POLITECNICO DI TORINO

Master of Science in Engineering Management

Master of Science Thesis Project

Optimization of the supply process of brazed subassemblies in subcontracting work: a case study in Carel Industries S.p.A.

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A tutti voi,

Vita, vita, vita!

INDEX

FIGURE LIST

TABLES LIST

INTRODUCTION

The present thesis work is the result of a project of improvement performed during an internship of six month within the planning department of Carel Industries S.p.A. HQ, located in the province of Padua. The object of the work is the analysis of the As-Is of a process and subsequent optimization of the issues depicted. The process at stake concerns the supply of brazed bodies in external work, which is a specific family of semi-finished goods employed in the internal production of electronic expansion valves. The role of Carel within this process is to procure the components, redirect them to different companies in charge of brazing production and receive back the subassemblies goods for final assembling production. The necessity of a project work arose from frequent delays and shortages of components in the associated value stream, which were causing loss of service levels towards clients, major KPI of the company efficiency. The basic logic of the work is based on an optimization of back-end operations to improve front-end requirements.

The project articulated in multiple phases, some of them carried on in parallel, others in sequence, due to the complexity of the process and the number of stakeholders involved. The dive into VS4 processes has been preceded by few weeks of training upon the business of Carel, its corporate operability, manufacturing system and products.

The early phases consisted in an analysis of the codes involved and belonging families, with the scope of identify characteristics and issues related to the codes nature. At the same time it has carried on a value stream mapping of the process, deepening the analysis of all the stakeholders involved: vendors of raw materials and suppliers of brazed bodies in external work. Their characteristics were essential to understand the dynamics of relationship and bad developments of the process during time.

Subsequently, shadowing the planner activities, it has been drafted the raw materials procurement process, with issues that came into light only after the analysis of the downstream part of the process, the release of purchase orders for brazed items. In general, criticalities were both within the engine system and its

application, plus various situations led to loss of focus on objectives of process and its maintenance. Precisely, MRP had not an aligned netting phase due to the 'buy' nature of the brazed items, resulting in a blindness of the raw material at their lower BoM levels. Consequently, the Min/Max system in charge of material replenishment towards subcontractors could not work correctly due to on-hand stocks that were apparently high, but in reality, they were considering materials already committed by orders. Automatic release system were not aligned with suppliers calendar, items lead-time and buffer stock, creating overcrowding and compression of orders that were destabilizing the supplier production.
At the end of the state of the art analysis, it has been noted that the problems were many. Principally the optimization has focused on two main field: a review of the parameters for the automatic POs release, with addition of new implementations, and the creation of a new program inside the ERP that could have depicted the components committed, hence creating a netting phase aligned with the reality. In parallel, it has been conducted implementations on the manual release system and an overall maintenance of the sub-processes involved.
The work has been concluded with the implementation of the encountered solutions and their monitoring, depicting an early improvement on performances; however, mid-term analysis of the optimized process is still in act and not presented in this work. Early reports gives good sign, reason why it has been decided to extend the methodology and the optimization to every item in subcontracting work, with all the considerations of the case. With this perspective, it has been drafted a series of standard and best practices that will be applied in Carel HQ and, after, in the other international plants in the long-term; overall, they can constitute a guide for similar manufacturing companies.
There will follow two introductive chapters on the company background and supply chain management, aiming at explain the theoretical concepts behind the project. Chapter three will be a draft of the process As-Is, followed by the fourth chapter in which will be presented the solutions depicted. In the last one, the previous hypothetical solution will be implemented in the real case and analyzed their impact on the initial problems.

1. THE COMPANY

Carel Industries was founded in 1973 in the province of Padua, Northeast of Italy, as a firm for the design and production of electric panels. Its production focuses on high tech components (hardware and software) and solutions for high energy efficiency in the control and regulation of air conditioning systems equipment, ventilation and refrigeration sectors (together "HVAC/R"). Specifically, Carel designs, manufactures and distributes control and humidification solutions for the residential, industrial and commercial segments. It offers solutions for each application segment to be integrated into individual units, like heat pumps, shelters, rooftop, computer room air conditioners (CRAC), chillers and air treatment systems as well as complex systems such as entire systems for shopping centers, supermarkets, museums and data centers. Offering innovative solutions, their products want to guaranty efficiency and energy saving for the system in which they will be applied; trying to ensure benefits for the environment. This is why research, innovation and technology are at the base of the business: for more than forty years, customer needs have been at the center of the roots of the company.

The company, consolidated mostly outside the national borders (80% of sales are made outside of Italy), operates both directly through subsidiaries and an organization that is present all around the world. Indeed, since the early nineties, Carel has been operating abroad through a large number of subsidiaries, local offices in 75 countries and various affiliates. In the last 20 years, four new production plants have been established in order to respond to a constant growth and needs of a large number of customers.

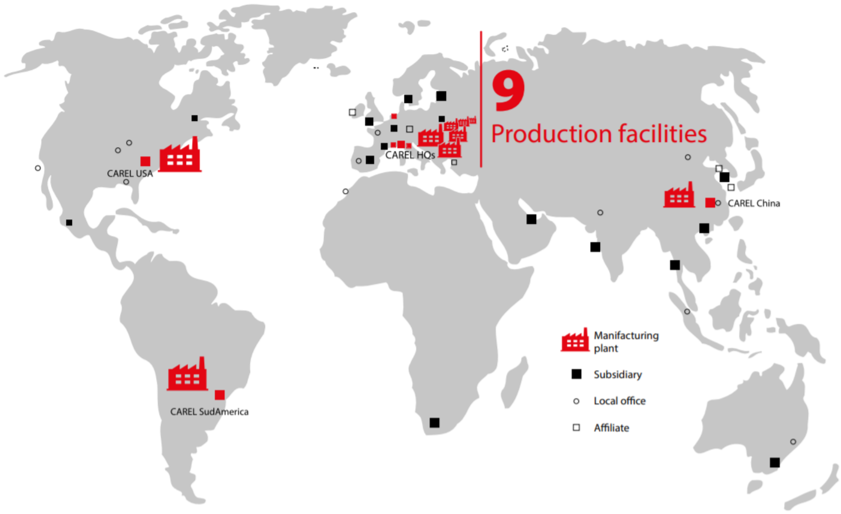


Figure 1.1. Carel in the world (source Carel internal documentation).

The expansion process brought the company to reach in the 2019 financial year 327.36 mln€ of sales, with net earnings of 10.7%, reaching a quote of nearly 1600 employees. Carel, with 6,200 active products and an annual production of more than 7 million units, has grown year by year thanks to a constant reinvestment of consolidated sales in R&D and internal program, almost 7% every year. Strategy that ensured Carel to pursue a continuous improvement of the performances.

Worth mentioning the important role that Carel's products played during the 2020-2021 health crisis. Indeed, humidification solutions, along with other solutions for the control of air systems, were and are an important piece of the puzzle to prevent the spread and transmission of the virus. A solid correlation has been recognized between dry air and immune system impairment: provide correct levels of humidity can reduce the viability of viruses through air.

1.1. The Organization Structure

In 2007, Carel decided to set an important milestone for its growth: the beginning of the Lean journey, still in act, which started a process of transformation of the company in every area. That was precisely the moment in which the organization changed radically, moving from a traditional structure, based on functions, to a more efficient one based on processes, called value streams. The choice of this strategy came from two main objectives: on one hand the will of being more competitive on a market in expansion and on the other not to let some areas of the company hash, fulfilled of the past results.

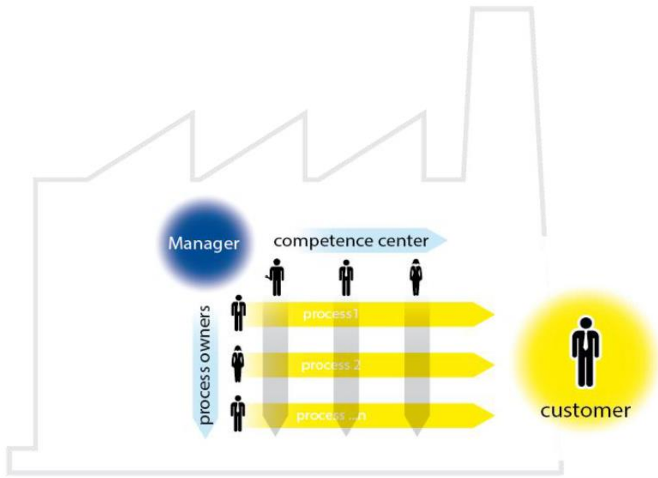


Figure 1.2. Carel organization (source Carel internal documentation).

The process of change started from the R&D department, with the introduction of lean basics concepts and tools, such as the constant pursue of the client value. It was the first implementation of a miniature matrix organization: each project (meant as a value stream) was formed by a compact team, in charge of it. The team has relationship with cross-functional teams (representing the competence centers), which are in charge of the technical-knowledge of the main product system platforms (e.g. Valves Drives and Flow Control, Inverters and Compressors …).

From the 2009, Carel started the real transformation of the structure and of the operation department. In order to ensure a smooth flow of the value all along the various functions and processes, it was necessary to break down all the obstacles, physical and not. The functional structure did not optimize the value of the process but only of the single function, letting each department without the overview of the big project. The "walls" between the multiple function departments have created difficulties in the exchange of information between them. Instead, the use of a matrix structure consider an optimization of the process looking along the flow of all activities, overcoming the walls of the functional structure. In this way, functions become competences, which provide technical and specific support to all the value streams. The value stream generation follows the processes (Programmables, Inverters, Valves …) and, with the support of the competence centers (e.g. Planning, Quality, Platform, Engineering …), creates greater results in terms of efficiency and customers satisfaction.

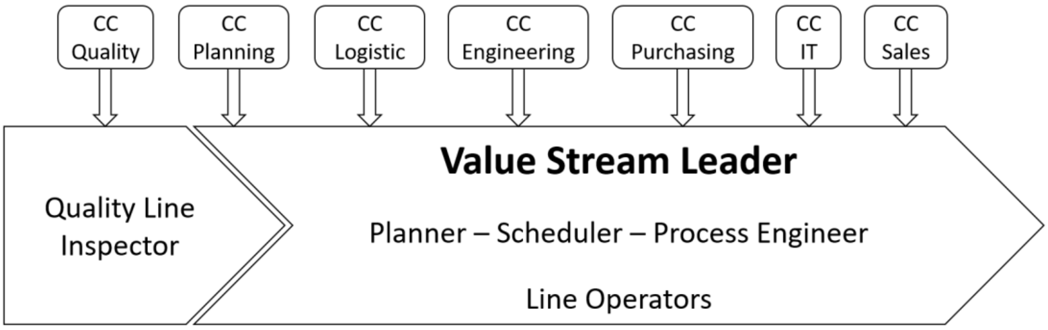


Figure 1.3. Value Stream structure (source Carel internal documentation).

The VS team members respond hierarchically to the VS Leader and functional to the Competence Centre.

The lean transformation has continued the following years and it is still in act, just like the philosophy of continuous improvement suggests. Indeed, these applications have brought surprising results. Carel estimates that for every hour spent on continuous improvement in production, three are saved in cycle times. In addition, production rejects have fallen by 59%, turnover per square meter has increased by 47%, service levels have risen by 9% and the number of defects has halved (source Carel reports).

1.2. Products Categories and Applications

The products portfolio of Carel is wide and suitable for a vast variety of different application, thanks to their flexibility and great innovation of control solutions. Automotive, cleanrooms, data center, hypermarket, offices, shopping centers, industry and many others are just few of a large collection of sectors in which Carel's products can be employed. Products categories are presented as follows:

- *Controls*
  Electronic controls used for the set up and control of thermodynamic parameters in HVAC/R systems. They are divided in parametric controls and Programmable controls. The first are composed by a simpler architecture, with small number of relays managed and parameters controlled. Programmable controls are characterized by the presence of software, with the possibility of an integration with the building management system; they have a large number of settings and interfaces.

Figure 1.4. Programmable controls for managing HVAC/R applications and systems (source Carel Industries products portfolio).

- *Speed controllers and inverters*
  They are used to control electrical engines, which directly controls the functionalities of HVAC/R systems and other particular applications. Inverter and controllers operating in fan, pump and compressor speed control ensure considerable energy savings, especially at low range of speed or pressure.

Figure 1.5. DC inverter for BLDC compressors (source Carel Industries products portfolio).

- *Remote management, supervision and monitoring systems*
  Complete and reliable solution for management, monitoring and optimization of refrigeration and air-conditioning systems. They are distinguished in local supervision or remote supervision, with the latter that can be used to analyze and compare the data collected by the local supervisors on each system for centralized site management.

- *Sensors and protection devices*
  Sensor technology for temperature, pressure, humidity, air quality, gas leakage detectors and protection devices, to prevent problems can cause system shutdown.

- *Electric panels*
  Power solutions for the management and supply of humidifiers, cold rooms, compressors racks and other application. This product family was born with Carel, as the name of the company suggest 'Costruzione ARmadi ELettrici', which in Italian means "control cabinet manufacturing".

- *Humidifiers*
  A humidifier is a device that adds moisture to indoor air, keeping and controlling a constant level of humidity of the space; the technology is a fundamental application in hospitals, museum, textile and tobacco industry, offices, food industry and many others. Carel offers two main type solutions: isothermal humidifiers and adiabatic humidifiers. They differ principally on the source that transform the water into steam or moisture. Isothermals keep almost a constant temperature, balancing the incoming energy (gas, resistances or electrodes) and the outgoing steam; differently, adiabatic humidifiers have no exchange of heat and use centrifugal, ultrasound, pressure or atomizer to create moist air. Closely related are the water treatment systems, which generate demineralized water with

physical/chemical, flow-rate and pressure characteristics suitable to supply the humidifiers.

Figure 1.6. Pressurized water humidifier (source Carel Industries products portfolio).

- *Electronic Expansion Valves*

  Called with the acronym EEV (or ExV), electronic expansion valves are the finished goods involved in this case study, and precisely, in which the brazed semi-finished good takes place.

  EEV are used in refrigeration systems to control the flow of refrigerant into the evaporator and obtain the best heat exchange performance with the highest possible efficiency. Among other things, the valve has also the function of protecting the system against the return of liquid. The combination of mechanics and electronics generates much more efficiency and accuracy than a simple thermal expansion valve. The principal benefits of their use are wide range of control, energy savings, better performances and faster response to surrounding conditions.

  There are many different designs for an EEV, as show in the figure below, depending on the type of system, the refrigerant used and the working pressure. Anyway, the basic working principle remains the same: a stator creates an electromagnetic field influencing a permanent magnet directly connected to a needle. The needle controls the position in and out of a seat, hence closing and opening the valve. EEV has temperature and pressure sensors downstream, which take measurements, used from the control stator to know how much the flow should be opened or closed to maintain the correct superheat.

Figure 1.7. Electronic Expansion Valves (source Carel Industries products portfolio).

1.2.1. Brazed Bodies: the main components

The brazed component of the valve is the principal object of the process in analysis and main reason of production delays in the associated Value Stream. In the majority of cases, this semi-finished good is composed of a brass or steel body and two copper connections, brazed to the body. The latter has the function of hosting the valve cartridge and a stator above, whereas the two connectors of connecting the body to the pipes.

Of all the methods available for metal joining, brazing may be the most versatile. It can be distinguished from a welding process by the working temperature and the use of an external metal to join the two parts. In welding, high temperatures are used to melt the base metals together; instead, for a brazing process such temperatures are not even close comparable. The molten filler metal cools to join the workpieces together providing a considerable strong join between similar or dissimilar metals, just like in valves case. The melting point of the filler metal is above 450°C, but always below the melting temperature of the parts to be joined. To achieve a robust brazed joint, the filler and workpieces should be metallurgical compatible, and the joint design should incorporate a gap into which the molten braze filler can be distributed by capillary action. The filler metal is in this case a silver-based alloy, which is protected by a suitable atmosphere, often a flux, while heated slightly above melting point. The atmospheres in which the brazing process can be undertaken include air, controlled atmosphere and vacuum; the latter allow reducing oxidation of the joint. Since brazing does not melt the base metal of the joint, it allows much tighter control over tolerances, which is a fundamental aspect if the EEV need high accuracy of the flow control. In addition, brazed joints repel gas and liquid, withstand vibration, shock, and are unaffected by normal changes in temperature, essential characteristics for a valve application. The joint clearances, fixture, etc. are much more forgiving in brazing than in welding, however, it is usually required to galvanize the jointed product in order to clear and remove imperfections, such as oxidation of the jointed surface.

A perfect brazing process requires high experience and knowledge, paying attention to few but non-negligible aspects. Determine the joint spacing, choose the right brazing alloy, eliminate grease and contaminants and clean the joints, add flux, position parts carefully, control the heat. This latter is typically provided by a hand-held torch, a furnace or an induction heating system; following a brief description of these methods:

- Torch brazing suits better small assemblies or complicated assemblies, since the skills of the operator can be a goal or, contrary, an issue if not well trained.

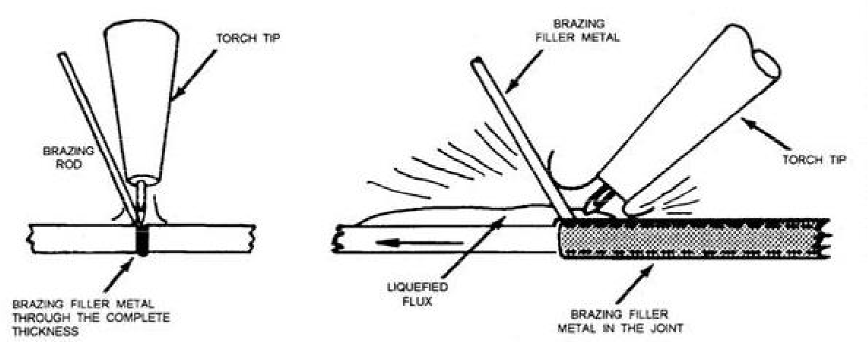


Figure 1.8. Torch brazing process (source tpub.com)

- Furnace brazing does not require skilled operators, it is used only in case the filler can be pre-positioned in the joint gap. It is not particularly energy efficient since the furnace needs long start-up and long cool down, consequently not sustainable for low volumes.

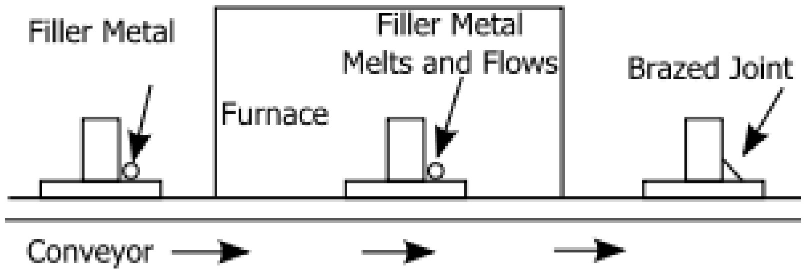


Figure 1.9. Furnace brazing process (source totalmateria.com).

- Induction brazing is the best in terms of speed, accuracy and consistency, but only if the induction system is well designed. If this is the case temperature can be controlled, having feedbacks on the part of the joint which need more heat, just like the cycle time, in order to obtain more a precise production schedule.

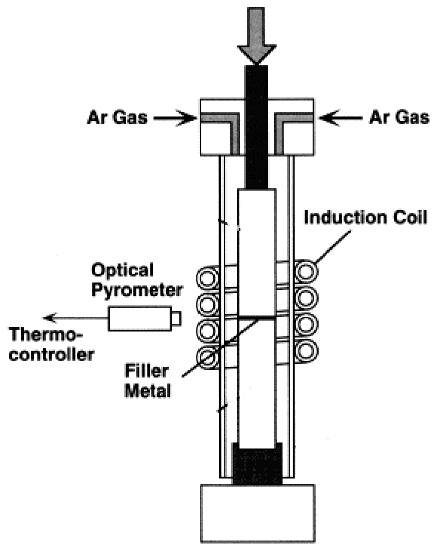


Figure 1.10. Induction brazing process (Noda, Shimizu, Okabe, Iikubo, 2004).

As described above, brazing is a delicate process that cannot be internalized if there is not the right know-how. The core competences of Carel do not include welding processes, since it is centered just on humidification and electronic solutions for the control of HVAC systems. This is why the company chose years ago to externalize the process, purchasing the brazed connectors from specialized third-party suppliers.

2. SUPPLY CHAIN MANAGEMENT

Nowadays, many tools such as advanced information technologies are shaping the business environment, helping managers and specialists to operate in wide logistic infrastructure. Goods can be moved globally in just few days and information exchanged instantaneously. In order to establish and maintain competitive advantage in such complex background, companies are moving from cost-reducing to profit-maximizing strategies. Objectives of firms are not only enhance back-end logistic efficiency but also improve front-end customer satisfaction, through innovative supply chain management systems.

Supply chain is a term that groups into a complicated system all the activities, organizations, people, resources and information involved in delivering a certain product to a customer. All these actors concur to the transformation of raw materials to finished products, from the point of view of the end customer. It can be seen as an aggregation of multiple supply/demand systems, linked together with different needs and strategies. In the management of a supply chain, multiple aspects have to be taken under analysis:

- Materials supply and supplier selection
- High-level strategies
- Organization structure and make or buy decision
- Price and cost management
- Delivery and logistic
- Legal and ethics matters

This chapter presents a theoretic overview of how the supply chain is managed, focusing just on the planning phase of the production and material supply, which is the field in which the case study is collocated. At the same time, a theoretic explanation is integrated with descriptions and consideration on how Carel manages this crucial area of the business.

2.1. Types of Production Systems

In a company or, more generally, in every business organization there is a point in which the supply has to meet the demand. In manufacturing system, demand coincides with sales while supply means production of goods. The interface and relationship between these departments is a critical aspect of running a business, which needs accurate considerations, good strategies and even greater implementation of them. The department of sales and operations and the department of production planning often work in silos, jeopardising good outputs. In this situation, lean management comes to help, assuring an agile relationship between the two competence centres, which have to work closely together in order to fulfil the gap between what the client needs and what the company offers. In charge of ruling this part of the business, an "ad hoc" planning strategy has to balance the fulfilment of the clients and the minimization of waste and production cost. Planning department, in order to satisfy both production and sales offices, has to grant the right product at the right place with the right quantity in the right time. Carel, since 2008, to achieve these goals, had understood the necessity to create a lean environment, both physical, with the creation of an open space office for all the logistic departments, and at system level, with a constant innovation in E-business tools and training. As discussed in the previous subchapter, the planning modules are the engine that creates and controls the linkage between demand and supply.

Especially if the products portfolio is very wide and with many different families among it, the running production system strategy may not be optimal for every products family. A production system strategy depends on the degree of interaction between the technological development of the product and the market needs. Another important variable that distinguish a system from the others is the way demand is managed and at which point of the production process buffer can reduce its unpredictability. These two factors can be summarized in one concept called 'Customer Order Decoupling Point'. It refers to the point in the value chain of mass customization at which a customer triggers the production activities, and in most of the cases, the last moment at which inventory is held. All activities before the CODP are drive by firm's market researches and planning department (Swamidass 2000, p. 138). This order penetration point acts as a fork, dividing customer-dependent (downstream) and customer-independent (upstream) production, actual demand and forecasts.

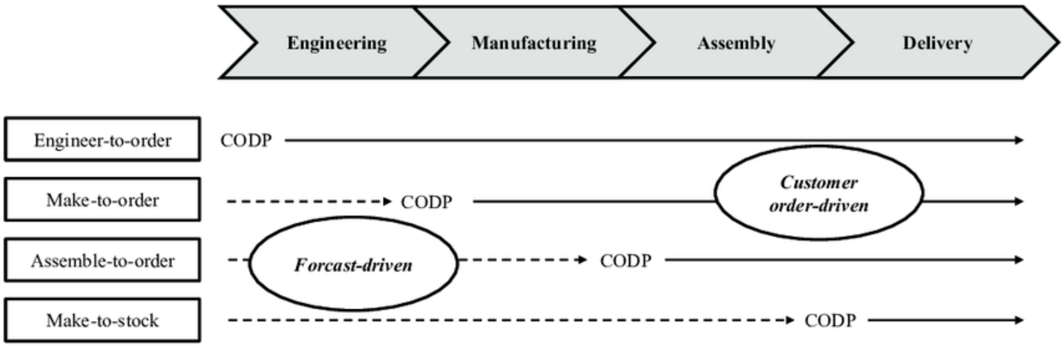


Figure 2.1. Basic customer order decoupling points, (Bogner, Lowen, Franke, 2017).

Now follows a description of the four major strategies to connect sales and production, with a focus on the one chosen by Carel to run its business.

- *Engineering-To-Order*

ETO is a strategy implemented when complex structure are build, not only in terms of dimensions but more in term of product's structure, which can be not only a building or a ship but also a specific and customized software. Major characteristics of this method are the presence of strong relationship with the customer in all project's phases, long lead-time and high cost, new specifications never implemented before, need of project management tools. For an ETO the CODP is always placed before the engineering phase.

- *Make-To-Order*

In this case, products have standards specifications, created by R&D and product development department. CODP is now placed after the engineering phase. Production, from materials procurement to finish good completion, starts only after the customer's order comes in: sales 'pull' the production from the beginning until the end. There are no forecasts on products and no stock is available to fulfil the incoming orders. Lead-time is not as long as for ETO but still very significant. The major issue in MTO system is the saturation of production lines and find the right balance, which is a difficult task since demand is hardly predictable.

- *Make-To-Stock*

Commodities can be sold out of a catalogue, which is defined and specified through a master record: in this case planning has a crucial role in foreseeing demand. When customers do not accept long lead times for a commodity, the firm is required to have goods in stock ready to deliver. This explains why precise forecasts and smart planning are important. CODP is placed just before the delivery, which let forecast drives production and not customer orders as in MTO. Customer is no more a 'king' of the production, but more a 'prize' that have to be caught by the product, a metaphor that tries to explain a push-approach of the strategy.

Aspect	Make-to-Stock	Assemble-to-Order	Make-to-Order
Interface between production function and customer	Low	Medium	High
Customer delivery time	Short	Medium	High
Production volume of each sales unit	High	Medium	Low
Basis for production planning and scheduling	Forecast	Forecast and backlog	Backlog
Order promising	Based on available finished goods inventory	Based on availability of subassemblies and components	Based on available capacity for manufacturing and engineering

Handling of demand uncertainty	Safety stock of sales units	Planning of components and subassemblies	Little uncertainty
Master scheduling unit	Sales unit	Components and subassemblies	End products, major subassemblies or stocked fabricated parts
Final assembly schedule	Close correspondence to the master schedule	Determined by customer orders received in OE	Covers most of the assembly operations
Bill of material scheduling	Standard (one BoM for each sales item)	Planning B/M are used	B/Ms are unique and created for each customer order

Table 2.1. Relative characteristics of MTS, ATO and MTO, (Journal of Operation Management).

2.1.1. Assemble-To-Order: the strategy of Carel

ATO manufacturing system is a hybrid system that merges a MTS strategy, where products are sold “off-the-shelf”, and the MTO strategy, where products are produced only after the order of the customers. In this case, the CODP is placed right in the middle of the value stream, inside the manufacturing activities, which, if well managed, allows benefiting strengths and avoiding criticalities of both systems. In a lean context, it could speak of *push-pull framework* inside the supply chain. The push control bases its planning and production mechanisms on forecast demand, while pull control on customer orders satisfaction.

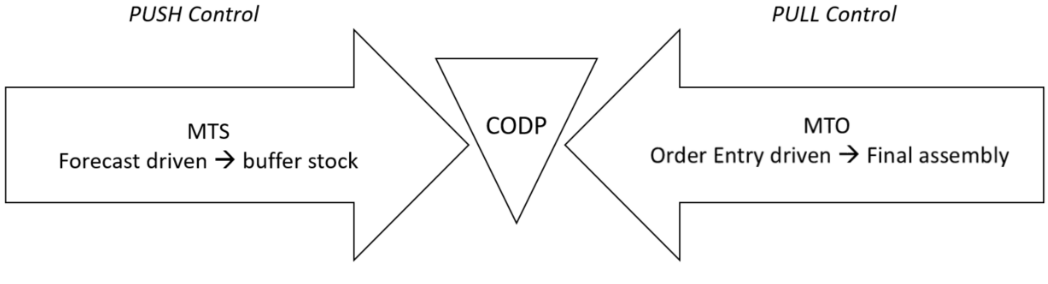


Figure 2.2. Push-Pull framework in a nutshell.

In general, pull control takes from the MTO system the possibility to keep lover level of stock, increase the flexibility of the production lines and improve promptness in customer requirements. On the other side, looking at MTS mechanism, push control allow managing greater level of volumes and production efficiency, it grants stability of supply and reduces gaps in Order Entry management, going towards sales requests.

In a company, push-pull boundary can be very thin and blurred, and besides often varies from product family to product family. Any inconsistencies or contradictions between the two sides of the value stream can undermine the stability of the overall system: in Carel, Available-to-Promise planning is the module that coordinates demand and supply across push-pull edges. This means downstream from the inventory/order interface there is a lead-time to the customer based on final assembly, whereas the availability checks just for the presence or not of the required materials and subassemblies. If there is the presence of components shortage, the system can provide a reasonable date for finished product delivery, in compliance with customer request. In such circumstances, almost daily, it might create conflicts of interests between the sales department, which pull the production from the client side, and the planning department, which push the production: constant communication and alignments have great value.

Company has to decide at which point of the BOM material is kept ready available in stock (upstream the CODP), after that products are produced only in response to a customer order. Consequently, operation department has to design a mechanism that guarantees, to all products having an internal CODP, the best support along the value stream. Then, one of the most important issue will be to adapt the planning and control approaches to each tasks, based on the position with respect to the CODP.

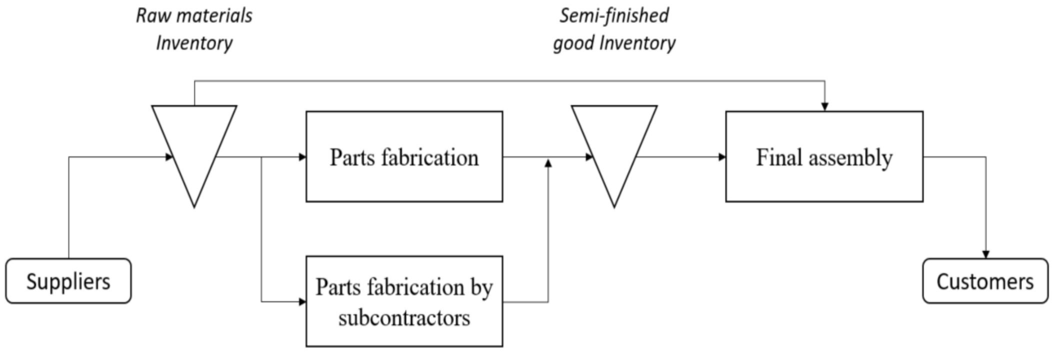


Figure 2.3. Materials flow diagram for Carel (ATO system).

As schematized in the figure above, the ATO system of Carel, just like a common ATO system, has a buffer stock for standard parts and components that are acquired, according to the BoM overturning of finished products forecast. In addition, some semi-finished and sub-assembled goods are produced to create buffer stock, such as SMD components for electronic production. In Electronic Expansion Valves, value stream together with cartridge and needle subassemblies, also the brazed components are produced for stock.

The necessity to guarantee a sufficient level of customization is one of the main reasons for which a company chooses to follow ATO systems. Moreover, year after year, customer delivery time became more and more an important and competitive KPI, which allows a firm to gain important portions of the market. Hence, an implementation of MTO system cannot be the right strategy, especially for Carel market position, since it would require an increase in delivery times, crucial metrics of its success. They would not be as low as in case of MTS systems but can guarantee improvements upon the reliability of promised shipping dates. In conclusion, ATO can provides flexibility, speed and waste reduction, which can be placed under the wings of agile and lean methodology.

2.2. Planning Systems

Planning systems can be classified in hierarchical structure, as in figure below, based on the horizontal time they look at and the level of value chain they refer to, with the scope of providing the material flow along the supply chain. Each activity of the matrix can be represented and executed by specific software, which compose the modules of the Advanced Planning & Scheduling system of a company. APS system supports the decision making process inside the firm, giving the possibility to implement what-if analysis for different scenarios, create production plan, link different actors and maximize the planning visibility, from the demand forecasting to the procurement activity.

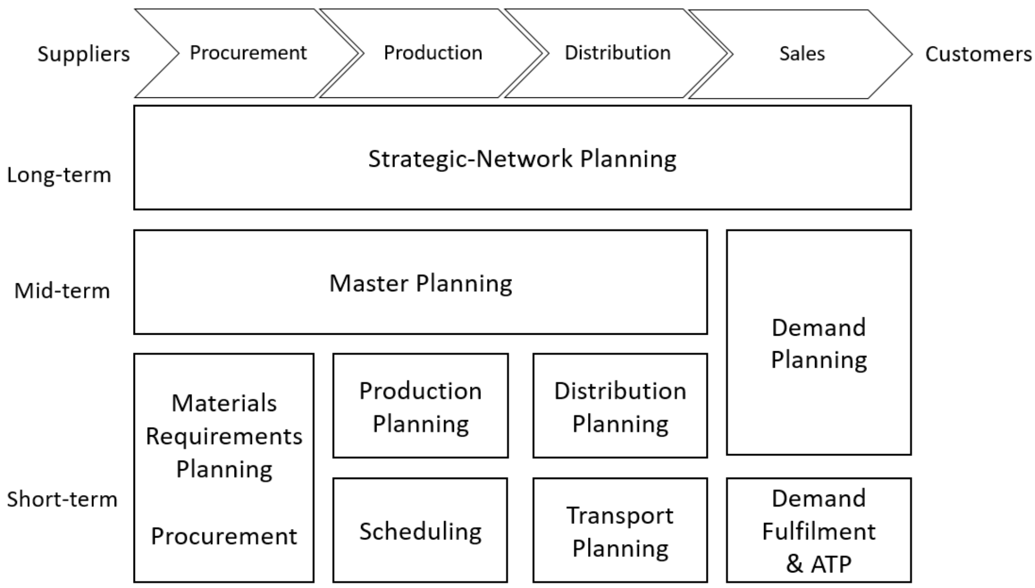


Figure 2.4. Supply Chain Planning Matrix, (Stadtler and Kilger, 2000).

