be properly categorized as a step variable cost, because costs are fixed only within a specified range and they increase at discrete points; for the sake of example, let's say a quality assurance worker can process up to 1000 components a day, then quality costs are fixed for productions ranging from 0 to 1000 daily components with 100% inspection or 0 to 10000 daily components with 10% inspection and change as these thresholds are exceeded because a second quality worker has to be hired. This would be the correct approach on paper, but reality often differs, and some suppliers somewhat rightfully can claim that quality is a fixed cost to them because, as production volumes increase, quality assurance simply deteriorates. This is not the case for most suppliers however, especially for those who have the necessary technological solutions to tackle most mass quality assurance problems. Given these observations, I would say that quality as a fixed cost is mostly justified but ABB's SCM Office could use some more insight into suppliers' quality operations.
3. Depreciation can rightfully be considered a fixed cost for most capital, but I would argue that for presses (and molds on the side of ABB) perhaps a usage-based depreciation model would be more appropriate: a ten years-old mold or press with a hundred hours of production depreciates differently than the same mold or press with a thousand hours of production, the depreciation rate is not linear. Both presses and molds work with constant parameters: a mold requires a precise tonnage to work and is almost always used with a single compound and, in the rare cases in which more than one compound is used, extremely similar polymers are employed; presses exert the same force over and over and thus do not require any adjustment to their usage to figure out the depreciation tied to a single hour of usage. While it could be argued that presses are very difficult to depreciate this way because of the various components that make up one and that are independently maintained and replaced and thus depreciate at a different rate I would say that these differences are offset by the maintenance costs already accounted for.

The variable costs field is therefore severely underutilized since it only encompasses the following cost item: Production operator. From a theoretical point of view this field is flat out wrong since wages are fixed costs and would be correct only if these operators were paid under a piecework scheme, which is actually illegal in Italy and most of Europe: only bonuses can be awarded with such rationale. However, this approach can be explained with the following observations:

1. Production operators are usually outnumbered by presses, with the most common ratio being one worker every eight presses. In this case the hourly wage of the operator is then split with each press (and related supplier) paying 12.5% of said hourly wage.
2. Manufacturing lines with higher production rates (shorter cycle times and/or more cavities), with more tricky technologies or more complicated setups may require more supervision and interventions by the operators. These conditions reduce the number of presses that a single operator can oversee thus increasing costs, with this in mind it is now easy to understand why this item is categorized as variable (or rather step variable) cost.

While these observations do justify this categorization as variable cost, they do not condone the practical approach of leaving a lot of information out of the equation:

- A field should be dedicated to the operator percentage in order to properly track this information and compare it across suppliers and manufacturing lines. This would also allow the supplier to report the flat hourly rate for the operator which is then computed in the fixed costs field.
- Maintenance should be re-allocated in the variable costs field as explained above.

6 Improvements and Suggestions

6.1 VMI Invoices Handling

In order to understand the rationale behind the improvement suggested it is important to know what the main difficulties and problems are:

- Withdrawal are split among different invoices, often with random criteria.
- Invoices do not reflect the timing of operations, an invoice billed first could contain withdrawals made after the ones contained in an invoice billed later.
- Withdrawals can be split in several tranches, both at the operational level and at the invoicing level; however, a split tranche can be later reconjoined by the invoicing team.
- Where time-framed invoicing is applied, the need to register withdrawals before a given deadline can create delays or missed registrations. For example, if invoicing is done at the end of each week (e.g. on Fridays at 12:00) all those withdrawals made later on during the weekend will not be reported in the correct weekly report, this same reasoning can also be applied to months etc.
- On the bright side, the prices of these compounds are very stable and as such withdrawal of the same quantity always lead to the same final price, if inverted.

A near worst-case scenario is exemplified in the diagram below.

