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DEALING WITH PROCUREMENTS IN A SHORTAGE MARKET

The Schneider Electric Case

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INDEX

ABSTRACT

It is widely agreed that nowadays we live in a world where technology runs our lives: computers, smartphones and wearables tools have become essential and many people cannot imagine living without them. Cars are being equipped with automated gadgets that monitor the vehicle status and that are used to assist the driver in the main and simplest tasks he has to deal with. In addition, in the last five years, thanks to awareness campaigns made on the harms caused by pollution and the incentives promised, the demand for electric cars has recorded a rapid increase. The same radical transformation is also being applied to the industrial sector. Many companies are, indeed, investing in the so-called “Industry 4.0”, equipping machines with sensors to collect data, enabling them to communicate and exchange information in real time. At the same time, several technological solutions have been developed in the medical sector too, with the aim of giving patients the possibility to receive medical treatments and be monitored directly from home.

Due to the rapid technological evolution and the demand increase recorded for high-tech products, therefore, the need for electronic components has got to a level that had never been reached before.

The result is that manufacturers are forced to allocate reduced amounts of components to their main clients or even turn down orders on the most critical parts; lead times for the majority of components are stretching to more than 70 weeks, while standard lead times are generally between 20 and 30 weeks maximum. In addition, many prices have increased by 6 to 10% in one year, since demand is too high compared to offer, and that producers are not able to keep up with the orders they receive.

Manufacturers have, then, to adopt strategies in order to overcome this difficult moment. On the one hand, they are trying to boost their capacity in order to increase the output volumes; on the other hand, some of the main manufacturers have decided to join and merge together, so that to share Research and Development costs and propose a more appealing and complete offer to their clients.

The unprecedent demand level, mixed with strategical decisions taken by electronic components' makers and the raw material shortage that can be recorded on certain ores, is forcing companies, that use electronic components to assemble their finished products, to look for solutions in order to avoid line stop and respect commitments towards their customers.

In the short term, the main strategy is to anticipate orders to give the supplier the possibility to know in advance company's need or to increase the quantity ordered to cover potential decommitments. Nonetheless, the problem with this solution is that manufacturers do not have a clear vision on real clients' needs in the end, since no distinction can be made between quantity ordered to cover forecasted demand, and the part that is placed just to secure and that will subsequently be cancelled. In addition, the traditional MRP systems used inside companies are not configured to deal with orders that are confirmed beyond the planning horizon, therefore false exception messages are generated, making it more complicated for planners to deal with procurements and production planning.

In the long term, companies are trying to look for alternative solutions in order to replace critical parts with components that can be more easily found on the market. However, quality tests should be performed to be sure that the new part does not have any quality and safety impact on the finished product, therefore the process requires time.

The aim of this thesis is to analyse in detail the main issues that are generated by electronic components shortage, both from a logistic and a production point of view. First of all, a general overview of the theoretical aspects linked to procurement and demand planning is provided, with a particular focus on requirements calculation. The analysis will then move to the investigation of the current market situation: causes and effects of components shortage will be explained, as well as the solutions that have been adopted in order to limit its impact on production and end users. The analysis will, then, be focused on the main problems generated by these strategies, providing a practical case of application at Schneider Electric.

ABSTRACT

È opinione ampiamente diffusa che oggi, si vive in un mondo in cui la tecnologia gestisce le nostre vite: computer, smartphone e tecnologie “indossabili” sono diventati essenziali e, molti non potrebbero immaginare di farne a meno.

Le auto sono dotate di dispositivi automatici che monitorano lo stato del veicolo e, assistono il conducente durante lo svolgimento delle operazioni più semplici.

Negli ultimi cinque anni, inoltre, grazie alle campagne di sensibilizzazione sui problemi causati dall'inquinamento e alla promessa di incentivi, la domanda di auto elettriche ha registrato un rapido aumento. La stessa trasformazione radicale può essere applicata anche al settore industriale. Molte aziende stanno, infatti, investendo sulla cosiddetta "Industry 4.0", dotando le macchine di sensori per raccogliere dati, consentendo loro di comunicare in rete e scambiarsi informazioni in tempo reale.

Analogamente, nel settore medico, sono state sviluppate nuove soluzioni tecnologiche, con l'obiettivo di dare ai pazienti la possibilità di ricevere cure mediche e di essere monitorati direttamente da casa.

A causa della rapida evoluzione tecnologica e dell'aumento dell’uso di prodotti high-tech, oggi, la domanda di componenti elettronici di base ha raggiunto un livello mai toccato prima.

Il risultato è che i produttori di questi componenti sono costretti ad assegnare quantità ridotte ai loro principali clienti o addirittura a non accettare ordini sulle parti più critiche; i tempi di consegna per la maggior parte di questi prodotti sono arrivati a più di 70 settimane, considerando che in una normale situazione di mercato, essi sono compresi tra le 20 e le 30 settimane. Inoltre, sulla maggior parte dei prezzi é stato registrato un incremento del 6-10% in un anno, poiché la domanda è troppo elevata rispetto all'offerta e i produttori non sono in grado di soddisfare prontamente gli ordini ricevuti.

Questi fornitori devono individuare soluzioni che permettano loro di superare questo momento difficile. Da un lato, la strategia è quella di aumentare la capacità produttiva, al fine di aumentare i volumi di output; dall’altro, alcuni tra i principali attori operanti in

questo mercato hanno deciso di fondersi, in modo da condividere i costi di Ricerca e Sviluppo e proporre un'offerta più attrattiva e completa ai propri clienti.

Il livello di domanda senza precedenti, combinato con le decisioni strategiche prese dai produttori di componenti elettronici e la carenza di materie prime, costringono le aziende, che utilizzano componenti elettronici per assemblare i prodotti finiti, a cercare soluzioni che permettano di evitare l'arresto delle linee produttive e di rispettare le date di consegna concordate con il cliente.

A breve termine, la strategia consiste nell'anticipare gli ordini, in modo da dare al fornitore la possibilità di conoscere in anticipo i bisogni dell'azienda o di aumentare la quantità ordinata per coprire eventuali disimpegni. Tuttavia, il problema, in questo caso, è che i produttori non hanno una visione chiara delle esigenze dei clienti, poiché non viene fatta alcuna distinzione tra la quantità ordinata per coprire la domanda pianificata e la parte che, invece, viene posizionata solo per una questione di sicurezza, e che sarà successivamente cancellata. Inoltre, i tradizionali sistemi MRP utilizzati all'interno delle aziende non sono configurati per gestire ordini confermati oltre l'orizzonte di pianificazione, pertanto generano messaggi di eccezione non corretti, che rendono ancora più complicata la gestione degli approvvigionamenti e la pianificazione della produzione. A lungo termine, le aziende stanno cercando soluzioni alternative per sostituire le parti più critiche con componenti che possano essere trovati più facilmente sul mercato. Tuttavia, il processo è lungo e complicato, poiché è necessario eseguire test funzionali e di qualità per assicurarsi che il nuovo componente non abbia alcun impatto sulla qualità e la sicurezza del prodotto finito.

Lo scopo di questa tesi è quello di analizzare in dettaglio le principali problematiche generate dalla penuria di componenti elettronici, sia da un punto di vista logistico che della produzione.

Viene, innanzitutto, fornita una panoramica generale dei principali aspetti teorici legati alla pianificazione della domanda, con particolare attenzione al calcolo dei bisogni. Successivamente, viene presentata un'analisi della situazione attuale del mercato: vengono, infatti, spiegate le cause e gli effetti della penuria di componenti, così come le soluzioni adottate per limitarne l'impatto sulla produzione e sul cliente finale. L'analisi sarà focalizzata sui principali problemi generati da queste strategie, fornendo un caso reale sviluppatosi all'interno della realtà multinazionale di Schneider Electric.

CHAPTER 1

LOGISTICS AND SUPPLY CHAIN

1.1 Introduction: Definitions and aims

Logistics can be defined as: *"the process of planning, implementing, and controlling the efficient and effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements."* [1]

The more in-depth analysis of this definition, provided by the Council of Logistics Management in 1991, allows us to clarify the main aim of logistics and the different activities that contribute to its achievement.

As stated in the definition, a logistic process should guarantee the "efficient and effective flow" of goods and services, which means that logistics aim is double. On the one hand, it aims at minimising costs by optimising goods transportation and reducing the inventory level. On the other hand, it has the objective of maximising the service level, that is to say, the degree to which the company is able to respond and satisfy the end user requirements.

In other words, a logistic process should be able to provide the customer with the right product, at the right moment, in the right quantity, at the right place and at a reasonable cost.

Moreover, when talking about flow an important distinction should be made. As a matter of fact, we can identify a physical flow, generally moving from the supplier to the final client, the flow of information, moving in the opposite direction, and the financial flow.

The physical flow refers to the movement of products, parts and materials that are manufactured and delivered to the customer, as well as to returns and rejections.

Direct flow is, then, the management and movement of raw materials, parts and components that are bought, transformed during the manufacturing process and, then, delivered to clients. Reverse flow or Reverse Logistics, on the other hand, handles the movement of raw materials, semi-finished products from their final destination point,

[1] Council of Logistics Management

backwards along the chain, with the aim of capturing value from all the products that are at the end of their life cycle.

Physical flow, whether direct or reverse, is considered a value-adding flow since, at every step, the product that is moved acquires a greater potential value the customer is ready to pay for. As a matter of fact, at every stage, goods are transformed and altered or, simply, made available for the following step or the end user.

The flow of information moves in the opposite direction of the direct physical flow and refers to the collection and the consolidation of data that can be found at the company level, such as BOM[2], inventory levels, order information, delivery scheduling and others. The analysis of this information can support the decision making-process and simplify the planning and coordination of several activities. Collecting all the data needed is not often as easy as it might seem, but it requires the collaboration of several actors in the supply chain, such as clients, suppliers, transporters and other subcontractors. As a matter of fact, it is only when a certain amount of data and information is available that requirements planning and demand forecast is possible.

Finally, the financial flow can be analysed from two different points of view: cash outflow and cash inflow. Both kinds of financial flows move upstream in the supply chain, from the organisation to the raw material supplier or from the end customer to the organisation. Basically, the aim of every company is to receive payments earlier enough to cover and manage supplier payments which should be issued before a specific due date. Any lateness in invoice payment can produce penalties or the supplier refusal to deliver additional quantities. Organisations, therefore, have to deal with Accounts Payable which is all the invoices an organisation should pay once the Purchasing Order is shipped and Accounts Receivable, which are all the invoices the organisation should cash in from its clients.

Actually, the word logistics is used to describe a whole system composed of several activities which should interact and work together in order to reach a common goal: the final customer satisfaction. The literature generally analyses three different fields

[2] Bill of Material – the description of all the elements that compose a finished product

that can be considered part of the logistic process: Inbound logistics, Production support and Outbound logistics or physical distribution of the final output.

The term Inbound Logistics is used to define the activities that manage the flow of goods moving from the supplier to the organisation. It includes tasks like sourcing, buying, storing and delivering the raw materials, parts and components to the production department. Therefore, its main objective is to make goods available in quantity and time for all the operational processes that follow. In other words, Inbound Logistics includes all the actions that aim at feeding the transformation process. Hence, several supplying sources are evaluated according to the portfolio of products and prices proposed, and orders are placed respecting the organisation’s needs. Raw materials and components are, indeed, bought in an economical way, balancing order and inventory costs and respecting quality and scheduling requirements. The main activities can be easily described using the graph in Figure 1.

Figure 1: Inbound Logistics main activities

Outbound logistics is, on the contrary, the management of the physical and information flows connected to all the goods that move from the organisation to the customer, whether it is the final user or an intermediary one. It includes all the activities that go from the client order receipt to its delivery, through its processing and storing. The main aim of outbound logistics is, then, the effective placement of finished goods on the market according to clients’ fixed orders or forecasts.

Finally, the third and last logistics function is the one that allows making a connection between the inbound and outbound process. As a matter of fact, in order to transform raw materials into finished products, the logistics service has to interface and work closely with the department which is in charge of the manufacturing process. In this case, logistics is responsible for providing the Production department with the volume of the outputs needed on a certain horizon, based on already existing orders and forecasts. On the other hand, the production team should define and commit to a certain level of capacity which will be able to satisfy demand. This confrontation allows both functions to take corrective actions if needed and prevent that eventual problems or delays directly impact the client. Other important activities are linked to the intermediary stock management as well as the internal movements of materials.

Therefore, logistics has to be considered as an interfunctional process which should be able to integrate both the physical and the information flow, as well as the functions it is composed of. Indeed, researchers today insist on the fact that the logistics process should be managed as one whole system, where the different activities and functions are focused on the achievement of a common goal. This new concept would permit to overcome the previous approach which aimed at optimising every single activity, often setting conflicting objectives between the tasks.

In order to understand the reasons behind this approach change, a brief overview of logistics evolution is given in the following chapter.

1.2 Logistics evolution: from Logistics to Supply Chain

The term “logistics” arises from the military field as it was referred to the procurement and transportation of military facilities and personnel. With the passing of time, the evolution of the industrial world and the increase in the demand level, the concept starts to be applied to the industrial field too. For several years, however, logistics has been considered as a support activity, a task that serves the department which has the major impact on the decision-making process inside the company.

For instance, in the 1950s, Production is the most important department for a manufacturing company, the activity that leads an organisation strategy and on which investments are focused on. The reason that explains this behaviour can easily be found and understood when analysing the economic situation of this period, which is often referred to as the “Post-war economic boom”[3] or the “Golden Age of Capitalism”[4]. As a matter of fact, with the end of World War II, the United States, Western countries, Soviet Union and East Asia experienced a period of unusually rapid and unexpected economic growth. Markets expanded rapidly, and the demand was much higher than the offer, which means that competition was not intense, and companies did not have to attract and “steal” customers from other organisations. In such a situation, where the vendor has to satisfy a large number of buyers, the critical aim is to minimise manufacturing costs and produce big volumes of output. The economic model characterising these years is, therefore, the Fordism.

This economic theory is based on the concept that companies are acting in a stable market where customers’ demand is characterised by a very low variability. Factories should, then, divide the whole transformation process into simple, repetitive and standard tasks in order to increase the production rate. The result of this production organisation is a big batch of standardised products manufactured at the minimum average cost.

[3] Definition according to Academic literature

[4] Definition according to Economic literature

When evaluating production costs, indeed, we should take into consideration both fixed and variable costs. The first ones are independent of the volumes produced, whereas the second ones are strictly related to output quantities.

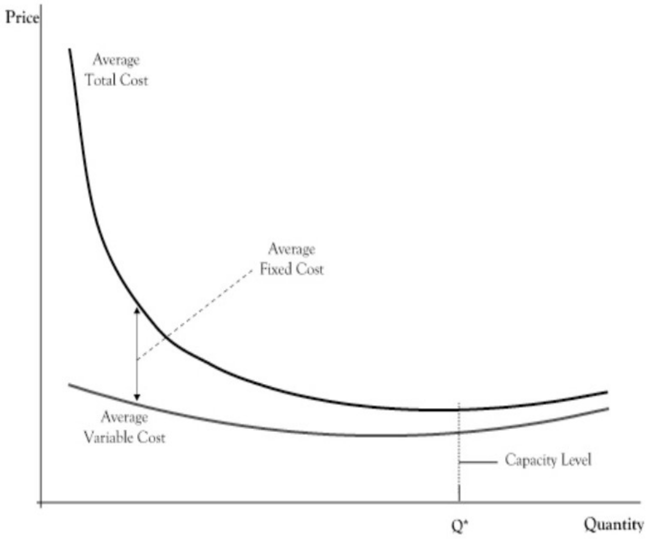

Fig 2: Average Total Cost

As you can easily understand looking at the graph above the average total cost decreases when the quantity produced increases. As a matter of fact, when the volume of goods is bigger, fixed costs can be shared on a larger basis, reducing the sum belonging to every unit. However, once the maximum capacity is reached the average total cost starts to increase too. Companies need, therefore, to employ new resources or overuse already existing resources, slowing production down or increasing the maintenance costs per unit.