In broad terms, a planning macro activity can subdivided in the following, and ordered, phases (B. Fleischmann, H. Meyr, M. Wagner, 2008):

- Recognition and analysis of a decision problem,
- Definition of objectives,
- Forecasting of future developments,
- Identification and evaluation of feasible activities (solutions),
- Selection of optimal solutions

Plans are not made for eternity and have to be monitored constantly, in order to depict as soon as possible the moment in which they have to be revised. Every strategic level has a different planning horizon, as follow.

2.2.1. Long-term: Strategic Planning

Design of a supply chain is certainly the crucial activity in a long-term perspective, usually from one to three years, requiring great efforts and capabilities. In the last decades, globalization requests organizations to implement Strategic-Network Planning more and more frequently, given the rapid changes a business is exposed. Such activity is necessary not only in case of expansion but also in retraction. Companies have to identify their market position, in terms of both value chain position and key products, and therefore the core manufacturing processes and the third parties, which will feed them with materials. Usually decisions undertake by companies are of go/no go type, helped by analysis of data in situation of certainty (forecasts and economic trends) or uncertainty (stochastic optimization models).

Choices that comes out from a new design can be different: choice of new partners, re-design of distribution networks, closing or openings of new plants, definition and allocation of manufacturing and distribution capacities. Thereafter, the capacities become the constraints for the master planning process, which determines a more detailed material management, in smaller periods.

2.2.2. Mid-term: Tactical Planning

The planning horizon usually ranges from 6 to 24 month, but can varies from company to company. Here takes place regular operations activities such as the determination of rough quantities of resources and materials needed, demand forecasting and distribution planning.

After the determination of which products to place in which markets, the mid-term planning analysis starts from the definition of available and planned customers' orders. Since *customers' demand* is the input for most of the planning activities, forecasting demand is seen as a crucial aspect of the business, helping production to find the right capacity dimension with all its consequences. The methods used from companies can be divided into two main categories, univariate time series and multivariate life cycle models.

Once the demand is planned, including both forecasts and orders confirmed, *Master Planning* becomes relevant, since it looks for the most efficient way to fulfil this planned demand, often over a seasonal interval. In this phase, the demand allocation to different lines or different plants, based on available capacity, can be re-assigned and levelled in order to avoid bottlenecks or production delays. Available capacity can be modified as well, usually with the redistribution of resources among production value streams, and adding or eliminating temporary workforce based on demand fluctuations. In mid-term or short-term scenarios, master planning either becomes the major input of procurement activities, along with the previous choice of suppliers and contracts establishment.

Then comes into play the flow of goods between sites and on the network. Usually stock levels have already been set in master planning, but now there is the necessity to guarantee transports of goods to customers with or without a 3PL (third party logistic provider. *Distribution planning* as well as inventory management set rules and procedures to guide the correct flow and storage of goods, trying to reach the targets set during master planning phase or even during strategic network planning.

2.2.3. Short-term: Operational Planning

Despite of the other levels, at this lowest planning level, the modules that take place need the highest degree of accuracy and details of them all. Activities have to receive all specification and details for an immediate execution and control thereby. The planning horizon can vary between few days and few month, based on the type of business of the company. As has already been said, all the upper modules serve as constraints, because at this level all the strategic and tactical decisions have to be transformed into operative modules and tasks. The purpose switch then into the concretization of objectives, through the achievement of performances along the supply chain: lead-times, delays, service level and other strategic KPIs.

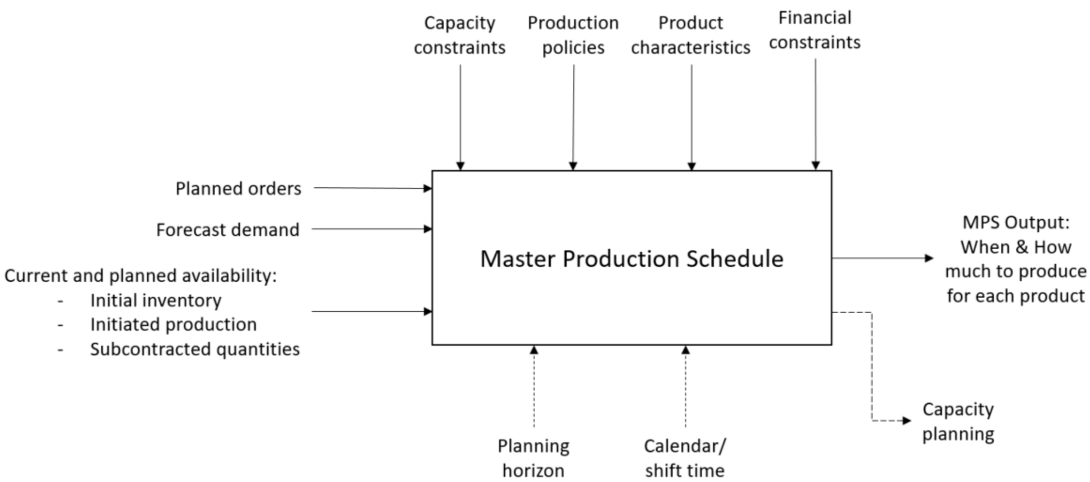


Figure 2.5. Master Production Scheduling process.

Production planning and *detailed scheduling* modules are implemented at this level, coordinating flows within the same plant and with more detailed the same productive department. As shown in the figure above, inputs and constraints come from the master planning or even higher-level planning phases. The scope of this module, which is indeed the bread and butter of a planner specialist, is to set quantities and dates (start production, schedule ship date …) for each product.

A module does not have a unique collocation among the three levels presented, but depends on the production strategy of a company and LT of suppliers. Actually, *purchasing and material requirements planning* may take place only after the production schedule of the finished good (short time horizon) in case of Make to Order or Engineering to Order strategies. Whereas, in case of Assemble to Order or Make to Stock strategies, the procurement of raw materials or semi-finished goods may take place various months before the scheduling of production, but always after the master planning, which provides the planned quantities required. Ordering of materials are often managed by MRP or ERP systems, which through the BOM explosion of the planned demand create the suggestions in terms of quantity and dates for the procurement activity.

Finally yet importantly, there are two important modules, mutually dependent: demand fulfilment and Available-to-Promise functions. These are at the forefront of the business, because they play the important role of linking customers' orders and enterprise production, hence under the back-end versus front-end trade-off. *Demand fulfilment* aims to match order entry, order execution and order delivery, planning promised due date on the base of available-to-promise policies. Consequently, *ATP* policies depends also on the orders already placed and promised to customers. In this case, an APS should also give priorities to orders in case of unforeseen events, such as the breakdown of a machine or materials delays.

Briefly, Advanced Planning Software are not isolated blocks inside the supply chain management, they are instead correlated each other, often with the possibility to directly exchange information between them. Moreover, all planning levels and modules have the same importance, because if just a piece is missing the puzzle cannot be completed.

2.3. Materials Supply Management

In this chapter will be presented the principals materials supply management systems from a theoretical point of view, focusing on the aspects specific to Carel Industries. The digression starts from the explanation of the different types of demand to which a code is subjected, and then the supply systems will be divided in two major categories, with a focus on the MRP system.

Before going on with the presentation of the two major procurement systems, it is relevant to look at the two different types of demand that compose a production system: dependent demand or independent demand.

Typically, considering the generic structure of a Bill of Material of a generic item, an independent demand affect the "father codes", finished goods which demand cannot be calculated with deterministic models, but just related to demand forecasting or market sales confirmations. On the other hand, it is simple to deduct that the "son codes" are the ones subjected to dependent demand, since the explosion of the BoM overturn univocally the consumption of their "father", weighted by coefficient of usage. In a BoM, beneath father codes, there can be either raw materials, components of subassemblies, which are as well dependent of their father demand. However, whenever a component or subassembly is sold separately, for example as spare part, both a dependent and independent demand will affect it.

The duty of a material supply management system is to define with extreme precision the right quantity and reorder timespan for every item of the BoMs. In simple words, it has to answer to two questions, always in the mind of a planner: how much and when to reorder. In table below there are presented five major characteristics of an item that have to be considered when choosing the right materials management system, they will be remarked in the following subchapters, where the two major systems of materials supply are presented.

Features	**Stock base**	**Demand base**
Employment value (unit cost)	Low	High
Turnover Index	High	Low
Demand type	Dependent	Dependent, Independent
BoM width	Short	Large
BoM depth	Not deep	Deep

Table 2.2. Five characteristics of an item w.r.t. the selection of supply base system.

2.3.1. Stock Base systems

In systems based on stock, historical consumptions are the drives for the calculation of expected requirements, and that is why they have the appellation of "look back" system. The reorder of the material is notified when the stock goes below a fixed level, which is called reorder level. As show in figure below, the classical trend of the storage assumes a saw-tooth aspect, more or less sharp on the base of turnover indexes. The area below the curve represents the investments in stock that the company has to bear. Then there are two lines: line P represents the reorder point level, which has the role of preventing possible stock-out with a previously determined SL, usually 95%, as used in Carel (figure 2.6. (b)); whereas line B indicates the buffer stock level, and represents the most likely consumption of that good during LT.

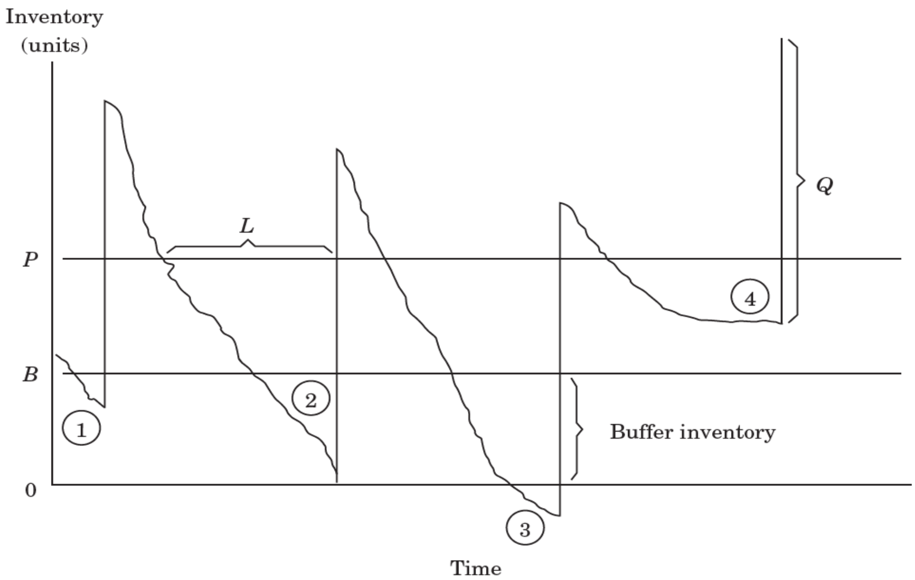


Figure 2.6. (a) Example of stock based model: Fixed-Order-Quantity model with buffer inventory and variation in demand (Fraser Johnson P., Flynn A., 2015).

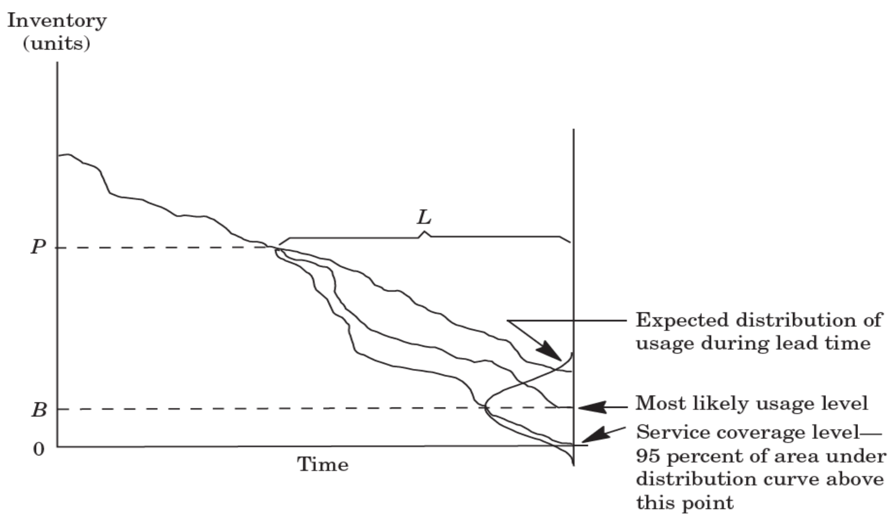


Figure 2.6. (b) Example of stock based model: determination of buffer inventory to achieve desired coverage (Fraser Johnson P., Flynn A., 2015).

The items mostly indicated for this type of operation have low vlaue, in order to minimize the stock value, and for the same reason are chosen items with high turnover indexes.

In general it has been said that stock systems replenish the storage with a certain quantity, when it goes below a certain level, with respect to future expected consumptions, but on the base of past consumptions. Basically, the stock based system that can be depicted are five, as illustrated in table 2.3. However, there won’t be a depth descrition of them, but just a mention during the description of the two variables that have to be combined when choosing the right system:

<table>
<tr><td colspan="3" rowspan="2"></td><td colspan="2">ORDER QUANTITY</td></tr>
<tr><td>Fixed (Q)</td><td>Variable (till S)</td></tr>
<tr><td rowspan="3">STOCK REVIEW</td><td>Continuous review
(ROL – Reorder Level)

Variable reorder frequency
(T=0)</td><td>With reorder level (R)</td><td>(Q,R) Systems
(ROP)</td><td>(S,R) Systems
(Min Max system)</td></tr>
<tr><td rowspan="2">Periodic review
(ROC – Reorder Cycle)

Fixed reorder frequency
(T>0)</td><td>With reorder level (R)</td><td>(Q, R, T) Systems
(ROP with fixed frequency)</td><td>(S, R, T) Systems
(Min Max system with fixed frequency)</td></tr>
<tr><td>Without reorder level</td><td>---</td><td>(S, T) Systems
(Max system with fixed frequency)</td></tr>
</table>

Table 2.3. Classification of stock based systems, (De Toni, Panizzolo, 2018).

- *Order quantity*

  The quantity of the order, which can be both purchased or produced internally, can be fixed or variable. Of the five systems, three, with a min-max methodology, have a variable order quantity, which depends on the difference between the available stock at the ordering moment and a max level of stock (S) that has to be reached. In the other cases the replenishement order will always have a fixed quantity, previously determined by economic analysis.
- *Frequency of stock review*

  In this case there are two possibilities: the presence or not of a stock review interval. In case this interval does not exists, an order is released just when the stock quantity fall below a predetermined value, the reorder level (R). When the system presents this review frquency, an order can be released only if the event occurs in time T and simultaneously the stock is below R. in other words, both cases expect a order releasing only in case stock level is below a certain quantity, but in the first case it is applied a continuous review of the stock, while for the second the review is required only at fixed point of the time horizon.

2.3.2. Demand Base systems: MRP

Unlike stock base systems, in a demand base system, as the name suggests, the needs are calculated overturning of the father's item demand on the lower levels of the BoM; they hence results to be subjected to a dependent demand. The material reorder point is not fixed in time, neither is triggered by the presence of a reorder level quantity; materials are rather re-ordered when the available stock is not sufficient to cover the future demand of a certain period. The shorter the period between the receipt of the material and its picking, the lower the financial investment in storage, which becomes necessary with the presence of higher economic costs, due to the complexity of managing these kind of systems.

The system managing the material requirements is the MRP procedure (*Material Requirements Planning*), physically a software, and the engine of material planning. Its scope is to define the exactly demand of all items which fathers are object of the MPS (Master Production Schedule), and plan the emission of an order, usually through a suggestion on the vertical plan. The material planning phase include all items in BoM of a finished goods, from the first raw material to the last subassemblies; moreover, an MRP looks at the Final Assembly Schedule (FAS), checking possible missing items, not available for the production. In this latter case, it will create a warning to highlight critical situations, and then will plan a reorder of material covering the shortage.

An MRP, just like any software, is fed by data in *input*, in order to fulfil its final purpose, listed below:

- *Bill of Material*
  It is the list of all the items, which compose an end item. When the MRP explode the BoM of a master item, the quantity of every components is determined by a coefficient, defined as the quantity of a 'son item' consumed or employed in order to produce or assemble a single unit of its 'father item'. Moreover, items are not classified just by their coefficient of use but also by their usage sequence. Just like a hierarchical structure, every bill of material is divided in levels, which can have a different number of items within. It is called depth of a BoM the order of magnitude of the levels which is composed by, whereas the width represents the number of items per level, more items in a same level means a wide BoM. Level zero is usually assigned to the finished good.

- *Master item registry*
  It is a database containing the lists of all the items processed and utilized inside the company; it gives the possibility to identify an item univocally, providing whatever sort of information is needed. In an MRP optic most relevant information are: cod item, item type (make or buy), lead-time, unit of measure, MOQ, MPQ, sourcing rule, supply method and reorder policy.

- *Inventory stock*
  The net quantity, also called available-to-promise, relevant during the netting phase of the gross requirements.

- *PO released*
  Production and purchase orders released still not competed, for which the system has to know the completion date in order to calculate right net requirements.

- *Production plans (MPS/FAS)*

  The planning systems, on medium and short term, plan the production of finished goods based on their independent demand, looking at market sales and forecasts. Therefore, based on these planned order demand or work order demand, the MRP elaborates a plan for the dependent items.

After the processing of inputs and appropriate calculations, the system generates *outputs* for further planning activities:

- *Planned work order demand*

  They refer to both make and buy items, and represents planned consumptions based on the father BoM explosion. They are generated by the MRP when the available stock cannot satisfy the production requirements. A planned work orders demand can be modify whenever the overall demand experiences some changes or the inventory receives or consumes stock. Usually they are transformed in work order demand when the father item that recalls them has a job order consumption.

- *Planned order*

  These are suggestions of order towards external suppliers, with the same mechanism of the work order demand explained previously. The planner will take the order suggestion and transform a planned in a released order.

- *Warnings and suggestions*

  Usually MRP systems create messages, alarms and warnings, which notify the planning specialists' eventual issues, such as the need to re-plan dates of delivery or receiving of a material that is in delay.

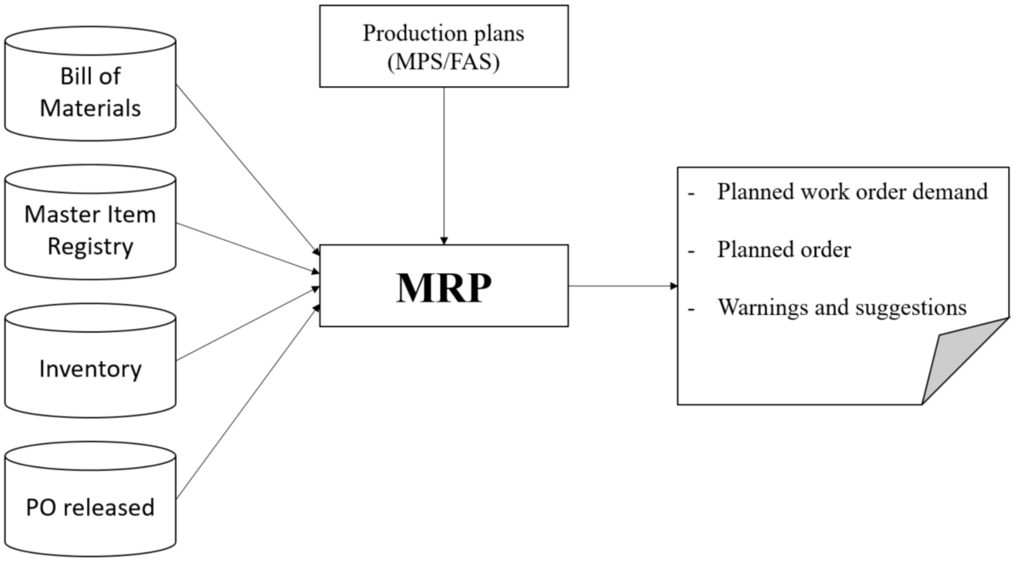


Figure 2.7. MRP: Input and Output.

The logic process of a generic MRP starts from the "timed" explosion of the BoM, in which going backwards from the end item, every sub-item is represented by the length of its lead-times; the view that should come in mind is similar to a Gantt chart. This representation helps to locate on the time axis the moments in which orders should be placed. The starting point of the algorithm is the completion date of the end item, and with a backwards mechanism, it identifies the release dates "at the latest", whether they are referred to an assembly order, a production order or a purchase order. Then, once the gross requirements are placed, a netting phase follows, in which the gross needs generated in the 'i-th' period are cut from already outstanding orders and stock of the good; MOQ and MPQ policies determine the final net quantities to be released. In brief, for every item, final requirements are consequence of the planned demand of the father items, netted by existence of stock, outstanding orders and lot sizing policies, always related to a time period. Usually, the planned horizon of an item considered by MRP systems is at least equal to the sum of the lead times of its fathers.

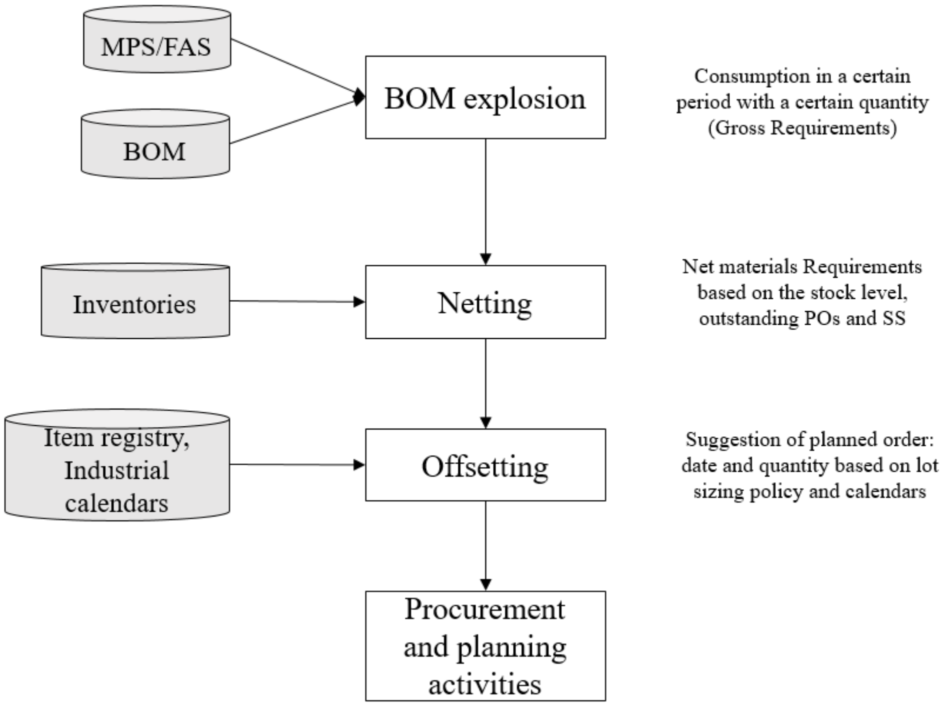


Figure 2.8. MRP: operating logic.

It has to be said that this description represent the base of a generic MRP system, usually the calculation behind can be more complicated; moreover, every system has ‘ad hoc’ set up in order to meet business requirements of different companies. A major example, which represents the case of Carel, is the method to increase protection against demand uncertainty. As it has been described, in Carel ATO manufacturing systems, gross requirements of raw materials and subassemblies are calculated on the base of demand forecast, and then their realization can be different from the expected. In order to prevent situation in which net requirements overcome the predicted ones, the MRP is integrated with Safety Stock: net requirements do not generates when remaining stock in a certain period becomes negative, but when it fall below the safety stock level.

2.3.3. Kanban

The term 'Kanban' born in Japan, son of the Toyota engineer Taiichi Ohno during 50's and 70's, which mean stands for signboard or billboard. It is a scheduling system and material reorder system for lean manufacturing, developed to improve manufacturing efficiency. This method is at the base of pull operating logic, where products are made to order, under which in a supply chain downstream phases pull components and goods needed from upstream, rather than let this latter to push the goods towards clients. This framework has the goal to limit the excess of inventory at any point of the logistic chain and production, since Kanban system can be implemented also within the same production unit. When supply time is long and demand forecasting is difficult, the use of a demand sign that travels immediately through the supply chain allows quicker response to demand fluctuation and a mitigation of losses due to stock shortages or overstock. Kanban system can also improve flexibility, integration and collaboration between the actors involved in the process chain; moreover, if there is an electronic operation, the IT system allows a better management of the production with the presence of instantaneous information.

The signboard scope is to point out in upstream phases that a certain quantity of a specific component is needed downstream, creating an almost instantaneous replenishment of the materials. This precious indication can be obtained in various ways; the most traditional way is the use of a single or double signboard (card) containing the message to move, deplete or produce products, part or inventory. It can be represented by an empty bin (or space) to be fill, this systems are called 'three-bin system' or 'empty for full'; this system requires a full bin on the factory floor, another one at the inventory control point and the third at the supplier, empty. Once the production bin is consumed, the storage quantities replenish it and, at the same time, supplier fills and delivers the batch in his possession. Nowadays, Kanban signal are almost all electronic, thanks to the use of barcodes. Anyway, whatever the shape it can assume, the functionality is largely the same: the production phase consume materials stored inside standard boxes, placed upstream with respect to the production line, in a place commonly called 'supermarket'; every box ha a card, containing all information about that product and its barcode. When all items have been processed, the empty box is delivered upstream to the production process in charge of replenish it, together with the associated card or simply triggering the replenishment production by shooting the barcode.

In a common Kanban system, the number of 'cards' determines the overall maximum value of the buffer stock for an item, which in turn represents the number of standard boxes employed. The trade-off is always between the financial cost of keeping higher stock, hence higher number of 'cards', or the risk of material shortages in case of lower stock level. As example there will be presented two methods for the calculation of the optimal number of signboard:

- The following is the most popular model, which counts the total quantity on the base of average demand fluctuation and safety factor.

$$N° \, cards \geq \frac{Avg \ Demand * Time \ Span * (1 + Safety \ Factor)}{Box \ Std \ Quantity}$$

- In Carel, the overall quantity is otherwise obtained with the sum of three factors: cycle stock based on the reorder lead-time, buffer stock based for external risk factors and safety stock for internal risk factors.

$$N° \, cards \geq \frac{Cycle \ Stock + Buffer \ Stock + Safety \ Stock}{Box \ Std \ Quantity}$$

Carel adopt a Kanban production system for intra Value Stream material flow, hence semi-finished goods produced in a specific unit and employed for the final assembly in a different one. The outstanding logic uses a single 'card' system, associated to each standard box in which it is disposed a barcode that identify univocally the card. When the basket is empty the operator scan the barcode generating the release of a new work order, which will replenish the stock as soon as possible; below the figure of a Kanban card in Carel electronic production.

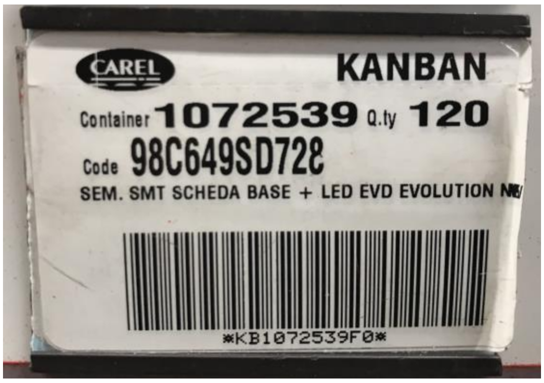


Figure 2.9. Internal electronic Kanban in Carel production lines.

2.4. Make or Buy

Purchasing, supply management, and procurement can be used interchangeably to refer to the integration of related functions to provide effective and efficient materials and services to the organization. However, since it has already been discussed, this subchapter will focus just on the presentation of the three potential way of managing the procurement of goods: make them internally, buy from external suppliers or subcontract the production. The standard and closely related functions of procurement are listed below, even if no deeper investigation will be conducted:

- Recognition of needs (from MRP)
- Translation of needs into a commercially equivalent description (make or buy decision)
- Search for potential suppliers, with market investigations
- Selection of suitable source, analyzing bid
- Agreement on order or contract details
- Delivery of products or services
- Payment of the suppliers

When a product is designed, the business has to decide, for each component inside the Bill of Material, whether to produce it internally or procure it from an external supplier. Between this two opposite scenario there can be a gray zone in which characteristics of both method can be mixed in order to satisfy particular conditions.

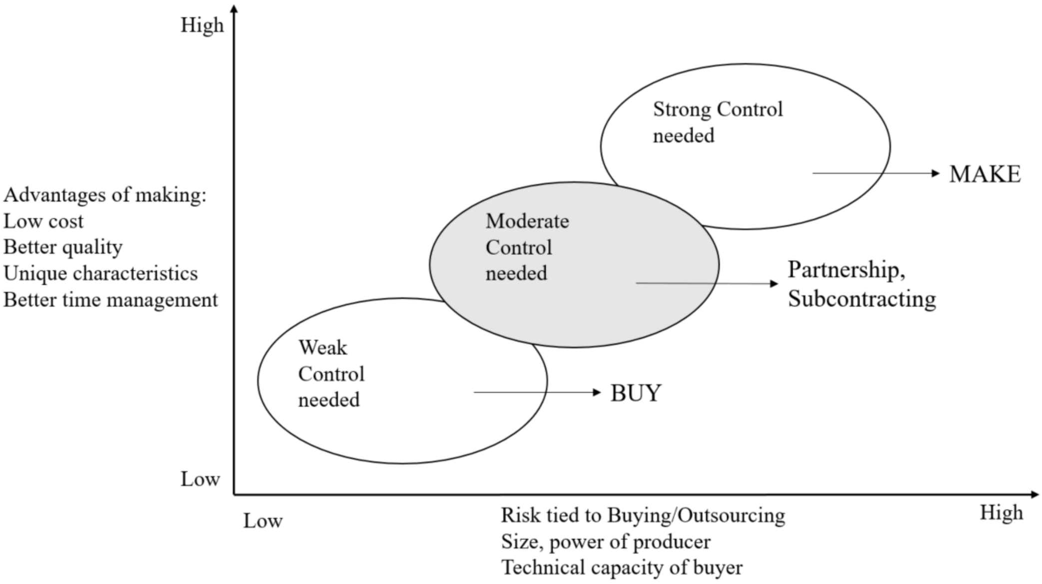


Figure 2.9. Make or buy decision boundaries (adapted from Luenendonk, 2019).

As a fact, it is usual in a fast pace industrial environment to change the procurement strategy of a material, especially when events modify circumstances and equilibria. Increasing in global competition, cost reduction policies and focus on core strength are the main drivers of the affirming outsourcing trend. Managements are increasing emphasis on buying strategies in order to improve productivity and competitiveness. However, some conditions suggests insourcing changes, as an opportunity to diversification or the right moment to exploit the death of a major supplier, conquering its market share or at least part of it. For simplicity, the table below summarize the major reasons that lead to the choice of insourcing (make) or outsourcing (buy).

Why Make?	***Why Buy?***
• The quantities are too small and/or no supplier is interested or available. • Quality requirements may be so exacting or so unusual as to require special	• The organization may lack managerial or technical expertise in the production of the items or services in question.

processing methods that suppliers cannot be expected to provide. • Greater assurance of supply or a closer coordination of supply with the demand. • To preserve technological secrets. • To obtain a lower cost. • To take advantage of or avoid idle equipment and/or labor. • To ensure steady running of the corporation's own facilities, leaving suppliers to bear the burden of fluctuations in demand. • To avoid sole-source dependency. • To reduce risk. • The purchase option is too expensive. • The distance from the closest available supplier is too great. • A significant customer required it. • Future market potential for the product or service is expanding rapidly. • Forecasts of future shortages in the market or rising prices. • Management takes pride in size.	• Lack of production capacity. This may affect relationships with other suppliers or customers as well. • To reduce risk. • The challenges of maintaining long-term technological and economic viability for a noncore activity. • A decision to make, once made, is often difficult to reverse. Union pressures and management inertia combine to preserve the status quo. Thus, buying outside is seen as providing greater flexibility. • To assure cost accuracy. • There are more options in potential sources and substitute items. • There may not be sufficient volume to justify in-house production. • Future forecasts show great demand or technological uncertainty, and the firm is unable or unwilling to undertake the risk of manufacture. • The availability of a highly capable supplier nearby. • The desire to stay lean. • Buying may open up markets for the firm's products or services. • The ability to bring a product or service to market faster. • A significant customer may demand it. • Superior supply management expertise.

Table 2.4. Reasons for making and buying (Johnson, Flynn, 2015)

Further, these reasons will be useful to understand the complexity beyond the procurement process of brazed item in Carel, and will help to find a viable solution to the problems. Precisely, the state-of-the-art will describe that the procurement process of brazed goods is right in the middle of the two options 100% make or 100% buy. Researchers call this middle range of options "gray zone", in which characteristics of make and buy can coexist, offering 'ad hoc' opportunities for both supplier and purchaser. The major area among this spectrum of options is represented by *subcontracting*.

It is called subcontractor a third entity, external to the relationship between a common supplier and purchaser, which assumes responsibilities upon activities to be carried on behave of the bidder (purchaser). This class arose mainly in the construction industry, where the prime contractor usually bid out part of the work to other contractors. Nevertheless, it is a common practice also in manufacturing industry, with prime contractors bidding other contractors to carry on part of their business, both production phases and collateral services (such as HR management, IT service, financials…). In case the company decide to *externalize* a production process, there can be several reasons:

- Some phases are non-core for the bidder,
- No possession of the right know-how
- No adequate facilities and machinery
- Not enough capacity
- Cost reduction due to economies of scale and specialization of the subcontractor.