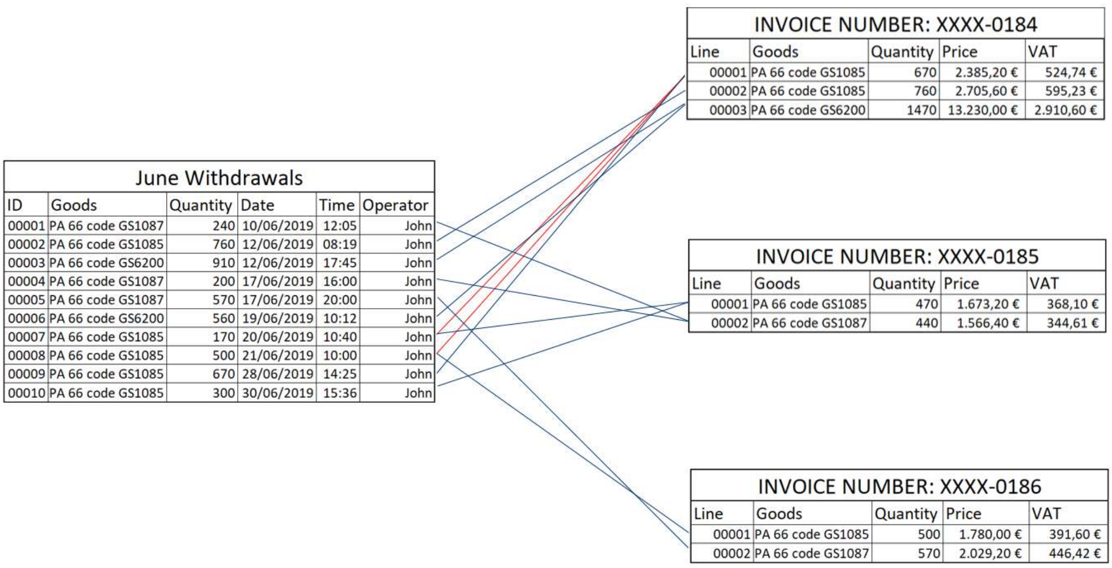

Figure 6.1: Simulated Invoicing Process (red lines represent possible errors)

Looking at the image below it is easily understandable how such a process can spiral out of control, especially considering the number of monthly withdrawals which usually is around ten to fifteen for each material. The red lines describe the error of "substitution" which can happen when a single withdrawal is equaled by other two or more, then further down the line those added withdrawals are needed to obtain another subtotal.

All this was done manually when I arrived in the SCM office, the relevant buyer would take four hours out of its working day -once every month or two weeks- and sift through all this data to match each invoice line with the related withdrawals. I was assigned this task after a month in the office and immediately started to develop workarounds and shortcuts in order to speed up this task due to the loss of time and boredom tied to it, I also felt I wasn't going to learn anything while doing it so I decided to learn and figure out how to automatize it.

The first approach was mostly manual with some workarounds:

- Collect all monthly invoices and calculate the total quantity for each material.
- Do the same for all withdrawals, then figure out the difference between invoiced quantity and actual withdrawn quantity.
    1. $Total\ Monthly\ Withdrawal - Total\ Invoiced\ quantity > 0$
    2. $Total\ Monthly\ Withdrawal - Total\ Invoiced\ quantity < 0$
- In case number 1, the most probable case is that withdrawals have been made in between the invoicing and the end of the month.
- In case number 2, the previous month was a "case number 1" and the carryover has to be accounted for.

While this process does remove the most common errors, it can only be applied over longer time periods and does not reduce drastically the time spent.

The second approach was quicker and generalized, I employed Excel solver to automatically match data using only the time constraint of the invoice date:

- Collect all unpaid invoices, withdrawals only up to the latest invoice date.
- Calculate total quantity by material for each invoice.
- Group materials across invoices.
- Run Solver.

Goods	Quantity
1085	760
1085	170
1085	500
1085	670
1085	300

	Invoices			
	0184	0185	0186	Checksum
Material	1085			
	1	0	0	1
	0	1	0	1
	0	0	1	1
	1	0	0	1
	0	1	0	1
Target	1430	470	500	
Result	1430	470	500	

Figure 6.2: Solver Solution

Formulas:

$$Result_i = \sum_{j=1}^{n} Invoice_{ij} * Quantity_j$$

$$Checksum_j = \sum_{i=1}^{n} Invoice_{ij}$$

This method de facto reduces the time spent on this task by around 95%, what used to be around four hours of painstakingly sifting through lines and lines of numbers became a ten-minute task for me. Once I developed this solution, I was given the chance to offer it to the other buyers who had to handle VMI Invoices, the opportunity was presented to me when the buyer who had asked my help for this task was astonished by my quickness. He was initially trilled to learn this new method, however when I explained it to him he struggled to get a good grasp on it; I went through the explanation over and over but ultimately he did not accept it due to his familiarity with the old method and the fear of making mistakes when employing the new one.