After all, this condition of excess demand didn't last long, and companies had to revise their strategy in order to stay in the market. As a matter of fact, in the 1960s market conditions start to evolve: the demand level shrunk, and the so-called Second Wave of globalisation, supported by communication and transportation development, deleted any geographical boundary. Customers do not ask for standard products anymore but for something that completely fit their needs and expectations since they have the possibility to choose from several sources. Product life cycle decreases, as well as the time and the price customers are willing to pay. Therefore, companies are forced to face a more intense and fierce competition to attract customers. Their strategy changes from being "market-oriented" to being "customer-oriented". But what does this mean?

As Kotler says in his book "*Marketing Management: analysis, planning and control*"[5], modern companies should not try to sell what they have made, but know what to make before even starting to produce. In other words, customers' needs have to be studied and analysed before starting any transformation process in order to ensure its satisfaction in the end.

In a market where several companies are competing to gain market shares, and the offer is characterised by a high variety, every organisation should then try to diversify the product it is offering from the competitor's. However, product differentiation on the base of its quality characteristics is not often enough. This is why the concept of extended product starts to develop. Companies provide their clients with the main product and a series of services that will help them to distinguish from competitors as well as to add value to the final output.

In this period, therefore, logistics transforms itself from a support activity to a strategic function which has the value to make the product available for the customer in terms of place, time and quantity. The focus then, moves downline to the transformation process, from production to transportation, packaging and physical distribution.

With the theorization of the "Value Chain" by Porter in 1985, the definition and role of logistics changed. As you can see in Figure 3, the organisation is divided into sub-processes which should work together and exchange information in order to reach the common goal and gain competitive advantage.

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[5] Kotler P.(1967), Marketing Management: analysis, planning and control, Prentice-Hall

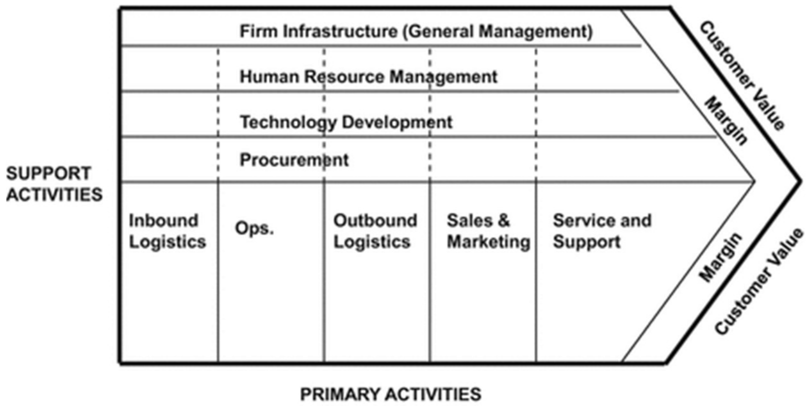


Fig. 3: Porter's Value Chain

According to Porter's theory, companies can choose between two different solutions in order to conquer market shares: cost leadership or product differentiation.

The first strategy consists in proposing a standard product which is able to distinguish from the competitors' thanks to its lower price. For several years this has been the strategy adopted by the majority of companies since it appeared as the more effective one. Indeed, to reduce their costs, many organisations focused on the increase of the output volumes or on offshoring and subcontracting solutions that helped them to enlarge the margin between costs and revenues. In recent years, this strategy has been partially replaced by the one based on product differentiation. The focus of companies has, therefore, shifted to customer service level, which can be evaluated throughout several parameters:

- Product availability in terms of time and place
- Responsiveness, which is defined as the speed to which the vendor is able to satisfy customer's demand
- Flexibility or the ease with which the company is able to adapt to buyer order changes
- Quality, considered as the capability to provide the customer with the required products, focusing on its ability to deliver complete orders, to respect scheduling and provide information on order processing
- Reliability which is the ability to assure regular shipments

With the aim of providing the client with a product having the highest recognised value possible, companies start to apply a systemic approach toward logistics which is not seen as the sum of several activities but as a whole system, where parts need to be coordinated in order to optimise the final result.

The outcome of this new vision is, therefore, integrated logistics which can be defined as *"the combination of many functions, none of which alone constitutes logistics: production planning and distribution, materials procurement, inventory management are not individually logistics. To define logistics, these and many other functions must be organized, directed and executed as an integrated system"*[6].

The three different areas that were presented before, procurement, production support and physical distribution, are now considered and managed as three interdependent functions that cannot exist separately. Production should be organised and planned according to customer's needs, respecting their schedule. At the same time, raw materials and components should be available in order to start the transformation process on time and respect the delivery dates that were promised to the final customer.

Therefore, organisations do not focus on the optimisation of singular variables anymore, but on the development of relationship between different functions. This allows, on the one hand, to reduce production, procurement and stock costs, and, on the other hand, to increase the service level, since any activity is pulled by demand and customers' needs.

Finally, the latest step in logistics evolution is its transformation into Supply Chain. At this stage, every organisation becomes part of a wider network of companies that need to coordinate their processes.

This new need for integrating external actors is mainly due to two different changes that characterised the 1990s. On the one hand, technological evolution makes it easier for companies to share information and communicate, reducing the time and cost needed to collect data. This allows a better organisation of business processes both inside the organisation and with suppliers and subcontractors. On the other hand, customer demand continues to evolve and change, becoming more varied, and, therefore, difficult to satisfy. As a matter of fact, due to the availability of several sources

[6] Candiotto R., Spano F. M., Turolla A., Logistica e magazzino. Aspetti organizzativi, gestionali e di controllo. Valutazione civilistica e fiscale delle scorte, Cosa e Come Giuffrè editore, Milano, 1995. P9

and the ease with which goods can be moved from one point to the other, clients' expectations have increased in comparison to the past. They ask for a product which is customised to their needs and available quickly after the order emission, with the price of a standardised good. Consequently, the integration explained before, now includes suppliers, distributors and transporters which synergistically work together to reach the common goal: providing the customer with a high value-added product.

Supply Chain can, then, be defined as *"the set of entities that are involved in the design of new products and services, procuring raw materials, transforming them into semi-finished and finished products and delivering them to the end customers"*[7] . The single organisation, then, is not responsible for its own success, since its performance level is strictly linked to the one of all the actors included in the chain, both upstream and downstream.

[7] Swaminathan (2001).

CHAPTER 2

MATERIAL MANAGEMENT

2.1 Material classification

Material management is the process that involves the planning, organization and control of material flow from the input point, the supplier, through the different phases of the manufacturing process, to the final destination point.

When talking about materials inside a factory we refer to:

- Purchased items, raw materials, components and subassemblies that are used to manufacture the finished product;
- Work in process materials, all the parts that can be found along the production line and that are being transformed;
- Finished products, all the goods that are ready to be shipped to the end user

Researchers have highlighted the fact that the cost of materials can represent almost 50 to 60% of the final product price. Therefore, they are considered as an investment, and priority should be given to their management in order to avoid wastes and reduce the amount of unnecessary costs. At the same time, however, they represent the lifeblood of a manufacturing plant. Materials, indeed, should be available at the right moment, in the right quantity and at the right price so that production can start and delivery schedule promised to customers can be respected.

The primary aim of material management is, therefore, being able to answer to two main questions: when to order and what quantity so to minimize stock level and costs without impacting service level.

Two different criteria of material management can be identified in literature: stock control and flow control. The element that distinguishes these two techniques lies in the difference between the moment in which the procurement order is placed and the time the material is really needed.

Stock control method is based on the reconstitution of a certain stock level. As a matter of fact, every time the number of products available in stock goes under a defined level or after a pre-established time interval, a purchase order is placed. This technique, which is also known as “look back method”, aims at maintaining a fixed stock level to avoid shortage even before the need is expressed through customer orders or forecasts.

On the other hand, flow control techniques of management are based on the calculation of real needs. The objective, here, is to look ahead, at future customer requirements and plan production and procurement on that. Starting from the finished product, indeed, the need is then divided into components and orders are placed according to the lead time and the quantity which is really needed. Therefore, the moment in which the purchase order is issued and the one in which the item is required correspond.

Every method has, of course, its advantages and drawbacks, but when confronting them, the second one immediately appears more efficient and cost saving than the first. As a matter of fact, when planning the different process flow and forecasting future needs, the amount of stock built is reduced and flexibility increased. The company is, indeed, able to adapt more rapidly to any change in customer demand and to reduce the risk of parts and raw materials obsolescence.

However, it can be difficult to clearly define what the real needs are with the result that, sometimes, forecasts are uncertain and the probability of stock out and shortage becomes higher. How to define which is the best strategy then?

Several parameters have to be taken into account when evaluating the two possible solutions. First of all, demand characteristics should be analysed and, in particular, if you are speaking about dependent or independent demand. The first one is generally identified as the final product demand or the consumer goods demand and it is based on market requirements. Historical data are used to calculate and forecast future needs. On the other hand, dependent demand is the demand that characterises all the elements which are part of a bigger entity. For instance, the number of table legs that should be bought or produced in a certain period of time is strictly correlated to the number of tables that the company is supposed to sell at the same time, because every table is composed of four legs. Therefore, table demand can be classified as independent whereas table legs demand can be defined as dependent. This kind of relationship is called vertical dependency.

It exists, thus, another type of dependency which is called horizontal dependency and can impact components which are at the same level. This kind of dependency is not linked to quantities but depends on delivery schedule. For example, when producing a table, you need table legs but also a top and a base. As explained before, the quantity you need to order of both materials will depend on the number of tables that will be sold on a certain period. However, if one of the part is shipped two week later, the assembly phase cannot start until both components are available, therefore, the need of the part which is on time has to be rescheduled too.

When analysing demand, however, another important aspect should be taken into consideration: Wortmann[8] classification of production systems, which is illustrated in Figure 4 below.

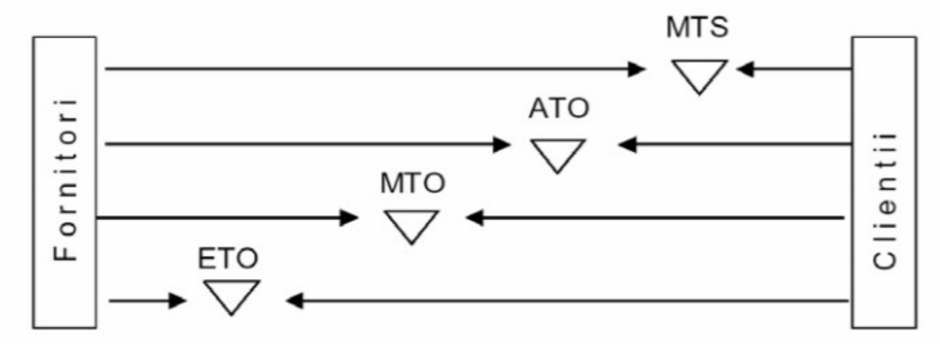


Figure 4 - Wortmann Classification

This model classifies different products according to the position of the customer decoupling point, that is to say the moment in which production switches from being based on forecasts to real customer order.

MTS and MTO product represent the two opposite situations. A Make to Stock product is generally produced to be put in stock, waiting for the customer order to be placed. This kind of products are standardised, do not have a very high value and market demand is high. Moreover, production lead time[9] is often longer than customer lead

[8] Johannes Casper (Hans) Wortmann - 1950, Emmen

[9] Time that is between the moment in which a Purchase Order is placed and the moment in which finished products are ready to be delivered to customers

time[10], which do not give companies the possibility to wait for the customer order to be placed before starting to buy raw materials and start the production.

On the other hand, a Make to Order product start to be manufactured only when a fixed customer order is placed. Only design and development phases can be anticipated. this is the main point that distinguish MTO from ETO products, where the product is developed and thought in collaboration find the end user.

Finally, Assembled to Order products can be considered as a mix of MTO and MTS ones. As a matter of fact, since the production time is still higher than the customer lead time, companies need to prepare a stock of standard products before the fixed orders are placed on the base of forecasts and previous level of consumptions. Once the customer order is placed, standard parts can be assembled according to end user requirements. This strategy allows, therefore, a reduction of stock levels and gives companies the possibility to provide the client with an offer which better fits its needs and expectations.

Another element that should be analysed when deciding the best control criteria is the value that each part has and its impact on the total cost of the inventory. Pareto's law is used to divide materials into three different categories:

- A products: they represent the 80% of the entire inventory value, therefore the aim is to reduce stock to the minimum level possible, avoiding, nevertheless to prevent stock out. In this case, a flow control method is preferred, since the procurement will be based on forecasted needs;
- C products: they represent almost 80% in the total stock quantity but only 15% or 10% of the whole value. That is the reason why they can be managed following less "strict" rules and rebuilding the stock which has been consumed on the base of past consumptions;
- B products: they have a moderate impact on inventory level, therefore, no specific control method is preferred but they are often associated to A or C product according to the easiness with which the part can be supplied.

[10] The time that is between the moment in which the customer places his order and the moment in which he expects to receive the delivery

Finally, the relationship between procurement and consumption frequency should be taken into account too. As a matter of fact, parts can be classified as materials with continuous and discontinuous consumption. The first ones are picked from stock continuously, even in small quantities, whereas the second ones are used less frequently and picking from stock is done in larger quantities. The same distinction can be done for procurement. Some materials, due to their lead times, MOQ or requirements, are bought once or twice a year, whereas for others the flow is continuous. It is evident, then, that for high frequency materials the preferred criterium is the one that aims at recreating a certain stock level, although for products characterised by a low frequency the objective is to buy them when a real need exists.

Before describing in detail the two control methods, a deeper analysis of stock and its management is needed.

2.2 Inventory management

Inventory is the term used to talk about any part, **raw material or finished product** which is used **inside a factory** and that becomes part of the manufacturing process.

Literature distinguishes between three different kind of inventory according to the step reached in the transformation process. You can, therefore, have **raw material inventory**, composed of all the parts that are generally bought from suppliers and represent the basis of the final product; **finished goods stock**, which is the downstream inventory where all the goods that are ready to be sold wait before being shipped to the final user; **work-in-progress inventory**, that includes all the subassemblies and materials that are stocked between different workstations and queue, waiting for the previous batch to be finished in order to be processed.

Another way of classifying inventory, though, is based on the purpose and use of the material.

The most common kind of inventory is **cycle stock** which is used to manage the differences existing between procurement and production times. As a matter of fact, when a contract between the factory and the supplier is established, buyers should negotiate a price and a MOQ that have to be respected every time an order is placed, in order to avoid additional costs. However, MOQ does not necessarily reflect the part consumption or need in a fixed time interval. An average monthly or weekly quantity can be forecasted according to historical data and previous orders, but it is almost impossible to perfectly synchronise the inbound and production flow, reducing the inventory quantity to zero.

Another important kind of inventory is **safety stock** which is created by the factory to prevent stockout or, at least, to reduce the percentage of customers which will not be served. As a matter of fact, procurement activities and production are based on forecasts which do not always really correspond to real needs. In addition, suppliers can be late with deliveries and accidents can block or reduce production capacity. Since companies work in a non-deterministic environment, safety stock is the element that helps them to reduce the impact of unforeseeable events on final customers, and to guarantee product availability within the replenishment lead time.