In this regime, it is common, as it happens for Carel brazed procurement, that the bidder is in charge of supply raw materials to the subcontractor, as long as other materials related to the process. In some cases, even the equipment is supplied from the purchaser, but in this case, Carel do not pursue this practice. The goods in external work are delivered to the subcontractor without billing; there is no transfer of ownership: the bidder pays the subcontractor only the cost of production, or any cost related to it, previously agreed in the contract. More information about how Carel manages the external work for the brazed bodies will be discussed in the next chapter.

3. CAREL CASE: STATE-OF-THE-ART

During the last year, the process suffered constant handovers of owner; the results obtained are a serious chaos of information regarding the process, data and know-how split among many "heads" and a non-linear mapping of the criticalities. Indeed, the scope of the internship and, afterwards, of the thesis project was to rebuild the mechanism of the process, recalling information from all actors involved, activity that takes a great effort because of the complexity of the infrastructure. Purpose of this chapter is, in the first place, to present and map the status-quo of the process charged of not being under control. It starts with the statement of the general problem, describing the various elements that take part of it. Then the presentation is split between the two main processes that compose the overall supply of brazed: the mechanism that rules the release of SFG orders (from now on associated to the brazed bodies) and the procurement mechanism of raw material that feeds the subcontractors. All data presented in future discussions have been extrapolated from 'Oracle' E-business system, the ERP used by the company; data were analyzed and processed directly from the candidate during the project.

3.1. Problem Statement

It has already been said that Carel, starting with the new millennium, has implemented a transformation of the production structure, switching from a functional structure to a matrix structure. The industrial divisions have been transformed on the base of macro value streams, following the product family production. Following a list of how the production divisions are divided in the HQ plant of Brugine, with the aim of giving a hint about the context in which the valves value stream is located:

- VS1 & VS2: parametric controls and miscellaneous.
- VS3: programmable controls.
- VS4: electronic expansion valves.

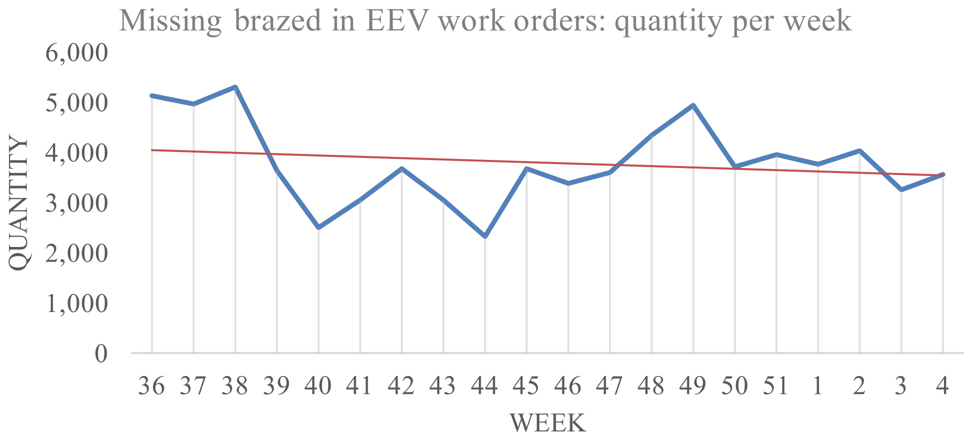
- VS5: inverter.
- VS7: electric panels.
- VS8: humidification.

As already highlighted, the critical process in analysis is part of VS4 and affects the production of EEV, one of the top products of Carel portfolio. The principal items creating issues are the brazed bodies described in chapter 1.2.1., the procurement method that Carel chose is the one described in chapter 2.3.3.: externalization of the brazed production process among three different subcontractors, which receive also the raw material, procured by Carel. These semi-finished goods once back in Carel are processed in two ways:

- For small size, they are assembled with the valve directly in line, where the cartridge is laser welded into the body of the brazed component
- For bigger size, brazed goods are placed directly into the final good packaging, letting the final user to assemble the valve inside the brazed body, once it has been welded to the pipes.

Since later 2019, the impacted value stream suffered of constant lack of brazed, causing major delays in production and falling of service level KPI. Moreover, it is not just the delay of incoming materials affecting production, but also frequent quality issues of the processed goods. Delays and non-conformities creates difficulties in the scheduling activity of the production lines; consequently, leading to constant out-of-standards activities in order to fill the gaps with planned demand and scheduled job orders.

The graphs below has the scope of giving an order of magnitude of the problem, highlighting how many instances and quantities of missing item has occurred from late August till the end of January, just before the application of the new implementations, discussed in chapter 4. The analysis started from the collection of the daily "wdj" database (work demand job), for every working day in the analyzed horizon, which shows for each job order the codes processed and the possible shortage quantities. Lines considered were just the one with a 'need by date' lower than the operability window ('missing in date' + 'lead-time' of the item), condition that depicts only shortage that could have been compensated by a prompt new order to the subcontractor.



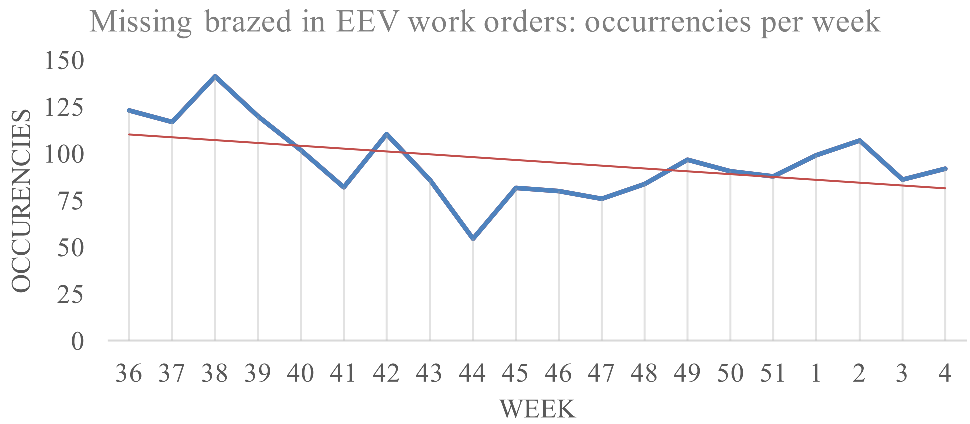


Figure 3.1. Shortages of brazed in VS4: weekly trend, by quantity and by instances, (source Carel internal data).

The importance of shortage instances have to be related to the fact that every instance of shortage can delay an entire order. This means that on average, at least 90 orders per week are on delay because of missing brazed item, which considering an average of 280 scheduled orders, impact in packaging delay due to braze shortage is around 30%. In terms of quantity, knowing that, on average, the weekly quantity of brazed processed in valves production is around 11.000 pieces, the percentage of missing brazed over the average consumption is around the 35%, (3.700/11.000). As depicted in figure 3.2, service level trend of the second semester of the year 2020, plus January 2021, shows a slightly improvement, however, on average, the percentage is far below the 95% target imposed by the management, which offers to the project margin for better performances.

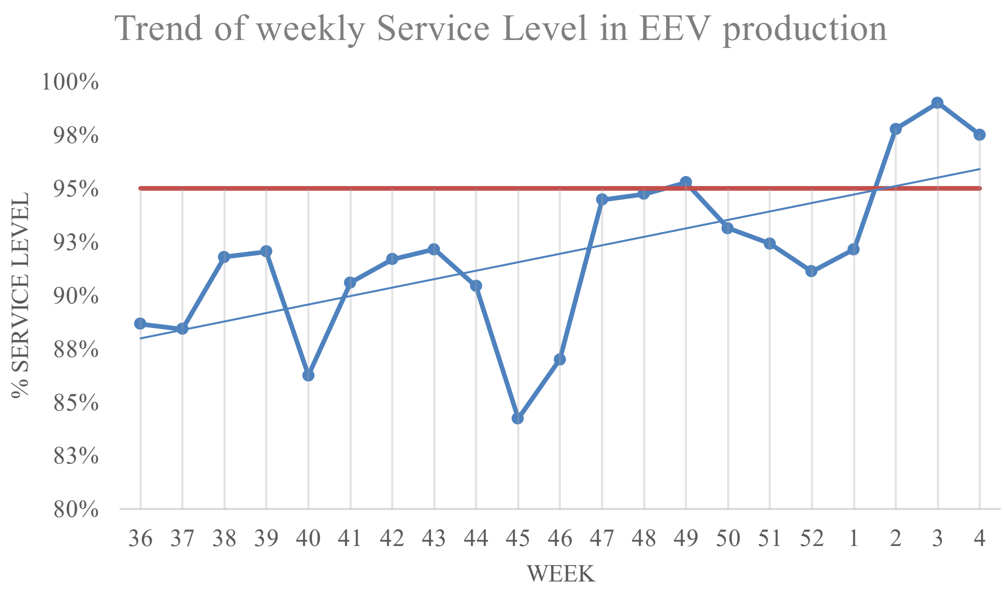
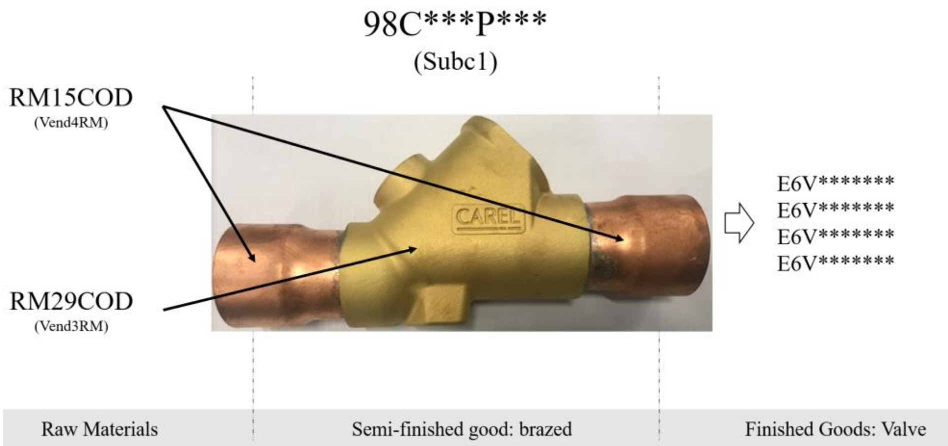


Figure 3.2 Weekly service level trend in EEV production, 2020-2021, (source Carel internal data).

Such a constant disservice over time can only let people think that the basic problem is inherent to the process. The loss of a lean process arose when the company decided to manage in subcontractor work the procurement of a large number of codes, with an even larger number of raw material on top. The following subchapters will describe the items involved, the actors (materials vendor and subcontractors) and the streams of goods and information between them.

3.2. The Items

In the long journey that brought to the process mapping, the first step was a deep analysis of the items involved, in order to create a feeling with them. They are divided and allocated to three different levels of the BoM: the figures below shows an example for each of the three subcontractors; for simplicity, the additional levels between brazed item and finished EEV have been omitted, since they are interphases production items. After that, there will be a description for each levels, trying to underline characteristics and criticalities suffered.



(a)

(b)

(c)

Figure 3.3. Example of family tree for different types of brazed items, (source Carel internal data).

3.2.1. First item: Raw Materials

The raw materials that compose a brazed good can be of different materials and shape. There is always a body, made of steel, for small size valves (see figure 3.3 a), or brass, for medium to big size valves (see figure 3.3 b); brazed to this body there are mainly two, or just in few cases three (ejectors), copper connectors of different diameter and length. In this case, the brazed body is ready to accommodate the cartridge or to be placed directly into the finished good box. For smaller types of valves, the subcontractor (named Subc3 in figure 3.3 c) brazes a copper connection to a steel tube; then, a precise phase of the production process in VS4 welds, with a laser-welding machine, the two single brazed steel tubes to a single steel body, similar to the one in figure 3.3 b.

Every code is characterized by multiple parameters, fundamental for the production planning system: the status (new-beta, active, obsolete, phase-out, dead …), lead-time, a minimum order quantity and a multiple reorder quantity, definition of make or buy (always buy for raw materials). Raw materials, for simplicity and privacy, are encoded as per the figures above, RM***COD, where the asterisk represent a number: this is specified in order to aware the reader that whenever encounters such type of array it refers to a raw material. The total number of codes involved in brazed production are 124, supplied by nine different vendors. The graph 3.4 gives a hint of the volumes of raw materials employed for the brazed bodies manufacturing, using a Pareto chart.

In an ABC framework, the number of codes that contribute in creating 80% of the total consumptions are 25 (20% of total).

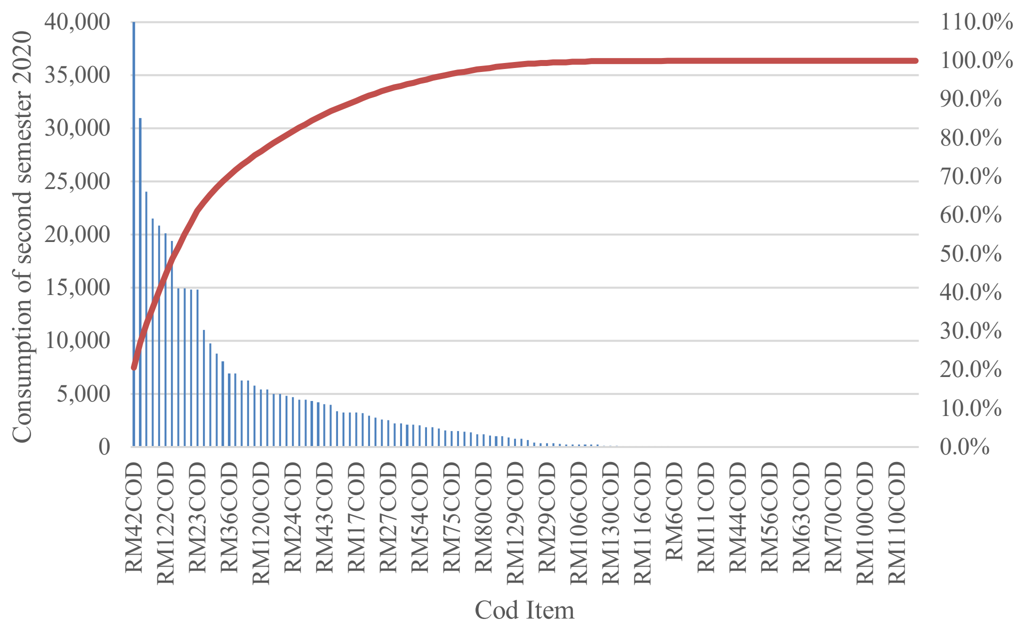


Figure 3.4. Pareto chart of raw material items, based on pieces consumed in the first semester of 2020, (source Carel internal data).

In addition to the base issues related to the procurement processes, which will be presented in the future chapters, items are subjected to various punctual problems that make even more critical their procurement. A list of all the possible criticalities affecting raw materials will follow: the sum of the number of codes affected to them exceeds the total number of codes, this because there are codes with more than one criticality. Precisely 53 over 124 presents more than one problem, 32 items just one and 39 none.

- 23 codes have to undergo a *quality check* from the metrological laboratory, located inside the main warehouse. These controls allow to verify the basic characteristics of the product (pitch diameter, external diameter, internal diameter, pitch, thread angle, pressure tests) and to evaluate the degree of finishing. Main reason is to control the conformity to legal requests, according to the use of the material; secondary reason comes from frequent *quality defects* that creates shortages of materials towards the subcontractors. Often the unknown processing time of the lab causes delay in delivering the goods to the external process.

- 19 codes have frequent delays in delivery, because of suppliers' defaults or transportation troubles.
- 37 codes has 'out of standard' issues: share between more than one subcontractor or with Carel internal production, typos and inventory mismatches, MOQ related to a family and not to the single code (if a just single code is needed, necessarily the MOQ has to be reached with other codes belonging to the same family). As a whole, these features make even more complicated the procurement process.

3.2.2. Item level 1-2: Brazed Bodies

As already said, brazed item has the function of connect the two extremities of the pipe, allowing the valve to regulate the flow of refrigerant inside the cooling system. Materials and components have been presented during the description of raw materials, and the production processes in the dedicated chapter 1.2.1; a division based on size or production method will be made in the chapter that shows the three different subcontractors. External firm in subcontractor regime has always produced these families of semi-finished good with this supply method, principally because there were never such a great demand in order to justify nor a direct purchasing nor an insourcing of the process by Carel.

For the majority, brazed items can be found at level one of a valve BoM, since there are no other work phases between them and the raw materials. However, only for the brazed bodies family of figure 3.3 c, the Subc3 provides to 'conify' the steel sleeve before brazing it to the copper connection, this is why the final sub-assembly is positioned in the second level.

The codification is different from raw materials, precisely, 98C***P*** is the pattern followed by every item in subcontractor work, not only brazed items; the first three digit characters representing the belonging to semi-finished good and the letter "P" suggesting it is an item in external work. There are also a specific codification for the items allocated to intercompany sales, which from now on will be called '–H' since they have this addition on the code tail. This customization was implemented in order to separate the two flows and type of usage, to separate the availability for internal production and international plants demand (specifically from Croatia and China); in addition, for intercompany sales, prices are different due to different logistic management costs.

Total number of brazed codes are 182, divided in the various valves families, which will be presented in the next bullet point, and produced by three different subcontractors. The graph below gives a hint of the volumes distributed on brazed codes, using a Pareto chart; the codes name are fictitious for privacy of internal data.

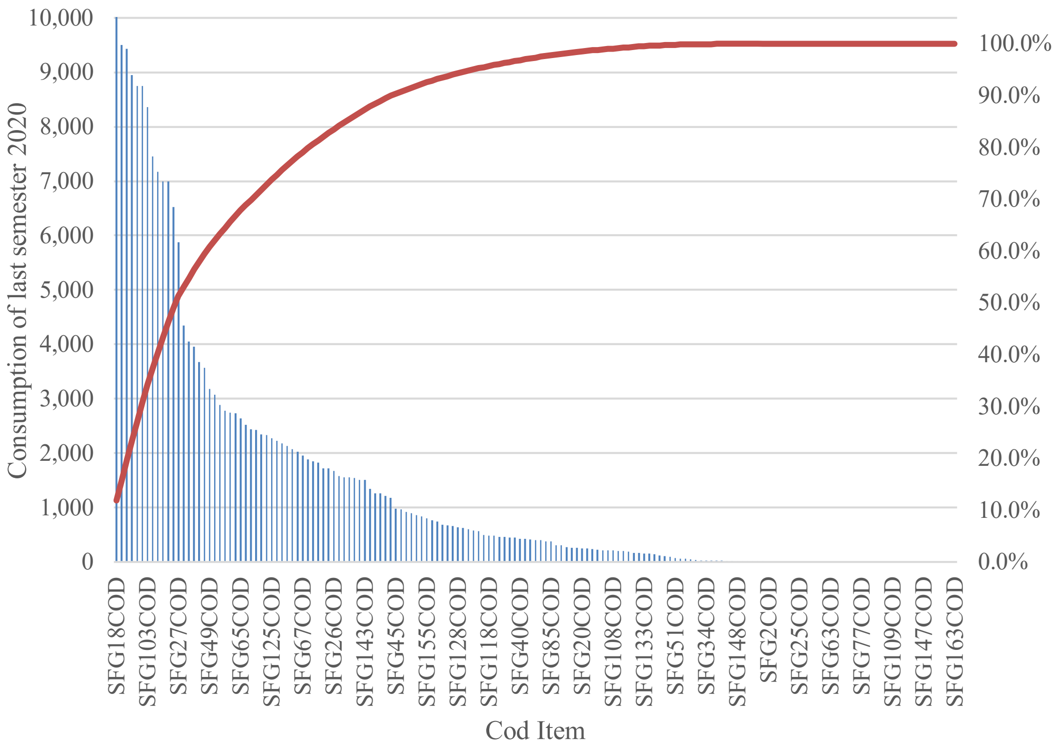


Figure 3.5. Pareto chart of brazed items, based on pieces consumed in the second semester of 2020, (source Carel internal data).

In an ABC framework, the number of codes that contribute in creating 80% of the total consumptions are 40 (21% of total).

From a quality point of view, brazed joints are very sensitive to external factors, this leads to frequent non-conformities: for examples, little holes and oxidation in the joints that create pressure losses. For this reason, incoming goods, before being charged as available for the inventory, has to be checked and tested by the metrological lab. Legal regulations set precise compliances for this type of product family, in order to guarantee the client about the maximum reliability of the system; usually the average time for the processing is one to three days.

Going deep into planning details, item in external work are set as ‘make’ like every product produced internally, either semi-finished or finished good, and not as a ‘buy’ like a common material in direct purchasing. The reason stands in the fact that, since Carel purchase and manage the components, the only way to unload them automatically is to set the brazed production as a ‘make’ production: for the automatic release system, there is a scheduled program that, once the products are checked in, discharge from the stock the materials inside the brazed good BoM. There is not a job order associated to the brazed purchase order, as it happens for the manual release process; as it will be described, this is one of the main reason of the issues discovered. Just like the most of internally made subassemblies, brazed items are ‘made to order’, which means that their production responds only to a demand of outstanding sales, work orders, intercompany sales or discrete demand, not to forecast and planned demand.

3.2.3. Last item: Electronic Expansion Valves

EEV, as already presented in the first chapter, are part of the mechanic production of Carel and an important element of the products portfolio, which complete the other controls systems offered by the company for the refrigeration sector. The production of a valve starts only if there is a confirmed sales order that opens automatically a job order, no stock is created. Some subassemblies, rather, such as cartridges and needles are made to stock, since they are associated to multiple end items. The customer order decoupling point is positioned right before the final assembly. Four production lines operates for final assembly and a different line is used just to produce subassemblies; every line has its own phases that check possible pressure losses, with the use of a pressure test or bubble test.

Unfortunately, lines has often suffered of non-conformities due to pressure leakage due to joints not perfectly brazed.

The company currently offers a total of 643 different valves, of which a part is related to 'ad hoc' customization requested by the customer. They can be distinguished in eight major families:

- E2V and E3V are the smallest sized valves, mainly composed of a steel body and copper or steel/copper connectors; the body of E3V is made of brass in the majority of the cases. For both families the shape conformation of the connections is perpendicular.
- E4V and E5V are valves of medium size, in both cases connections are axial to the body, which is always made of brass; the two connectors are made of copper, with a larger diameter than smaller families.
- E6V, E7V, E7BTWIN are valves of big size, with the same composition of E4V and E5V, employed in big systems, they have to support high pressures and capacity.
- EJ are the ejectors, having bigger dimensions than the previous, they are used in jet refrigeration systems.

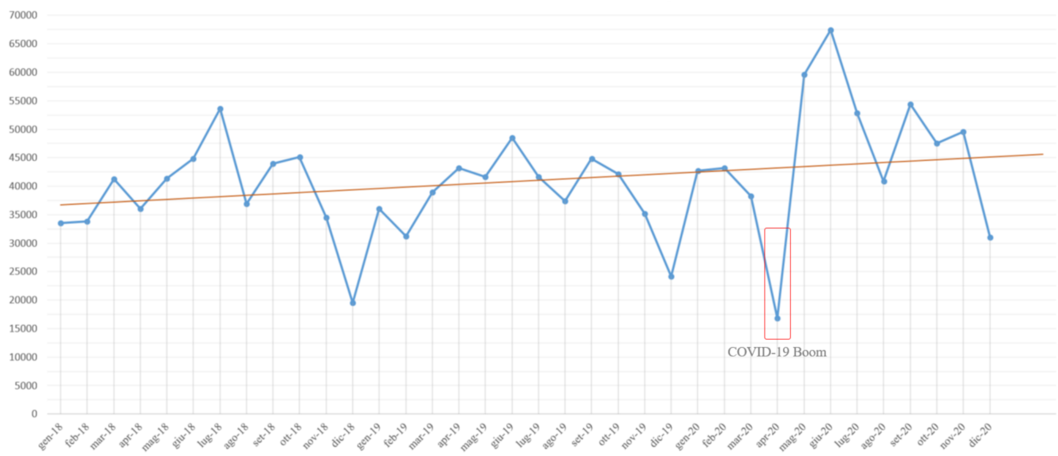


Figure 3.6. EEV orders trend and seasonality in the last three years (source Carel internal data).

Valves production is characterized by a marked seasonality, as depicted in graph 3.6, with a growing demand from March to august and a depression during the winter season. The peak in late spring of 2020 was due to a re-schedule of the production plan, caused by the forced closure during the initial spread of the COVID-19 pandemic. As mentioned in the first chapter, the curve shows a positive trend for this product family, reason to mitigate every issues in order to follow the positive growth.

3.3. The Actors

This chapter will present the two main external parties involved in the supply of brazed goods, trying to give an idea of their responsibilities, strength and weaknesses; it is clear that the focus will be on the *two types of suppliers* respectively of raw materials and brazed. For privacy regulations, their name will not mentioned, as in figures 3.2.

Carel acquires components for the brazing process from nine different *vendors*; everyone is specialized in the production of the four main material families: copper connectors, brass bodies, steel bodies and steel tubes. Two single producers, specialized in deep-drawn metal production, respectively supply the two categories of steel products, whether copper and brass components are divided among the other seven suppliers. Among them, there is a producer of copper connectors, Subc2 of figure 3.2. (b), which accomplishes two services: it supplies connectors for two subcontractors and, at the same time, brazes them to steel bodies, provided by Vend8RM, always under subcontractor regime. It can be useful to share some data of Vend8RM in order to give an idea of the difficulties in having a lean and smooth flow of material. Total codes produced by this firm for brazed production are in total just nine, but an explosion of the BoM shows that they enter in 64 different brazed. The impact of this wide range of utilization can be very dangerous in the case just a single component evidences quality issues or suffer of constant delivery delays. Unfortunately, this is really what was happening: quality measures of tolerances was often not accepted by Carel metrological laboratory; data shows that from July 2020l this codes accused on average 38,5% of non-conformities per week. In addition frequent delays stretched the supply of brazed, causing slowdowns in production lines. There are another two suppliers affected by quality issues during the past year, but they are will not be presented in order to simplify the presentation.

In addition, from an analysis on the consumption of these components, showed in the graph 3.7, it leaps out that there is not a clear seasonality trend, which with the presence of unexpected peak due to COVID-19 pandemic, do not help in leveling the demand. Anyway, the reader has to keep in mind that, beyond the difficulties in running the procurement activity of raw materials, due to the problems of the system configuration, there is a background of issues related to vendors' service and risk related to BoM configuration.

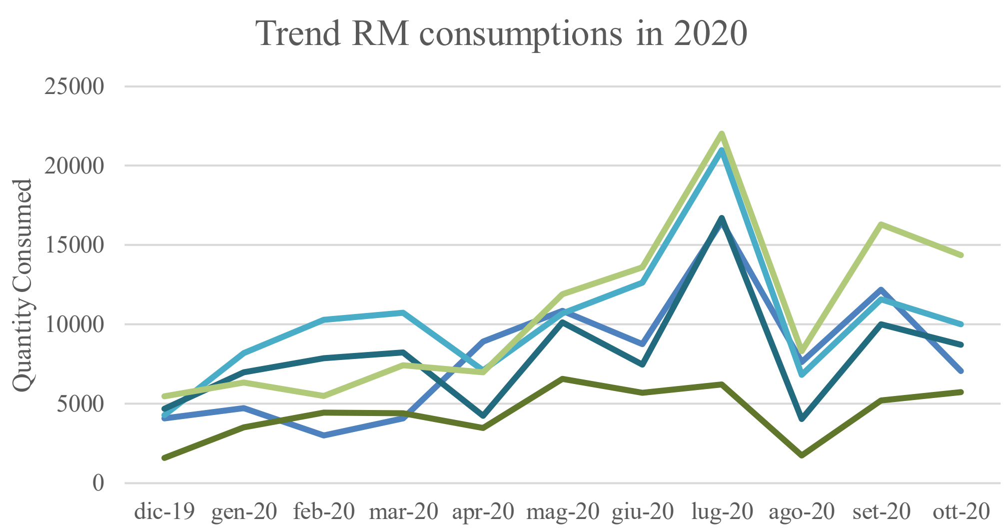


Figure 3.7. Consumptions of RM for brazed production, trend of 2020, each lines represents a specific Vendor (source Carel internal data).

The second category of suppliers refers to items level 1 and 2, the brazed. They are three and operates, as already said, in external work regime: the cost of their service is due only to the braze process. In this way, *subcontractors* receive the components based on Carel supply planning system, once they receive an order for a 98C, they can start producing. To simplify their presentation, below there is a table that summarize all the information needed to understand their structure and their position with respect to Carel business.

Subc1	Subc2	Subc3
Last annual turnover: 1.340k€ % Carel turnover: 31% Carel is the first client for the HVAC sector.	Last annual turnover: 2.430k€ % Carel turnover: 7% Carel is among the first five clients.	Last annual turnover: 170k€ % Carel turnover: 91% Carel is actually the only client.
Number of employees: 12 The higher number of employees do not implies a solid structure behind: few employees are under the "command" of the owner, running the production; his wife is in charge of the back office activities.	Number of employees: 10 The owner, with the son in charge of back office activities, manages the technical production. Form of a basic firm structure with the recent presence of an internal quality office, in mid-2020.	Number of employees: 2 Rather than a firm, it is more appropriate to call it workshop, since only father and son run it, with a couple of workers only in case of demand peak. There is not a full-fledged firm structure, since they operate only in subcontractor work regime.
Types of braze mechanism used: flame; galvanic treatment made externally. Braze of brass-copper, steel-copper.	Types of braze mechanism used: induction, no need of galvanic treatment. Braze of steel-copper.	Types of braze mechanism used: flame and induction; galvanic treatment is made externally. Braze of brass-steel, copper-steel, brass-copper.
Number of codes: 118	Number of codes: 32	Number of codes: 32
Valves families: E2V, E3V, E4V, E5V, E6V, E7V	Valves families: E2V, E4V	Valves families: E2V, EJ
Good quality of the products, but not	Discrete quality of the products, which is	Good quality of the products, due to a long-

maintained constant, due to non-standardized production process, which has often led to a lack of control over it. Weekly % of Non-Conformities = 2.13% (on average)	improving since the new quality office activity. More sensitivity towards Carel requests, but sometimes suffers of important delays. Weekly % of Non-Conformities = 0.98% (on average)	life experience of the owner on the sector; in the past he was also useful in engineering phase of some brazed components. Great commitment to Carel. Weekly % of Non-Conformities = 0.18% (on average)
Risks: Financial Lack of positive confrontations Unpredictability in production continuity Low bargaining power with RM vendors No chances of innovation	Risks: Financial Brazing process is not a core activity Low bargaining power with supplier Low chances of innovation	Risks: Unpredictability of ceasing operations Know-how on the hand of just a single person, next to retirement Low bargaining power with RM vendors No chances of innovation

Table 3.1. List of subcontractors' structure and characteristics (source Carel internal data).

As clarified in the table, the situation beyond the production of these families of semi-finished goods is not quite optimistic. The actual subcontractors do not present a reliable and solid structure, which along with the blurred management of materials flows do not assure continuity and sustainability of production. The reason lies in the fact that at the beginning Carel has preferred to rely on nearby producers, in order to have a closer relationship and possibility to develop the production of brazed more smoothly. The growing number of valves items, caused also by lot of customization by particular customers, led to complications especially due to the low strength of subcontractors and the type of outsourcing strategy employed. However, besides the theme of insourcing and outsourcing, which will be discussed at the end of the next chapter, major issues came from the inability of the system to create a reliable supply system, without incurring on out of standards procedures in order to guarantee materials to the production lines. Focus of the next chapter is about streams of goods and information of this complicated process, which will clarify better the externalization of this production.

3.4. The Streams

This chapter starts with a schematic representation of the whole procurement process of brazed, figure 3.8, showing the connection between actors involved and the methods employed to, in chronological order, procure raw materials, transfer the components to the subcontractors' warehouse and release the purchasing order for brazed items. It can gives a hint of the complexity of the process due to a non standard supply method and the large number of business unit involved.

Vendors procure the components that are purchased from Carel and redirected to the subcontractor through, 'min/max' recall method, or not the company main warehouse, Kanban – free pass method. Subcontractors process the materials based on purchased orders released automatically or manually, plus, they monthly receive also a forecast planned demand prospect, with six month visibility. Brazed goods then returns in Carel: first checked by the metrological lab, components are discharged and finally made available for the internal production or intercompany sales order.

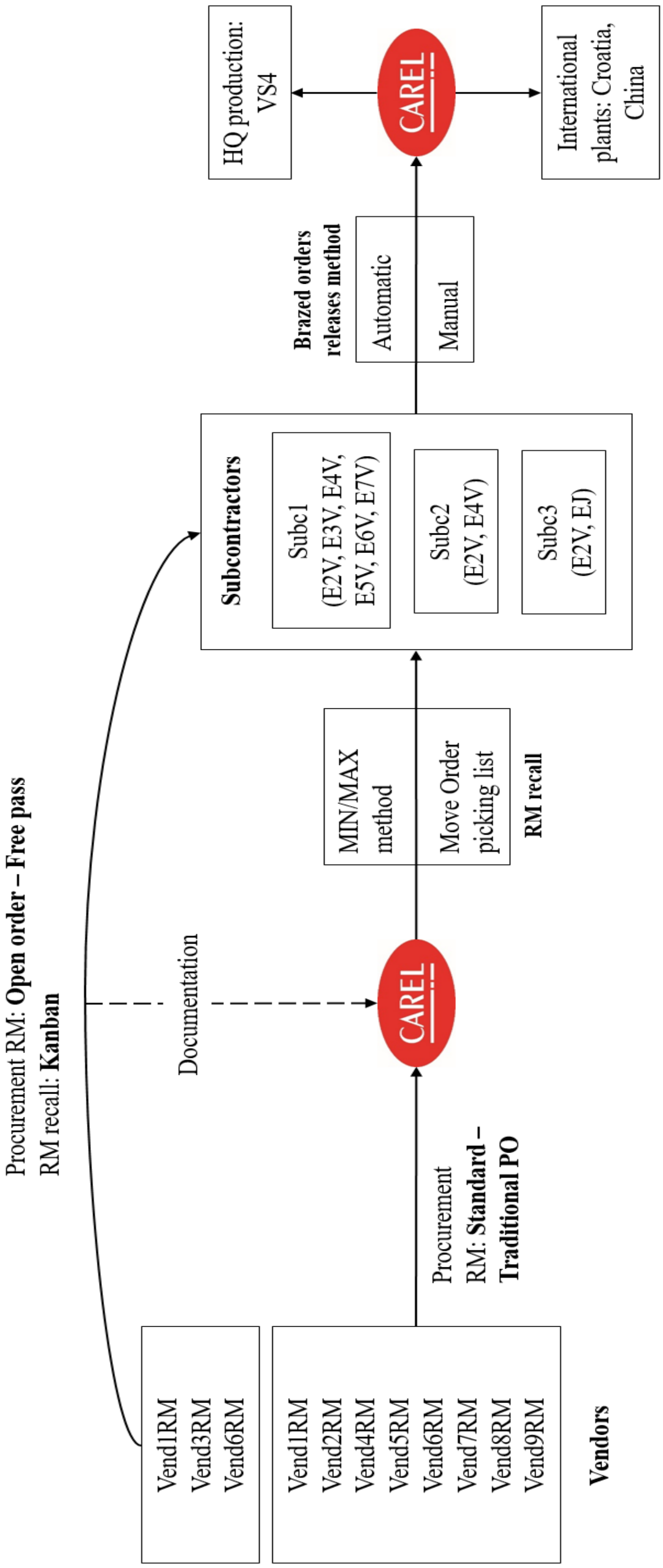


Figure 3.8. Scheme of the brazed procurement process in Carel.