Overall only one out of the three buyers I collaborated with decided to adopt the new method even though it would have given them much more time to focus on more productive, value-added and engaging activities: resistance to change is often a prevalent trait in companies, especially among those who have been working the same way for many years; in these cases is very important for management to identify the reasons behind the resistance in order to act on the root causes rather than trying to force a cure on the symptoms.

Result: Solver found a solution. All Constraints and optimality conditions are satisfied.

Objective Cell (Value Of)

Cell	Name	Original Value	Final Value
$H$40	Result Invoices	0	1430

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$H$34:$H$38		**0**		**1**

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$K$34:$K$38 <= 1					
$H$40	Result Invoices	1430	$H$40=1430	Binding	0
$H$34:$H$38=Binary					

Figure 6.3: Solver Report

7 Conclusions

I ended my internship in ABB after six months, proud of my work and grateful for the things I was able to learn either directly through practice or indirectly by looking at my co-workers and listening to their advices. I later enlisted for a position within the SCM Office offered

The first things I would take into account when evaluating this experience are the skills I acquired working in the SCM Office:

- Interpersonal skills, this category describes accurately what I learned by interacting with my colleagues and both my supervisors and subordinates; supplier relationships and negotiations processes would also fit in this category and represent the brunt of those functional skills which are not studied in academics and were totally foreign to me before this opportunity in ABB.
- Data analysis and interpretation, these skills -especially the first- were mostly honed during my studies but during this experience I was able to confront my findings with those of more experienced and knowledgeable workers. The main difference between academia and the working environment would be:
  - In academia I was taught to evaluate data ex-post and use it to evaluate the results of decisions which had already been taken so every interpretation I could extrapolate from data was inherently biased by hindsight.
  - In the workplace I had to interpret data to decide what which decision was correct or more beneficial without the benefit of hindsight and, as far as I could see, most workers were inherently biased by past experiences.
- Organizational Skills, while working in ABB I was often, if not most of the time, committed to various activities which could be either linked or totally unrelated. This simultaneity of operation meant that I had to be able to organize each activity and coordinate several meetings across various offices located throughout Italy; various professional figures were involved with these meetings, this meant that I had the chance to observe different approaches to the same activities and to learn tidbits of knowledge concerning the multiple facets, technological and organizational challenges of each activity.

I consider these skills to be quite transversal and transferable across different jobs and positions, which gives me the ability to adapt with fewer difficulties in the case of changing workplace or entering a new professional reality. However, I do hope to be able to hone these skills further and apply them within the company with further success and responsibilities entrusted to me; when reflecting on these skills to try and tie them together trough theory to write up this document I mostly struggled with the intangibles behind the negotiation process and its subtleties, which are probably also the least transferable since different markets and positions require different approaches, the basics can still be applied however.

The second step of this self-evaluation would be that of the sector-specific knowledge which I was able to acquire either directly or indirectly, this learning process was fostered by my supervisor and tutor which encouraged and enabled me to work side-by-side with several colleagues:

- Supply Chain Management logics and strategies, this category encompasses most of what I learned and has been invaluable both throughout my last academic year in Politecnico di Torino and during the drafting process of this document.
- Procurement strategies and inner workings, I learned what are some of the main challenges and problems to modern cross-continental procurement and how they can be faced or lessened and which I tried to describe and improve in this document.
- SAP structure, testing and both procurement and warehouse transactions. This also meant that I had to learn how to be compliant with NYSE requirements and company policies concerning SAP management and data reliability.
- Plastic injection methods and specifics, mold requirements and supplier (molders) challenges; most of this knowledge was accrued by discussing with my tutor, the engineering team of ABB and directly with various suppliers.
- Suppliers' necessities, common complaints and mistakes which I learned once I was entrusted with the direct management of one of ABB's growing suppliers in northern Italy.
- Organizational structure theory which I had already studied at Athlone Institute of Technology and was able to expand by analyzing ABB's own structure and its pros and cons relative to the various operations which I was able to witness firsthand.

When taking into account everything that I learned during my internship, I can say with a hundred percent certainty that this was the best working experience in my life and I am grateful to have had this chance to prove myself and to mature the knowledge and experience to write my master thesis.

As of the day I finished writing this document I was offered a permanent position in ABB's SCM Office as Buyer after a successful internship which led to a recommendation by Paola Cialini - which was promoted in the meanwhile- and an equally successful selection process with her substitute and the SCM Manager.

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