Several strategies are used to calculate the right amount of safety stock in order to avoid, on the one hand, unnecessary costs and, on the other hand, to increase the service level.
The most common and widely accepted formula takes into consideration both demand and lead time variability, according to the level of service that the company wants to reach:

$$\textit{Safety stock} = Z\ x\ \sqrt{\left(\frac{LT}{t}\ x\ \sigma_d{}^2\right) + \left(\sigma_{LT}{}^2\ x\ D_{avg}\right)}$$

- LT = Replenishment Lead Time
- t= the time for calculating standard demand deviation
- σ_d = standard deviation of demand
- σ_{LT} = standard deviation of lead time
- D_{avg}= average demand

Seasonal stock, instead, is built when dealing with seasonal demand, that is to say a demand which is not constant all over the year but has peeks in certain specific periods. Let us consider, for instance, the demand for swimsuits. Many can argue that they can be purchased in winter too, but the highest level of demand is, of course, recorded during the summer period. It is then difficult for companies, which have to manage seasonal goods, to organise and plan production, and to adapt capacity. Seasonal inventory helps companies dealing with this problem: during the low demand period excess capacity can be used to manufacture goods that will be stocked and then sold during the period in which demand will reach its peak.
This strategy allows organisations to satisfy customer demand and to smooth production, avoiding the need to continuously adapt and change capacity. The red portion of the curve that can be seen in the graph below, indeed, represents the amount of requirements that would exceed maximum capacity and that an organisation wouldn’t be able to serve. However, if you take a look at the previous period, the demand is definitely lower than organisation capacity, therefore production can be anticipated and goods stocked, waiting for the demand peek to come.

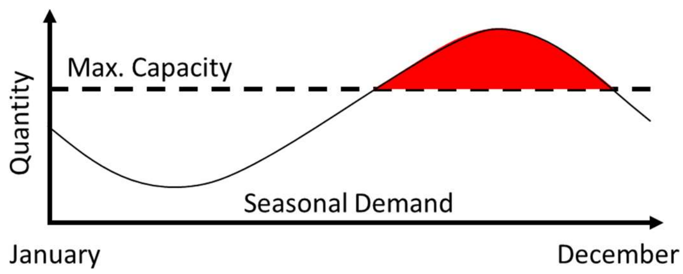


Figure 5: Managing capacity with seasonal demand

Finally, **decoupling inventory** is all the material which is stocked with the aim of unbundling different steps in the production process, making them independent from the previous ones. As a matter of fact, it can happen that several tasks along a production line have different output rates, different capacity. The presence of a decoupling inventory allows following workstations to start working before the previous activity is totally completed. On the other hand, when dealing with a linear production line, where workstations are organised one after the other and wait for the material of the previous station to come in order to start working, an issue or an unforeseeable failure could block the entire process. Here again, the presence of inventory between workstations will allow each of them to be independent until it is totally consumed. Production can, therefore, continue in parallel with maintenance interventions on other workstations to repair the failure.

Whatever the type of inventory is, the main objective is the same: **matching demand and offer in terms of time and quantity** and trying to be protected from unexpected events or delays that could impact the final customer.

It is, indeed, undeniable that inventory represents a resource for a company, but quantities should be managed attentively and constantly revised, since it represents an economic burden that cannot be neglected.

We can, indeed, distinguish between several different types of costs that can be dependent on the period of time materials remain in stock before being sold, to the space that these materials occupy or to their management.

Holding costs are, for instance, all the costs that are linked to the fact that a certain amount of material is physically blocked for a certain period in a fixed place. A part of these costs is due to the rent of the warehouse, and the payment of resources, people and supply contracts needed inside a logistic facility. This is probably the amount of costs which can be more easily quantified and calculated, together with insurance costs that insure inventory against losses, theft and destruction. Moreover, the costs, or better, the possible revenues lost, due to product obsolescence, damage or depreciation should be taken into account when evaluating inventory value, too. However, it can result more difficult to calculate them since they do not necessarily correspond to cash flow and are strictly connected to the product value. That is the reason why for every material that is stocked, holding cost is calculated as a percentage of the whole inventory value.

Material management costs can, instead, more easily be estimated since they often correspond to real amounts which are invoiced and paid. For instance, **purchase costs**, which are calculated as the product between the quantity bought and the unit price, are an example of material management costs. However, every time a purchase order is placed, **ordering costs** should be considered too. In particular, these costs are linked to all the administrative operations that are related to the calculation and payment of needed quantities, to their inspection once they are received in the warehouse plus all the expenses generated by purchasing teams.

Finally, when speaking about inventory costs, **shortage costs** cannot be forgotten. These are probably more difficult to estimate than holding costs, since they try to monetise the losses an organisation should face when confronted to product shortage and the impossibility to satisfy customer demand. As a matter of fact, when a factory runs completely out of raw materials and parts, or the requested need is higher than the available quantity, production is blocked and consequently delayed. Products will then be ready later than expected and could be delivered to customers behind schedule. Late deliveries can oblige companies to pay penalties, or in more serious cases, customers could decide to address to competitors, reducing the company market share and harming to its image.

2.3 Stock control method

Now that the concept of stock has been clarified, the analysis can move back to the first strategy of material management, that is based on historical data and that aims at the recreation of a certain level of inventory, in order to avoid stockout.

As explained in the previous chapters, the focus of any material control strategy is to define the quantity that should be ordered and when the new order should be placed.

When materials are managed looking back at what has been consumed, two different techniques are used to define both the quantity needed and the interval between two orders.

The first method defines a **fixed order quantity**, called EOQ - **Economic Order Quantity** - and an **interval that can vary** according to material consumption and the moment in which the inventory threshold level is reached.

EOQ is the order quantity which permits to minimise total inventory costs. In the previous chapter the different types of inventory costs were presented, therefore, total inventory cost can be now defined as the sum of holding, purchase, order costs plus an estimation of the shortage cost:

$$C_{tot} = C_{imm} + C_p + C_o + C_{sh}$$

Before explaining in detail the calculation of each element of the global formula, it is important to highlight the fact that this model is based on assumptions that are created in order to simplify the analysed environment.

First of all, the demand is considered constant and known during a certain period of time.

If this is true for finished MTS products which are manufactured even before the order is placed, it is completely unrealistic for all the MTO goods, that start to be produced only after the customer specifies the quantity needed. Moreover, the order and the holding costs are considered constant and the no backorder is accepted. Therefore, under these assumptions, the quantity held in stock would decrease uniformly, based on the consumption rate, to increase instantaneously when the order quantity is received, as represented in Figure 6.

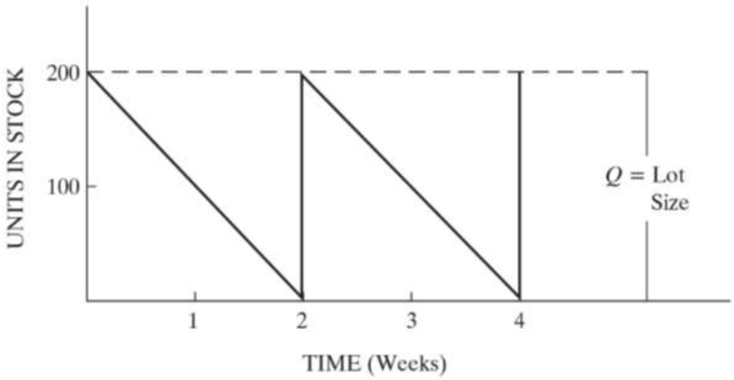


Figure 6: Available inventory over time

When analysing the total inventory cost, the first two elements of the formula are very easy to calculate since they represent real cash outflows. As a matter of fact, the purchase cost is the product of the quantity ordered on the year and the good unit cost, whereas the ordering cost depends on the number of orders placed during a certain period and the cost of each one.

When calculating the holding cost, in opposition, the average inventory quantity should be taken into account and multiplied by its unit cost and a percentage value, normally included between 10 and 50%, which represents an estimation of the carrying costs over the global price. Finally, the last element of the formula can be calculated taking into consideration the probability of shortage for each order, the number of orders that are placed in the year and the duration and cost of the possible shortage. As explained before, this last part is very difficult to estimate since it is especially based on customer reaction to stockout, which is hardly predictable.

Generally speaking, when the order quantity increases, the holding cost will increase too, but it will reduce the number of order to be placed, consequently reducing the unit cost per order. The aim of the EOQ method is, therefore, to find the right balance between these two costs, minimising the total one.

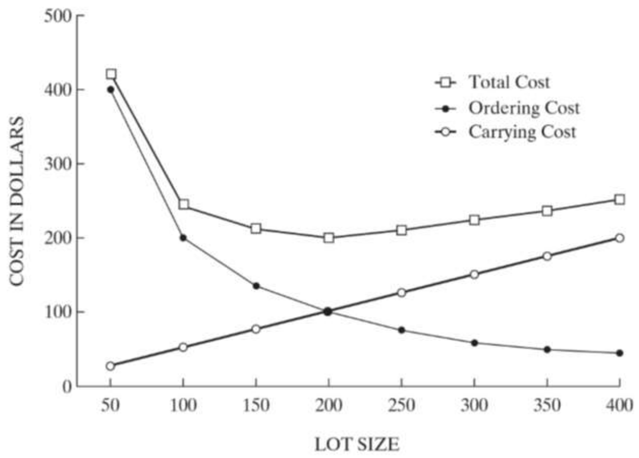


Figure 7: Ordering and carrying cost

From a mathematical point of view, as you can easily understand from the graph above, it means calculating the quantity for which the carrying cost is equal to the ordering cost.

The result of this calculation will then be the EOQ which is equal to:

$$\textit{Economic Order Quantity} = \sqrt{\frac{2*Q_0*a}{p*i}}$$

- where Q_0 represents the annual demand quantity, *a* is the order cost, *p* the unit price and *i* the percentage representing the carrying cost of the single product.

Through this calculation you should, then, be able to answer to the first question and define the optimum quantity in order to minimise costs.

Therefore, just one more thing is left to be analysed: the moment in which the order should be placed so that a certain service level can be maintained. The EOQ method, indeed, also includes the calculation of a ROP – Reorder Point, which corresponds to the amount of stock that can be reached before a new order is placed. This threshold level is defined taking into consideration both the average demand on a part and its standard deviation. According to the probability of shortage that the company decides to accept, the standard deviation of a part demand is rectified through a coefficient, the security level, that can vary between 0 and 3,75. The higher this coefficient, the lower the number of shortages accepted during the year.

On the other hand, however, a company hardly aims at the highest coefficient, since it would result into a bigger inventory and a more expensive carrying cost.

The solution described so far can easily work for all those parts that are characterised by a uniform demand and that are produced and delivered all at once. However, to provide with a complete and deeper analysis, two other possibilities should be considered.

In the real everyday material management, it can often happen that the part demand varies on a fixed time interval. When that happens, another strategy can be adopted in order to avoid unnecessary inventory costs and optimise material management: POQ, period order quantity. The objective remains the same of the EOQ, but the difference lies in the fact that the total order quantity does not stay the same over the year, but it is divided by the average weekly consumption, and will represent the real part demand.

The other variant that should be taken into consideration is the possibility that the quantity which is ordered is not received at once, since it requires a certain amount of time to be produced and that it is shipped as it is manufactured. In this case, the EOQ formula differs from the traditional one because it takes into consideration the production rate related to the demand rate on a preestablished time interval.

The new EOQ will then be calculated as:

$$\sqrt{\frac{2 * Q_0 * a}{p * i} * (\frac{p}{p-d})}$$

- where *p* and *d* are, respectively, production rate and demand rate.

When purchased materials belong to C class, and they only represent 5 to 10% of the entire inventory value, another replenishment method can be used, always with the objective of rebuilding the stock which was consumed. This technique differs from the EOQ method, since it will be based on fixed time interval and variable purchased quantity. Of course, the amount of products stocked in the inventory will be higher than the one that result from the previous method. However, given the low value that these materials represent compared to the one of the whole inventory, the economic impacts of this strategy are negligible.

In order to implement this second stock control method, a fixed time interval is defined and generally calculated on the base of the procurement lead time, since the general rule states that a new order is placed when the previous one has been completed. Once the time span has been calculated, the analysis can move to the definition of the quantity that should be ordered, which will not always be identical to the previous one. A maximum stock level is, indeed, chosen and every time the order should be placed, the difference between the maximum and the presumed stock level is calculated in order to always guarantee the target inventory quantity.

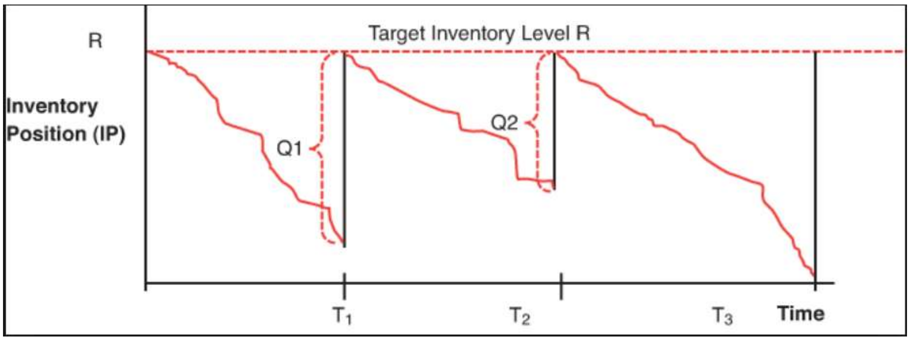


Figure 8: Fixed period ordering system

In the actual everyday life, however, the target inventory level is rarely reached since procurement lead time and consumption in a period cannot be considered fixed and deterministic. Therefore, the stock level needed to calculate the order quantity cannot exactly be defined. Generally, it is calculated using the formula below, which takes into consideration both demand and procurement lead time variability

$$\textit{Presumed stock level} = (D_{avg} + \sigma_d) \quad * (\sigma_{LT} + LT)$$

Consequently, companies should always be ready and prepared to manage the excessive stock quantity or lower than expected inventory level and adapt production to material availability.

2.4 Flow control method

2.4.1 From Strategic Business Plan to MPS

The second strategy that can be used to manage materials is the flow control method: in this case future requirements and forecasts are taken into consideration in order to calculate the quantity that should be ordered. It is often used for all the products characterized by dependent demand; therefore, components need is calculated downstream, starting from the finished product.

We can identify five different levels of planning that can be distinguished based on their aim and the interval of time which is analysed:

- Strategic Business Plan
- MPP – Master Production Plan
- MPS – Master Production Schedule
- MRP – Material Requirement Planning
- CRP – Capacity Requirement Planning

As you progressively move down the list, the level of detail deepens as well as the period of time which is considered, moving from years to weeks to arrive to a day by day schedule.

Strategic Business Plan is a statement which is used to define company vision and objectives for the following two to ten years. It gives information on the markets the company wants to reach, the lines of products they want to focus on as well as all the activities and strategies that will be needed to reach the defined objectives. The creation of a strategic business plan involves several business functions: marketing, finance, production, logistics and Research and Development. Every function is responsible for one or more tasks, linked to their field of expertise, that will finally result in the drawing up of a complete strategic plan. Marketing team, for instance, will be in charge of understanding customers' needs and expectations, deciding then how the company should respond: what products should be sold, at what price, with what strategy. Production and logistics, on the other hand, should look for solutions to respond to market demand, checking for resources, machinery and material availability. Engineers in the research and development team should, instead, be concerned with the design and development of new products that will be able to satisfy clients and that will be manufactured in the most economically way possible. Finally, Finance will be in charge of choosing the sources and use of funds which are available, defining budgets cash flows and trying to calculate future profits. Once the global strategic business plan is set, every function will be able to extract and decide about the best way to reach the objectives that have been defined by senior management. Therefore, production, engineering, finance and marketing will create a master plan in which actions and responsibility will be defined more precisely and that will be coordinated with one another and with the strategic business plan.

Due to the objective of this thesis, Finance, Marketing and Engineering master plan will not be detailed, but a deeper analysis of Production Master Plan will be provided in the following paragraphs and chapters.