The discussion about flows of information and material has to start from details of chapter 2.1.1, where it has been presented the type of production system chosen by Carel. In Carel, Assemble-to-Order system, job orders of finished goods automatically open the day before the schedule ship date, covering only the demand of registered sales orders. The E-business system creates the requisitions of brazed to cover the demand of valves for all the periods ahead. These negative planned quantities of the vertical production plan have different names based on their nature; they are synthetized in table 3.2.

In order to provide a mid-term visibility of what could be the future needs of Carel, every month the planning team sends to all suppliers a report; it shows, for all codes associated to, future forecast quantities, monthly aggregated and with a forward window of six month. Such quantities are the projection of finished goods forecast, inserted by Sales&Operations planning team, and overturned from the MRP system.

Planned "dash" – Operating Plan	**Planned – Operating Plan**	**Planned – ATP Plan**
It covers: sales order, intercompany demand, job order, discrete demand, planned demand, forecast	It covers: sales order, intercompany demand, job order, discrete demand, planned demand, forecast	It covers: sales order, intercompany order, job order, discrete demand
Horizon: 1 to 55 days	Horizon: 55 days to infinity	Horizon: today to infinity
Frozen for the current week	Frozen for daily operation: daily run of MRP changes it	Dynamic and live updates
It is a job order still unreleased, it will be released the day before the schedule ship date	It is a MRP suggestion, it transforms in "dash" when entering the 55 days window	It is the net Available-To-Promise quantity, what is already confirmed
Manual load once per week by the planning team	No manual load, automatic creation every day	No manual load, automatic and live creation

Aggregation of one week demand in one work order	Aggregation of one week demand in one work order	One planned 'line' per order

Table 3.2. Carel planned demand categories for make items, (source Carel internal data).

The planner role is to fulfil the planned demand of raw materials, overturned from the final valve with the temporized BoM, looking at all three types of planned demand. This happens because only final products are 'make to order', whereas lower level items look at the demand coming from both sources (operating plan plus ATP plan); yet the case of brazed is slightly different. As figure 3.8 shows, there are two different types of methods to release an order: automatic looks at the planned "dash" and ATP plan, while manual looks at all three types; next chapter will describe in depth their functionality. Looking at components procurement activity, also here there is a duality in the method adopted, which will be discussed in the next chapter. The planned demands trigger a purchasing order of a brazed and the consumptions of brazed triggers a purchasing order of raw materials; however, even if this two processes will be presented separately, they are strictly dependent and run side by side.

In summary, vendors receive a purchase order in two ways: if standard, Carel will be in charge of stock the good and redirecting them to subcontractors; if open, the vendors keep the goods ready toward their warehouses and subcontractor will recall directly the materials needed, with a Kanban method. Subcontractors may receive purchasing orders released manually or automatically by system; once the brazed batch arrives in Carel warehouse, operators redirect it to production in VS4 or ship it to the other two plants with valves production, Croatia and China.

3.5. Procurement Processes: As-Is and Criticalities

This chapter represents the gist of it; the base of all the problems is divided equally between the two phases of procurement of the items involved, which are strictly correlated each other. Since it will be too confusing treating them together, the presentation will follow the natural cause-and-effect relationship and order of optimization that have been carried on: first, the order release of the subassembly and then the procurement of its components. It is hoped that at the end, the reader could understand the situation of uncertainty, out of control and non-lean that the process have been living.

It was often underlined how the 'automatic release' is the principal release method of brazed in external work, however, as seen in the scheme of the process, there is another method, which is simply called 'manual' since it is the operator that manually release the orders. Even if it is not the principal object of the studio, the focus of the first part of the chapter will be on description of how this secondary method works, since it is responsible of part of the total procurement, trying to depict possible criticalities and improvements. Then the focus will switch to the main objects of the project: automatic release method of purchase order for subcontracting work and procurement of the processed components.

3.5.1. Manual Release

Over the total number of brazed codes only 14 (7.7%) are managed with this method; in details, this codes are associated to the whole family of ejectors (EJ produced by Subc3) and E4V*F family with steel body, produced by Subc2. Just to mention, associated to VS4 there are also 51 codes in external work that are not brazed bodies, but either way under manual release system. It is still not perfectly clear why these codes did not switch to the automatic release system, but main reason could be a lack of effort in implementing a new method, or the presence of projects associated to this codes that did not permit further changes. Moreover, the almost null volumes of E4V*F associates and extremely high cost of ejectors raw materials, might have thrown off the will of change, keeping the traditional format of external work. The best solution could be analyze these codes and implement a change of release method in order to standardize the whole process under a single tool; activity that, due to time issues, was postpone for further analysis.

Manual release of an order is the traditional and most dated method in procurement activity, in which the operator confirms the order suggestion depicted from the ERP system and release the order associated.

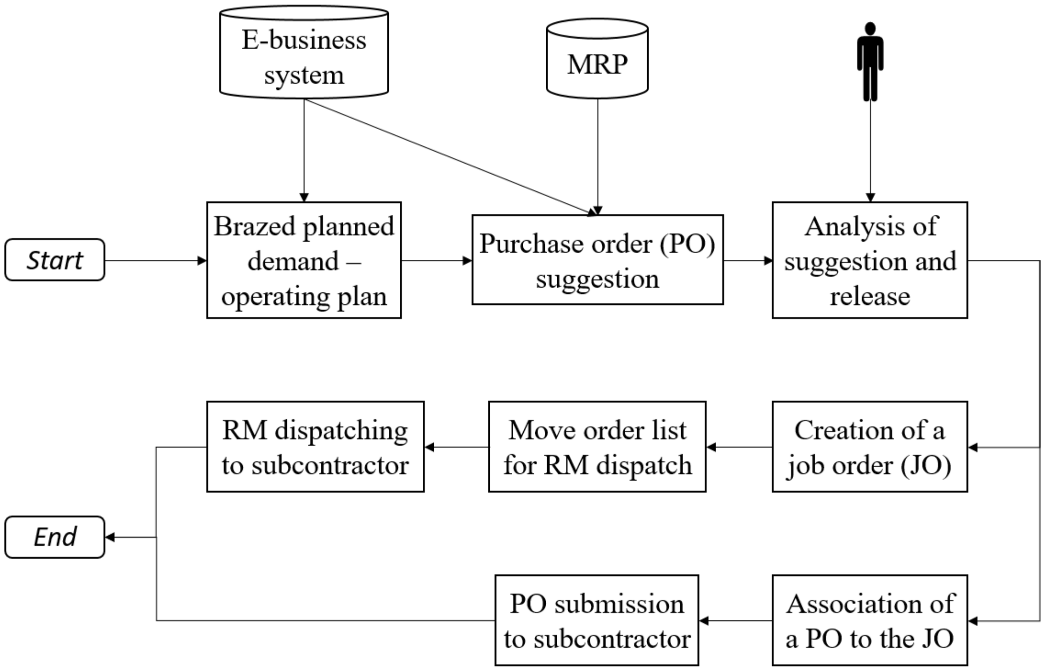


Figure 3.9. Manual Release scheme.

Starting point of the manual release process is always the planned demand, output of the mid-term master plan and results of Sales&Operations department activities; but differently from the automatic release, it considers the completely operating plan demand. For the mechanism and characteristics of goods in external work, the plan sees them as 'make' items, hence the only way to fulfil this type of demand is to place an internal work order that fictitiously produces the needed quantity, used only to create the components commitment. The ERP system, in addition, suggests a list of purchase orders, which are analyzed from the scheduler: comparing the suggested quantity and date in the operating plan in the intranet portal, basically thinking as a MRP, he/she depicts the right quantity and due date of the order. Since this items do not have a processing lead-time, there is a parameter called 'fixed lead time', which is used from the system to recall a suggested order date from the suggested due date set by the MRP. In the example below, showing the manual release workbench of some codes, knowing that the first code has a fixed lead time of 20 days, it is easy to see how the mechanism of backwards suggestions work. When the suggested order date falls inside the led-time window that precedes the due date, a field shows that the order is in compression, hence in possible delay.

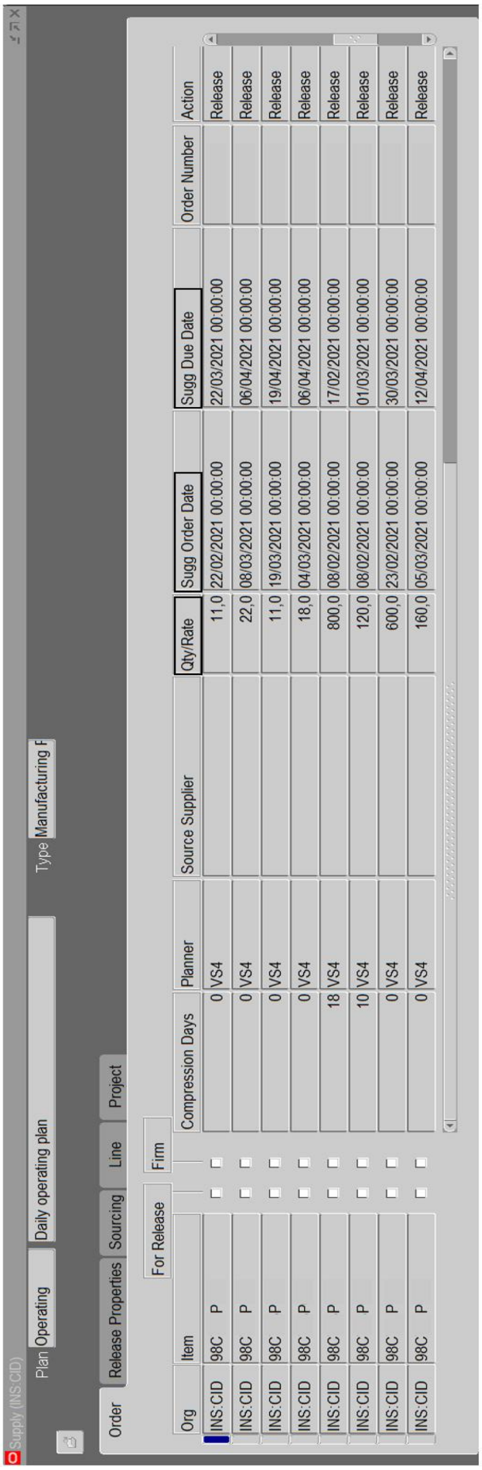


Figure 3.10. Example of manual release workbench in the ERP system (source Carel internal data).

After the release of the orders, the scheduler extracts the list of work orders, automatically generated by the system and associated to the released order, and send the ‘move order’ list request to the warehouse, for the dispatching of the raw materials to subcontractors. The list contains, as a shopping list, the exploded BoM of the freshly ordered brazed. Simultaneously the system, on request of the operator, sends via email, or other logistic software, the purchase requests associated to each supplier.

Factors in support of this method are without doubts the possibility of release an ‘ad hoc’ quantity and due date, decided by the owner of the activity, which can know inputs outside the IT system process. In addition, the scheduler before release an order can detect if a sufficient presence of components is available in-house; if not he/she has to revise quantity or dates in order to match the supply of raw materials. The best characteristic is the fact that the system first creates a work order, and then associates the PO to it, allowing the system to commit automatically the components quantity, keeping a clean situation of the inventory and ATP. Despite these big *pros*, in Carel there is a long list of *cons* inside this process:

- The suggestions do not consider shortages of components at warehouse, only manual computation can, which requires a lot of time, especially for wide BoM.
- The fixed lead-time does not take into consideration the transit time, both for the components outgoing and brazed incoming, plus the time for metrological lab check-in.
- If the activity is rarely run, an order entered in compression, usually not covered by forecast, may be depicted too late, with difficulties in reducing the delay gap.
- The owner has not visibility on the activities downstream the order release activity: he/she does not receives confirmations of components dispatch from the warehouse, neither order confirmations from the subcontractor.
- The activity were currently handled by the VS scheduler, which has for sure a better view of production lines necessities but lacks on the raw materials situation, which is in charge of the planner activities. In case of order

reminder towards subcontractors, the scheduler cannot have a prompt response if the focus suddenly switch to shortages of components.

After all, top criticality is certainly the lack of visibility of the scheduler on the move order processing once it is delivered by hand to the dispatching office. Under suggestion of this latter, in case of move order for external work, the office instantly approves and redirects it to warehouse operators for the dispatching; simultaneously to the approval, the system generates automatically the delivery document associated. However, it might pass few days between the move order handling and the effective dispatching of the goods, mainly caused by the fact that this kind of dispatching do not part in the warehouse KPI: operators prefer to dispatch a sales order rather than components in external work. Although it might seem to be the right decision at the eyes of a warehouseman, this bad habit triggers a chain of future lack of service level: production delays occurs due to late come back of the externalized components. Possible and implementable solutions to these problems were analyzed and taken into considerations: activities and standard implementations will be presented in the final chapter.

3.5.2. Automatic Release

This kind of methodology has taken hold more and more within the company because it allows slimming and reducing low value adding activities: in fact, the higher the number of codes, the greater the alleviation of activity effort.

The automatic release has two *main upgrades* with respect to the manual release system: the analysis of suggestions and related releases takes place every day, more precisely during the night. Moreover, there is no need of human computation or effort in approve them, if not providing a constant control of its results after a correct initial set up of the planning parameters. The number of codes managed with this service are the majority, 178 over 182, embracing all three subcontractors.

The characteristics of items involved are the same of the one discussed in manual release, 'make' item, but with a *major problem*: the automatic release system sees them as ‘buy’ item; hence there is no creation of a work order to which the PO can be associated. This absence does not permit to create a *commitment* upon the materials inside BoM of released brazed. Historically, problems stand upstream, because this type of automation was born only for item purchased directly from the vendor, which does not have a BoM, and not in subcontractor work; this latter instead, due to its nature, needs a system that commits the work-in-process quantities, in order to avoid non-clean situations of stock. The free availability of quantities committed to outstanding POs is precisely what was happening inside the process, and one of the major causes of inconsistencies.

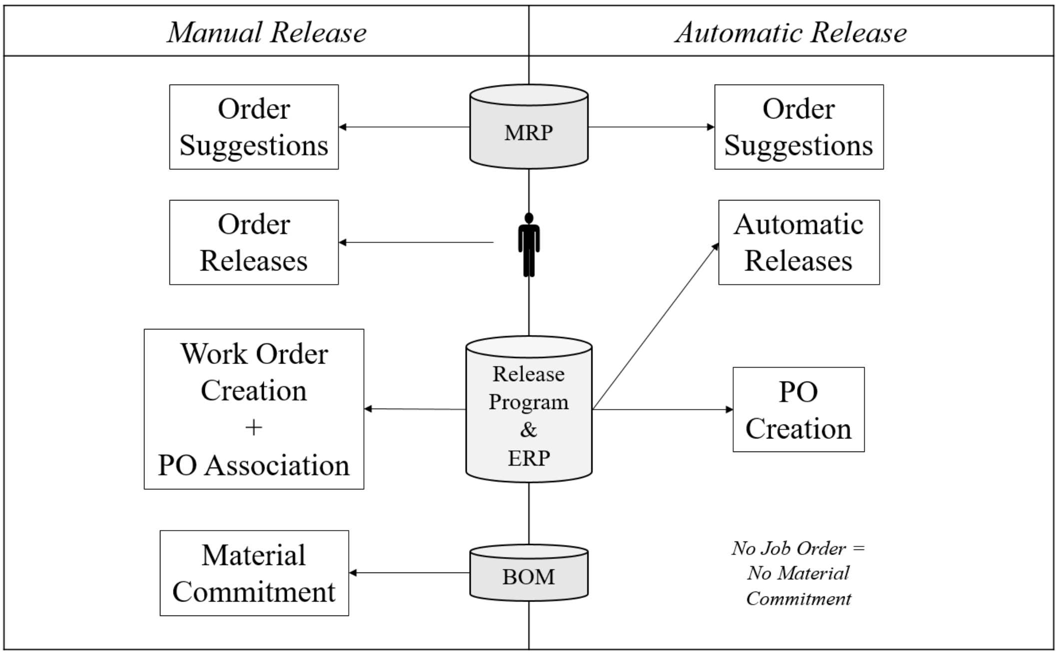


Figure 3.11. Differences on the logic of the commitment material: comparison between the two methods.

The standard of the automatic release of external work orders, ruling the process, states that “… items with a ‘make’ nature will have to maintain its nature even during the subcontractor purchase order, hence routings and bill of materials must exist. In addition, there is the need to associate an approved supplier list and a supply base. The raw materials unloading will happen through a scheduled program that verifies daily incoming items in external work, and discharge the inventory after the BoM explosion …” (Carel internal documentation, 2011). In conclusion, raw material is discharged only when the brazed good is check-in by Carel warehouse, letting the ERP to consider still available quantities during the time span that occurs since the order release.

Demand covered by an automatic release is fundamentally different from characteristics of manual release. The reorder suggestions are set from the MRP with the logic previously explained, but in this case, the system looks only at demands of the ATP plan. The reason of this difference stands on strategic decisions: it has been decided that orders of brazed must not cover planned demand coming from forecast. This means that subassemblies in external work differ from other semi-finished goods internally produced: customer order decoupling point places before their production and not after, just as the majority of goods directly purchased externally.

The mechanism beyond this type of release, for the first steps, is the same of the previous. The ERP runs automatically the program, depicting the suggested order quantities and dates, placed whenever the stock falls under safety stock level; then, instead of letting the user insert order lines manually, it fills them automatically and releases all the suggestions processed. In addition to sending orders directly to subcontractors, the program creates and send via a mailing list a list containing all the outstanding released orders, new orders, and lines showing ‘forecast’ quantities. The figure below shows an example for Subc1. The simple layout shows few essential details, every line corresponds to an order line: item code, quantity, date in which the order has been released, delivery due date at Carel warehouse, number of the order (only for released) and a status, depicting if the line is freshly released on that day. Yet at a glance, it is possible to note two strange facts that may highlight a possible non-optimization of the process.

ITEM	QUANTITY	ORDER CREATION DATE	CAREL DELIVERY DUE DATE	REFERENCE NUMB.	RELEASE STATUS
98C***P***	2	25-DEC-20	07-JAN-21	87451/2010	
98C***P***	70	12-JAN-21	12-JAN-21	87451/2020	
98C***P***	48	13-JAN-21	13-JAN-21	87451/2021	**NEW**
98C***P***	96	25-DEC-20	14-JAN-21	87451/2010	
98C***P***	70	01-JAN-21	14-JAN-21	87451/2013	
98C***P***	210	01-JAN-21	14-JAN-21	87451/2013	
98C***P***	60	08-JAN-21	14-JAN-21	87451/2017	
98C***P***	126	01-JAN-21	14-JAN-21	87451/2013	
98C***P***	42	01-JAN-21	14-JAN-21	87451/2013	
98C***P***	24	01-JAN-21	14-JAN-21	87451/2013	
98C***P***	48	11-JAN-21	21-JAN-21	87451/2019	
98C***P***	24	08-JAN-21	21-JAN-21	87451/2017	
98C***P***	96	13-JAN-21	21-JAN-21	87451/2021	**NEW**
98C***P***	9	13-JAN-21	21-JAN-21	87451/2021	**NEW**
98C***P***	24	07-JAN-21	21-JAN-21	87451/2016	
98C***P***	24	05-JAN-21	21-JAN-21	87451/2014	
98C***P***	48	13-JAN-21	21-JAN-21	87451/2021	**NEW**
98C***P***	48	01-JAN-21	21-JAN-21	87451/2013	
98C***P***	126	08-JAN-21	21-JAN-21	87451/2017	
98C***P***	126	08-JAN-21	21-JAN-21	87451/2017	
98C***P***	72	13-JAN-21	21-JAN-21	87451/2021	**NEW**
98C***P***	96	12-JAN-21	21-JAN-21	87451/2020	
98C***P***	840	08-JAN-21	21-JAN-21	87451/2017	
98C***P***	4	08-JAN-21	21-JAN-21	87451/2017	
98C***P***	27	08-JAN-21	28-JAN-21	87451/2017	
98C***P***	24	08-JAN-21	28-JAN-21	87451/2017	
98C***P***	48	08-JAN-21	28-JAN-21	87451/2017	
98C***P***	210	08-JAN-21	28-JAN-21	87451/2017	
98C***P***	18		04-feb-21	PREVISIONE	
98C***P***	18		11-feb-21	PREVISIONE	
98C***P***	640		28-JAN-21	PREVISIONE	
98C***P***	42		02-DEC-21	PREVISIONE	
98C***P***	924		28-JAN-21	PREVISIONE	
98C***P***	336		04-feb-21	PREVISIONE	
98C***P***	48		28-JAN-21	PREVISIONE	
98C***P***	192		04-feb-21	PREVISIONE	
98C***P***	112		04-feb-21	PREVISIONE	
98C***P***	48		18-feb-21	PREVISIONE	
98C***P***	24		25-feb-21	PREVISIONE	

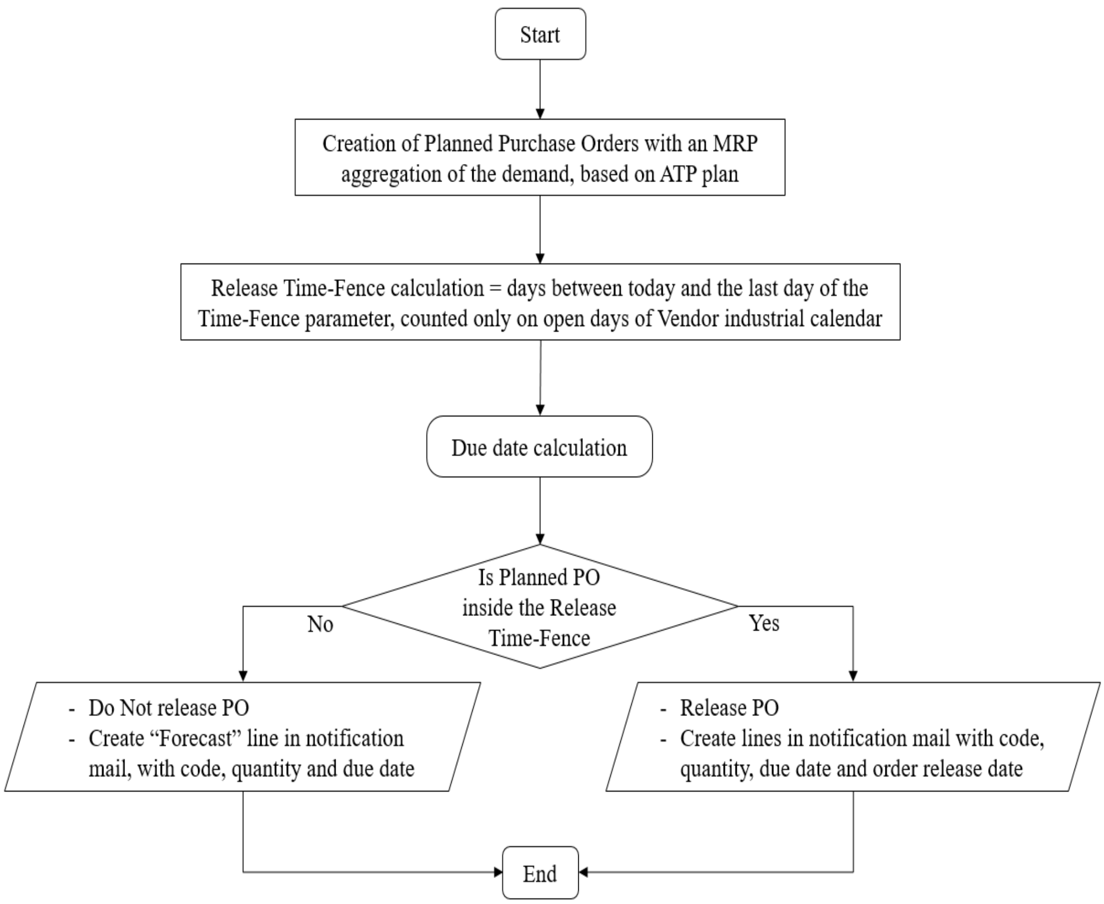
Figure 3.12. Example of daily notification list for automatic releases: released orders and future orders of Subc1 (source Carel internal data).

The first is a pattern on the delivery due date: calendar at hand, dates are placed only on Thursday. Second, in some situations, 'order creation date' and 'delivery due date' perfectly match, e.g. second and third line, or differs of only one week, e.g. '**NEW**' lines. This is clearly a fallacy of the program: it is impossible that a supplier could ever receive, process, produce and deliver an order in the same day, being the average lead-time of brazed items at least 10 days. This means that most of the order released are in compression, resulting in delivery delays. In addition, there are lines called 'forecast' with a delivery date equal to lines already released, and a question should arise naturally: why are they still unreleased if they look at the same planned demand? As a fact, 'forecast' is not the correct nomenclature since the demand seen by the program covers only planned demand from confirmed sales orders and work orders, it is not in response to forecast demand.

Consequences of these fallacies have impacts on both supply sides:

- Subcontractors receives order that cannot be fulfilled on time. This creates a huge amount of 'fictitious' backlog caused by orders in lead-time compression and a situation that is not clear at the eyes of an external employee.
- Carel does not receive quantity on time, falling in a circle of reminders and information that runs outside the system (mail, calls …), plus delays in production and loss of service level towards the clients.

The explanation of how the *automatic release algorithm* works starts with a flow chart, which will clarify how 'release time fence' works together with calendars.



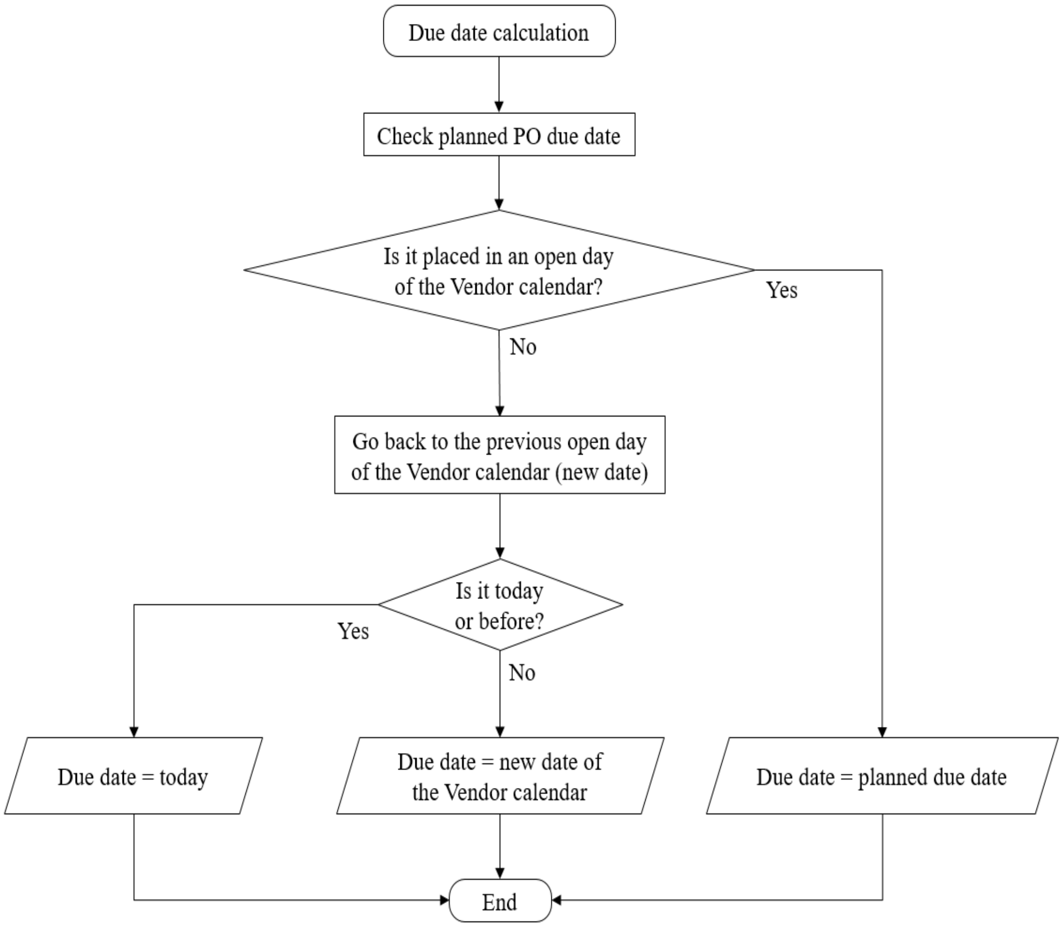


Figure 3.13. Flow chart of the Automatic Release simplified algorithm.

The analysis of the logic behind the automatic release program and the parameters associated to them showed that the problems relied on four pillars:

1) Wrong set up of the vendors' *calendars*: there were only one open day for both three subcontractors, but in the reality they deliver whenever they can. Note in figure 3.14 the presence of open days even on Christmas Eve and 31st of December.

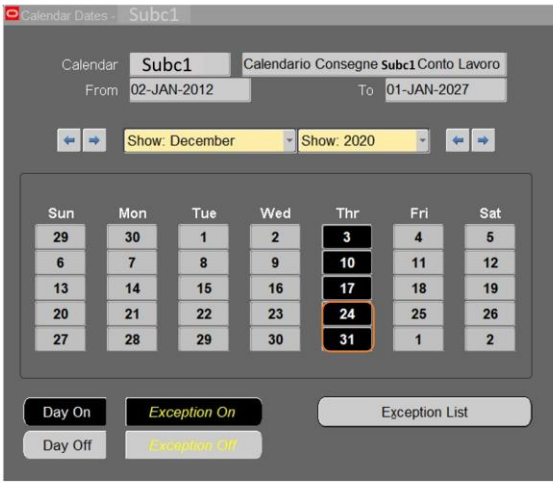


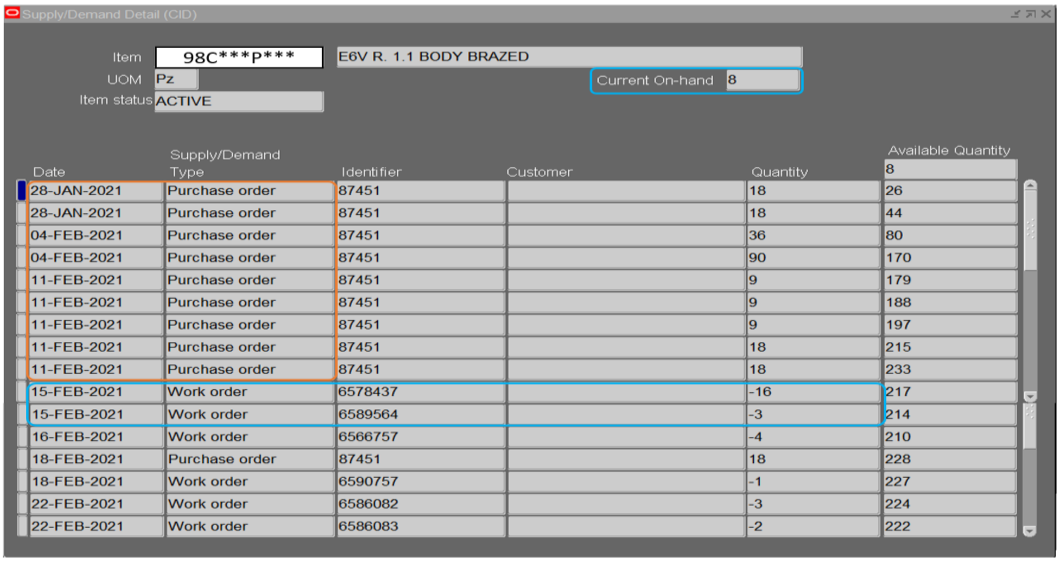
Figure 3.14. Example of industrial calendar, for Subc1.

2) 'Three' were the number of days set for the '*release time-fence*', which means that, with this type of calendars, the demand coverage was of three weeks. Giving that the 'lead-time' range of brazed items goes from 10 to 15 working days, release order dates were most of the time too much strict.

3) The automatic release system releases the purchase order as if it was a work order, and since goods in external work do not have a 'processing lead-time', the cycle time is equal to zero. For example, looking at the calendar in the figure above: if 'today' is 16/12 and there is a demand that reduces the stock below safety stock on 22/12, the system thinks that the replacement quantity can be produced in almost 0 minutes. Then it creates a planned order for 22/12, but since it is not an open day for the supplier calendar, it releases the order for the previous one, the 17/12. The results is that the subcontractor will find Thursday 17th an order for the same day.