The Master Production Plan is then one of the several plans that directly comes from the Strategic Business Plan. Here, the interval of time which is analysed reduces from several years to several months and all the outputs are divided into groups which can be considered similar in terms of production process and resources needed. Taking into consideration the orders that have already been placed and the forecasts that are calculated on the base of historical data and marketing information, the quantity needed for each product group is defined as well as the ideal inventory level that should be reached. The aim of MPP is to define the production volume that will allow the company to satisfy demand, according to the service level chosen, and considering the constraints imposed by capacity.

The planning horizon, indeed, is often six to eighteen months, with monthly revision. Therefore, no large change can be done in term of capacity: addition or subtraction of machines and equipment are very difficult to be implemented but little adjustments can be done in order to fit with the work load. For instance, some shifts can be added and removed, some activities can be done by subcontractors and stock levels could be boosted during low workload period to be then reduced when demand increases. All these decisions should be taken and discussed by the Production and the Logistics functions in order to optimise material flow and respond to customer expectations.

Therefore, several strategies can be adopted to respond to demand according to the objective that one aims to reach:

- **Demand Matching**: the company exactly manufactures what is needed to respond to customer demand. On the one hand, this technique allows organisations to minimise inventory levels, since everything that is produced is then sold to a final customer and not kept in stock for a long time. On the other hand, however, a company that chases demand should be as flexible as possible and have enough capacity to respond to demand peaks. In some situations, like for instance in a restaurant, this is the only possible technique, since food is prepared according to customers' orders, but in most of the cases, other strategies are preferred.
- **Production levelling**: in order to simplify capacity management and reduce production costs, some companies focus on the production of the same quantity, which generally corresponds to average demand level. The excessive quantity is stocked and sold whenever consumption is higher than the average quantity produced. The drawback of this solution is, however, that inventory costs, especially carrying cost, increase since some products are stocked before being sold to clients.
- **Subcontracting**: an organisation can decide to set its production to the minimum level and to ask a subcontractor to produce extra quantity. The main advantage linked to this strategy is cost. As a matter of fact, production remains constant on a fixed period of time as well as capacity level. On the other hand, company should be very careful when selecting subcontractors, since the price of the purchased item could be higher than its production cost. Therefore, this strategy is preferred for all those parts and components a company doesn't have the expertise for. For all other items that the organisation generally makes, an attentive evaluation of advantages and drawbacks should be made before taking the decision.

To benefit from the advantages coming from different alternatives and reduce the impact of drawbacks often companies opt for a hybrid strategy which consists in mixing the three methods that were presented, adapting them to their specific needs.

To practically write down a Master Production Plan, for Make to Stock products, Logistics takes into consideration both the total forecasted demand and the orders that have already been placed, according to the planning horizon, plus the opening and the desired ending inventory level. Production will, then, be able to engage on a certain output rate on the base of its capacity. In table below, an example of calculation is provided in order to make the concept clearer.

Period		1	2	3	4	5	Total
Forecast		300	200	150	220	250	1120
Planned production		200	200	200	200	200	1000
Inventory	250	150	150	200	180	130	

Figure 9: MPP for make to stock goods

The exact same reasoning can be applied for MTO products, but the focus will be different in this case, since goods are not produced to be put inside an inventory but to be directly sold to customers. Therefore, besides forecasted demand and customer orders, logistics should take into consideration backlog of customer orders, which represents the list of all orders that have not been processed yet.

Once production has defined the quantity it will be able to realise over the planning horizon, the difference between the promised quantity and the needed one should be calculated and analysed. It is at this point that decisions should be taken to avoid problems connected to missing or excessive capacity.

The following step in material planning is the creation of MPS – Master Production Schedule. The main difference between this plan and the one presented before is the time interval which is taken into consideration as well as the level of detail that it aims to reach. The groups of products that were used in the MPP are now split into end items that are analysed individually. It represents the actual production plan that allows the company to respect and respond to market demand, and make valid order promises, taking into consideration its maximum capacity. Moreover, MPS gives the inputs to prepare the MRP – Material Requirement Planning that allows the planning of components and parts production and procurement, according to the end items needs which are presented in the MPS.

The first time the MPS in created, however, capacity is not taken into consideration, but companies prepare the what is called Preliminary MPS which only considers needs and inventory level. To give a clearer and more in-depth explanation, an example is provided. Imagine a company producing three different models of cars: A, B and C. The total quantity per period that was presented in the MPP will be broken down in the MPS and then shared between the three different models. Starting from the previous example, the table below aims at pointing out the difference existing between MPP and MPS.

Period	1	2	3	4	5	Total
Aggregate Forecast	300	200	150	220	250	1120
Product A	180	50	20	50	70	
Product B	120	150	80	70	80	
Product C	100	100	50	100	100	

Figure 10: MPS for make to stock goods

Any product is then analysed separately from the ones belonging to the same group, taking into consideration the available beginning inventory level and the quantity that should be produced or received on a specific week in order to cover demand.

Once the preliminary MPS for all products are ready, a comparison between needed capacity and the available one should be done. This process is known as rough-cut capacity planning. In this phase all critical resources such as labor, bottleneck operations and scarce materials for a specific item are listed and the amount needed to satisfy demand is calculated, generally in terms of standard hours. The result of this operation is then compared with the available capacity of the specific work-centre. Of course, if available capacity is higher than the needed one, demand can be satisfied and the MPS is workable. On the contrary, if available capacity is not enough, solutions should be investigated in order to cover for the missing capacity, and if gaps are still present, MPS should be revised.

MPS really represents production commitment, what will physically be manufactured, consumed and remain available for future orders. In this sense, production schedule can be considered a realistic base to make delivery promises.

That is the reason why it should be as realistic as possible. Any time engagements are not respected, the results will be:

- Delayed deliveries and poor service level
- Overload or underload of factory resources
- Excessive final and work-in-process inventory level

2.4.2 MRP – Material Requirement Planning

So far, the analysis has been focused on finished goods, all the products that are assembled and then sold to customers. However, every finished good is composed by parts and components that must be available at the right moment and in the right quantity in order to respect MPS requirements. Any lateness in material shipment will produce delays in product assembly and delivery.

MRP – Material Requirements Planning is the tool used to avoid missing parts, since it helps to calculate, for every component of the final good, the quantity and the moment when these parts will be needed, taking into consideration lead times.

In order to correctly make the calculation, MRP systems need three data as an input for the analysis:

- MPS requirements, which permits to define the quantity and the dates in which end items should be completed;
- Available stock and planning factors such as safety stock, lead times and MOQ;
- BOM - Bill of materials.

Before going any further with the explanation of MRP functioning, some more details on what a BOM is and its importance should be given.

The APICS[11] defines a Bill of Materials as "*the document that specifies the components needed to produce a good or a service. It lists the parts, raw materials, sub-assemblies,*

[11] Association for Operations Management

and intermediates required by a parent assembly. A BOM specifies the quantity required to make one item, specifying the quantities of each".

In other words, a Bill of Materials lists all the components that are needed to build one and only one end item. Every element inside a BOM is characterised by a unique part number that identifies its specific form and function: for instance, if a PCB is coated at a certain stage of the production process, it becomes a different part and its identification code must be changed. Several structures can be used to present a BOM, depending on its purpose.

The easiest way to visualise it is through its product tree format, but it is rarely used inside companies since the product structure is often too complex to be represented graphically. However, the product tree structure, can help to have a clearer vision on the topic. Figure 11 and Figure 12 provide two examples of single – level and multi – level Bill of Materials.

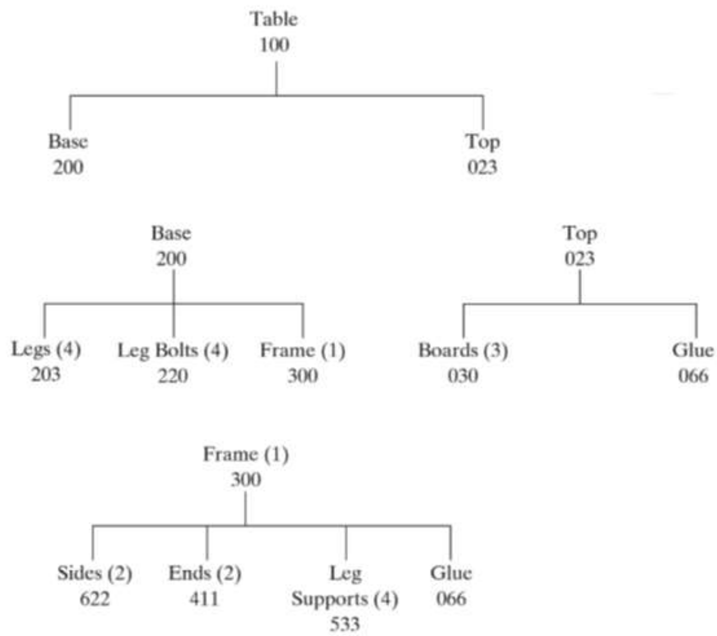


Figure 11: Single level BOM

As you can easily see from the two pictures, for every component the identification code is indicated as well as the quantity needed to for every end item. The main difference between the two structures is that the single level only indicates the "parent" and its immediate components, therefore, more than one single level bill is necessary to describe a complete end item. In the example below, if we consider the bill of material for the base (P/N 200), we will need four legs, identified by code 203, one frame, identified by code 300 and four Leg Bolts which are characterised by code 220. All these parts are assembled together and used to manufacture a base that with the Top will be transformed into a ready to be sold table.

On the contrary, a multi level bill lists all the parts that are needed to manufacture the finished good, starting from the subassemblies and ending with all the raw materials that should be bought from external suppliers. The top level, which corresponds to the finished product, is called level zero, whereas its components level is considered as level one.

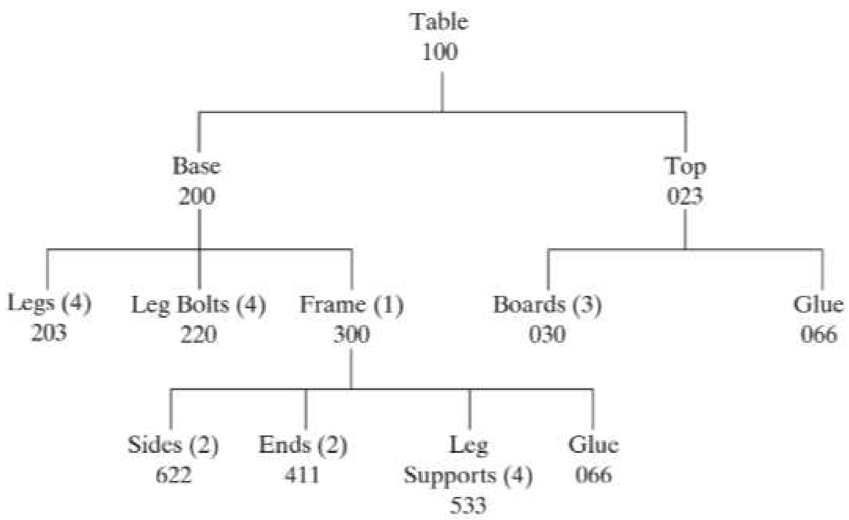


Figure 12: Multilevel BOM

More often, in manufacturing environments, a summarized part list is preferred. All the parts and components are listed in a table and quantities are presented in the near columns.

The components of the parents are generally listed flush left whereas the components' components are indented immediately after their parents.

MANUFACTURING BILL OF MATERIAL
TABLE P/N 100

Part Number	Description	Quantity Required
200	Base	1
203	Legs	4
220	Leg Bolts	4
300	Frame	1
622	Sides	2
411	Ends	2
533	Leg Supports	4
066	Glue	
023	Top	1
030	Boards	3
066	Glue	

Figure 13: summarised BOM

Now that the concept of BOM has been addressed, the analysis can move back to the MRP method and its functioning.

The first thing to do when calculating material needs is to explode requirements, which means exactly defining the quantity needed for each part, starting from the MPS requirements and multiplying it by the component usage quantity. For instance, if fifty tables should be assembled, the exact same quantity of bases should be available before the transformation process starts. In everyday operations, however, a part of the total need could be already available on stock, therefore, this quantity should be subtracted from the initial quantity in order to obtain the component's Net Requirement, which will consequently define, multiplied by the usage quantity, the gross requirement of the following component.

The following step will, then, be the offsetting of the exploded requirements. As a matter of fact, every component has its proper lead time, that can be the production lead time for all the parts that are directly manufactured by the company, or the procurement lead time, which corresponds to the time between the moment in which the order is placed to the supplier and the moment in which goods are received and available to be used. Lead time analysis is important in MRP analysis since it permits to correctly schedule the placement and reception of orders.

Let us, for instance, go back to the previous example and imagine that table lead time is one week whereas base lead time is two weeks. If fifty tables should be ready to be sold in week 5, there should be a planned receipt in this same week but production must be started one week before, which means that a planned order release should be placed in week 4 for this same quantity. However, to start the assembly of tables, bases should be available, therefore a planned receipt of fifty base should be placed in week 4 and a planned order release for the same quantity in week 2, since bases' lead time is two weeks.

To make a more realistic example, and to clarify the distinction between gross and net requirements, we can imagine to have fifteen pieces already on stock for base component, which means that planned receipts and planned order realise quantity will not be 50 anymore but only 35. Calculations details are provided in the two tables below

Part number	LT: 1 week	Weeks				
		1	2	3	4	5
100. Table	Planned order receipt					50
	On hand inventory	0	0	0	0	
	Net Requirement					50
	Planned order release				50	

Part number	LT : 2 weeks	Weeks				
		1	2	3	4	5
200. Base	Planned order receipt				50	
	On hand inventory	15	15	15		
	Net Requirement				35	
	Planned order release		35			

Figure 14: MRP example

Consequently, 35 pieces will become the gross requirement for all the parts that depend on part number 200.

As previously explained, MRP is one of the last step in the process of production planning, the one that is able to give the highest amount of details and for which the planning horizon is shorter. As a matter of fact, time bucket for MRP is generally the week, even if some companies are moving to daily time buckets to try to be more flexible and reactive.

So far, the analysis has been focused on the definition and planning of required quantities to be purchased or produced. However, several lot sizing techniques exist and each one of them can respond to a specific company need, aiming in general at reducing the global cost.

The main lot sizing techniques could be classified into two different categories:

- Fixed quantities, and in this case the EOQ method is used
- Variable quantities: the most used methods are Lot for Lot, Covering Period and Least Unit or Total Cost.

The first rule, which is probably the easiest one, consists in placing an order for a quantity that exactly matches with the net requirement. No stock is built and no safety stock exists, no anticipation is done on following needs. This technique is beneficial when holding costs are expensive, while all the administrative costs linked to order emission are not, therefore companies prefer placing orders frequently rather than holding parts on stock.

An alternative to this method, which can reflect some constraints imposed by suppliers, is the lot for lot technique with minimum lot size: orders' quantities match the requirements, but every time the net requirement is lower than a minimum lot size, this latter quantity is ordered.

Often suppliers require, indeed, the purchase of a minimum number of pieces in order to stay on the negotiated price; if a lower quantity is bought, additional administrative costs should be added to the pure purchase ones. Another common lot sizing technique used by MRP systems is the covering period. In this case, the quantity ordered is calculated taking into consideration several subsequent periods. Therefore, an amount of weeks to be covered is selected and then ordering quantity is defined accordingly.

As its name suggests, the LUC method is used to define the lot size that will allow the company to minimise both the ordering and inventory cost per unit. Therefore, requirements on subsequent periods have to be added up together, holding and purchasing costs for all probable order quantities should be defined and then divided by the lot size. The lot size that corresponds to the lower unit cost is then ordered to cover the first period; the same process should be implemented to determine next order size.

In a world in which variety and customisation is one of the main solutions to conquer market shares and obtaining a leading position, the majority of companies, today, are dealing with a huge amount of different finished products and consequently an even bigger number of components and parts. Moreover, requirements change continuously, orders are placed and cancelled, orders quantities can be modified and inventory level change since quantities are consumed or sometimes scrapped. Planners need, therefore, an automatic system that helps them to deal with such a dynamic environment, that daily recalculates planned order release, verifies component availability and allocates parts to manufacturing orders.

Thanks to technological evolution and the widespread of computers, many companies have invested on ERP systems - Enterprise Resource Planning – a series of modules and applications that are used to standardise business processes, simplify planning and controlling and integrate different business units inside the same organisation. These tools permit a more rapid share of information as well as to have a wider picture on all the organisation processes.

2.4.3 How to daily manage MRP

Even if many tasks are automatically processed by ERP, planners are still responsible for taking specific decisions in order to optimise material flow and adapt MRP requirements to the firm capacity.

As explained in the previous chapters an MRP permits the calculation and the positioning of planned orders, on the base of product's lead times, requirements and available stock. Planned orders should then be released into an open order and transformed, then, into a planned receipt on time to respect the committed MPS dates and quantities.

The main issue linked to an MRP system is that it works considering an infinite capacity, this means that, for instance, if planned orders were released automatically on the base of the company need, the amount of resources available at that time would not be checked and it would be impossible for the production department to respect promised dates.

That is the reason why the biggest part of production planned orders should be transformed by the planners and not directly by the MRP system.

In addition, a Material Requirement Planning works on the base of the forecasts that are uploaded in the system. However, since companies act in a non-deterministic environment and that customer needs and requirements can evolve with the passing of time, the date on which the order is really needed can change. To avoid shortages or reduce the inventory value, actions and decisions should be taken by planners in line with suppliers or the production department. To simplify the task and advise the planner that his or her action is needed, an MRP system should be capable of generating exception messages. For instance, when overconsumption is enregistered on a part or a portion of the available inventory is scrapped or lost, the quantity needed for that specific part increases. Therefore, two exception messages can be generated by MRP systems.

On the one hand, it could ask the planner to change the delivery date in order to anticipate the shipment and prevent shortage. It is then up to the planner to negotiate with the supplier in order to receive components earlier or look for alternatives solutions. The element that should be attentively analysed before doing any action, however, is the amount of safety stock required for the specific part. As a matter of fact, for almost all MTS parts, a certain amount of stock has been created in order to be protected from lead time and demand variability.

Theoretically, this amount of stock should be rebuilt whenever it is consumed in order to maintain a constant level on average, therefore, in the MRP logic it is considered as a requirement which is added to the forecasted ones. Safety stock consumption should be, therefore, attentively analysed. For instance, if you look at the examples provided in the two images below, you can easily note the difference existing between the two new proposed dates. In Figure 15 Safety Stock is considered as a requirement and not as a resource, therefore, the planned receipt should be anticipated by three months in order to satisfy client requirements and rebuild the inventory.

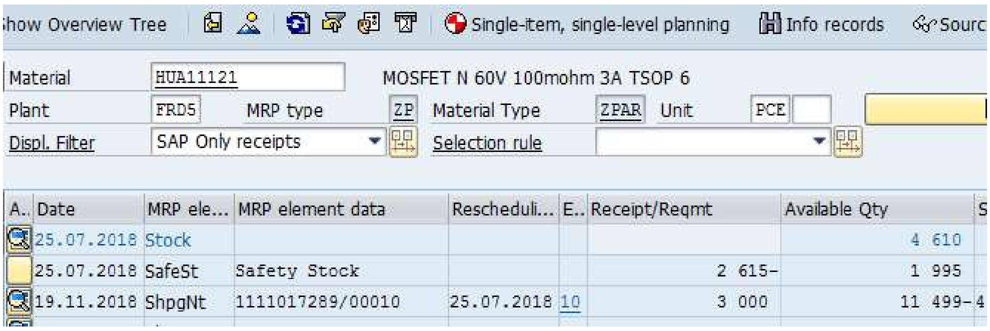


Figure 15: Pull in exception message with SS reconstitution

On the other hand, in Figure 16, the Safety Stock is included in the quantity of available inventory, therefore, the pull in date is later and the missing quantity smaller. However, the second date represent the real shortage date, the moment in which stock will be completely consumed if no order is received before.

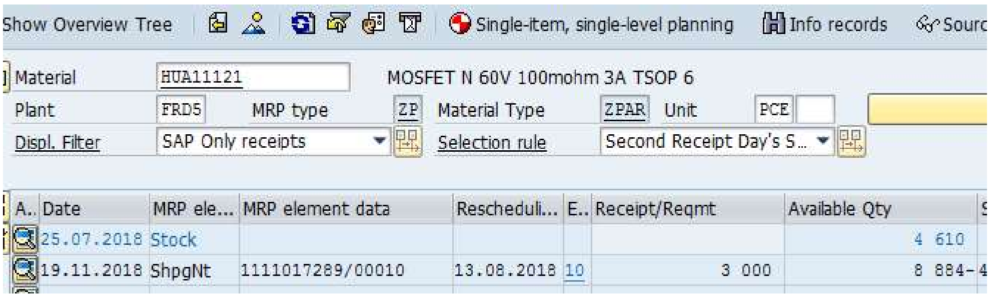


Figure 16: Pull in exception message without SS reconstitution

The other exception message that can be generated is linked to order placement. As a matter of fact, planned orders are automatically placed by the MRP, depending on the component lead time and forecasted demand, beyond the replenishment lead time horizon. If consumption increases on a part and the quantity ordered is not enough to cover the needs within the time bucket, the MRP generates a message suggesting the planner to place an additional order with a requested date that will fall inside the replenishment horizon.

It can also happen that forecasts were too optimistic compared to real consumption, therefore a lower quantity is needed, and orders confirmed on a certain date could be required later.

In more critical cases, when an excessive amount of orders has been placed due to forecast inaccuracy, very low consumption, end of life product, the MRP system can ask the planner to cancel a portion of the PO already confirmed by the supplier.

However, order annulation should always be managed carefully and be accepted by the counterpart.

CHAPTER 3

THE ELECTRONIC COMPONENTS MARKET

3.1 The current market situation

Electronic components can be defined as all the devices and elements that are used inside a circuit and that are necessary to ensure its proper functioning. They can be classified into two different categories:

- **Active components** such as transistors, vacuum tubes and silicon-controlled rectifiers, that normally rely on source of energy and are able to give energy to the circuit;
- **Passive components** such as resistors, capacitors, inductors and transformers that cannot inject power in the system they are part of but can only attenuate it.

The demand for electronic components is a dependent demand since needs for these parts are directly generated by the requirements on the so called "OEM"[12] products, such as telecom equipment, factory automation system, consumer electronics and others. Basically, the term is referred to all the devices and equipment that are then installed inside finished products and on which the final maker can put its own brand.

Over the last several years, both active and passive components' demand has rapidly evolved, following the structural changes characterising modern society. According to the report "Electrical and Electronic Manufacturing Market Briefing" published in 2017 by the Business Research Company, the global electronic components market is expected to reach $ 191 billion by 2022. As a matter of fact, we are now moving towards an era in which electronics and "smart devices" play a fundamental role and are becoming essential in people' everyday life.

One of the most astonishing and probably evident example is the one related to the automotive industry. The first electronic contents of the car were non-critical entertainment and comfort elements, such as AM radio, that soon evolved into other, more innovative forms of audio option, power windows, speed alarms and power locks. With the passing of time, however, the electronic content inside cars has increased, transforming a vehicle into a smart device. The main goal of car manufacturers, today, is, indeed, providing their clients with a better driving experience, increasing its safety

[12] Original Equipment Manufacturer

and connectivity. Thanks to the installation of embedded software and sensors, cars are becoming capable of self-diagnostics, to assist the driver while parking and to reduce the number of accidents and fatalities. In addition, in the last five years, thanks to awareness campaigns made on the harms caused by pollution and the incentives promised by national governments or cars' manufacturers, the demand for electric vehicles has recorded a rapid increase. This results in the growth of the number of electronic devices that are installed inside vehicles, to the point that it is estimated that in ten years electronics will make up about 50% of a car's value – 15% more if compared to the data of 2010.

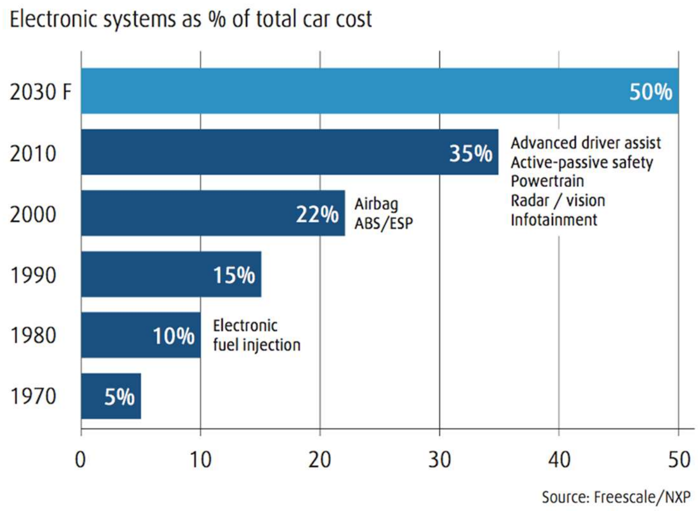


Figure 17: Percentage of electronic systems as % of cars' value

However, with 23 million motor vehicles produced in Europe in 2015 – almost 25% of the global production – the automotive industry only represents 10% of the electronic market even if it is considered as the fastest growing one in the next five years.

Indeed, Consumer Electronics industry is the sector which is considered the greediest in terms of electronic components' consumption, since it is estimated to reach 838.85 billion by 2020[13]. When speaking about CE[14], we refer to any device containing an electronic circuit board, which is designed to be used by the end customer for personal or professional purposes, such as smartphones, wearable devices, laptops or household appliances.

13 Grand View Research, Inc

14 Consumer electronic

One of the main reasons leading to the increase of sales in this sector is the rapid development of IoT[15], an extension of the classical Internet, which allows objects, devices, sensors and mobile phones to connect and interact with one another in order to exchange information and collaborate through unique communication schemes and protocols. The advantage of smart and connected devices is double. On the one hand, they make people life easier, since objects are enabled to do tasks that are normally performed by humans. On the other hand, thanks to their ability to detect and monitor external environment conditions, smart devices can contribute to cost reduction and energy efficiency. Smart products are, indeed, equipped with sensors able to collect and store data, which are then analysed and accessed by people through apps available on smartphones, tablets and smart watches.

The same principle of smart, interconnected products has recently been applied to manufacturing companies too, allowing the development of IioT – Industrial Internet of Things. The main aim in factories is to create a unified network which allows an easier communication between machines and with humans. Machinery can, then, become self-aware and self-maintained; in other words, the whole fleet is capable of defining its own health and, thanks to historical data and comparison to other peers, it can also reduce potential issues, optimise maintenance intervention schedule, improve operators' safety and boost line's productivity.

As you can see from the graph below, the number of connected devices worldwide is rapidly increasing, and it is expected to reach 75 billion by 2025[16], which represents a threefold increase compared to the figures of 2018.

[15] Internet of Things
[16] Statista 2018

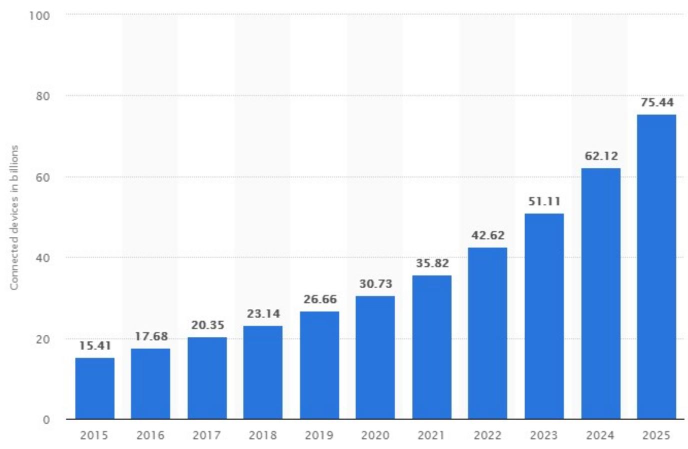


Figure 18: Number of connected device worldwide

If we go further back into the timeline and analyse connected devices according to the category they belong to, figures do not even need to be explained. If the number of smartphones, PCs is thought to increase by 2020, its growth cannot even be compared to the increment that is expected for all the "smart" objects connected to the development of the Internet of Things.

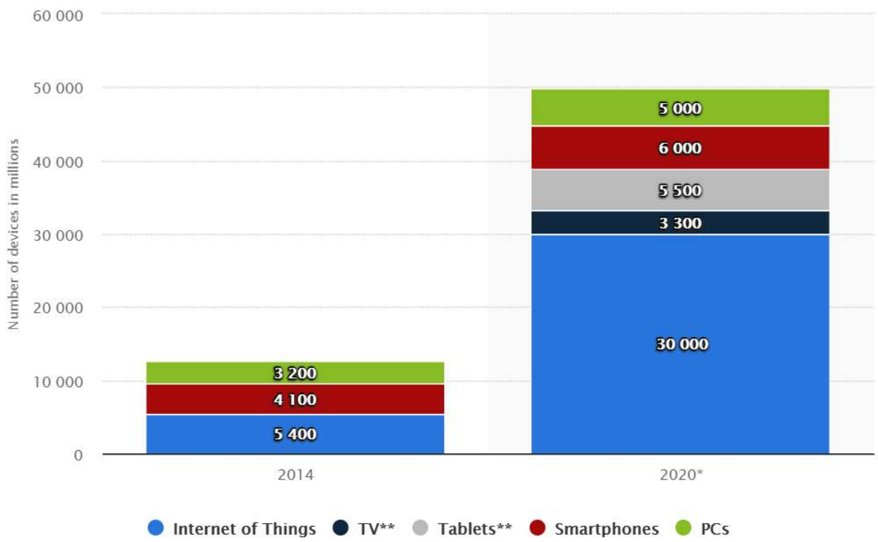


Figure 19: Number of connected devices worldwide in 2014 and 2020, by device (in millions)

It is undeniable that the increased need for sensors to be installed on industrial machines or on household appliances, as well as the ones for devices such as laptops or smartphones to interact with connected objects, is having an important impact on the demand for basic electronic components.

Finally, another important sector in which electronic manufacturers see their opportunities increasingly growing is the healthcare industry. Due to the ageing of the European population and the increase of chronic diseases, healthcare facilities such as hospitals and clinics, need to revise their management strategies in order to deal with the rise in the number of sick people and the lack of space and resources. The main solution, today, is to provide patients with the so called “telemedicine” or “e-heal” devices, tools that can detect diseases earlier, monitor people health conditions and treatments, without forcing them to move from their houses.

Of course, these new trends and solutions are based on the use of electronic devices which, in the end, increase the demand for electronic components.

3.2 The reason behind components shortage

The rapid technological evolution, the higher requirements for miniaturization and efficient equipment, mixed with the rising popularity of smart and connected devices is pulling an unexpected demand for electronic components. Therefore, companies on the market have to deal with a critical shortage for these parts, which mainly results in higher purchasing costs and longer lead times, between several other issues.

The signs of a possible components' shortage started to appear at the end of 2016. The World Semiconductor Trade Statistics, indeed, predicted a 3% increase in 2017 and a climb of 2% in 2018 on semiconductor sales. Forecasts were revised upwards some months later to reach 7,2% increase in 2017. The same rise was forecasted for IC[17], for which sales were thought to increase by 11%.