4) There is no parameters impeding the release of an order in compression, i.e. inside the lead-time window.

Subcontractors, in the light of this complex process, tended in one hand to anticipate Carel's orders, processing raw material on the base of their gut feeling or historic demand behavior, or in the other, simply delaying deliveries, creating production delays and service level losses. Figure 3.15 is a snapshot of the supply/demand situation for a brazed item on 12th of February, highlighted in orange the backlog accrued.


Supply/Demand Detail (CID)

Item: 98C***P*** — E6V R. 1.1 BODY BRAZED
UOM: Pz — Current On-hand: 8
Item status: ACTIVE

Date	Supply/Demand Type	Identifier	Customer	Quantity	Available Quantity
					8
28-JAN-2021	Purchase order	87451		18	26
28-JAN-2021	Purchase order	87451		18	44
04-FEB-2021	Purchase order	87451		36	80
04-FEB-2021	Purchase order	87451		90	170
11-FEB-2021	Purchase order	87451		9	179
11-FEB-2021	Purchase order	87451		9	188
11-FEB-2021	Purchase order	87451		9	197
11-FEB-2021	Purchase order	87451		18	215
11-FEB-2021	Purchase order	87451		18	233
15-FEB-2021	Work order	6578437		-16	217
15-FEB-2021	Work order	6589564		-3	214
16-FEB-2021	Work order	6566757		-4	210
18-FEB-2021	Purchase order	87451		18	228
18-FEB-2021	Work order	6590757		-1	227
22-FEB-2021	Work order	6586082		-3	224
22-FEB-2021	Work order	6586083		-2	222

Figure 3.15. Example of supply/demand of a brazed item, highlighting the supplier backlog (source Carel internal data).

Automatic release represents the downstream issue, in the next chapter will be presented the downstream consequences of raw material procurement, directly affected.

3.5.3. Raw materials purchasing

In case of external work allocation, the procurement process can be divided in two stages: the first takes care of placing right order quantities and dates to cover the MRP suggestions; the second takes charge the redirection of components to third-party producers. It is mandatory to recall that for raw materials the procurement process looks at all the operating plan, covering all demands range (sales order, intercompany demand, job order, discrete demand, planned demand and forecast).

In accordance with the above division, each stage has further two different types of methods, respectively the purchase orders have two different types of nature and the redirection of the components to subcontractors follows two different strategies.

The nature of these decisions is embedded on the various structure of the vendors, volumes at stake and contracts agreement.

The planner can release two *types of purchase order*:

- Standard PO
  Information included are a list of which items will be purchased with relative quantities and price, a delivery date and location that must match the agreement. It is the most detailed PO type, and used in situations where businesses are very certain about the requirements surrounding a purchase.
- Blanket PO
  Known also as 'standing orders', it omits delivery information, item quantity, the list of what items will be purchased is obviously included. When a blanket PO is established with a supplier, a maximum period of validity for the partial deliveries is determined, alongside the maximum quantity of items that will be ordered within that period. Once the period expired, if the potential remaining quantity has to pay off, if stated by the agreement.

The table below shows the features of these two methods from a planner point of view.

	Standard PO	**Blanket PO**
What	Coverage of the demand inside a LT periods	Coverage of the demand inside n-times the LT period, from 6 to 9 months
When	Due date according to the lead-time, at best, and fixed by the agreement	Due date placed at 1-2 years after for purchasing standards, in order to not interfere with pricing activities and not obscure mid-term forecast
Location	Goods are delivered to Carel main warehouse	Goods are stocked at vendor's warehouse, usually ready to be delivered

Table 3.3. Types of purchase order for raw materials in outsourcing.

For blanket PO, Carel agrees with the vendor for having the material ready to delivery, based on forecast reports, which will receive an order directly from the subcontractor whenever he needs, adopting a *Kanban* recall. This latter, due to the characteristic of bypassing Carel facility it is internally called ‘Free Pass’. On the other side, for goods stored at Brugine warehouse, a *Min/Max* system recalls the needed quantities to the ‘brazer’. The two figures 3.16 summarizes in details the two *material recall methods*, and all the physical and informative flows that occurs between the actors involve, showing the value stream all along the supply chain, from the final customer to the components vendor.

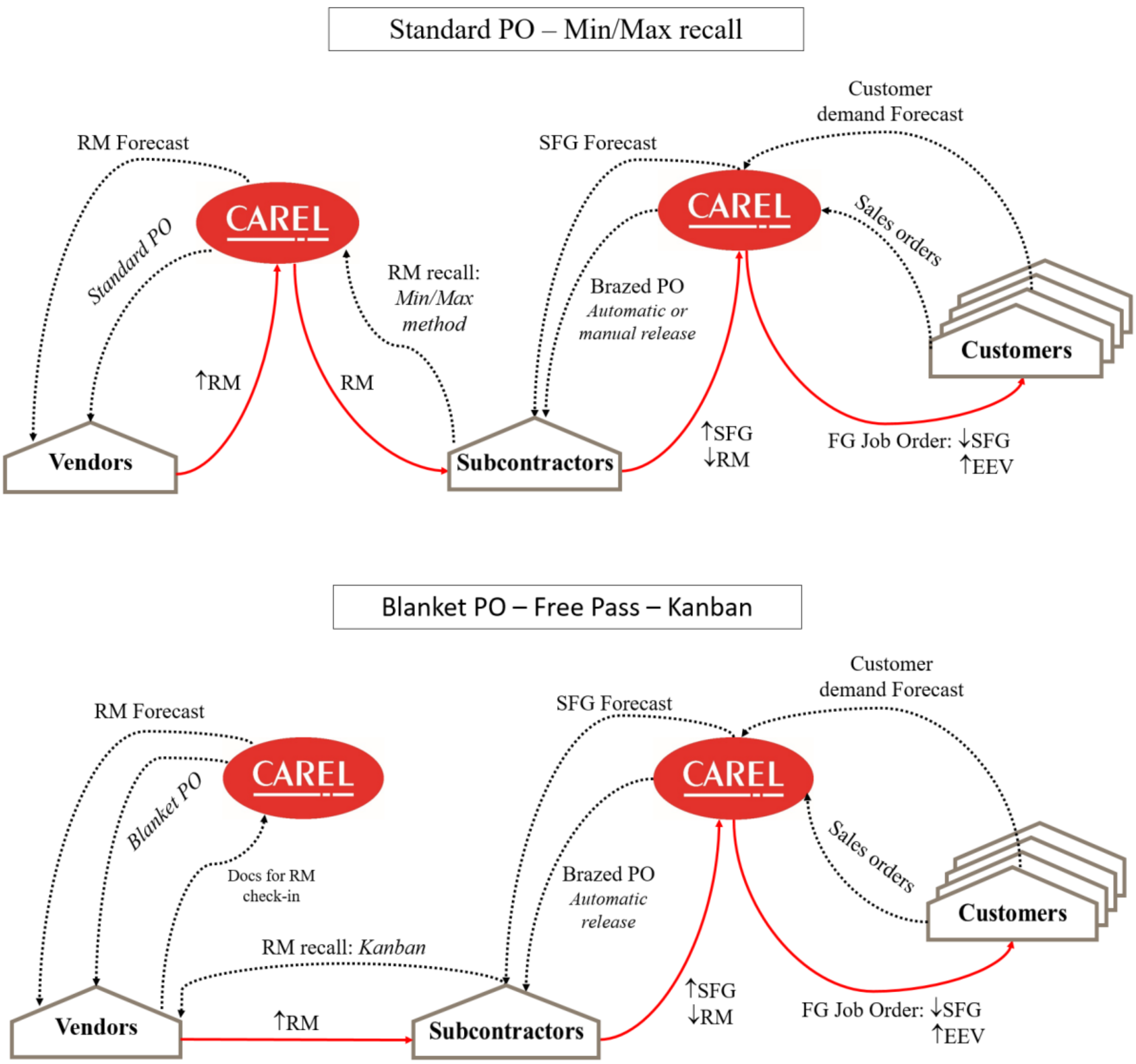


Figure 3.16. Scheme of the overall value streams for the two procurement methods; physical flow in red, informative flow in dotted-black.

Summarizing, brazed are released with two methods, automatic and manual, with the latter absorbing material only from standard POs and the first exploiting also blanket POs. The last piece of the puzzle, in order to understand how theoretically works this complex process, is the way material is redirected to the subcontractor. The figure 3.17 shows all the possible scenario combinations.

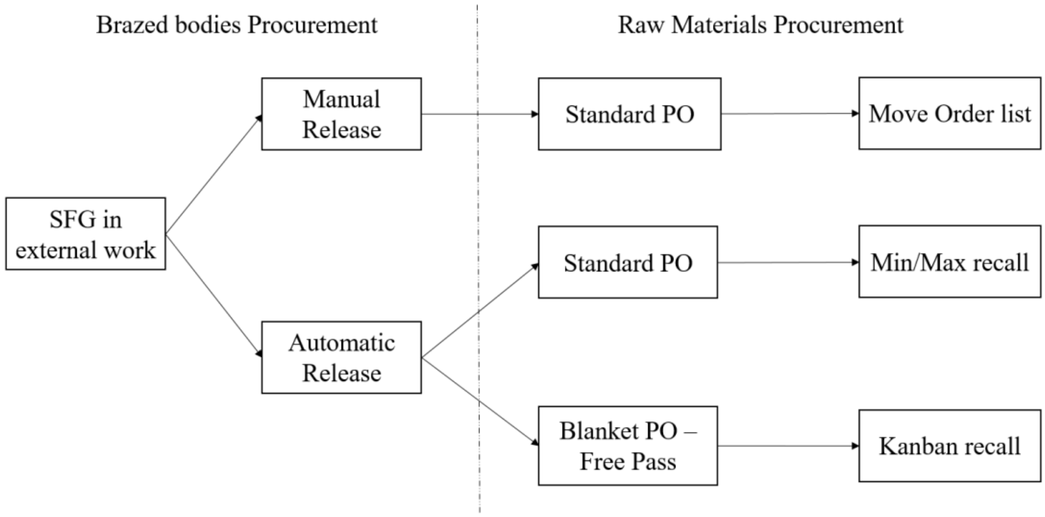


Figure 3.17. Schematic representation of all the scenarios combinations.

- *Move Order List*

Only for manual release orders there is no particular supply system used. Once the orders are placed, the scheduler sends the list with codes, cumulated quantities and date to be delivered to a specific subcontractor; when quantities leave Carel warehouse the ERP system upload them in the subcontractor inventory. Differently from the next methods, the quantities transferred to third party warehouse match perfectly the ordered quantities; this means that the supplier does not keep any stock, it is all managed in Carel. Ratio of number of codes controlled with this system is low, 24/124.

- *Min/Max system*

Theory of min/max system relies on (S, R) stock based systems in which the reorder is triggered from the fall of stock quantity below a fixed level, properly the Min value. However, reorder quantity Q is not fixed, but is so to bring back the stock level to a Max value, defined in function of cost-benefits analysis between inventory cost and service level security.

$$\text{If Stock} < \text{Min}$$

$$Q = \text{Max} - (\text{stock at the reorder time point})$$

For external work, the stock managed with this system is the subcontractor's warehouse with the reorder quantity pointing at Carel stock availability. The ERP automatically redirects the reorder quantity to the dispatching office, creating a move order list; the office creates then a delivery documents and simultaneously the quantity flows from Carel warehouse to subcontractor's warehouse, then an operator picks the materials and send them to the supplier. Figure 3.18 shows a typical outline in Min/Max systems. The 'min' value has to cover the brazed production during the replenishment lead-time; therefore, company main warehouse must keep always at least a stock higher than the difference between Max and Min value. Ratio of number of codes controlled with this system is 47/124.

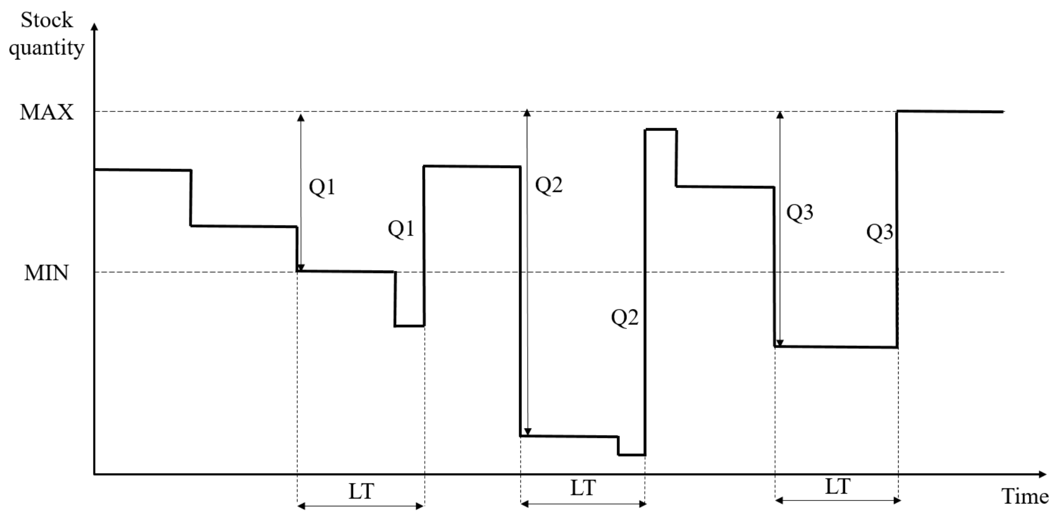


Figure 3.18. Stock outline of a min/max system.

- *'Kanban' system*

The procedure employed to recall materials from a blanket PO is not strictly an advanced Kanban system; it has taken this name, from formal point of view, only because the principal behind is the same. Due to the poor structure of subcontractors, the recalls are not made through a barcode shoot or other methods, but simply with a phone call, via e-mail or even redirected to VS4 planner. Once the vendor receives the request, it checks the remaining availability of the open orders and, if sufficient, send it. At the same time it redirects the shipping documents to Carel warehouse, which advance all the billing activities; consequently the ERP uploads the quantity on subcontractor's warehouse. The blanket PO-Kanban duo allows Carel to have always materials available, barring unforeseen circumstances, to take no charge of the replenishment activities and to have not additional immobilized goods.

Typically, the codes stocked in the main warehouse, used in manual release and Min/Max recalls, are subjected to material traceability legislation (97/23/CE (PED) European guideline on pressure equipment); for this reason, they cannot be transferred directly from the vendor to subcontractor, the metrological lab before going in external production must check them.

For all manufacturing operations, when a subassembly is produced, its components have to be discharged from the available stock, since they are no more single raw materials but they began a single new item. It is important that the *timing of materials discharging* matches at best the moment in which components are processed and transformed, if not two scenarios may arise. Technically, consuming a material before its production is impossible, since it is the work order that, once completed, discharge the various quantities inside the BoM, if not enforced with manual adjustment of the stock. If materials are unloaded after the completion of the working process, they create availability for other jobs, sales orders or whatsoever type of demand, and the wider the timespan between production and discharging, the more the possible misalignment between physical stock and system inventory.

Criticalities

For the subcontracting activities of Carel, as they were, components of brazed items are discharged when they are checked-in, back into the main warehouse.

Nevertheless, for automatic releasing, the PO emitted does not have a work order associated, and then the system cannot commits raw materials quantities. Considering an average lead-time of 10 to 15 days between the emission of an order and its completion, a committed quantity of material by an outstanding order remains available, at the 'eyes' of the system, and of the planner that interrogates it, for almost three weeks.

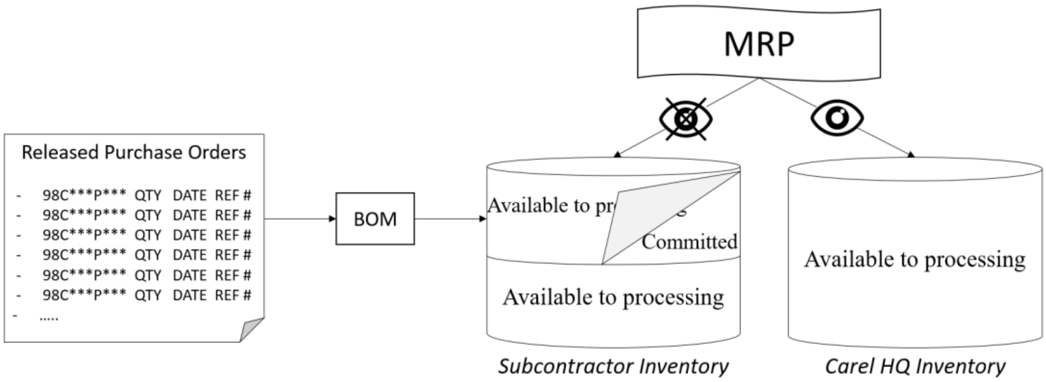


Figure 3.19. Visualization of how the system considers the inventories.

This is a major issue regarding the procurement process, creating four big impacts:

1) Since brazed items have just 'materials availability' as confirmation constraints parameter, the order entry of a finished good does not block since the committed raw materials are always available, especially if on blanket POs.
2) The discrepancy of subcontractor inventory, between the real physical stock and quantity in the informative system, leaves exposed incoming POs, creating a circle of inconsistence data.
3) Wrong and misleading suggestions of the MRP jeopardize seriously the procurement activity of the planner, due to a plan that is not aligned with the correct stock availabilities. In addition to the blindness on committed materials, the MRP does not see on the master plan the stock quantity of the subcontractors' warehouse, which can be recollect only with a manual interrogation of the ERP system, inside a precise workbench.

4) Min/Max material recall does not work under these conditions. The program that is going to check the stock of subcontractor inventory does not see the net situation, without the committed material, but a value that is higher. In the 100% of the cases, ‘on-hand’ inventory at subcontractor warehouse never fall below the ‘Min’ level, which means that the recall system does not create a dispatching notification to the warehouse and no material replenish the stock for incoming brazed production.

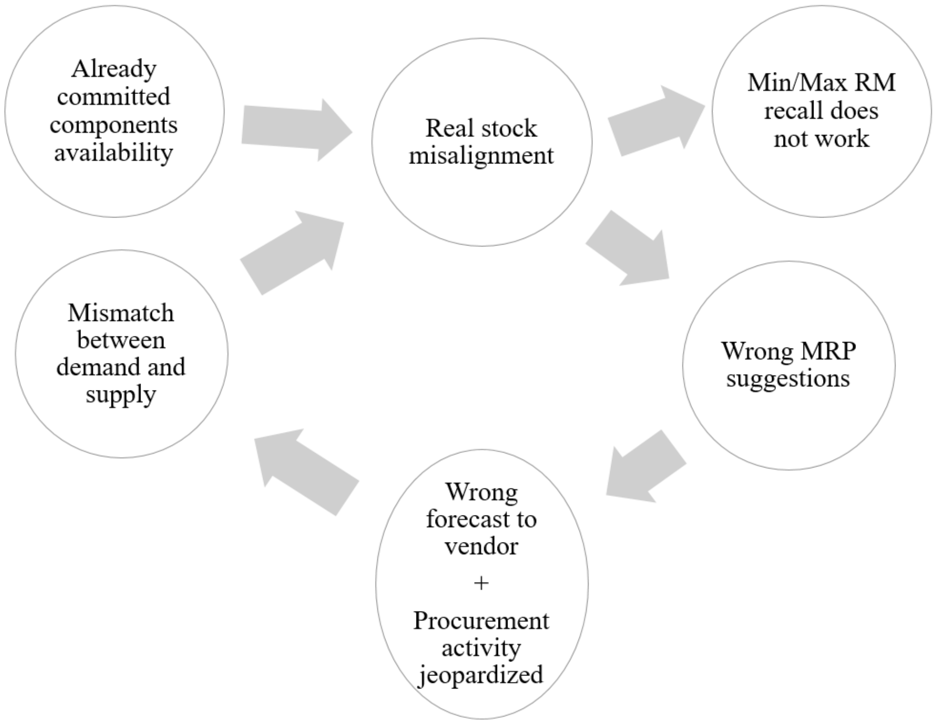


Figure 3.20. The vicious loop.

Consequences are terrible: the planner cannot trust the reorder suggestions of the MRP and, giving that vendors’ forecast are an aggregation of the MRP suggested orders, the visibility of these latter are not aligned with real manifestations of the purchase orders, thing that creates a dangerous mismatch between supply and demand planning. In addition, it has to reproduce the recall system manually, checking the net on hand availability of the subcontractor and in case send a mail to the dispatch office to immediately deliver the material. Below a list of all the issues and out of process considerations that the planner has to bear.

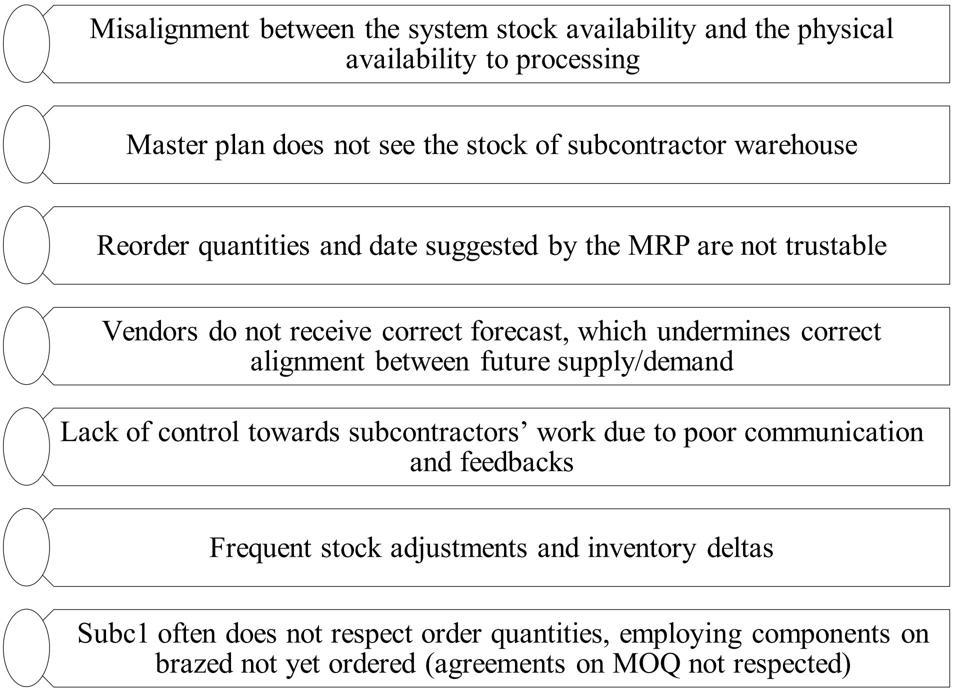
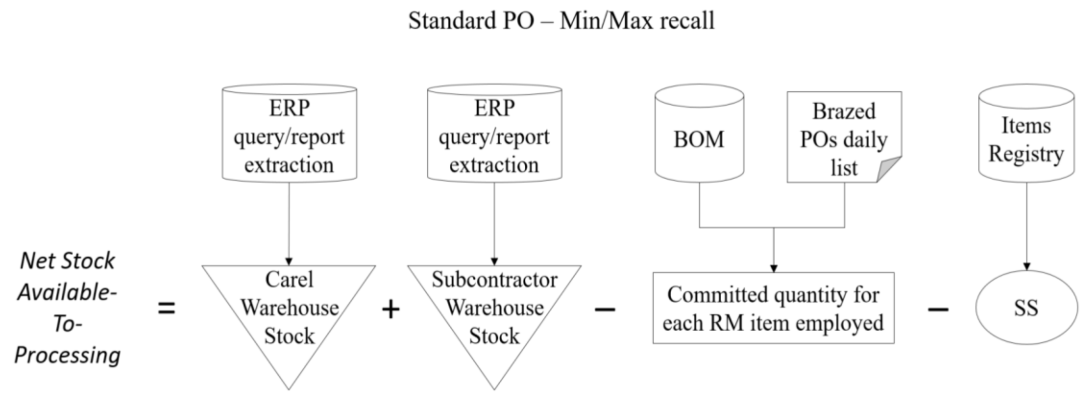


Figure 3.21. List of the overall criticalities affecting components procurement.

This intricate system of issues inside and outside the system has created the necessity of a *methodology*, a tool, allowing the planner to do his/her job: order and supply the right quantities of components for the right data. It has been created a massive Excel file collecting all the information needed in order to replace the MRP *netting* phase, manually. Five sheets are needed to calculate the quantities of the components committed in already outstanding brazed orders, by crossing the notification list of released orders and BoM explosion. In another sheet, the planner lists all the codes information about the variables involved in the netting process, the figure below shows how the computation works, based on the two different types of orders and recall methodologies. Every 124 codes follow a manual *offsetting* phase once the net stock is identified. The planner compares the net availability with the planned demand and outstanding POs, if any, on the operating plan, depicting quantities and dates; then decides if it is necessary to release new orders based on MOQ and lead-time constraints.



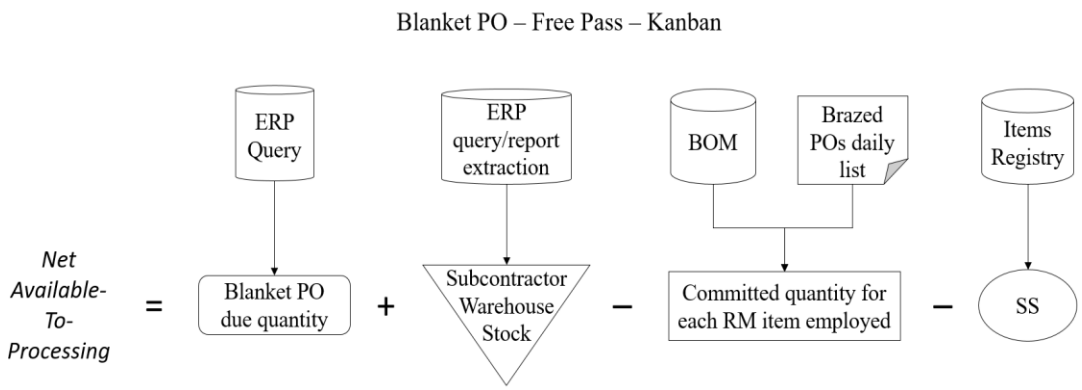


Figure 3.22. Netting phase: variables and computation (for standard PO above, for blanket PO below).

The nature of the two different purchasing activities and material recalls is strongly different. For *Free Pass* method the available quantity is visible only inside ERP order details, since the goods are not uploaded on any warehouse because of the characteristics of the order. The stock available, visible in the subcontractor inventory, is the sum of the Kanban recall quantities, including both available and committed quantity. For *Min/Max* method, materials may be present in both Carel and subcontractor, since raw materials flow through company warehouse before external dispatching. That is why the planner has to take into consideration both stock quantities for netting; however net stock do not represent the instant availability of supplier, the so called 'on house', but the overall availability. The figures below shows a snapshot of the files used by the planner, with highlighted netting data highlighted.

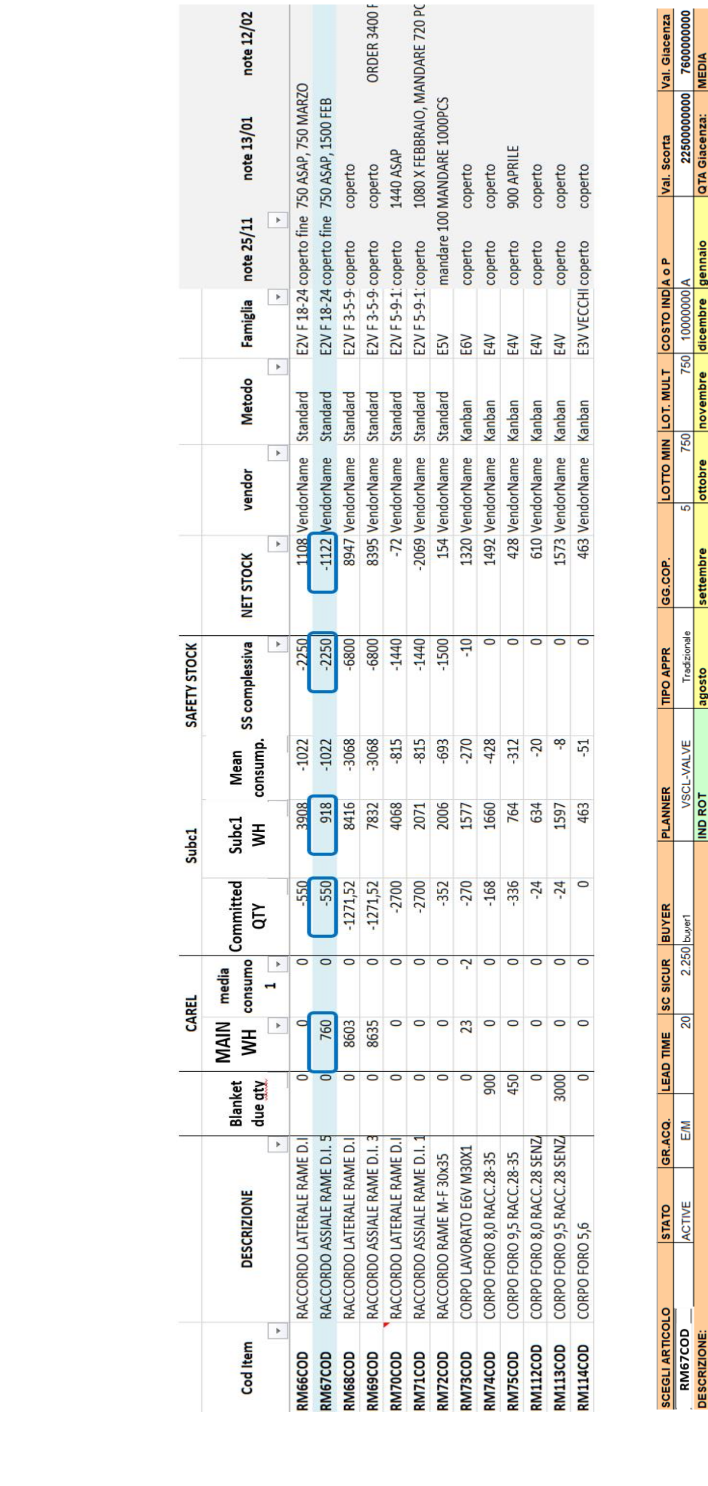


Figure 3.23. Example of the manual netting and offsetting activity, for a standard PO, made by the planner during the purchasing activity (source Carel internal data).

The analysis in example shows perfectly the failure of the MRP suggestions: the first line in the master plan do not show Subc1 stock, moreover its real stock should be 918 – 550 = 368, and not 918 as the ERP query shows. The overall offsetting gives an input, different from the MRP suggestion: reorder one batch of 750 pieces at lead-time, hence for March 12th, being 12th of February the date of the analysis, plus another batch of 750 pieces on 1st of April, because the offsetting quantity must always be positive, which means above the safety stock.

In addition to the order placement, for codes with Min/Max replenish recalls, the planner has also to notify the dispatching office the quantities to deliver to the subcontractor. The activity consists on an analysis of what the "brazer" has 'on hand' and what he will consume in the nearest future, based on the planned demand of the master plan. The automatic recall system run by the Min/Max system does not work first because parameters are not aligned with the high volumes at stake, and second because the value of the stock is always higher than the reality, due to the lack of materials commitment. In this way, the program never see a stock below the Min level, hence it does not creates the material move order. Generally, the planner seeks to maintain the highest levels of stock towards subcontractors in order to guarantee continuity of production, unfortunately with poor results.

From an objective point of view, the activity is extremely complicated and vulnerable to human errors, due to the enormous amount of manual calculation to be done. The acknowledge of the planner of this difficulty brings him/her to overestimate the orders so as to not go short. Moreover, a code may have an inventory discrepancy, may be shared between more than one supplier or used internally by Carel, may be available in the plan but still at metrological laboratory. All these punctual details, together with others not mentioned, are only in possession of the planner, which is a pro because he/she considers them, but on the opposite, a big con: know-how and cognitive bias hard to transfer to another person.

The analysis of the State-of-the Art ends with a summary of the concurrent causes of the process, represented in lean terms with a lean analysis that divides the factors that triggers the principal and root problem.

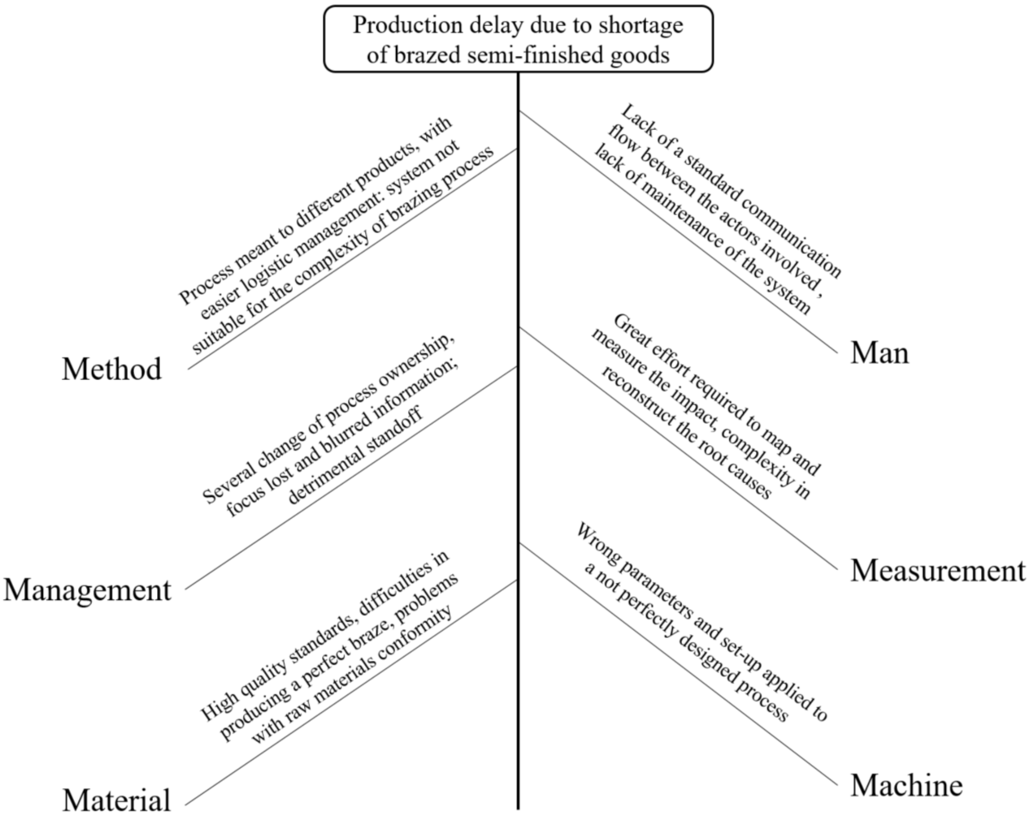


Figure 3.24. Six M's categorization of the problematic elements.