However, this sector has always been characterised by volatile and inaccurate forecasts which forced manufacturers to be more cautious and suspicious in production capacity planning. Therefore, signals were ignored or underestimated at the beginning, which contributed to aggravate the current situation. In addition to that, once again, forecasts were not that precise, and the actual demand rise has been higher than expected. If we look at the wider picture, semiconductors sales have increased by 6.9% compared to the first quarter of 2017 and they are 13% above the last quarter of the same year. The element that can be considered astonishing is that, as Steinberger[18] says: "In a nutshell, the smaller countries grew faster than the big ones". The greediest country is Italy that has recorded a 9,7% rise, followed by Germany and United Kingdom that registered a 6.3% increase. The same situation can be observed in Nordic Europe and Eastern Europe were semiconductors sales climbed to € 336 million.[19]

The problems were intensified by natural disasters and environmental incidents like for example the earthquake in Japan or the flood in Thailand that blocked production inside several manufacturers' plants before facilities were rebuilt and operational.

[17] Integrated Circuit

[18] Georg Steinberger, Chairman of DMASS (Distributors' and Manufacturers' association of Semiconductor Specialist)

[19] Electronic Specifier

Demand surge and signals' underestimation, however, is not the only element that led to electronic components' shortage. To understand the root cause of this problem we should go back to the 2008 financial crisis and its impact on global economy. In this period, in fact, electronic components' manufacturers had to deal with the increase of their stock level since the demand for electronic products plummeted and the prices dropped too. Therefore, companies were forced to reduce their capacity in order to overcome this recession period.

Since then, forecasts for demand and growth in the sector have been conservative and manufacturers preferred not to make investments to boost their capacity. Some electronic components' makers remain, today, very reluctant and cautious when dealing with capacity increase since they have already been burnt before. As a matter of fact, four years ago, an unexpected increase in the demand for tantalum capacitors created a shortage on these parts and manufacturers decided to invest on capacity expansion in order to increase output volumes and meet the new demand. However, once everything had been set up and producers were finally able to deal with increased requirements, they discovered that some OEMs had just boosted their orders by about three or four times but that the ordered quantity did not actually correspond to their needs. Demand started to drop again since orders started to be cancelled and electronic components' manufacturers had, then, to deal with the opposite problem: amortizing the sums they had spent on new machines and plants while having a very low demand level. They fear, therefore, that nowadays big customers are doing the same and few investments are focused on capacity.

On the contrary, many companies prefer to focus their efforts on the research and development of more advanced components rather than capacity expansion, in order to gain new market shares and respond to customers' new requirements.

The rapid technological evolution and development has a double impact, though. On the one hand, it creates great opportunities for all the companies that already exist in the market or that would like to enter the business, since customer's demand is very high compared to market's offer. Therefore, manufacturers could benefit from higher prices and a wider palette of customers. On the other hand, however, the fact that requirements and needs are evolving quickly is increasing the costs that manufacturers have to face when developing new products. Consequently, to maintain competitive advantage, many organisations have decided to merge in order to share costs and take advantage of another company know-how and expertise, reducing product development and its time to market. Furthermore, mergers and acquisition are also seen by electronic manufacturers as a strategy to enlarge their product portfolio and provide customers with more complete solutions, smoothing their demand and reducing seasonality.

If joint ventures and mergers between companies are seen as an optimal solution by electronic components' manufacturers, they are having a detrimental effect on supply chain, making it harder for clients to find the material they need. As a matter of fact, when two companies with a similar portfolio merge, the overall number of companies available on the market reduces, which forces buyers to choose among fewer alternative solutions. Consequently, prices are affected too: if the number of competitors on the market decreases, the need to attract customers by proposing more appealing prices reduces too. Therefore, electronic components' makers can allow themselves to increase prices in order to cover capacity and R&D investments. Greedy electronic components' buyers, therefore, do not have a high negotiating power: even if they do not accept price increase, fewer solutions are available on the market and normally at the same or at a higher price.

3.3 The impact of electronic components shortage

The difficulties that electronic components manufacturers are facing and the decisions they are taking in order to overcome the crisis are, of course, having a very huge impact on all the companies that purchase these parts and assemble them on their products.

When the crisis started in 2017 and some parts' lead times started to stretch, many organisations took the decision to secure their supply chain by anticipating or increasing the quantity ordered, with the aim of increasing their inventory level and cover their needs, waiting for the "storm" to pass. This strategy, however, did not have the benefits most companies expected.

As explained in the previous chapter, one of the main issues and causes of the components' shortage is linked to the increased level of demand and manufacturers' lack of capacity. Some of them are already working at 95% of their total capacity and are very cautious when asked to invest on new machines or solutions to boost capacity. As a matter of fact, even if the phenomenon of double ordering is not as important as it was in the past, several makers remain sceptical; "I'm sure [double ordering] is going on," Beck[20] said, "We're destined to face this kind of volatility and cyclicality on an ongoing basis from here on out".

Consequently, the strategy to boost order quantity and anticipate order placement in order to let the manufacturer know in advance its client's needs is producing a phenomenon which is well known in the Supply Chain world: the Bullwhip effect. When there is not a clear communication and information exchange between different actors working in the supply chain, and as forecasts are not always perfectly accurate, companies try to protect themselves by increasing the real need quantity. Since every actor in the network has the tendency to adopt the same strategy, the more you move upstream along the chain, the more the difference between real need and the amount ordered just to secure production increases.

Moreover, in the electronic components market, many organisations are not negotiating directly with the maker, but they are passing through authorised distributors in order to have a larger offer and to be protected from counterfeited parts.

[20] Sandy Beck, Vice president of marketing and quality at Kemet

Unfortunately, if the presence of a distributor is essential to purchase approved and quality materials, and to simplify logistic process, this adds a step in the process that links raw material suppliers to the end users, increasing the impact of bullwhip effect, which is strictly connected to the number of people included in the chain. The result is that demand is distorted and even bigger than what is really needed. The effects of real demand increase are then added to the ones produced by demand distortion and the impact on end users is catastrophic. Electronic components' manufacturers start to refuse orders on the most critical parts or to commit on dates which do not fit with their client's requested dates. Consequently, customers place new orders to cover shortage, purchase orders that won't be accepted and will be postponed again, creating a vicious cycle.

In addition, many components are being placed under allocation, which means that, according to customer projections and manufacturers' capacity, a limited quantity of parts is reserved to the specific customer. Whenever the quantity ordered on the year exceeds the allocated quantity, the manufacturer is not able to fit with that and the difference should be purchased from other sources.

Due to double ordering and the willingness to secure procurements and consequently production, the stock level of companies on certain parts is increasing to a level that has never been reached before, but components' users do not seem to perceive the effect of that. In the last ten years, electronic industry has been trying to adopt strategies that aimed at minimising the stock level. However, the stock coverage measured in the first quarter of 2018 moved from the 66 days on average recorded in the last five years to 74 days, which is the highest level reached in the last 10 years. Consequently, the same increase has also been recorded on inventory value: the usual quarter over quarter growth was 3%, whereas today companies moved to a 6% increase.

Another important impact of electronic components shortage on procurement is lead times stretching, both manufacturers' and distributors'. In a normal market condition, indeed, buyers are generally able to negotiate shorter lead times with distributors, since they buy parts and components for several different customers and a part of that is, generally, kept on stock. Today, however, the situation is critical, as even distributors' lead times are extending, becoming similar to the ones proposed by manufacturers. The longest logistic contractual periods are registered for passive components, the more impacted parts. In this case, lead times have moved from a maximum of 12 to 15 weeks, to the average value of 52 or even 70 weeks. For certain resistors from Vishay, for instance, leads times are more than 70 weeks long; Omron sensors have moved to almost 45 weeks and several parts produced and sold by Yageo stretched to more than 25 weeks. The average time to procure an entire BOM is, therefore, 20 weeks, more than four months.

The solution adopted by many buyers is, then, to diversify procurement, to look for new sources, in order to have more alternatives to buy the same part or to directly move to a component that is easier to find. The validation process, however, can be long and expensive. As a matter of fact, whenever a new source is found, or a new part is proposed, tests and trials should be made by R&D and quality team in order to be sure that the change has no impact on final product performance and safety.

Despite anticipation, the research for new alternatives, and critical components monitoring, some parts remain difficult to be found as they are too specific, without any possible substitutes, or because even alternative sources have difficulties in producing it. The only possible solution, then, is to pass by the non-traditional market and, thus, by brokers.

Brokers are a specific kind of distributors that look for available stock on critical components coming from both franchised and authorised distributors or manufacturing companies that do not use them anymore. Their aim is to build up a consistent inventory level and then resell these parts at a higher price when buyers need them and cannot find alternative solutions. Companies are then forced to deal with the extra-cost and have to be very careful when placing orders.

As a matter of fact, they have no obligation to buy parts from franchised and standard manufacturers, therefore, material part numbers and characteristics should be attentively analysed before passing the order to avoid the risk of counterfeits. That is the reason why manufacturing companies generally have a list of trustworthy brokers, on which previous trials and tests have been made and on which there is no doubt about parts' origin.

Another big issue created by the crisis is the management of obsolete parts. Generally, when a manufacturer announces production stop on a certain component, it gives its client two different dates: LTB and LTS[21]. The first one represents the deadline customers have to place their orders. It permits, on the one hand, to the vendor to understand what quantities are needed as well as to define a production plan that will allow to match with the requirements. On the other hand, buyers that receive the obsolescence information have the possibility to decide whether to create an EOL[22] stock, that will permit the company to continue to serve customers orders till the end of commercialisation of the finished product and grant spare parts and assistance to clients for several years after product end of life, or to look for alternative solutions to replace the obsolete part. The LTS is, instead, the date indicating the last possible shipment from the manufacturer of that specific part. After that date, production will be stopped, and no more pieces could be sold. This date is generally defined on the base of manufacturers' forecasts on the orders that will be placed before the LTB, but it could be postponed if real orders are too high and the production rate between LTB and LTS will not allow them to serve all the customers.

However, the rapid technological evolution and the increased demand for miniaturization, especially on passive components, is speeding the obsolescence process up, increasing both the number of evolving parts as well as the frequency with which evolutions are announced. In addition, given the difficulties and lack of capacity manufacturers have to deal with, LTB and LTS dates are becoming stricter and stricter, and vendors hardly accept to postpone production stop on obsolete parts. Their objective is, in fact, to accelerate the process of moving towards the new part's manufacturing and free capacity that could be used on more profitable product ranges.

Furthermore, as it happens in every crisis period and in every market which is characterised by a low offer, electronic components' prices are rising and clients are forced to accept them. For instance, for some capacitors, manufacturers have increased prices by between 6 and 10% and the same growth has been registered on resistors and MLCCs[23]. Electronic components' makers explain price rise in two distinct

[21] LTB – Last Time to Buy and LTS – Last Time to ship

[22] End of Life

[23] Multi-Layer Ceramic Capacitors

ways. On the other hand, they are trying to recoup the margins they have lost in the past years due to price cuts and low demand level. On the other hand, they are trying to increase their profits in order to invest on capacity growth, buying new facilities and new machineries.

Now that a general overview on electronic components' market has been given and that the main reasons behind raw materials' lack have been investigated, the discussion can move to the analysis of a practical case study.

The aim of the following chapters is to show how a big and international group as Schneider Electric has decided to respond to this challenging market conditions and what are the consequences brought by the adopted strategies.

CHAPTER 4

THE SCHNEIDER ELECTRIC CASE

4.1 The Group history

Schneider Electric is a French industrial group, specialised in energy management and automation. The group exists today at an international level, with operations in more than 100 countries and 24.7 billion of revenues in 2017[24].

The group has always been characterised by a high versatility and differentiation in the activity sectors explored, one of the elements that has allowed its rapid growth and that has become one of its main strengths. The company, indeed, moved from steel industry and heavy machinery manufacturing to shipbuilding, to end with energy management and automation, with a specific focus on industrial setting.

The history of Schneider begins in 1836, when the two brothers Adolphe and Joseph Eugene Schneider took over an abandoned foundry that two years later was transformed into the Schneider & Cie company, focused on steel industry.

The organisation grew rapidly thanks to the great opportunities created by the Industrial Revolution, and the tragic events of World War I and World War II. They were able to introduce new processes and techniques in order to manufacture stronger steel at a lower cost, becoming the European leading manufacturers of weapons and infrastructures. When the war ended, however, Schneider, as many other companies in that period, had to reconvert and to look for new businesses: France had been freed but the country had to be rebuilt and civilians' needs had to be taken into consideration.

Soon after the end of World War I in 1919, the organisation decides to broaden its horizons, creating affiliates both in Germany and Eastern Europe. In the same period, they were also able to lean on Westinghouse, one of the biggest and leading company in the electrical market. The same strategy was adopted in 1948, when the weapons manufacturing was permanently abandoned, and new sectors were explored.

However, after several years of difficulties and many failed attempts to diversify businesses, Didier Pineau-Valencienne, at the head of the group in the eighties, decided to sell all branches of activities that were not profitable, focusing on the field of electricity. From then on, the company has experienced a rapid growth

[24] Schneider Electric FY 2017 Financial Results

characterized by the acquisition of several companies that gave the group the opportunity to expand its areas of expertise and increase profits. In 1986 the group decided to buy Merlin Gerin, a pioneer company in the electrical distribution sector. Ten years later, it is the moment of Télémécanique which allowed them to integrate a new sector of activity and to launch themselves into the market of the management of industrial automation. In 1991, Square D, a major US producer of electrical distribution equipment, also became part of what it was transforming into a new organisation. The company's strategy is very clear: to develop and focus its activity and expertise in the field of electricity.

To make that even more obvious, in 1999, the name of the group was changed to Schneider Electric and the company launched a strategy based on the “elimination” of any kind of border, adopting new designs and production processes. They think and act according to customers’ demand, regardless of their activities and geographical location in the world (unlike previous offers that were developed by the manufacturer forcing the customer to adapt to the product), while continuing to acquire new companies.

In a sector characterised by high competition level and rapid growth, Schneider Electric decides to buy Lexel, the second European company acting in the electrical field and invest almost € 70 million venture capital fund with Alstom in order to help the development of innovative start-ups in field of energy and environment.

In the XXI century, the company continues to grow and becomes one of the main actors in the new market sectors of industrial automation, building automation and safety.

Today, thanks to the know-how developed during almost 180 years of history, Schneider Electric has become the global leader in energy management and it is capable of providing its clients with trustworthy solutions for several critical infrastructures such as nuclear power plants.

Recently, to answer to the growing demand in the field of energy management and efficiency, the group has launched several initiatives to simplify energy access in many world regions, and to reduce power consumptions and wastes. At the same time Schneider is also trying to reinforce its positioning in the market as suppliers of high efficiency energetic solutions, able to integrate power and automation.

4.2 The main business units

The company's growth has been great and today Schneider Electric can count almost 144,000 employees operating all over the world. Its activities are spread over the four different markets you can see in figure 20.

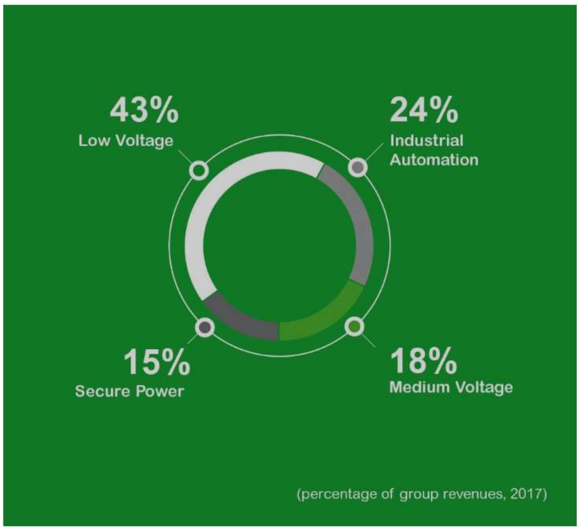


Figure 20: Diversified end markets – FY 2017 revenues

- **The Industry business**, where Schneider mainly aims at providing software solutions and products that are then installed on industrial machines to grant automation and control. The proposed products are really varied, and go from motion controllers to PLC, from human-machine interface panels for operators to push buttons and discrete sensors. Thanks to the acquisition of Invesys in 2014, they were able to expand in the Process Automation space, developing industrial software that help dealing with operation management as well as with modelling and asset management.
- **Residential market**, in which Schneider supplies products for the management of lighting, temperature, electricity as well as communication between men and machines;
- **Infrastructure market** where the group engages in the function of ensuring and guaranteeing the quality and safety of the transport and distribution of energy;
- **Building market** for which Schneider Electric is seeking solutions for low voltage power supply and distribution.

In all these markets and in all its activities Schneider is guided by the principles that are at the base of its strategy. All its products are designed to meet the needs of customers who are at the heart of every design process. Nevertheless, great attention is also paid to the quality and safety of the solutions that are offered. As a result, the desire to offer to the customer a product that is safe and capable of responding intelligently to its demand is also reflected in the development of very simple and intuitive solutions, easy to install and to use every day. Schneider is also committed in respecting the planet by trying to ensure energy efficiency, following and supporting the massive digital transformation that is taking place during our century. To do this, the group invested nearly 5% of its turnover in the R&D sector, employing more than 11,000 engineers in 25 different countries.

Given the different businesses and sectors Schneider Electric is involved in, the group has to deal with several competitors. Among the numerous companies SE[25] has to confront to, five organisations can be considered as its principal competitors, mainly operating in the energy industry

On the top of the list you can find ABB Ltd, a Swiss company, based in Zurich since 1988. With a turnover of $34 billion in 2016 and offices and operations in more than 100 countries, ASEA Brown Boveri group, is one of the leading companies in the businesses of robotics, power, and automation. It proposes a wide range of low and high voltage products for energy transportation and distribution, that can be applied to the residential and non-residential market, as well as in the industrial field. In addition, always with the aim of increasing industrial manufacturing plant efficiency and productivity, the ABB group, developed several variants of industrial robots and PLCs that can be used and adapted to companies operating in many different fields, from chemicals and pharmaceuticals to the naval one and from metals to the one of oil and gasses.

Another giant competitor Schneider Electric has to deal with is General Electric, a company providing solutions for everything which is connected to generation, transmission, distribution and control of electricity. The group is, nowadays, divided into eight different segments which are focused on eight different businesses: Power

[25] Schneider Electric

& Water, Oil & Gas, Energy Management, Aviation, Healthcare, Transportation, Appliances & Lighting and GE Capital. General Electrics is, therefore, able to propose to its client a very large palette of solutions: healthcare monitoring devices and intelligent sensing and inspection Technologies exploitable in the industrial field, as well as financing solutions both for companies and consumers. In addition, they are investing part of its always increasing turnover in projects focused on the research and exploitation of natural resources. The group, that can boast a long and famous history[26], counts today roughly 36 branches and 300 000 employees all over the world.

In 2014 General Electric conflicts against Siemens for the acquisition of Alstom electrical branch, winning the challenge thanks to a 13 billion offer. This originally German company, founded in 1847 by the engineer Werner von Siemens, is, in fact, another fundamental actor to consider inside the market Schneider Electric is working in. With its 380 000 employees Siemens is, indeed, considered as the largest employer in Germany and the biggest engineering organisation in Europe. Four are the main divisions of the company, which also reflect its principal areas of work: Industry, Energy, Infrastructure & Cities and Healthcare. This last sector generates almost 12% of the company's total sales and it can be, therefore considered as the second most-profitable unit, behind industrial and building automation sector. One of the main strengths of this organisation is its attention and focus on research and development. As a matter of fact, Siemens can number more than 170 R&D centres all over the world, and every year, more than 5% of their total turnover is invested in the design of new solutions. The company ranks, therefore, today, among the largest patent holder in the world with a record of almost 60 000 patents filed in 2016.

Among the multinational groups acting in the power management field, Eaton Corporation Plc cannot be forgotten. The company has two different business sectors, the electrical and industrial one, with which it is able to serve customers in more than 175 different countries worldwide. The solutions provided aim at improving the quality of life and environment, thanks to the exploitation of power management services and technologies. The product's range stretches from the electrical and hydraulics sector to the aerospace and automotive one, for which the company develops automated

[26] The original company was founded in 1892 by Thomas A. Edison

truck transmissions, safety systems and hybrid powertrain systems. The corporate HQ is in Dublin and two years ago the company closed its balance sheet with $19,7 billion of sales.

Finally, probably the best known and the fiercest among Schneider's competitors is IBM. The company, born in 1911 from the merger of four different organisations, operates today through five different segments: Cognitive Solutions, Global Business Services, Technology Services & Cloud Platforms, Systems and Global Financing. Among the most popular products there are software, hardware, hosting and consulting services for several different organisations. IBM is the biggest technology company in the world, with a turnover of almost $ 79 billion in 2017, which returns to grow after six long years. The main strength of IBM was the speed with which they understood the impact of the data phenomenon on technology and business and the reactivity that gave them the possibility to rapidly adapt.

4.3 Carros site

Carros plant is a relatively new site, built in 1971, as a part of a subsidiary of Schneider Electric, Schneider Automation, that was then integrated inside the group on July 1, 2016. The site is specialised in the production of electronic boards and PLC modules, that are installed on industrial automated machines. It is located in the valley of the Var, a few kilometres away from Nice, a very dynamic environment which is in full development in recent years.

The goal is to transform this valley into a "Silicon Valley, à la sauce niçoise", a French technopole in which the companies installed can benefit from the know-how of others and grow more quickly. This is the main reason that convinced many organizations to come to set up their R&D centres there.

This is the exact same decision taken within the Schneider Electric group, which invested € 14 million in 2011 and moved its innovation centre from Sophia Antipolis to Carros, creating the Horizon Site. The goal of this relocation was to bring together two different departments: manufacturing and R&D, in order to intensify and simplify exchanges between the two sectors. In this way, every product change or new product designed by the R&D department are directly manufactured on the site, a solution that allows a much easier and more effective communication by helping to reduce the time to market of new products.

Horizon is also used as a showcase for all the products manufactured by the group, products that are directly installed on the site, guaranteeing the energy self-sufficiency of the building, as well as the reduction of environmental impacts. For instance, the orientation of the north-south building allows to take full advantage of natural light, while the coloured grids on the west facade provide thermal protection. In addition, the measurement of energy performance is ensured by Schneider’s products which make it possible for everyone to monitor consumption in real time, a collection of data that is available to all the employees who want to access it.

Carros site has nearly 800 employees, including 350 in R&D, 300 in production while the rest is working for all the support functions: logistics, purchasing and accounting. It can therefore be said that the site is composed of two different and well-defined parts:

production and R&D. This structure is also evident in the organization chart and division of responsibilities. There is, indeed, a site director that manages, on the one hand, the development of new products and, on the other hand, production. The factory manager is responsible for managing the support function managers, such as HR and Finance, as well as the heads of the operational functions, including Quality, Industrial Management and Logistics, Methods and Production.

4.3.1 The product physical flow

The Production service is divided into four different sectors that allow the transformation of a PCB[27], purchased from the supplier, to an assembled module that constitutes an API (industrial programmable logic controller).

The first sector is the CMS-Surface Mounted Components - where PCBs are received, and the first components are laid on the surface of the blank boards. The first step that can be found on the Production Order is, therefore, the marking on the PCB, of a data matrix, a code that identifies the card internally throughout the whole production cycle. Then, using an assembly sheet and respecting the priorities established by the Scheduling manager, the operators take care of the preparation of the setups in order to launch the production of the established batches. Reels, containing specific components for that batch, are picked from the supermarkets found next to assembly machines and mounted on trolleys that are then mounted on the reporting machines. The PCB then begins its on-line production cycle. A paste is placed on the board and on all the points where the reporting machines will place the components. The PCBA[28], therefore, is automatically moved inside an oven where the components are permanently soldered to the board surface.

Precision in laying the components is a fundamental element in this first phase. Indeed, an excess of paste or the offset of one or more components may compromise the proper operation of the card and then of the final module. For this reason, several control points have been established along the three production lines at the CMS. The first two are carried out automatically by machines that check the conformity of the

[27] Printed Circuit Board

[28] Printed Circuit Board Assembly

dough and the correct positioning of the components. A third checkpoint is performed on samples by operators as the assembled board comes out of the oven. Despite the high level of automation in this first sector, the presence of the operators is constant and very important. Indeed, the first card of each series is always controlled by a team leader, who must also be able, at any time, to solve the problems that prevent or slow down the production rate.

The PCBA can then move to the IM sector - Manual Insertion - where the components are placed by operators on the boards arriving from the CMS and then passed inside a machine called “la vague[29]” that allows them to be soldered. The difference between the components that are placed on the CMS and those assembled at the IM is that the first ones are only placed on the surface of the board, while the second are crossing the card’s surface. The reason that can explain the difference in the assembly process is that, given the different shape of the parts, the installation of the crossing components is more complicated and therefore requires an expertise and precision level that cannot be achieved by an automatic machine. In addition, components that are mounted on the surface of the PCB are common to multiple cards, which allows them to be placed with the same setup and assembled with a speed that would be impossible for a human being.

Once the cards are checked at the exit of the oven, they pass to the next sector where the cards are tested on nail boards, where the correct functioning of all the assembled components is checked. If problems are detected, technicians are asked to take actions in order try to fix them, before deciding to scrap the defective outputs. Moreover, some of the boards need an additional assembly phase, the coating, which of course extends the production time.

It is after this stage that a further step can be done along the production line, towards the assembly of the finished products and thus to the last sector: the modules. This sector has a different structure compared to the first three. As a matter of fact, it is divided into three sub-parts, each one of them including a certain number of lines where different ranges of products are assembled. For each finished product, normally,

[29] The wave

a dielectric test and then a functional one is performed, before moving to the packaging phase.

Finally, the last step is thought and organised to simulate final customers actions and check the quality of end products. The operators, indeed, open a sample of finished goods and check the presence of all accessories and manuals, as well as the quality of the product marking and its external appearance. This ensures the quality of the product that is then shipped to the customer. Once the step is validated, the products are sent to the downstream store (or outgoing dock) from where they are shipped out the same day.

As a matter of fact, no finished product inventory exists in Carros: at the end of the day products are sent to Schneider Distribution Centre in Lyon that is then in charge of managing the relationship with national distribution centres. It is from there that they are then shipped to final customers or distributors.

In the below scheme, a graphical representation of the physical flow of products among the sectors is given in order to make the concept clearer and easier to visualize.

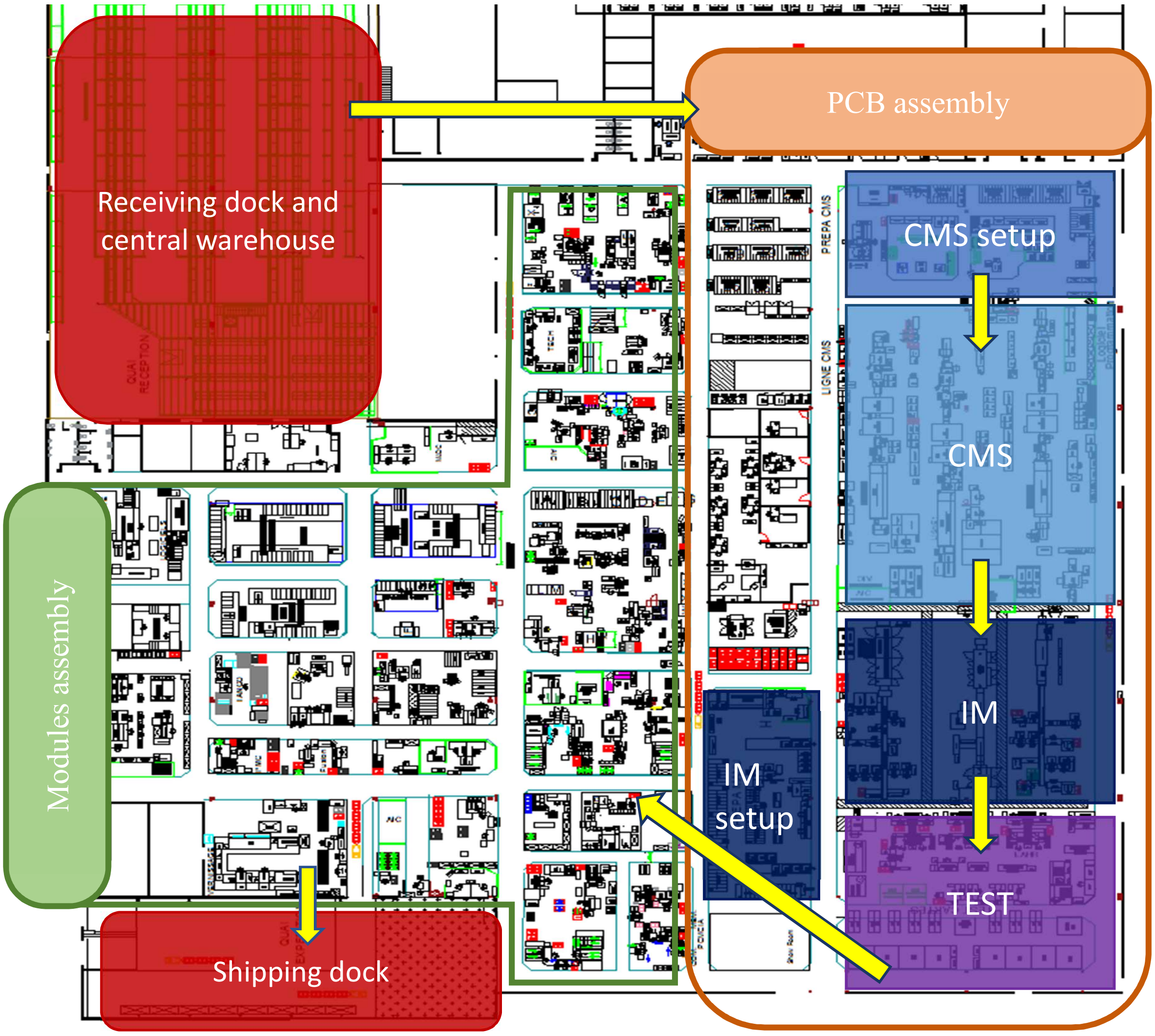


Figure 21: Material flow inside the factory

In order to reduce inventory costs and minimise the number of products stocked, the production system adopted in Carros is the pull one, meaning that raw materials and components are purchased or made available near the production lines only when the Production order is placed. However, this model has to be adapted to the constraints generated by the contractual lead time which is established between Carros production and logistic department and the distribution centre.

As a matter of fact, when the distribution centre emits an order to the manufacturing site, the production department has a specific number of days to satisfy it, specifically 10 days for an MTS product and 7 for an MTO. However, the overall production lead time is higher. The time needed to complete the manufacturing process is almost 17 days: 10 days should be counted for the first production phase that goes from components' placement on PCB to card coating and testing, plus 5 days of module assembly and one day of pick, pack and ship, to move products to the shipping dock and put them inside the truck. In the figure below a time line representing the overall production lead time is provided, in order to show the different phases.