4. TO-BE: ANALYSIS OF THE SOLUTIONS

At the beginning of the project, the goals expected by the managing directors were to find solutions that would have put back in control the process. During the months of the analysis, evisceration of problems has suggested that behind the directly imputable failure of wrong parameters, the root-problem is certainly the forced adaptation of the automatic release process to a product category that has deep differences by that for which it has born; adaptation that was not parameterized properly. This system was born for an external assembly process made by local cooperatives that simply added inside a sack a bunch of tiny components, such as screws or nuts. In this case, transit time was not influent due to subcontractors' proximity, limited number of codes and raw materials involved, no difficulties in the production process or need of an advanced quality check and much shorter lead-times. Supposing that even if the system was not able to depict the committed components inside outstanding orders, for reason previously explained, the high number of volumes involved, which resulted in high stock level and large Min/Max parameters, could bypass the omissions of the system. Orders were rarely in compression due to the combination of tight lead times and suppliers' proximity, and at the same time of huge material supply, however of little monetary value. The growing number of transfers of the process ownership have favored a loss of the focus on new variables and nature of the system, which day by day led to a melting pot of issues.

The chapter presents all the theoretic solutions depicted and hypothesized during the various activities and analysis, with the help of a parallel project in charge to different function departments within the company, the purchasing department. The first topic analyzes the possibility to change radically the purchasing process, switching from the complexity of external production to a direct purchasing, in which components procurement is no more an activity managed by Carel. The second topic, regardless the feasibility of the first option, will present a series of new parameters and new implementations for the optimization of the current process, divided between the automatic release of subassemblies and the consequences on the upstream material procurement. Chapter ended with a discussion on ongoing insourcing possibilities and future investments. The flow-chart in figure 4.1 shows the road map of the solutions examined, underlying the time frame in which they will be collocate and their dependencies. It is interesting to see how the initial project was in one side a part of a bigger project, and from the other, it opened the eyes towards new solutions.

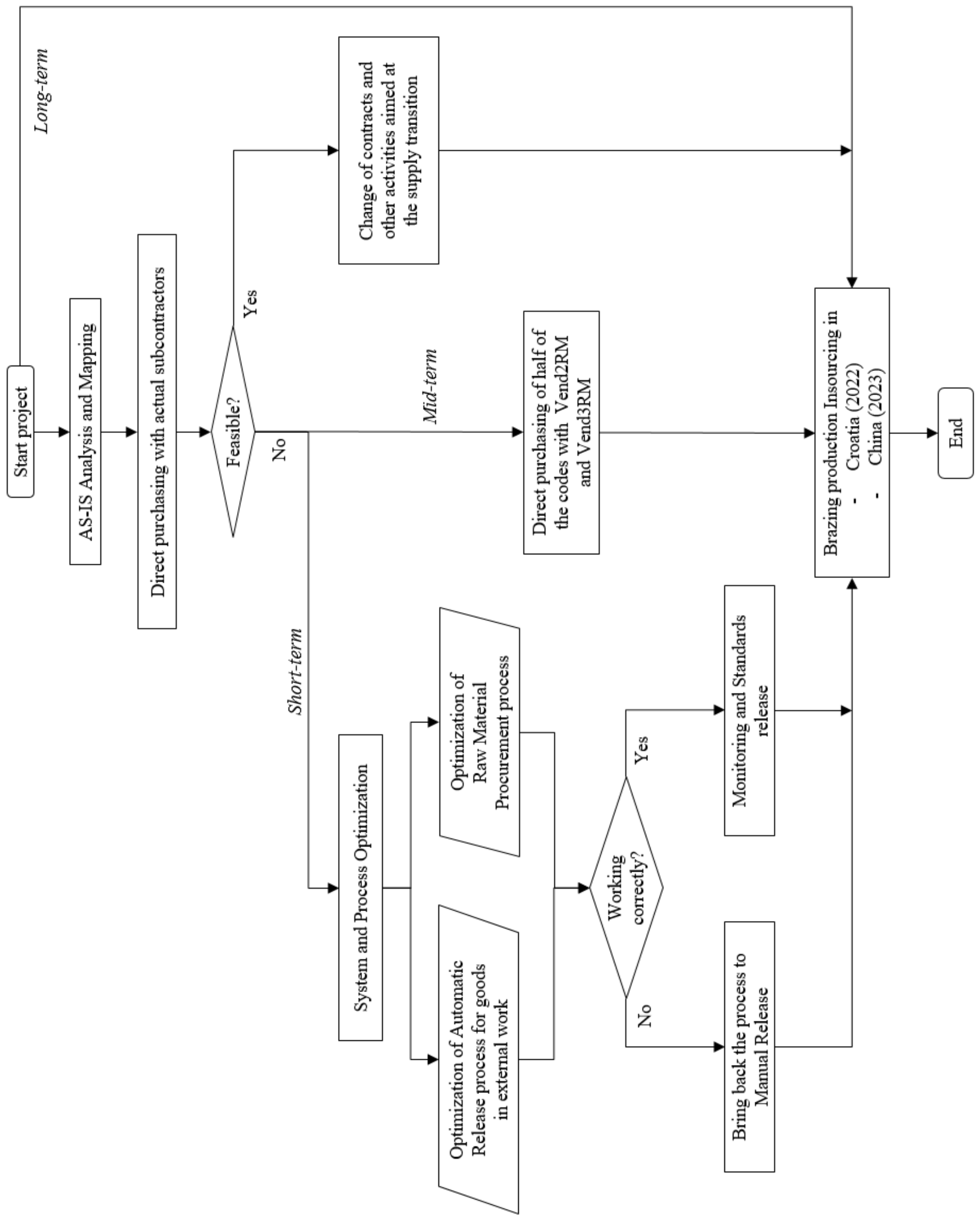


Figure 4.1. Explored solutions flow-chart, with operability horizontal.

4.1. Direct Purchasing

At a glance, the best solution that could cut the problem to the root was to redefine the commercial agreements, proposing to the actual subcontractor a direct purchasing in full account. The benefits resulting from this new strategy would be several, principally coming from responsibility relocation inside the process. Materials procurement would be handled directly from the brazing firm, which should bear all the risk linked to quality issue and purchasing activity: Carel would not have to suffer the criticalities related to components supply coming from the automatic release of items in external work. The orders release would follow the standard method, based on MRP suggestion and covering the demand of the operating plan. Customer order decoupling point would undergo a downstream shift, widening the demand window under a MTS management. In addition, another huge benefit would be the possibility for international plants to buy directly from the prime contractor, without redirecting the purchase order to Carel HQ. The lean effect in the management would allow saving time and risks due to conflict of interests between the HQ planners and intercompany sales.

Certainly all these benefits for the contracting company would be converted in a price markup, coming from new costs that the ex-subcontractor have to bear. This percentage and other reasons of commercial nature that may increase even more the price strongly impeded the change. Generally, any possible new candidate has to face an undeniable complexity behind the process, resulting in time and effort spent to manage wide and deep BoM, number of items involved and flaky suppliers. The concept is even more pronounced if the candidates are already into the process and know perfectly the intricate mechanisms. Nevertheless, the three actual subcontractors do not possess the structure and the competencies to carry on smoothly and independently such kind of supply:

- From a financial point of view Subc1 and Subc3 does not have the sufficient robustness to manage the supply of components, they would be exposed to risks they would never bear. Moreover, with respect to Carel, bargaining power on purchasing contract would be seriously pushed towards vendor side. Due to much lower economies of scale or MOQ not easily reachable standard prices of raw material could be higher, resulting in an increased final price of the braze item, which may be not competitive for Carel business.

- Their operative structure does not have sufficient competencies to manage a business as prime contractor; they have always been used to work under subcontractor agreements. If so, it would require investment in new employees and infrastructure to serve mainly a single client: it is not an attractive option for them.

If current subcontractors are not suitable for a direct purchasing agreement, the attention has to focus elsewhere. During first weeks of January, with the help of purchasing department and engineering department, it has been suggested to undertake early negotiation with two vendors that could be become new prime suppliers for a part of the total braze supply.

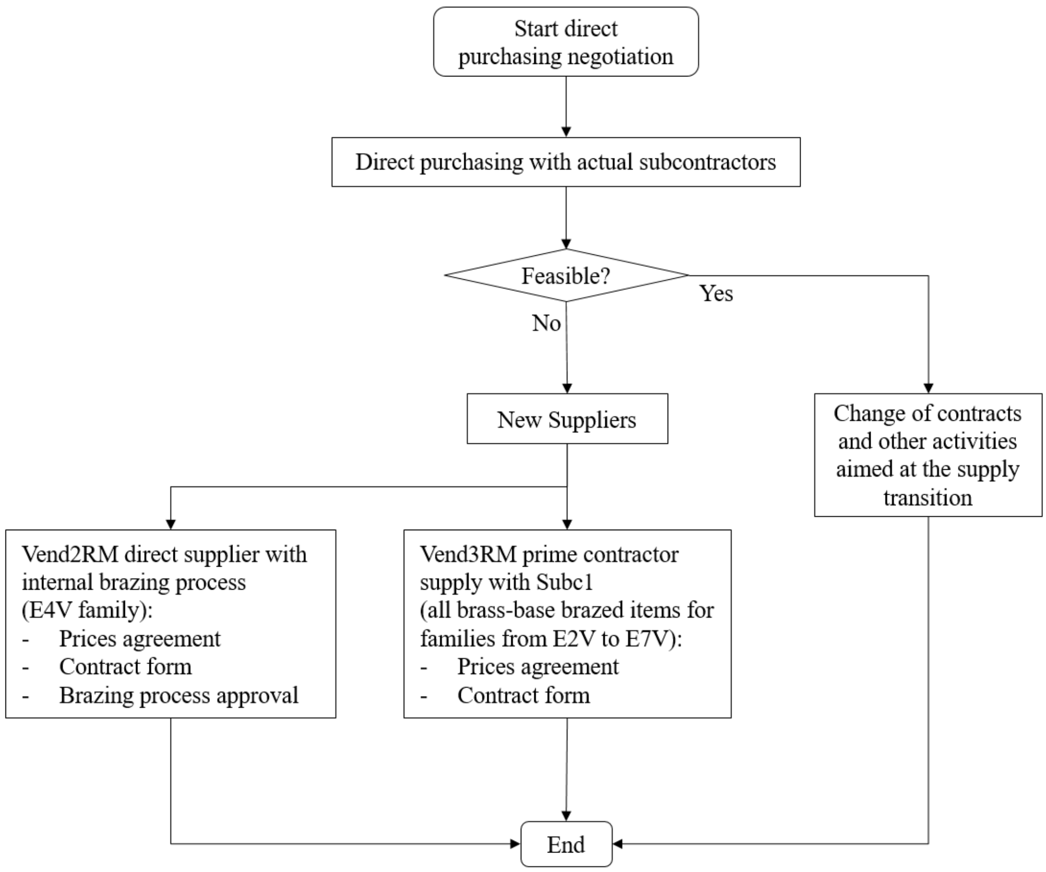


Figure 4.2. Direct purchasing option: flow chart of the ongoing solutions.

The idea started from the fact that, after all, quality assured by Subc1 is quite high with respect to competitors of Padua area; hence, the necessity to find another actor that would take Carel's role as prime contractors. The choice fell on the only current vendor of brass body for brazed in automatic release process, Vend2RM, having several characteristics in support:

- Proximity to Subc1.
- Previously outstanding relationship as supplier of brass bodies with Kanban recalls, serving with its components 91 codes over the 182 total.
- Reliability of the organization structure, an S.p.A., quality assurance and innovation of the processes.

As new prime contractor, Vend3RM would be responsible for quality assurance, service level and delivery lead-time, plus inventory of copper pipe connections; new costs for the supplier means price mark-up for Carel.

The situation of Vend2RM is still blurred: it was not clear if the supplier would take charge of the brazing process internally or third parties better experienced would assist it. Vend2RM is divided into three division: pipes and fittings production, and a third focused on welding services. During the years it has created a strong know how on copper workpieces, developing also a brazing division. In this case, the main problem relies on the homologation and approval of a new brazing process, which requires deep analysis on machines and reliability of the manufacturing process.

The holistic vision of this solution, which runs parallel to the initial optimization of the current process, is part of the strategy that tries to externalize part of costs and waste that were internal to the company. This is the reason why direct purchasing, net of an acceptable price markup, was the first and best solution that came in mind while starting the project. The goal was to transfer the existing cost of ownership and "muda" of the process to external third party, in order to avoid the risks linked to them. Brazing process of Subc1, Subc2 and Subc3 represents an old and artisanal manufacturing production that is no more sustainable; affirmed companies, among which Carel, need an industrial process at their support, which can respond in term of quality, innovation and organizational structure.

4.2. Optimization of the Brazed Supply Process

The optimization phases of the running process were carried on with the support of ICT function department specialized on ERP implementation and operating activities; during last phases, it has had the responsibility to approve the new solutions and implement them into the system. To-Be phase, contrary to As-Is, has started finding the right optimization to the root problem, i.e. the system that regulates the automatic generation of brazed purchase orders, then, going upstream, finding a solution for the right commitment of the components processed. Final goal was to "clean" as much as possible the procurement activity, allowing the planner to trust MRP suggestions without further manual calculations, and define the right method for the materials recall to subcontractors (Kanban and Min/Max methods).

4.2.1. Automatic Release System for Subcontractor work

The first decision, before starting the optimization of the parameters of the process, is upon the possibility of not releasing automatically the orders of brazed components, turning back to manual release, which has been previously adopted and still in place for some codes, as already seen. This option preserves the great advantage of creating first the work order and then to associate the purchase order; in this way, the system automatically commits the raw material quantity listed in the job order, without leaving it available in the system inventory. However, since components are dispatched to subcontractors only after the release of the order with the move order list, they should be stored within Carel HQ warehouse. If so, great impacts would affects the operability inside the company. First, there will be a problem of goods allocation inside the warehouse, this is a matter of great importance for an ATO-based factory that is seeking low level of immobilizations. Secondly, the delivery transit time and processing time of the various move orders will jeopardize the responsiveness of the process, slowing down the overall flow of material and not allowing subcontractors to have material ready to processing. Last but not least, manual release requires enormous effort by the owner of the activity, which translates in possible need of a new dedicated employee or redistribution of activities, currently a non-viable road.

Final output of this first option, as can be depicted from figure 4.1, is clearly unsatisfactory, negative impacts weight more than the benefits. The focus is then switched to the *optimization of the automatic release process*, and only in case of failure, last resort could be the return to a manual handling. As discussed in the previous chapter, the advanced offer to actual vendor of handling directly part of the braze supply is not sufficient to cover all the codes involved; even if deal would be reached, a part of the total braze supply will remain exposed to the current issues of the system. Optimization is undeniably the top priority activity to restore the control upon the system, followed by the new implementations for the procurement process.

The previous algorithm behind the automatic release had three main problems:

1) Due date pattern didn't match the actual potential delivery dates.
2) Safety stock replenishment and order entry based on raw material availability cause purchase orders in lead time compression.
3) Planning parameters of the 'time fences' were not in line with the items supply characteristics ('lead-time', 'transit time', 'atp' rules …).

After a discussion with each subcontractors, intermediated from the buyer associated to them, it has been identified the correct *calendar* delivery dates:

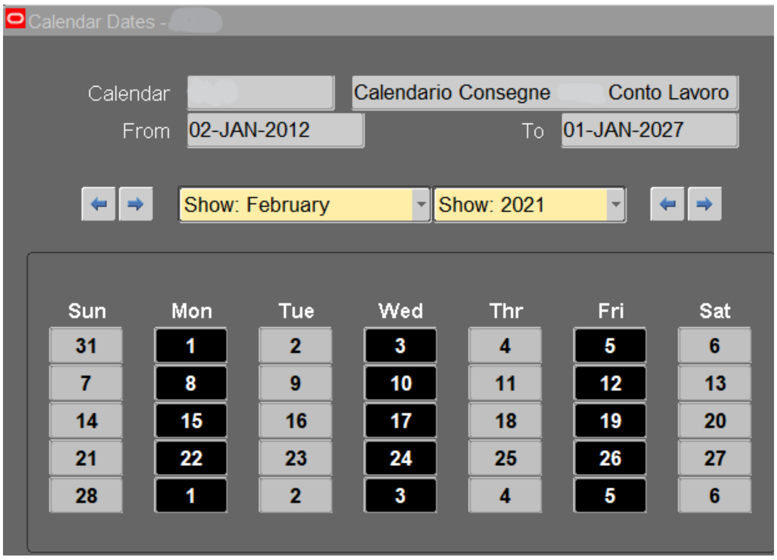


Figure 4.3. New set up of Subc1 calendar.

- Subc1 open day at industrial calendar: Monday, Wednesday, Friday.
- Subc2 open day at industrial calendar: every working day of the week.
- Subc3 open day at industrial calendar: every working day of the week.

In this situation the ‘3 days’ parameter of the ‘Release Time Fence’ would have considered only one week ahead from today for the order release, no longer three weeks; therefore, before entering the system the new calendars, it was necessary to rethink a new algorithm.

It has been decided not to obscure the safety stock level to the program: it is necessary to keep a reorder stock level based on a buffer stock kept in VS4 warehouse in order to prevent delivery delays or quality issues. However, the ‘aggressiveness’ of the system in replenish the safety stock needs a countermeasure that impede an order to be released in compression. Regarding this optic, the solution came from Oracle application guidelines; among the ‘Time Fence Control’ policy, which are restrictions and changes in operating procedure that shape the way whatever type of order can be placed. It has been decided to implement for each code a *Planning Time Fence Control*, from now on ‘PTF’: “The planning time fence is bordered by the current date and a date within which the planning process does not alter the current material plan or master schedule. You can specify whether to use planning time fence control when launching the planning process.” (at docs.oracle.com, 2021). This tool applied to the automatic release allows to 'freeze' a certain number of days, counting the days on working days of solar calendar from the current date, and release the order only the first open day after it, at vendor calendar. In order to have not lead-time compression and subsequent delays non-attributable to the supplier, the PTF must match perfectly the lead-times of the item, with an ad hoc set-up.

In parallel works the '*Release Time Fence'*, from now on RTF, "bordered by the current date and a date within which the planning process automatically releases planned orders to Oracle Work in Process as discrete jobs or to Oracle Purchasing as purchase requisitions" (at docs.oracle.com, 2021). Functionality of the release control will not change, if not the overall value of the window, which, considering lead-times between ten and fifteen days, should cover at least 20 days, but no more than 30, after the PTF, in order to fulfil a demand of approximately one month.

As seen in the daily notification list, figure 3.10, beyond the 'RTF', there is a region of time called 'Visibility Time Fence': the program did not release planned orders, but just notified them as 'forecast' to the subcontractor. It can be seen as the difference between the 'RTF' and the overall visibility of the program, which starts from the 'current date'.

- First, the misleading classification has to be changed into a more appropriate wording, such as 'future order', which depicts the fact that they are orders covering planned demand from confirmed work or sales orders. This means that, unless customer cancel the sales order on the back, they will be released with the highest probability as soon as they enter the 'RTF'.
- Secondly, the previous 'visibility time fence' was watching potentially to infinite, giving to much visibility to subcontractors and triggering advance production of future orders, without following the order schedule. This routine came from lack of control on external production and MOQ misalignment. The purpose is to set a finite future window of maximum 20 to 30 days, proportionate to the lead-times.

Figure 4.4 summarizes the concept behind time fences interaction.

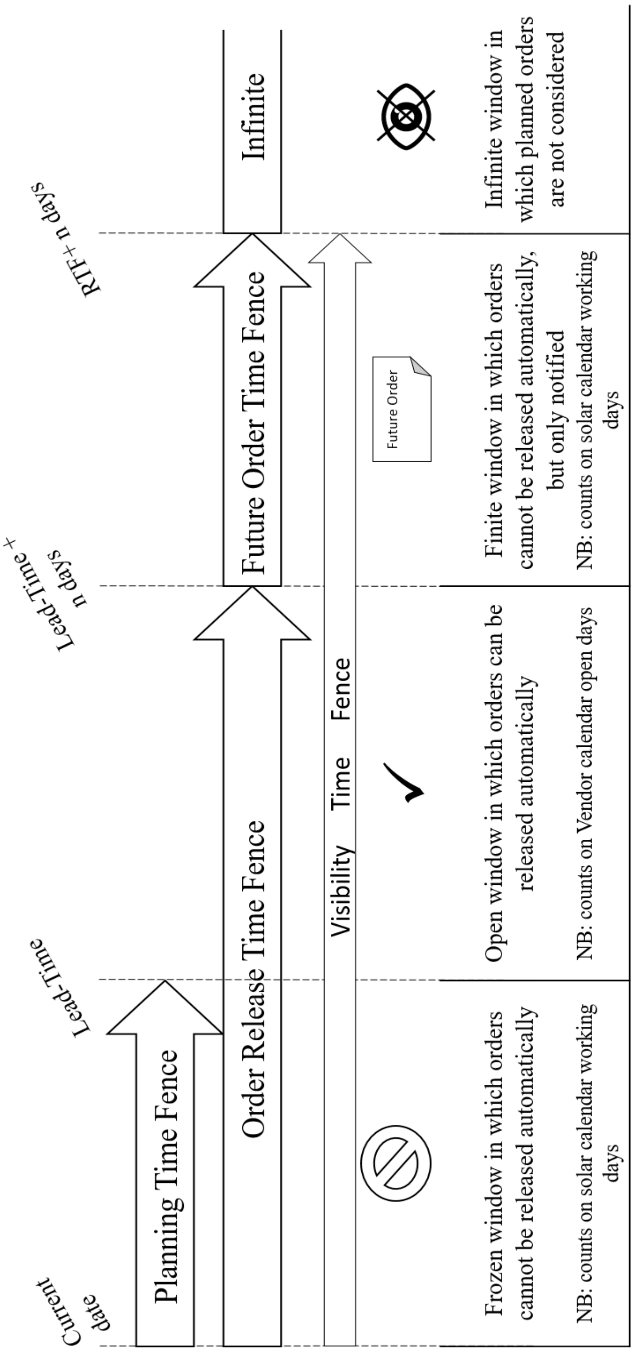


Figure 4.4. Time fence new concept for the automatic release.

When a closed window such as the 'PTF' is imposed, the focus of the process is to guarantee the supply of items within it. Either way, the system allows to manually modify outstanding POs, anticipating the 'need date' even inside the PTF, this latter commands only the automatic release process. However, the strength of the supply process cannot rely on the activity of bringing back future orders, compressing them, in order to avoid shortages of material. It has been decided to size the previous safety stock with respect to the 'PTF', so as to cover the processing lead-time of the subcontractor. The figure below wants to show the overall algorithm, before showing the calculation of the new safety stock level.

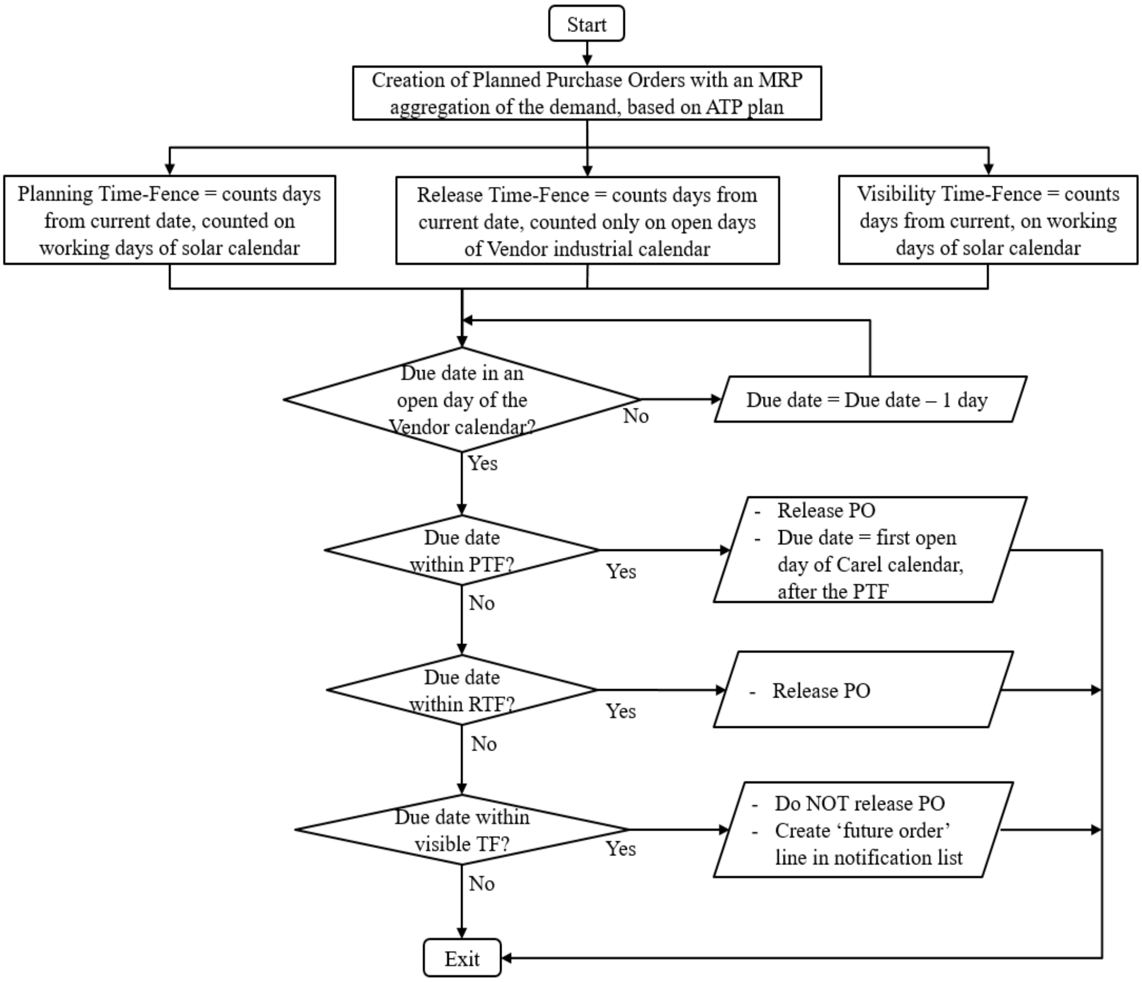


Figure 4.5. Flow chart of the new algorithm for Automatic order release, simplified.

Previous brazed safety stock were almost zero for the majority of codes because items were considered to be part of the final assembly phase, even if the edge was very blurred; only high running codes possessed a safety stock level. The decision of basing order releases only on ATP demand is indeed a factor supporting this thesis, though ignoring the issues behind (a supply lead-time and related uncertainty). Despite this, in the light of the complex dynamic of the supply process and the new methodology of automatic release, all data were suggesting to cover the frozen window with a set of new *safety stock level*, which for Carel ERP coincides with the reorder point level. Since items in external work at the eyes of the system has 'null' processing lead-time, purchase order can be placed automatically exactly in the date in which stock level fall below safety stock. Hence, it has been decided that their purpose will be to cover only the PTF, where orders cannot be placed. The drafted model is a simple ROP model with variable demand, in which the deviation from expected demand is covered by a safety factor, taken from the probability of guarantee a percentage of service level (1 – 'probability of stockout'). There can be mainly two types of cases discussed below, considering always a constant 'PTF'.

- With PTF = 10 days, if Available Stock < SS in 0 < t < 10, the order will be placed in t = 10 or t > 10, following the automatic release algorithm; consumption inside 'PTF' have to be covered by the 'SS level' for a certain service level. Optimum 'ROP level' have been calculated with the following formula.

$$R = \mu_d * PTF + Z * \sigma_d * \sqrt{PTF}$$

μ_d = average daily demand.

σ_d = standard deviation of the daily demand.

Z = safety factor corresponding to the service level probability. Since demand of brazed do not follows a normal distribution, Z factor were calculated on the base of subjective factor due to the criticalities of the item and related subcontractor.

At the end, the exact result has been rounded by excess to the MOQ. Figure 4.6 show the demand coverage for a normal distribution, with the aim of giving an explanation to the concept of safety factor and demand coverage with a certain percentage of probability. The term ' $\sigma_d * \sqrt{PTF}$ ' is the square root of the sum of the daily variances during the 'PTF' (i.e. the lead-time).

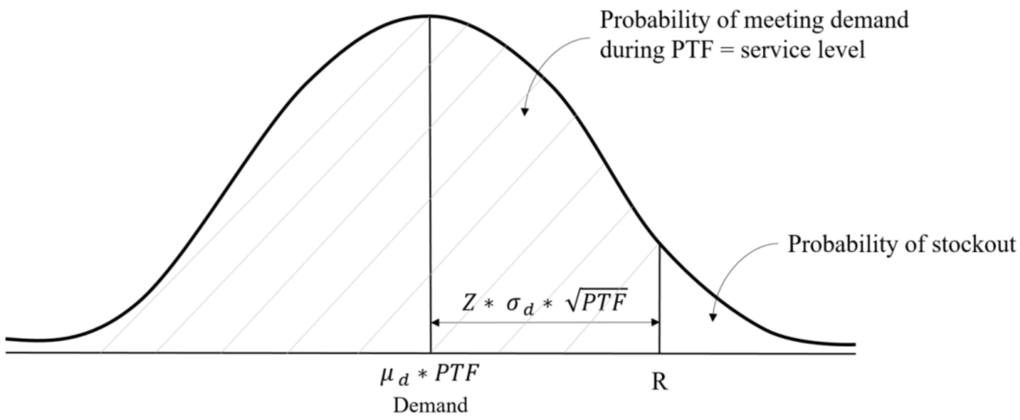


Figure 4.6. Reorder point level distribution, with fixed lead-time.

- With PTF = 10 days, if Available Stock < SS in t > 10, the order is placed exactly in ‘t’, following the automatic release algorithm.

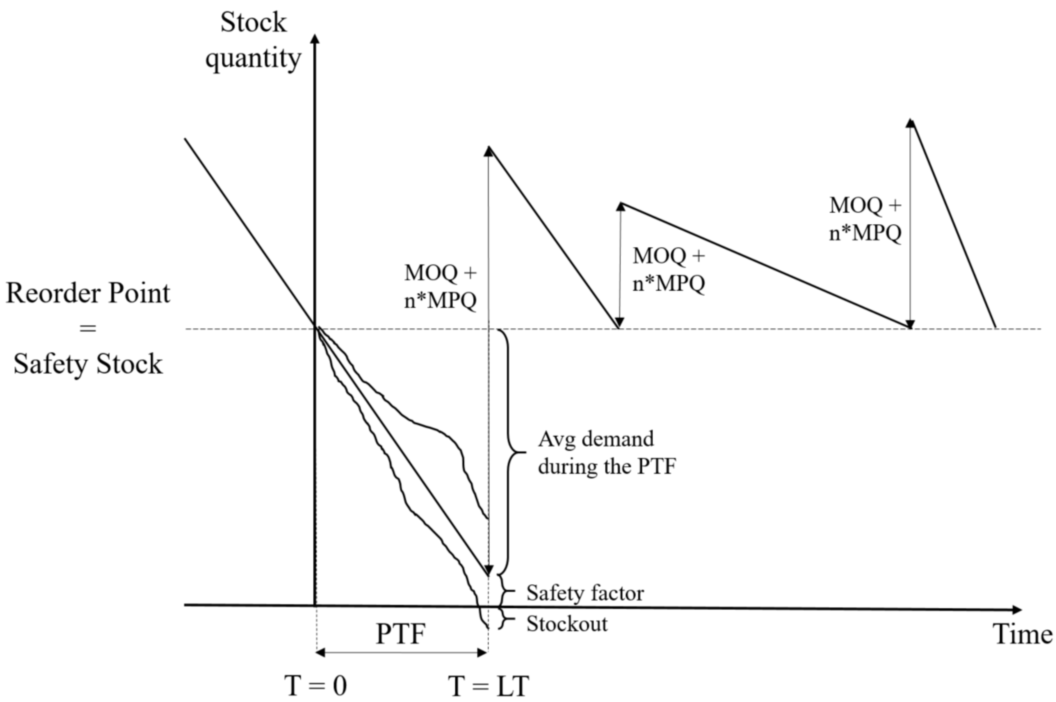


Figure 4.7. Reorder point model for the new automatic release.

To clarify possible misunderstanding, the standard ROP calls safety stock the quantity covering the fluctuation of demand exceeding the average consumption, considering the percentage of expected service level. Since actual Carel ERP consider safety stock as reorder point level, the object of discussion overlaps the two terms.

Data input used for safety stock calculation were the historical demand consumption of the last 12 months, from which it has been extrapolated the average demand and its standard deviation. The ‘Z’ factor has been set has an aggregation of an overall criticality factor of each subcontractor and another one for the belonging family of the brazed item. The correspondence to a family means an association to a vendor, which is a critical factor that has to be taken into consideration, especially for the material delivery KPI. Below, table 4.1 that shows how the Z factors were assigned and an example of parameters setup for Subc1 (figure 4.2); it has been assigned to an item the higher ‘Z tot’ with respect to the vendor supplying its components, with ‘Z tot = Z1 * Z2’.

Subcontractor	Z1	Vendor	Z2	Z tot
Subc1	1,45	Vend2RM	1,3	1,89
		Vend3RM	1,15	1,67
		Vend4RM	1,4	2,03
		Vend5RM	1,15	1,67
		Vend6RM	1,25	1,81
		Vend7RM	1,2	1,74
		Vend8RM	1,5	2,18
Subc2	1,5	Vend8RM	1,5	2,25
Subc3	1,2	Vend1RM	1,2	1,44
		Vend9RM	1,2	1,44

Table 4.1. Table of safety factors for safety stock calculation (source Carel internal data).

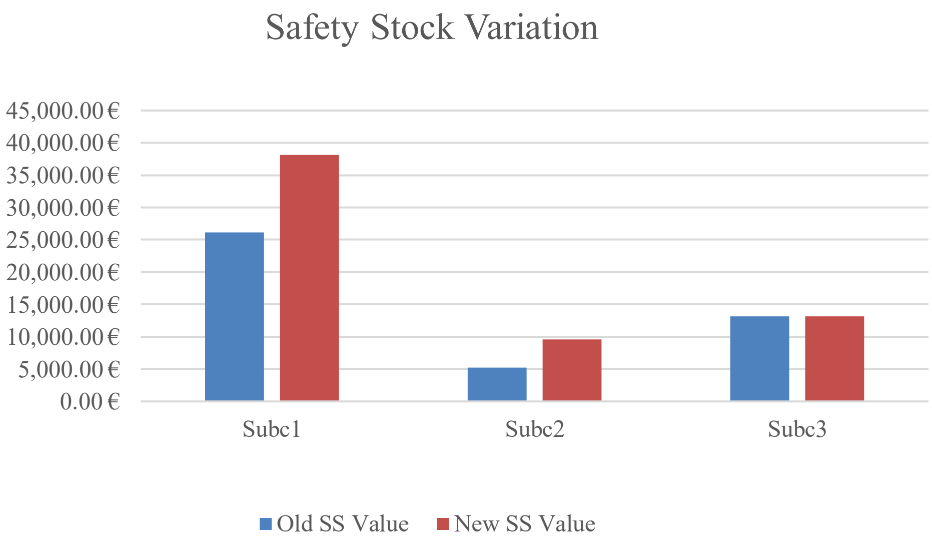
Cod Item	LT fixed	Calendar	Time Fence Control			SS
			PTF	RTF	FTF	
98C***P***	15	Mon, Wed, Fri	15	30	15	420
98C***P***	15	Mon, Wed, Fri	15	30	15	60
98C***P***-H	15	Mon, Wed, Fri	15	30	15	0
98C***P***	15	Mon, Wed, Fri	15	30	15	0
98C***P***-H	15	Mon, Wed, Fri	15	30	15	0
98C***P***	15	Mon, Wed, Fri	15	30	15	0
98C***P***-H	15	Mon, Wed, Fri	15	30	15	0

98C***P***	15	Mon, Wed, Fri	15	30	15	280
98C***P***	15	Mon, Wed, Fri	15	30	15	630
98C***P***	15	Mon, Wed, Fri	15	30	15	0
98C***P***	15	Mon, Wed, Fri	15	30	15	70

Table 4.2. Example of parameters setup for automatic release, a bunch of codes from Subc1, (source Carel internal data).

During safety stock analysis, it came into light that lead-time inside the ERP of all items supplied by Subc1 were not reflecting the contract agreements, stipulated in 2017. The two parts agreed for 15 days fixed for all items in the supply list, whether in the system they ranged from 5 to 20 days; old parameters were changed immediately. This later breakthrough confirms the deep misalignment of the process and justify constant delays from the subcontractor.

Regarding the procedure of the analysis, there has been made a distinction between items used in VS4 and items sold to international plant, the so-called '-H'. Considering this latter family, safety stock level were inserted in the Croatian plant for items with sales localization only in Croatia, while for items with sales localization also in China, safety stock have been set also for the HQ plant in Brugine, due to the still immature EEV Chinese production and a consequent high volatility of their orders. The overall impact of the new safety stock value is null for Subc3 and bearable for the other subcontractors; with a total increase of about 17.000€ there was no need for an official approval of the plant manager but only of the inventory specialist, with positive outcome indeed. Graphs in figure 4.8 show how the additive value of inventory is distributed with respect to the supplier origin: as expected from the allocation of safety factors, compared from the old level of safety stock, items from Subc2 have experienced an increase in value of 84%, of 46% for Subc1 items.



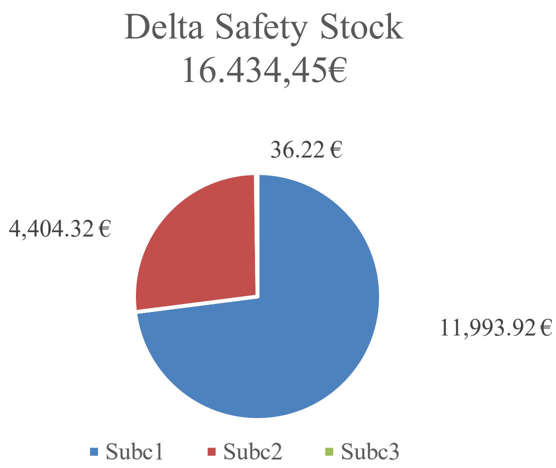


Figure 4.8. Graphs of the new safety stock impact (source Carel internal data).

The results obtained reflect perfectly the expectations after the analysis on the summary missing items during the daily production, carried on in the first part of the project: safety stock have been increased for the majority of codes with frequent shortages due to delivery delays, as expected. After the theoretical analysis of the solutions, the project has carried out the activities of implementation and monitoring of the new model, first with the less critical subcontractor, Subc3, and finishing with the most critical and with the higher number of codes, Subc1, in order to monitor slightly the new process and have all possible bugs fixed. Results and implementation method will be presented in chapter 5.

4.2.2. Materials procurement and Subcontractor supply methods

Implementation of the new optimizations regarding the automatic release of brazed subassemblies are the first piece of the puzzle towards the overall readjustment; in parallel, it has been carried on a series of meeting with IT department in order to discuss which could have been the best solutions for the procurement issues. Given the complexity of the process, the first important and fundamental point was to define clearly the main problems to solve. The system was not able to see the committed materials from 'in processing' released order of brazed subassemblies, consequently creating a fictitious stock value, higher than the real one. In addition, the MRP during the netting phase was not seeing the stock at subcontractor's warehouse either. Consequences:

1) Creation of false and wrong suggested orders from the MRP, which jeopardize the purchasing activity of the planner.
2) Min/Max recall system of the material, from Carel to the subcontractor, is overwhelmed by higher on hand availability and does not launch move orders for the dispatching office, i.e. the 'min' level is always below the stock level of the subcontractor.

The desire was to create a commitment on the material in order to have a clear situation of the available stock, free from outstanding orders; in parallel, the on hand quantity of subcontractor inventory has to be visible as well. In this way, MRP can elaborate a netting phase on quantities that reflects the real availability of the goods. Alongside, for items with standard purchase orders, the Min/Max recall system, which creates the movement of raw materials towards subcontractors, can be redesigned with ad hoc parameters getting back to its initial purpose, figure 4.9 shows the new desired process. Regarding items in blanket purchase orders with Kanban recall the optimization is limited. It is almost impossible to let the system see the due quantity of the PO, still available by contract; hence, the MRP can net the dependent demand only considering the availability at subcontractor warehouse, deferring the complete check to the planner, during the procurement activity.

However, despite the imperfections, activity of purchasing items in blanket open orders is scheduled once a month, at most; it has been decided to consider it a bearable effort.

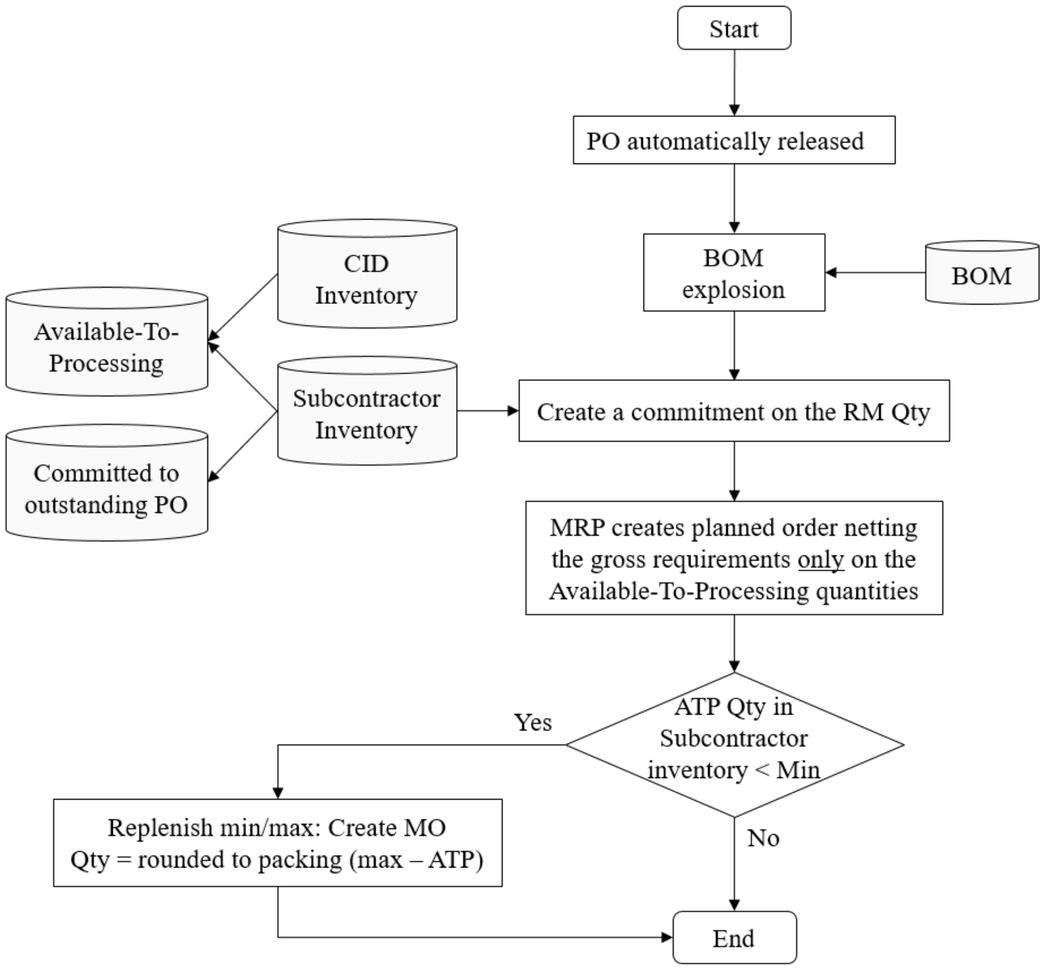


Figure 4.9. Desired functionality of the process for items in Min/Max recall method.

The first solution that came in mind was to modify the previous 'On-hand quantities' workbench of the ERP, splitting the 'On-hand Qty', see figure 4.10, between what is committed to outstanding orders and the remaining available to processing, still using an automatic BoM explosion of the brazed items in the daily notification list.

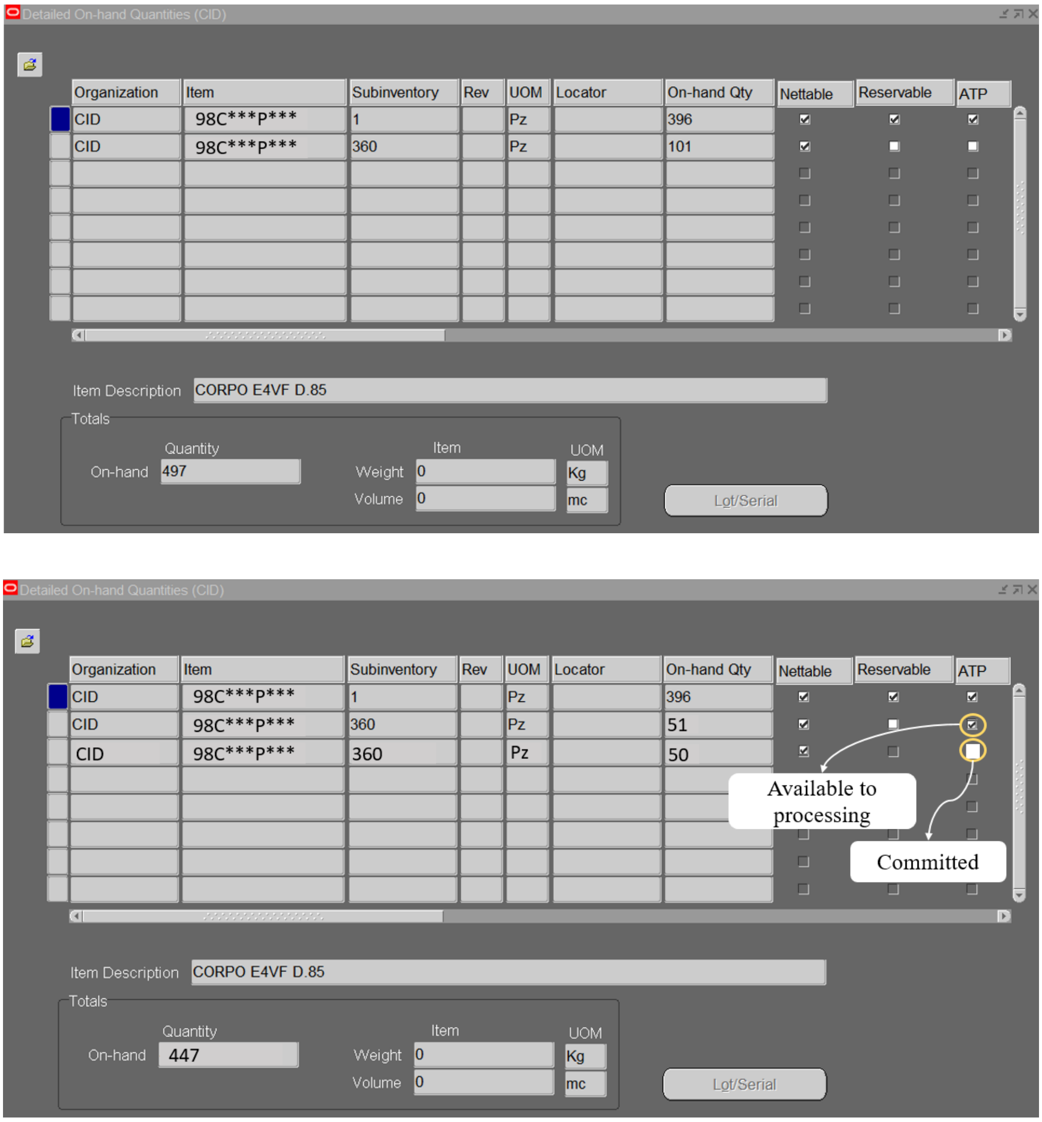


Figure 4.10. Previous and plausible new (in sequence) 'On-hand' workbench (source Carel internal data).

However, under advice of the IT department, this condition was not sufficient to ensure that the MRP could read only the available quantity. The new program would operate only on the workbench, as simple snapshot of the two quantities: the 'committed' looking at outstanding POs and the 'available' as difference with respect to the overall on-hand of the sub inventory, depicted by the system. There was the need to create a fictitious demand that reduced the stock, which was simply called 'manual demand'. The program has to explode the raw material quantities of the brazed items, with a BoM interrogation, and generate negative lines of the same quantities on the vertical master plan of the item. In doing so, not only the stock quantity will be netted but also it will be possible to assign a precise brazed PO to the relative consumption of raw material. Figure 4.11 represents an example of how the solution should appear in the ERP supply/demand workbench.

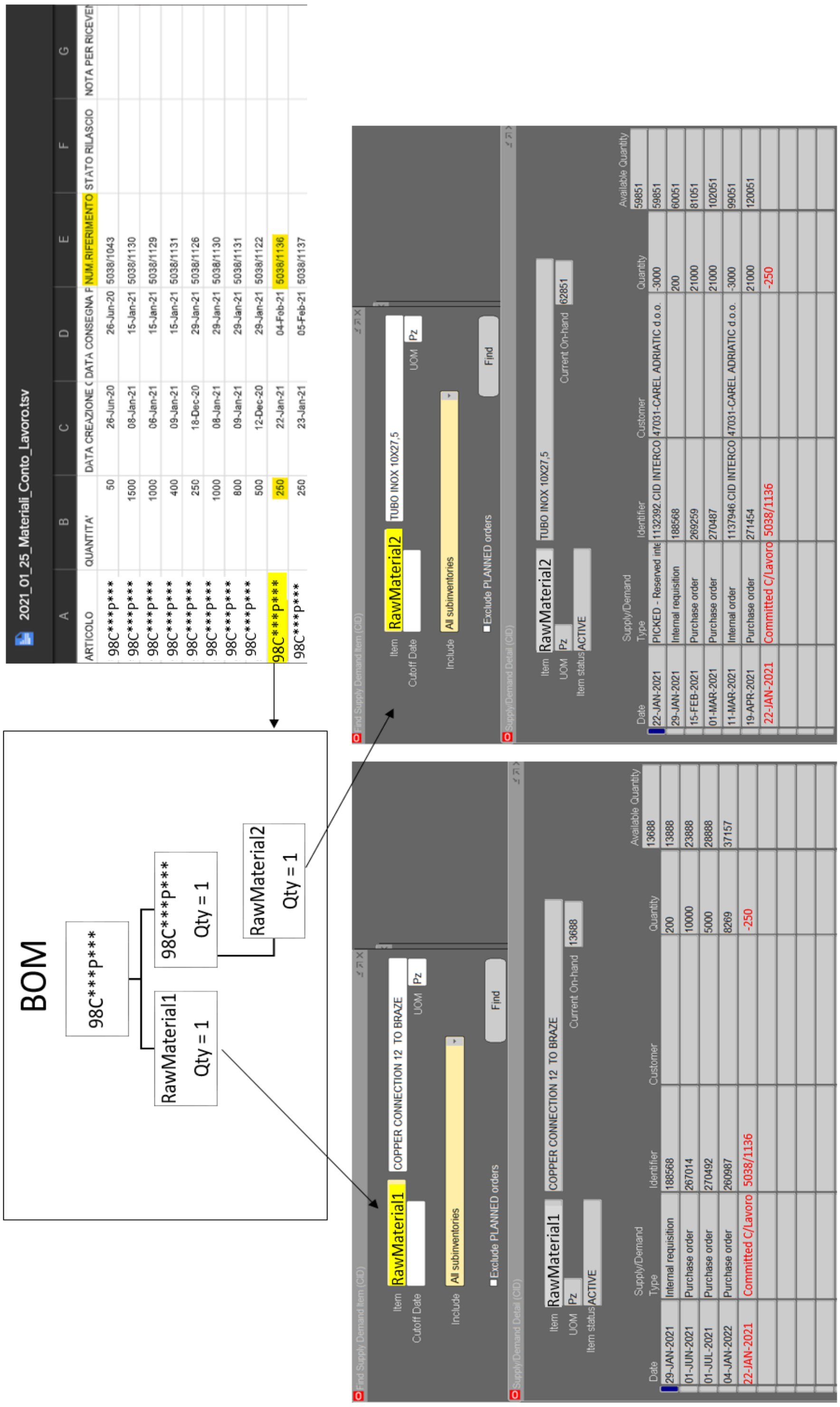


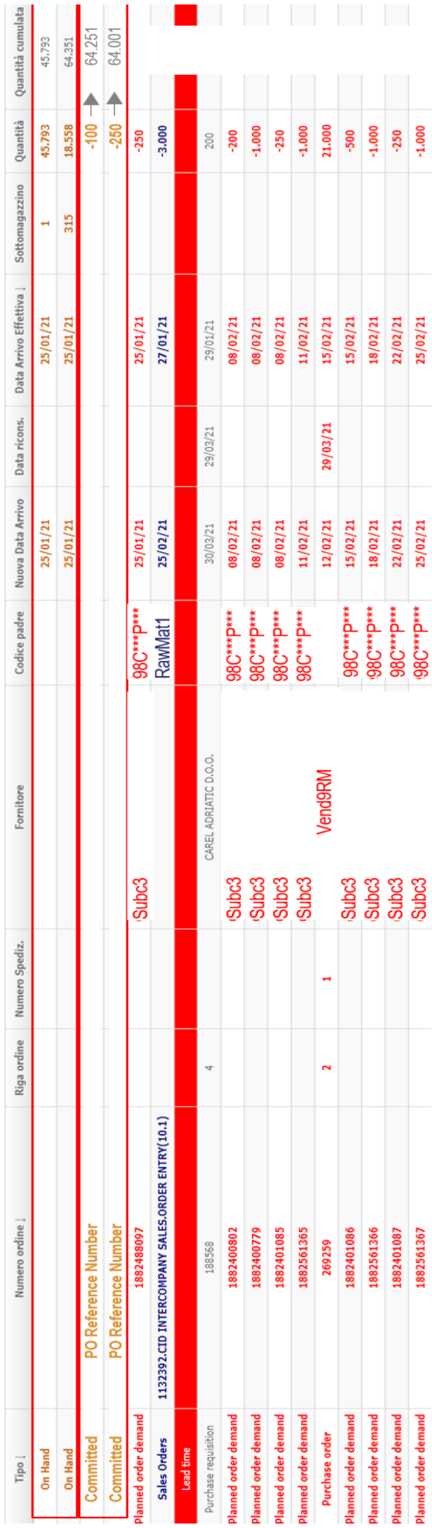
Figure 4.11. Example of the new system to commit components of outstanding POs (source Carel internal data).

‘Date’ corresponds to the date in which the order has been created, ‘type’ field will underline the nature of that demand, which is a commission for external work, and lastly, as ‘identifier’ the reference number of the referred PO. When the brazed item return to Carel, it is check in triggering an immediately delete of ‘manual demand’ lines associated to its purchase order number. At the same time, in order to balance the erased line that was committing the material, the program will unload the stock by the associated BoM quantity.

In combination with this new implementation, a flag will enable the vertical master plan and the MRP to view of the stock quantity at subcontractor inventory. Looking at figure 4.12 showing how the company intranet portal will look like it is possible to understand the mechanism adopted; consider that subinventory ‘1’ refers to HQ warehouse while subinventory ‘315’ is associated to Subc3. The sum of these effects will allow to:

- Create suggestions of planned order that match perfectly the offset demand, which means that the planner can now trust them, eliminating the previous low value adding procurement activity.
- Have a clear view of the goods committed to already released PO of brazed and have details that help associating quantities and dates with relative PO reference numbers.

As mentioned before, in case that the item is recalled directly by the subcontractor (free-pass/Kanban method), subinventory ‘1’ never shows stock, since the goods does not transit through HQ warehouse. In this case, the stock visible on the vertical plan is presented only in subcontractor inventory, if any, for both the MRP and the operator that is interrogating it. Clearly order suggestions would not reflects reality since the netting phase does not consider the available due quantity of the blanket purchase order. It has been decided that for the moment, relative purchasing activity will follow the same ‘iter’, since blanket purchase orders covers a time window of approximately six to nine month and periodic check is only once a month, waiting for further improvements of the system.



Tipo ↓	Numero ordine ↓	Riga ordine	Numero Spediz.	Fornitore	Codice padre	Nuova Data Arrivo	Data ricons.	Data Arrivo Effettiva ↓	Sottomagazzino	Quantità	Quantità cumulata
On Hand						25/01/21		25/01/21	1	45.793	45.793
On Hand						25/01/21		25/01/21	315	18.558	64.351
Committed	PO Reference Number									-100 →	64.251
Committed	PO Reference Number									-250 →	64.001
Planned order demand	1882488097			Subc3	98C***P***	25/01/21		25/01/21		-250	
Sales Orders	1132392.CID INTERCOMPANY SALES.ORDER ENTRY(10.1)				RawMat1	25/02/21		27/01/21		-3.000	
Lead time											
Purchase requisition	188568	4		CAREL ADRIATIC D.O.O.		30/03/21	29/03/21	29/01/21		200	
Planned order demand	1882400802			Subc3	98C***P***	08/02/21		08/02/21		-200	
Planned order demand	1882400779			Subc3	98C***P***	08/02/21		08/02/21		-1.000	
Planned order demand	1882401085			Subc3	98C***P***	08/02/21		08/02/21		-250	
Planned order demand	1882561365			Subc3	98C***P***	11/02/21		11/02/21		-1.000	
Purchase order	269259	2	1	Vend9RM		12/02/21	29/03/21	15/02/21		21.000	
Planned order demand	1882401086			Subc3	98C***P***	15/02/21		15/02/21		-500	
Planned order demand	1882561366			Subc3	98C***P***	18/02/21		18/02/21		-1.000	
Planned order demand	1882401087			Subc3	98C***P***	22/02/21		22/02/21		-250	
Planned order demand	1882561367			Subc3	98C***P***	25/02/21		25/02/21		-1.000	

Figure 4.12. Example of 'manual demand' in vertical plan, on intranet Carel portal (source Carel internal data).

4.3. Insourcing

As mentioned in chapter 2.4, make or buy decision can be reversed in particular conditions of the market or due to new development of the business. A new technology can permit a process that was previously only in the hand of third parties, or a new supplier may have entered the market with cost advantages; changing of trade-offs are at the base of this radical change inside the organization. During the second half of the project, thanks to the depicted state of play of the process, managing directors have switched the focus on important strategic decision: should Carel braze in-house what it is currently buying from external suppliers? After deep analysis at group level, which were not available for the purpose of the project, the outcome of the question was positive; all ongoing and future activities has to head towards the insourcing of brazing production. Reason behind touches every field of the business, from the high strategic level to the internal logistic, HR and core competences analysis, financial investments and future returns, localization and plant re-layout, and so many others. Below it is presented a table that compare aspects in favor of insourcing activities and not, which can come from both external and internal factors, highlighting especially reasons that might have triggered the insourcing initiative.

Advantages	*Disadvantages*
1) An existing supplier ceases its activity or cut a product or service line, and at the same time, no other suppliers can replace the gap. 2) Unpredictable increase in price, competitors' actions that reduce the total supply or political and regulatory event. 3) Non-competent or unreliable suppliers, not reactive to innovation. 4) Development of a unique process with specialization on internal	1) Increase in staffing and resources: employees, machines, materials, facilities… 2) Difficulties in managing a process that was not a core competence of the company. 3) Cost management issue: additional overhead costs and financial exposure.

product requisition: improvement in quality, control and flexibility. 5) Complete control over the process 6) Enhancing of competitive ability and strategic competences. 7) Increasing of volumes that may justify investments in new production activities. 8) Better logistic management.	

Table 4.3. Factors in favour and against insourcing activity.

The bullet point in favor of Carel's choice concern either external or internal factors. In the latest years 2020, a positive growth of the overall business increases the volumes of Electronic Expansion Valves: on average almost a +20% only in the last two years, as seen in figure 3.5, and a further positive trend for the future years. Consequently, new valves production lines have been inaugurated in the Chinese plant in latest 2020, following the previous opening in the Croatian plant the year before. Production of brazed experienced a positive peak in September, anticipating the upcoming Chinese production, creating great capacity issues among incumbent subcontractors. The business structure and technologies in their possession are not anymore sufficient to meet the growing needs of Carel: it has not been experienced proactivity and reaction to new needs, both in terms of capacity and innovation. In addition, due to law regulations, international plants cannot enter into subcontracting work with the current suppliers; as it is currently happening, this restrictions force the Headquarter to manage the entire supply, purchasing the subassemblies for three different plants. Finally yet importantly, supplying China there is a non-negligible risk in logistic management, with 45 to 55 days of ocean standard shipment days, that generates constant additional costs, totally disposable with the insourcing activity.

The company has then decided to undertake an insourcing program of the brazing activity with the use of laser-brazing brand new technologies, locating the new production phases in the other two international plants producing valves. As captured in the figure 4.13, the kick-off milestones are respectively early 2022 for Croatia and, after a monitoring phase, early 2023 in China.

Figure 4.13. Insourcing map for future brazing production.

5. IMPLEMENTATIONS AND RESULTS

Principal object of this last chapter is to report the results obtained from the solutions and implementation of the automatic release of items in external work and the subsequent raw material netting phase. In the first bullet point, it is presented the ongoing situation of the transition to a direct purchasing method for part of the codes involved. In addition, before the last subchapter, in which will be presented a series of best practices applicable to Carel and other general manufacturing companies, it has been summarized the additional improvements applied to the manual release process of all items in external work inside the company, not only brazed.

5.1. A new Prime Contractor

Negotiation with Vend2RM have not been concluded yet, it has been signed a pre-contract and started the phase of the homologation of the brazing process; to date there are no further insights in this regard. On the other hand, it has been signed the contract with Vend3RM, stating that it agreed on the direct supply of 52 brazed items, composed of a brass body, internally produced by him, and copper pipe connections supplied by other current vendors. Subc1 and Subc3 will perform the brazing production maintaining the previous specifications and costs, upon which Carel will pay a 5% markup on top of the total cost (components + external brazing service). The analysis in table 5.1 shows the overall additional direct costs for the brazed item involved, calculated on forecast demand of 2021, considering an estimated range of uncertainty of approximately +/- 6%. Estimation on delta turnover should be, in the worst-case scenario, less than 42.000€. Vend3RM will undertake to keep at stock a quantitative of items equal to 6 months of Carel demand based on forecast and ready to delivery; conversely, Carel agrees on the total collection of the goods produced after 12 months. It is a typical blanket purchase agreement that offers a tradeoff between quick responsiveness of the supplier to demand fluctuations and the risk of not matching the forecast, which is reversed upon the forecast accuracy of S&OP department.

	As - Is	**To - Be**
Direct Cost of the goods	2021 Total Turnover Range Estimation 739.811,50 € - 834.255,63 €	2021 Total Turnover Range Estimation 776802,07 € - 875.968,29 €
Other Costs	- Operating cost - Raw material inventory cost - Contingency risk - Complex value chain management	- Operating cost of standard purchasing - Blanket purchase order engagement
Overall Impact	Out of Standard	Standard

Table 5.1. Impact of transition from prime contracting to direct purchasing.

The ‘go live’ event is scheduled to early May, switching gradually part of the from the old supply method, after a changeover phase which will involve the transfer of in-house components to the new supplier, change of codes, new system setup parameters and other related operating activities that will be defined during the month of April.

5.2. Automatic Release outcome

Automatic release set up has been implemented with the new parameters presented in chapter 4.2.1, monitoring in sequence first the less critical subcontractor, until the final and most critical one, Subc1. *Subc3* and *Subc2* faced the same parameters since calendar open days were the same as well as the fixed lead-time of 10 days associated their codes:

- Delivery calendar days = weekly working days.
- Planning Time Fence = lead-time = 10 days, counted on weekly working days starting from current day. Highlighted in red in figure 5.1.

- Release Time Fence = 30 days, counted on delivery calendar days starting from current day. Highlighted in green in figure 5.1.
- Visibility Time Fence = 60 days, counted on weekly working days starting from current date. As a difference between the visibility time fence and the 'RTF', Future TF is highlighted in yellow in figure 5.1.
- Safety Stock = $\mu_d * PTF + Z * \sigma_d * \sqrt{PTF}$, with Z factor taken from table 4.1.

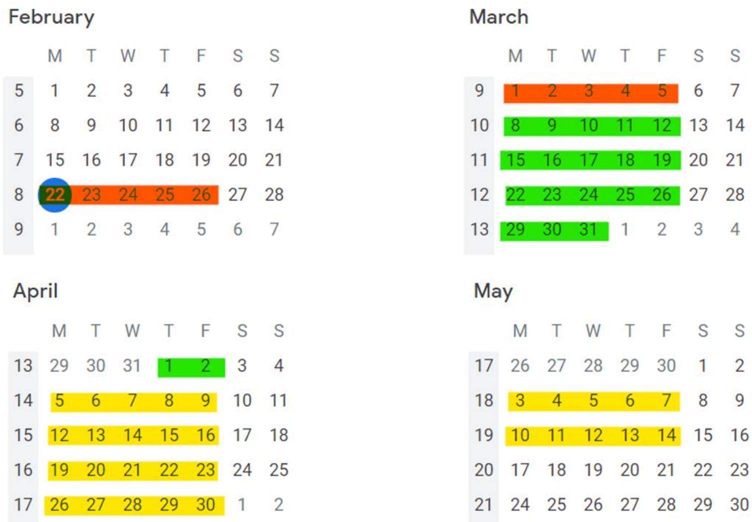


Figure 5.1. Calendar and time fences visualization for Subc2 and Subc3.

Subc1 instead, has communicated different lead times and different available delivery days:

- Delivery calendar days = Monday, Wednesday, Friday.
- Planning Time Fence = lead-time = 15 days, counted on weekly working days starting from current day. Highlighted in red in figure 5.2.
- Release Time Fence = 25 days, counted on delivery calendar days starting from current day. Highlighted in green in figure 5.2.
- Visibility Time Fence = 70 days, counted on weekly working days starting from current date. As a difference between the visibility time fence and the 'RTF', Future TF is highlighted in yellow in figure 5.2.
- Safety Stock = $\mu_d * PTF + Z * \sigma_d * \sqrt{PTF}$, with Z factor taken from table 4.1.

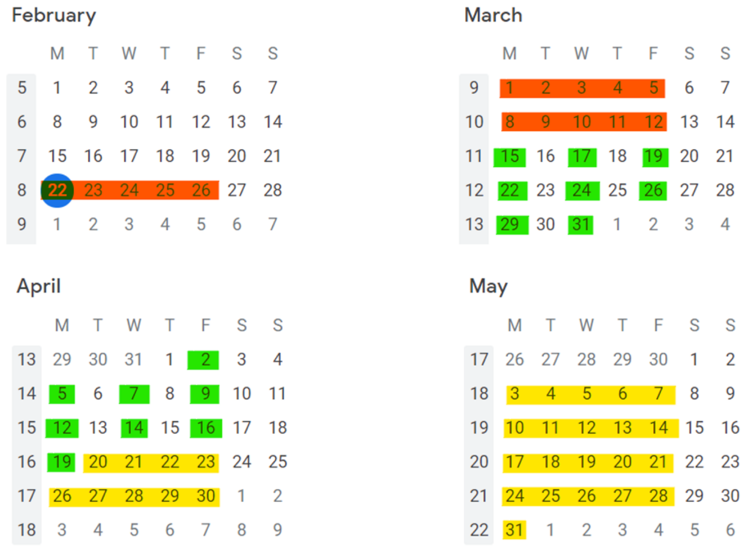


Figure 5.2. Calendar and time fences visualization for Subc1.

In parallel with the time fences set up, it has been checked the correct approval of automatic release in external work of all items involved. It has been revised the previous standard that explain the procedure, adding procedure snapshot and correcting old information, no more in place; it has been created a new section regarding the time fences setup with the explanations presented over here. The simple sequence of set up is listed below, without further description of the various phases:

1) Check the presence and, if the case, create a production routing with a phase that recalls the external process.
2) Check the presence of a BoM and, if the case, create the association.
3) Check and, if the case, approve the associated supply list that has to contain the related item.
4) Enable the item, associated to external work supply list, to automatic release method.

Lastly, in the notification list of item in external work, it has been added a column that depict if the outstanding order is in delay or not with respect to the current date, by the association of the voice “backlog” to the correspondent line. Below it is presented a series of scenarios that shows how the new parameters are working, proving the optimal outcome of the method; please note that codes in analysis refer all to Subc1 and its parameters.

Case 1: planned order due date inside the PTF

On 23/02/2021 available stock level of the item in object falls below the safety stock, equal to 16 pieces, however the system releases an order to replenish the stock the first day after the PTF, the 15/03/2021, as expected, with a quantity equal to the MOQ = 16 pieces. Order entry from 22/02 to 12/03 will be covered with on-hand quantity, over an expected service level of 95% almost.

Supply/Demand Detail (CID)

Item 98C***P*** E5V BRAZED BODY WITHOUT SIGHT GLASS 35 mm ODF
UOM Pz Current On-hand 14
Item status ACTIVE

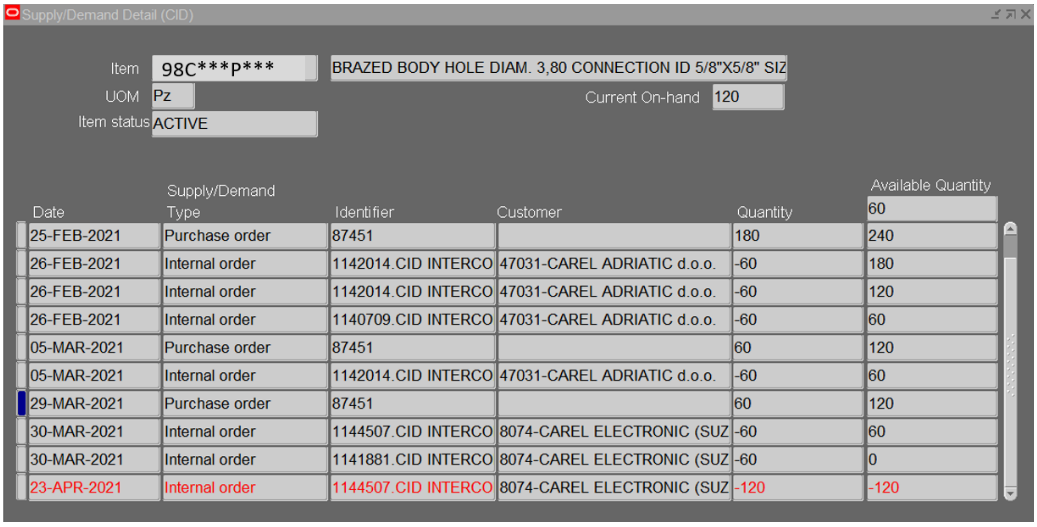
Date	Supply/Demand Type	Identifier	Customer	Quantity	Available Quantity
					14
23-FEB-2021	Work order	6588693		-5	9
04-MAR-2021	Work order	6598286		-5	4
15-MAR-2021	Purchase order	87451		16	20

ARTICOLO	QUANTITA'	DATA CREAZIONE ORDINE	DATA CONSEGNA PRESSO CAREL	NUM.RIFERIMENTO	STATO RILASCIO
98C***P***	24	16-feb-21	12-mar-21	87451/2049	
98C***P***	24	20-feb-21	12-mar-21	87451/2053	
98C***P***	84	18-feb-21	12-mar-21	87451/2051	
98C***P***	168	18-feb-21	12-mar-21	87451/2051	
98C***P***	160	18-feb-21	12-mar-21	87451/2051	
98C***P***	16	22-feb-21	15-mar-21	87451/2055	**NEW**
98C***P***	312	13-feb-21	15-mar-21	87451/2047	
98C***P***	840	19-feb-21	15-mar-21	87451/2052	
98C***P***	8	19-feb-21	15-mar-21	87451/2052	
98C***P***	16	16-feb-21	15-mar-21	87451/2049	

Figure 5.3. Example of planned PO inside the Planning Time Fence (source Carel internal data).

Case 2: planned order due date inside the RTF

The item in object is a –H, a code for both Croatian and Chinese intercompany sales, it has no safety stock because the buffer is located at the two international plant. Automatically the system places the planned PO the day before the dispatching, since it is required a day for incoming, packaging and delivery activities. In date 22/02/2021, an order of 60 pieces has been released, together with other 60 pieces in stock, to cover two contextual sales order the day after. As expected, the order has been released, being the planned PO ‘due date’ inside the ‘RTF’. There also an uncovered sales order in 23/04/2021: the system has not released the order yet, correctly, because the order is beyond the release time fence. The list will only show a line ‘future order’ and, if the client will not withdraw the order, the system will release it on date 25/02/2021.



Supply/Demand Detail (CID)

Item 98C***P*** BRAZED BODY HOLE DIAM. 3,80 CONNECTION ID 5/8"X5/8" SIZ
UOM Pz Current On-hand 120
Item status ACTIVE

Date	Supply/Demand Type	Identifier	Customer	Quantity	Available Quantity 60
25-FEB-2021	Purchase order	87451		180	240
26-FEB-2021	Internal order	1142014.CID INTERCO	47031-CAREL ADRIATIC d.o.o.	-60	180
26-FEB-2021	Internal order	1142014.CID INTERCO	47031-CAREL ADRIATIC d.o.o.	-60	120
26-FEB-2021	Internal order	1140709.CID INTERCO	47031-CAREL ADRIATIC d.o.o.	-60	60
05-MAR-2021	Purchase order	87451		60	120
05-MAR-2021	Internal order	1142014.CID INTERCO	47031-CAREL ADRIATIC d.o.o.	-60	60
29-MAR-2021	Purchase order	87451		60	120
30-MAR-2021	Internal order	1144507.CID INTERCO	8074-CAREL ELECTRONIC (SUZ	-60	60
30-MAR-2021	Internal order	1141881.CID INTERCO	8074-CAREL ELECTRONIC (SUZ	-60	0
23-APR-2021	Internal order	1144507.CID INTERCO	8074-CAREL ELECTRONIC (SUZ	-120	-120

ARTICOLO	QUANTITA'	DATA CREAZIONE ORDINE	DATA CONSEGNA PRESSO CAREL	NUM.RIFERIMENTO	STATO RILASCIO
98C575P198	70	19-feb-21	22-mar-21	87451/2052	
98C575P198	70	16-feb-21	22-mar-21	87451/2049	
98C575P198	140	13-feb-21	07-apr-21	87451/2047	
98C***P***	240	13-feb-21	19-mar-21	87451/2047	
98C***P***	60	22-feb-21	29-mar-21	87451/2047	**NEW**
98C***P***	140	19-feb-21	15-mar-21	87451/2052	
98C***P***	840	19-feb-21	15-mar-21	87451/2052	
98C***P***	60	13-feb-21	19-mar-21	87451/2047	
98C***P***	60	18-feb-21	31-mar-21	87451/2051	
98C***P***	60	13-feb-21	02-apr-21	87451/2047	
98C***P***	24	19-feb-21	17-mar-21	87451/2052	

Figure 5.4. Example of planned PO inside the Release Time Fence.

Case 3: planned order due date inside the FTF

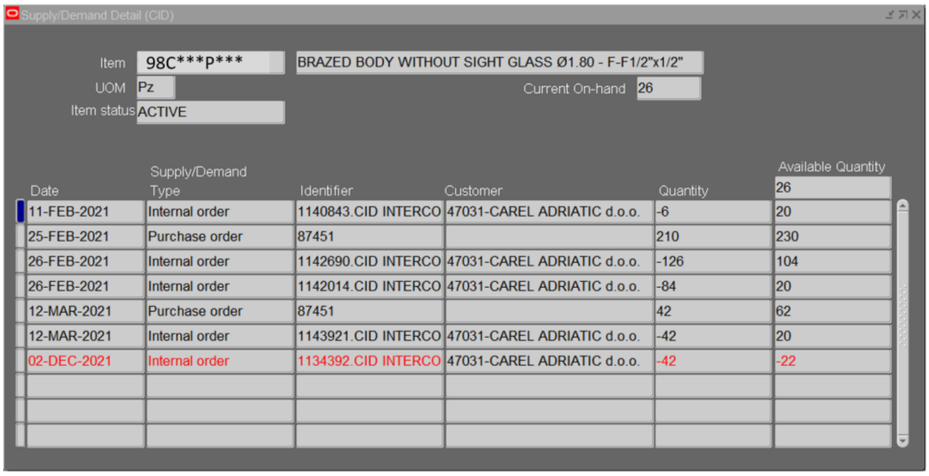
This case shows the creation of the line ‘future order’ of the previous item case, since the planned purchase order is placed after the release time fence, in date 22/04/2021.

ARTICOLO	QUANTITA'	DATA CREAZIONE ORDINE	DATA CONSEGNA PRESSO CAREL	NUM.RIFERIMENTO	STATO RILASCIO
98C***P***	490	13-feb-21	14-apr-21	87451/2047	
98C***P***	24	19-feb-21	19-apr-21	87451/2052	
98C***P***	16	19-feb-21	19-apr-21	87451/2052	
98C***P***	24	20-feb-21	19-apr-21	87451/2053	
98C***P***	16		07-MAY-21	ORDINE FUTURO	
98C***P***	16		26-MAY-21	ORDINE FUTURO	
98C***P***	2030		03-MAY-21	ORDINE FUTURO	
98C***P***	490		17-MAY-21	ORDINE FUTURO	
98C***P***	48		05-MAY-21	ORDINE FUTURO	
98C***P***	24		26-MAY-21	ORDINE FUTURO	
98C***P***	120		23-APR-2021	ORDINE FUTURO	
98C***P***	9		28-MAY-21	ORDINE FUTURO	

Figure 5.5. Example of planned PO inside the Future Time Fence.

Case 4: planned order due date outside the FTF

The item in object has an intercompany sales order with 'due date' on 02/12/2021, as shown in the supply/demand figure 5.6, which is beyond the time fence that notifies the future orders; notification list does not display any line with 'due date' = 02/12/2021 as future order indeed.


Supply/Demand Detail (CID)

Item 98C***P*** BRAZED BODY WITHOUT SIGHT GLASS Ø1.80 - F-F1/2"x1/2"
UOM Pz Current On-hand 26
Item status ACTIVE

Date	Supply/Demand Type	Identifier	Customer	Quantity	Available Quantity
					26
11-FEB-2021	Internal order	1140843.CID INTERCO	47031-CAREL ADRIATIC d.o.o.	-6	20
25-FEB-2021	Purchase order	87451		210	230
26-FEB-2021	Internal order	1142690.CID INTERCO	47031-CAREL ADRIATIC d.o.o.	-126	104
26-FEB-2021	Internal order	1142014.CID INTERCO	47031-CAREL ADRIATIC d.o.o.	-84	20
12-MAR-2021	Purchase order	87451		42	62
12-MAR-2021	Internal order	1143921.CID INTERCO	47031-CAREL ADRIATIC d.o.o.	-42	20
02-DEC-2021	Internal order	1134392.CID INTERCO	47031-CAREL ADRIATIC d.o.o.	-42	-22

ARTICOLO	QUANTITA'	DATA CREAZIONE ORDINE	DATA CONSEGNA PRESSO CAREL	NUM.RIFERIMENTO	STATO RILASCIO
98C***P***	490	13-feb-21	14-apr-21	87451/2047	
98C***P***	24	19-feb-21	19-apr-21	87451/2052	
98C***P***	16	19-feb-21	19-apr-21	87451/2052	
98C***P***	24	22-feb-21	19-apr-21	87451/2053	**NEW**
98C***P***	4		21-APR-21	ORDINE FUTURO	
98C***P***	70		21-APR-21	ORDINE FUTURO	
98C***P***	24		26-APR-21	ORDINE FUTURO	
98C***P***	24		26-APR-21	ORDINE FUTURO	
98C***P***	70		26-APR-21	ORDINE FUTURO	
98C***P***	16		28-APR-21	ORDINE FUTURO	
98C***P***	24		11-JUN-21	ORDINE FUTURO	
98C***P***	16		07-MAY-21	ORDINE FUTURO	
98C***P***	16		26-MAY-21	ORDINE FUTURO	
98C***P***	16		04-JUN-21	ORDINE FUTURO	
98C***P***	2030		03-MAY-21	ORDINE FUTURO	
98C***P***	980		17-MAY-21	ORDINE FUTURO	
98C***P***	48		05-MAY-21	ORDINE FUTURO	
98C***P***	24		26-MAY-21	ORDINE FUTURO	
98C***P***	120		23-APR-21	ORDINE FUTURO	
98C***P***	9		28-MAY-21	ORDINE FUTURO	

Figure 5.6. Example of demand outside the Future order Time Fence.

The daily monitoring phase has shown correct performances of the new optimized program, however there is still a small inconsistency: it seems like the MRP is blind beyond planned orders for safety stock replenishment. In other words, it might create a material reorder for the first RTF day, even if the day after there is another order that would have covered the shortage as well. Yet, no additional implementation have been started, but this is undoubtedly a future step towards the perfection of the system. In order to avoid order overcrowding, it has been scheduled once a week an activity in which a planner analyzes the outstanding orders and level possible peaks, simply moving delivery dates in accordance with the subcontractor. The planner is now able to change the delivery date, if necessary, in accordance with the supplier in following cases: advancing date inside the PTF, deferring date, split quantities of a single order in more than one; plus there is the possibility of a manually creation of an order for item subjected to automatic release in case of necessity.

In collaboration with the ICT department, it has been created a new workbench in the ERP system that can allow the user to modify independently the parameters of the time fence, without delegating the activity to IT specialists; action very important to create a smooth and leaner process. This initiative is part of a bigger list of actions that are taking place inside the project, having the aim to reduce all the possible non-value adding activities, in lean terms "muda", which impede a smooth flow of information, increasing then the overall operative responsiveness. Among these activities there is the adaptation of the automatic delivery of forecast, normally used for direct purchased goods, to items in external work supply, which until yesterday was implemented manually, thanks to the creation of a pivot table from a series of ERP extraction, with the use of MS Excel.

5.3. Raw materials: a new Netting phase

As presented in chapter 4.2.2, the solution of creating a new ERP workbench, which would have shown the two different natures of the subcontractor's stock, was not sufficient to provide the MRP of aligned inventory situation. Therefore, the team has opted for the second option structured as follows. Design and implementation of a new program within the ERP that creates a demand of raw material, from now on called ‘manual demand’, which will consume the inventory availability. The manual demand will be taken from a BoM explosion of the item automatically released. For a better view of the situation, each manual demand line will have an association with the order reference number, so as to create a visible link between the number of components in processing and the order to which it is associated. Once the completed subassembly return to Carel, the manual demand line will be erased and at the same time, the stock unloaded. In association with the visibility on the vertical master plan of the inventory storage, the MRP could then have a base of aligned data to work on: the planner will then trust the *reorder suggestions* since they will be a result of a netting phase based on correct available stock quantities, working correctly.

The traditional *material recall systems* that works in parallel to the procurement activity of the planner will definitely benefit as well. The pending activity regarding this process was the setting of the new parameters, in line with the new netting phase, that will allow the system to automatic release a move order directed to the dispatching office. It has been already explained how the Min/Max stock base system works, see chapter 3.5.3, but it has not been presented yet the nature of the two parameters. One of the future activities with highest priority will be the analysis and implementation in the system of the Min and Max level.

In case of material free-pass system that are recalled directly from suppliers with a Kanban system, no further implementations were feasible to the system. In the mid-term a new platform, for a cross-relationship between purchasing, planning and engineering functions will be in place, which should help monitoring and managing blanket purchase agreements with more cooperation and alignment between the three departments.

However, due to the limited time span of the project, the implementations regarding this last but fundamental part of the process were still in progress while drafting this elaborate, due to the complexity of the subject. The near future will tell if the solutions proposed were exhaustive or not in solving the related issues.

5.4. Manual Release improvements

Manual release method proved problems not at release engine level but in a logistic perspective, regarding the 'move order' delivery phase and raw material dispatching. In order of activity completion, the system first generates a work order, associate it to a purchase order, and at the end creates the move order list. This latter is specific for each subcontractor and contains all the codes and relative cumulated quantities, aggregated from different work orders (i.e. purchase orders) in external work, based on BoM explosion of the subassemblies. The big "muda" regarding this last link of the chain lies on the hand-held delivery of this document, with the relative work orders attached; the dispatching office is situated in a different unit located 700 meters away. The second inconsistency concerns the delivery document creation, contextual to the approve of the move order, and the physical check-out of the goods, events that are not concurrent. The system however automatically creates the delivery document once the move order is approved, hence creating a timing discrepancy between the physical and informative dispatching of the components.

First solution that came in mind was to separate this two activity, letting the operator to create manually the delivery document just before the checkout; due to the enormous flowing of shipments, it was clear that it was not the right solution. It has been decided to operate on advancing the suggested order: populating the pre-processing lead-time field of each code, the system suggests the reorder as many days before as the parameter value, see figure 5.7. In this way, the additional lead-time compensates for the poor responsiveness and reactivity of the move order dispatching.

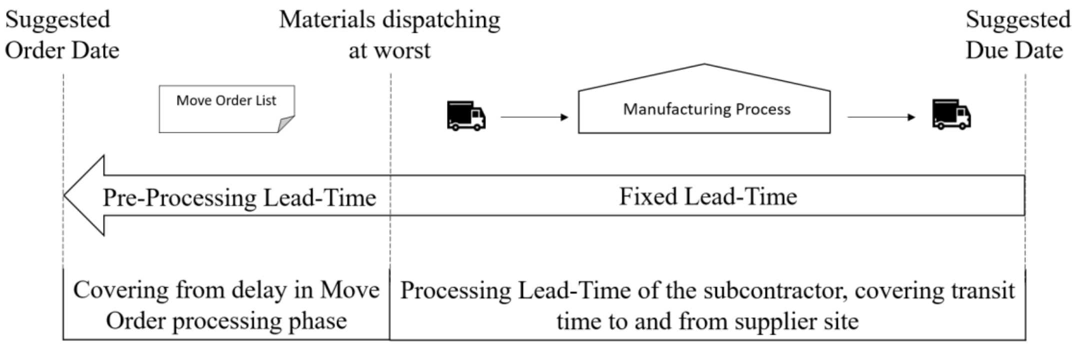


Figure 5.7. Concept of pre-processing lead-time for external work manual release orders.

On indication of the dispatching office, based on the maximum processing time of a move order list, it has been set a pre-processing lead-time of 5 days by default, equal to a week, for all the codes. As an example, there are subcontractors that collect directly the material from HQ warehouse once a week; with this lead-time, it is covered the worst scenario in which a new move order is created right that day, after the supplier pick up. Five days will cover the time between current date and the next delivery, a week after.

In parallel, ICT specialists has created an automatism to deliver the documents via mail to the dispatching office, eliminating time losses in hand-delivery. Since the software that creates the work order is different from the ERP, it has been necessary to create a new document that condense the information contained on the job order and the move order list. It was necessary for the warehouse man in order to keep the usual layout for the picking list and the same information needed for the subassemblies incoming as well, contained into the work orders. Figure 5.8 shows how the new report will present to the operators, the first snapshot represents the picking list, with all the codes information (e.g. quantity, warehouse location, …) while the second represents the list of job orders information condensed into a table, easier to interrogate with respect to the standard layout.

CAREL

Lista prelievo Materiali

Fornitore **Data**

Odl numbers: 658056 / 658600 / 658963

Oracle Inv Loc	Side up Inv Loc	Item	Udm	Qty	Disponibilità	Delta

# OdL	Codice	Descrizione	Quantità	Note Odl	Locazione	Stato
6580565	98C***P***	STATORE UNIPOLARE LC E2V 40 OHM CON CONNETTORE SUPERSEAL	450	N. 272103 M.O. N. 23893153 – 5438 Subcontractor52	xxxxxxx	ACTIVE
658600	98C***P***	RACCORDO BRASATO D.16 X TUBO 10X27	600	N. 275391 M.O. N. 23749128 – 85939 Subcontractor49	xxxxxxx	ACTIVE
658963	98C***P***	CORPO BRASATO D.95 RACC. 28X28 CON OBLO'	200	N. 269359 M.O. N. 23469314 – 15936 Subcontractor51	xxxxxxx	ACTIVE

Figure 5.8 Draft example of the new move order list (source Carel internal data).

In addition to the automatic delivery, it has been drafted and launched a new scheduled daily report, showing the list of all the move order still not processed, referred to the current date. The layout presents itself as the figure 5.9, split in two lines for simplicity. Information contained are fictitious. Goal of the report is to give both the value stream and the dispatching office a clear and daily view of the components not already dispatched, triggering reminders towards stakeholders involved in the process.

# M.O.	#riga	Data creazione	SideUp_inv_loc	Oracle_inv_loc	On_hand	Item	Qty	udm	Descrizione
21-548	1	18/02/2021	W.D.08.04		2000	09C575A187	150	pz	E2V COMPLETE UNIPOLAR STATOR

Delivery to	Indirizzo	SFG	# OdL	# PO	Planner
TECH PRODUCTION LTD.	via michelangelo, 57, Milano (MI), 10121	98C111P111	165329	16513	VS4

Figure 5.9. New report for outstanding move orders, yet not processed (source Carel internal data).

This new tools can be useful for:

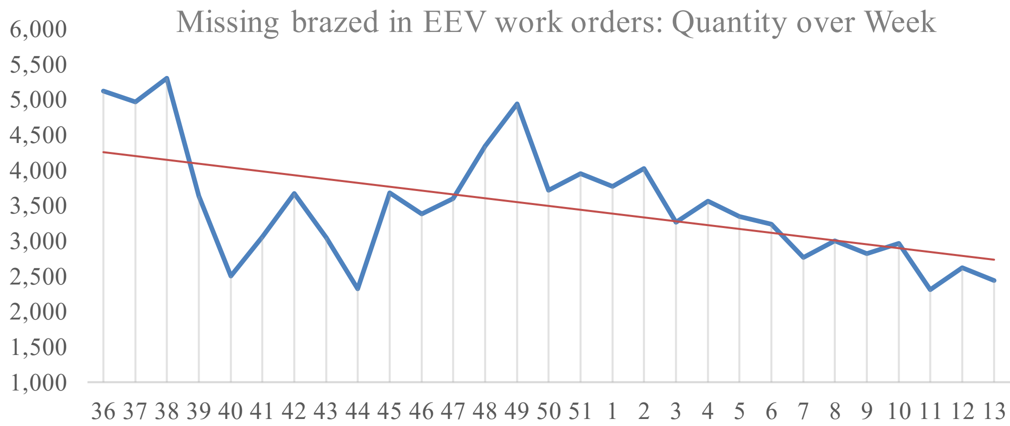
- Scheduler and planner can have every day a clear situation of the manual release work in progress: scheduler has visibility on the material dispatching delay, planner has visibility on the material availability and if there are move orders blocked by components shortage, he/she can undertake activities towards the vendors and consequently give answers to possible questions.
- Dispatching officers can work just on a single digital document that resumes the backlog, giving a clear view of the outstanding delay and workload.
- Warehouse manager can use the report to establish KPIs regarding the dispatching of material in external work, under-reported so far.

Future activities will focus on the transition of the ownership of the manual release activity from the scheduler to the planner; in addition it will be analyzed the possible purchasing of the new ERP software release, that should fix the discrepancy between move order approval and delivery document generation, together with other functionalities helpful for the logistic management.

5.5. Best Practices and Results

In order to give an order of magnitude of the results obtained after the partial implementations adopted it has been decided to replicate the initial analysis, carried on during the problem statement activity. The new data set reflects, as the previous, the service level trend of Valves Value Stream and missing brazed subassemblies but this time during the months of February and March, after the start of the optimization.

As it can be seen in figure 5.10, missing brazed subassemblies in production has experienced a remarkable decline after week 5, just a week after the initial implementation of the new automatic release system. Considering the average quantity of missing item per week in the last four periods, starting from the end of January, week after week the value decreased of a percentage on a range that goes from -2.4% to -5.6%.



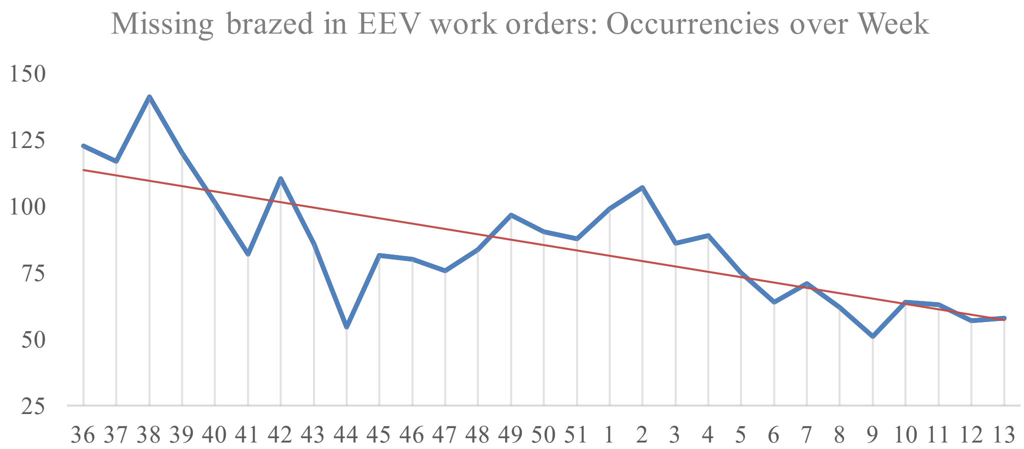


Figure 5.10. Weekly service level trend in EEV production after optimization, years 2020-2021, (source Carel internal data).

Beyond these data, VS4 scheduler faced lower issues due to delay in the delivery of the externalized goods. The analysis regarding the subcontractors' backlog, weekly on Tuesday, showed day after day a decrease in the amount of pending quantity, granting continuity and creating a more solid base for the final assembly production. As expected, the graph in figure 5.11 shows the positive consequences of this new and increased supply strength on the service level. During 2021, the % of fulfilled sales orders never fall below the 95% target, creating great satisfaction among the clients and the management. Future analysis will show if the positive trend could continue, maintaining such high levels.

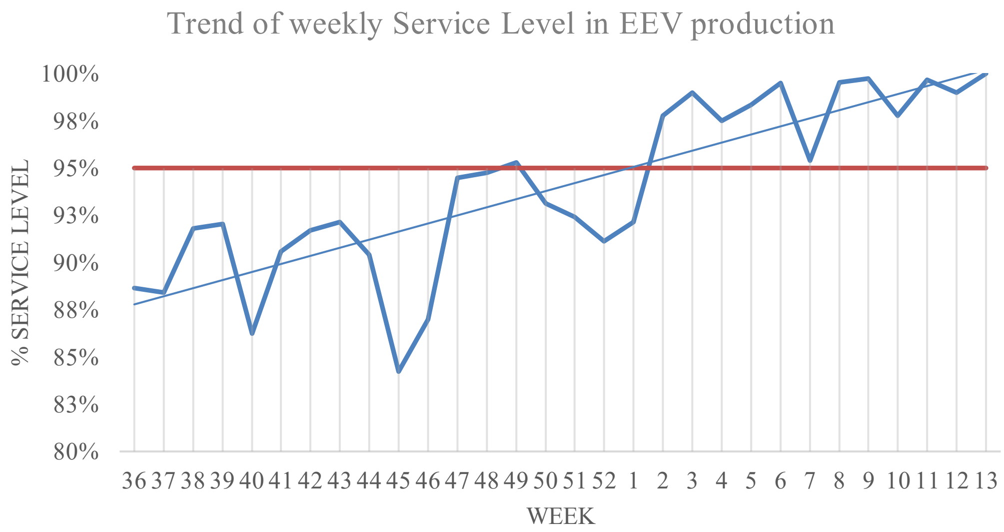


Figure 5.11. Weekly service level trend in EEV production after new optimization, years 2020-2021, (source Carel internal data).

It must be said that the positive results obtained are a mix of factors attributable not only to the actions undertaken but also influenced by external factors, such as seasonality, not controlled by the project team. Anyway, there are reasons to think that the new data were mainly a result coming from the new series of implementation,. Only the next months performances will confirm or reverse this assumption, but early results are proving that the undertaken path is the right one.

During the course of the project, started with the internship and concluded with the thesis, it has been met a lot of critical situation originated from the lack of control and maintenance of the process, mainly due to frequent change of ownership, negligence of stakeholders and operating inertia. This final section want to summarize in a list, see table 5.3, all the best practices depicted, directed not only to the operation department of Carel, but also to every manufacturing company that is facing a rapid expansion and transition from a SME to a multinational firm. This list of best practices is only the first of many that will come, aiming at establishing an efficient course of action; key factor will be interoperability and collaboration between the various departments.

Activity	*Ownership*
Periodic maintenance of the master item and relative parameters.	Operation department
Periodic review of the standards, depicting possible changes due to systematic updates of the system or of the business.	Operation department and ICT
For the project case scenario, automatic and manual release of goods in external work has to be revised every 3 months.	Planning unit
Periodic review of the safety stock levels for items with short lead-times on the base of seasonality variance and instability of forecast.	Planning unit and Inventory specialists
Periodic maintenance of the supply lists.	Purchasing unit
Periodic review of the parameters of the release system for external work goods, typically 3 months.	Planning unit
Drafting standards for high running activities in order to increase cross-competences and prevent lack of ownership.	Operation department
Periodic disposal activities of slow-moving items.	Planning unit and Engineering department
Creation of a standard tool or analysis to collect subcontractors' feedback: criticalities and other insights aimed at the constant improving of the process.	Purchasing and Planning units

Table 5.2. Best practices list.

CONCLUSION

Briefly, the complexity of the process was hidden behind a multitude of the root causes, which gave birth to the problems observed during the final assembly production stage. The first step was to determine relationship between codes and stakeholders of the process, reconstructing streams and process behavior. After this initial stage, the focus moved to raw materials, in order to understand the causes behind the wrong reorder suggestion, which relied on an incorrect netting phase of the MRP. This latter was also obscuring the Min/Max stock base system for the material replenishment towards the subcontractor. The parallel analysis on the automatic release system helped to put together all the pieces of the puzzle. There were in one side a lack of concepts regarding the operability of the automatic system, which was not suitable for brazed items characteristics, and in the other side the lack of maintenance and correct management of the parameters, which led to losses of control over the process. The implementation of the new automatic release system, and further improvements on a more stable manual release system, resulted, with high probability, in a service level increase of EEV value stream, also thanks to the decrease of missing subassemblies coming from brazing processes.

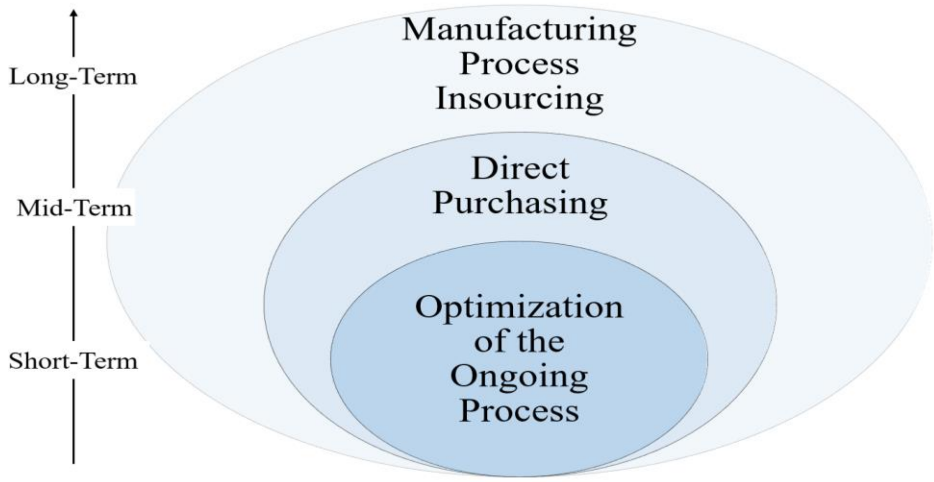


Figure 6.1. Strategy levels of the brazed items supply process.

It is reasonable to think to expand the analyzed methodologies to all the codes in external work supply, after a careful analysis of the characteristics and the streams involved, widening the spectrum of actions to other international plants. A further implementation inside the operation unit will be the design of a platform, called ‘PPP’, by the combination of platform department (engineering), purchasing and planning unit under a wide communicative tool, which will help monitoring the overall value chain, from the birth of a product to its material components procurement.

Perhaps, the most important insight stands in the fact that the initial project has triggered a “matryoshka” of considerations that were pushing further beyond the boundaries of strategy. First, it has been started a negotiation for a transition to direct purchasing strategy, in order to externalize the cost of ownership of the process. As seen, it has been signed a contract for the direct supply of 1/3 of the overall codes, relieving part of the subcontracting activity in the mid-term. Secondly and most important, high level management has started a long-term project with the ultimate goal of insource the total production of brazed bodies for Carel group in two international plant. The project has been an important example of how a short-term operational strategy, due to unknown breakthrough, can become a long-term business strategy.

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