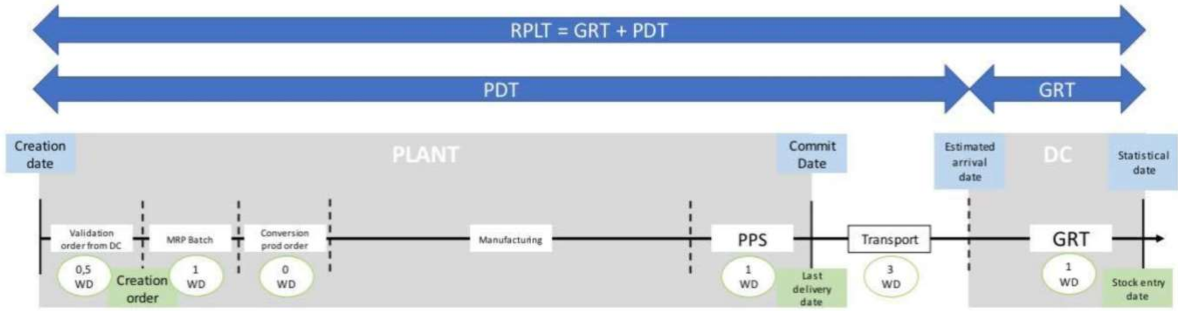


Figure 22: Production time line

As you can easily imagine, the actual time needed to manufacture a production order for modules is much smaller than 5 days. However, the waiting queue is used as a strategy to smooth demand variations. The general rule is that it should be kept between two and five days maximum on every production line. Whenever it drops below 2 days, indeed, actions should be set up in order to increase the workload on that specific product range. On the other hand, if it grows over the 5 established and agreed days, it means that production will be delayed due to capacity lack or the need to make up for the accumulated delay.

However, as you can easily understand if the production department waited for customer's orders to be placed before starting any phase of the transformation process, no product would be shipped out on time. Hence, the need for supermarkets which allow to respect contractual lead time and be on time. Since the average cycle time for module assembly would permit the factory to respond to the DC requirements, an intermediary inventory is, therefore, placed between the PCBA and module sectors. The supermarket can, then, be considered as the customer decoupling point of the production system, the moment in which the flux stops being pushed by raw materials' arrival and starts to be pulled by customer's orders. As a matter of fact, in a normal condition, when the DC places an order, the module sector should be able to find PCBA in the supermarket in order to start the last phase of the manufacturing process.

Supermarket replenishment, as any other kind of inventory, will depend on part lead time, its value or price, depending on the fact that it is bought or manufactured, and the costs linked to order placement.

Concerning raw material inventory, as explained in the previous chapters, every product has its own replenishment method, according to its specific characteristics, therefore, the best strategy should be adopted in order to minimise ordering and transportation costs on the one hand and holding costs on the other.

Carros site has, indeed, two big central warehouses, one placed inside the factory and the other one located at almost 4 kilometres from it. Starting from the production department transfer orders are placed in order to replenish the little inventory that can be found on the lines border. As soon as the concerned sector estimates that it does not have enough pieces to continue with production for the following two hours, another OT – Transfer Order – is placed that the central warehouse is supposed to deliver in one hour, under normal conditions. Once the finished products are ready to be shipped the central warehouse receives a message, asking them to collect the finished goods and bring them to the shipping dock.

Now that the main phases of the production process have been explained it will be easier to understand how the electronic components' shortage can impact manufacturing and logistics daily activities.

4.3.2 The solutions adopted to overcome the crisis

As many other companies working in the sector and producing automated solutions at an industrial level, Schneider has been also impacted by electronic components shortage. Despite its size and of needs in terms of quantities purchased, the group does not represent one of the biggest clients for electronic components manufacturers compared to big automotive and telecommunication organizations. Therefore, it is not the first company served when parts need to be allocated and solutions were searched to deal with this critical market condition.

One of the first strategy that has been adopted by the company to reduce the impact of components' lack or, at least to anticipate possible shortages, is the creation and daily consultation of the "Netshort" file, which represents the net requirements of all those parts on which available stock, safety stock included, and already placed supplying orders are not enough to cover company needs are highlighted.

As it is clearly showed in the picture below, for all the parts, a line with requirements and needs is available, showing both already placed customers' orders and forecasted demand, plus a line showing the amount of parts that should be received on a specific date. Finally, a third line is used to calculate the difference existing between available stock and incoming orders and the requirements. Every time the latter is higher than available resources, planners are alerted, and corrective actions should be taken.

TAGES				-1	0	1	2	3
	Material	Data	Stock	LATE	31	32	33	
3000	29220404BL	Need	5318	3076	3589	386	1538	
3000	29220404BL	Supply	5318	0	0	0	0	
3000	29220404BL	Stock e/o wk	5318	2 242	-1 347	-1 733	-3 271	-4

Figure 23: Netshort example

The file is built, taking into consideration the needs and requirements on the twelve following weeks, which allows planners to anticipate possible shortages and avoid that missing quantities block production lines. A column showing the late requirements is also available, to give the planner a wider picture. The logic existing behind the Netshort is that only actual shortages are taken into consideration. As a matter of fact, in this case, safety stock is considered as a resource, included in the available inventory. Therefore, missing quantities really represent the moment in which on-hand stock reaches zero level and production is stopped. Planners should then, define actions in order to cover the periods on which resources are not sufficient.

The first thing they generally do is to ask suppliers to pull in the orders. As previously explained, buyers prefer to cut through distributors, instead of dealing directly with the manufacturer for logistics and safety reasons. In a shortage market, however, the presence of a third intermediary slows the escalation process down. Indeed, if the distributor does not have any available stock or any possibility to "borrow" missing quantities from other customers, it should escalate clients' requirements to its vendor so that they could prioritise their production plan.

However, in a shortage market like the one companies are dealing with today, pull in actions are not enough, since manufacturers do not have the flexibility to respond to any requirement change: they are already working at their maximum capacity and very few adjustments are possible, but they are not often enough. Therefore, other solutions should be investigated. Generally, the first step is to look for available stock coming from other Schneider sites or a distributor different from the one that is usually used for that specific part. Of course, proposed prices will be higher, since the habitual source is supposed to be the cheapest one, but this is still considered as the preferred solution compared to following ones. For every purchased part, a list of possible alternative sources can be consulted, giving the planner the possibility to see which manufacturer part numbers could be bought to replace the missing one, their quality status[30] as well as the distributors that are authorised to sell that specific brand.

Offers are requested to franchised distributors and then sent to the purchasing team so that they can validate the extra cost.

Hum	Manufacturer Item	Color	CAS	Deviation	Comment	Quality Status	Purchasing Status
	741-0.032768-63 FOX ELECTRONICS *ZNE100000385215*		R3		-----	Approved without restriction	Commercialized
	CM519-32,768KDZFT-F1S CITIZEN *ZNE100000116835*		R3		-----	Approved without restriction	Commercialized
	Q13FC2550000914 EPSON *ZNE100000227948*		R3		-----	Restricted use Submit a deviation request	Commercialized

Figure 24: Alternative sources database

Given that the crisis is global and that almost all manufacturers are facing the same problems, few companies are willing to share their stock because they fear they will have to deal with the same problem in the future. In addition, some parts are specific, therefore they are produced by one single source and no other seller has the expertise to deal with that. Nowadays, many efforts are being made by buyers to differentiate procurement sources and reduce risks.

When all these solutions fail, available parts should be searched through a broker. Schneider purchasing team has a specific list of trusted brokers that have been tested and approved. As a matter of facts, given the big problems that franchised manufacturers have in producing components and keep up with customers' demand,

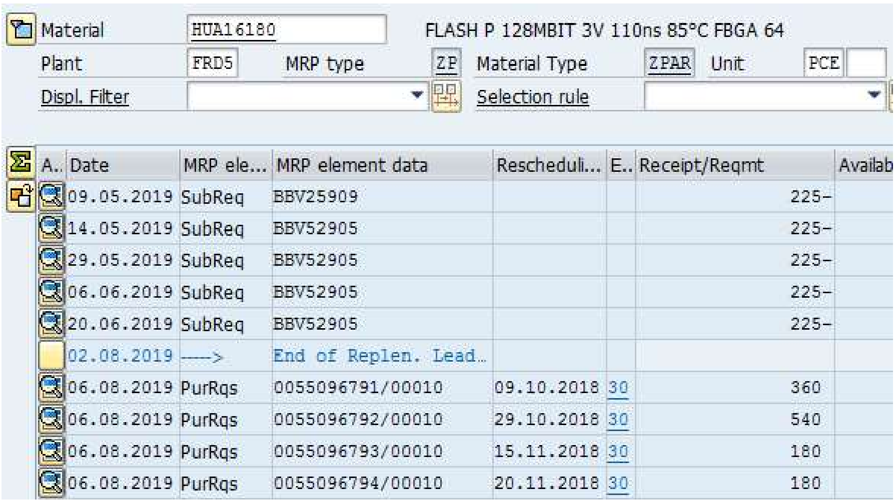
[30] Approved without restriction, Restricted use or Forbidden

the number of non-franchised distributors is growing very rapidly, therefore, great attention should be paid when buying parts directly from them to be sure that components are compliant and can be assembled on PCB without any problem. For the most critical parts, however, an action with manufacturer should be done directly by purchasing team, to ask them to prioritise certain urgent products rather than others.

Another strategy adopted by the group to try to secure procurements is the order anticipation. In normal market conditions, planners are asked to release procurement orders on the base of parts' lead time. For instance, if a part lead time is 30 weeks, the Purchase Order is placed 210 days before the shipment is really needed, for a quantity that will cover the production requirements that have been forecasted. To secure supply chain, a list of critical part numbers has been identified by the purchasing function on the base of the information received by manufacturers and of a deep analysis performed on current and future market conditions. For all the passive components, the request was to place orders till the end of 2019, since they represent the parts on which the biggest problems are recorded; on the other hand, active components were ordered till June 2019. The main idea behind this strategy was to be as transparent as possible towards distributors and manufacturers, so that they could plan and organise their production and capacity on the base of real orders and not only of forecasted quantities. However, when placing orders to cover horizons that are so far from the current date, a practical problem appears linked to forecasts and the maximum number of data that can be stored inside an MRP system. As already explained in the previous chapters, an MRP works on the base of forecasts that are uploaded and that represent company needs.

Nevertheless, no more than 15 months of forecasts can be uploaded in the system as any additional line is cancelled every night, when the MRP recalculates and relocate planned orders. Therefore, beyond the planning horizon, no planned order is available to be released since the system does not "see" any need. In addition, even if 20 months of forecasts could have been uploaded in the system, they wouldn't have been that accurate. Over such a long horizon, only a rough estimation of demand trend can be done, taking into consideration historical data and marketing forecasts on final product groups. That is the reason why, once all the orders are anticipated and placed, a regular review should be done, in order to verify if the purchase orders that were positioned still fit with the needs' evolution or if a part of them should be cancelled or, on the contrary, parts are still missing.

When parts are really critical, and manufacturers are not able to produce more than a specific quantity, they allocate a limited amount of parts to the specific customer, according to its forecasts. In addition, when orders are placed via a distributor, it is impossible for them to confirm a precise delivery date before having received the pieces from the manufacturer and the confirmation that the quantity is allocated to them. In order to rapidly recognise them the strategy was to change the component lead time, passing from, the one communicated by the distributor to 365 days. As you can see from the picture below, this solution also allows to generate exception messages indicating the moment in which the order quantity is really needed. In this case, when the planner releases the order, the requested date should be changed from the one defined by the system, beyond the replenishment horizon, to the one proposed in the exception message. In addition, for allocated products, the directive is to place orders to cover the "fictitious" lead time, so that supplier has a clear view of what is requested and can anticipate corrective actions when needed.



Material	HUA16180	FLASH P 128MBIT 3V 110ns 85°C FBGA 64					
Plant	FRD5	MRP type	ZP	Material Type	ZPAR	Unit	PCE
Displ. Filter				Selection rule			

A..	Date	MRP ele...	MRP element data	Rescheduli...	E..	Receipt/Reqmt	Availab
	09.05.2019	SubReq	BBV25909			225-	
	14.05.2019	SubReq	BBV52905			225-	
	29.05.2019	SubReq	BBV52905			225-	
	06.06.2019	SubReq	BBV52905			225-	
	20.06.2019	SubReq	BBV52905			225-	
	02.08.2019	----->	End of Replen. Lead...				
	06.08.2019	PurRqs	0055096791/00010	09.10.2018	30	360	
	06.08.2019	PurRqs	0055096792/00010	29.10.2018	30	540	
	06.08.2019	PurRqs	0055096793/00010	15.11.2018	30	180	
	06.08.2019	PurRqs	0055096794/00010	20.11.2018	30	180	

Figure 25: Example of an under allocation part – SAP view

One of the several reasons that encourages buyers to purchase electronic components through a distributor and not directly from the manufacturer is that lead times are generally shorter, since they work with different customers and they are more flexible.

However, shortage is making it harder, even for distributors, to find electronic components on the market, since manufacturers lead times are stretching; consequently, distributors are forced to propose to their customers longer lead times too. The strategy adopted is then to use manufacturers lead times inside an MRP system which permits to place the order to the distributor before it is too late and, consequently shipments delayed.

Another tool that logistics can use to limit shortage's impact on production and customers is inventory, and specifically, safety stock. The rough formula to calculate its necessary amount, which is generally used inside companies, when not all historical data are available is:

$$\textit{Safety stock} = Z\ x\ \sqrt{LT}xADU$$

- ADU: Average daily usage

It is evident, then, that every time the Lead Time increases, the amount of Safety Stock needed rises too. Let's take a practical example, to make the concept clearer.

If a part has a 77 days lead time in normal conditions and an average daily usage of 180 pieces, the safety stock needed would be of approximately 3300 pieces. Due to manufacturers' difficulties and capacity problems, lead time stretches, reaching 210 days. If the average daily usage remains the same, the new safety stock will rise to almost 5400 pcs. The general rule that is in place inside the group would suggest reducing security stock to zero when difficulties are encountered. As a matter of fact, safety stock is considered as a requirement which generates a bigger need for the part, therefore orders are needed earlier, and shortage is theoretically reached before. This solution can be considered effective on the short-term, but it would create serious problems if adopted in a situation in which market conditions are supposed to worsen and no end date is still available. Therefore, the complete elimination of safety stock increases shortage risk, since there is nothing that can protect from demand variability or suppliers' delays.

That is the reason why Schneider has decided to adopt the exact opposite strategy of the general rule. Safety stock were revised upwards for the most critical parts. This solution permits, on the one hand, to secure and be protected from unexpected events and, on the other hand, to create exception messages that really reflect the severity of the situation. The MRP, indeed, will ask the planner to pull in the placed orders earlier enough to rebuilt security stock too and corrective actions will be taken before a zero-stock level is reached.

Once parts are received, an additional day should be counted in order to give people working inside the warehouse the time to make the necessary actions to put, both informatically and physically, the received parts inside the right storage location. Only when all these operations are completed, parts appear as a resource for production and transfer orders can be placed in order to directly receive parts on the production line. However, given the warehouse workload, especially before suppliers' holiday periods, all these activities could be delayed, since many shipments are anticipated. It can happen, therefore, that very critical parts remain on the receiving dock several days before being available for the production department, which cannot place orders before the parts are physically put in stock. That is the reason why three times a week during the meeting on which the most critical issues are addressed, a representative working inside the warehouse is invited in order to be informed about the most critical shipments, the ones that should be closely followed in order to accelerate output recovery.

As you can imagine, logistics is not the only department which is impacted by components' shortage. As a matter of fact, every time a part is received later than expected, production is delayed, and when it is finally received solutions should be adopted in order to catch up with the accumulated delay. This can create difficulties in managing capacity and organising shifts. When parts are not available, not all the operators that usually work on the line are needed and they should be affected to other product ranges. Operators should then be trained on the assembly process of several production lines in order to increase sector's flexibility and easily adapt to demand variability. The need to continuously move operators from one production line to the other, and the fact that they cannot know the specificities of every product range can generate quality issues as well as the slowing down of the entire process. Training projects have, therefore, been developed by the production department, in collaboration with process and product engineers, to create supports that are directly installed and accessible on the lines. Workers have, then, the possibility to consult them while assembling the product and they do not necessarily need the presence of a trainer, or at least not throughout the whole production process.

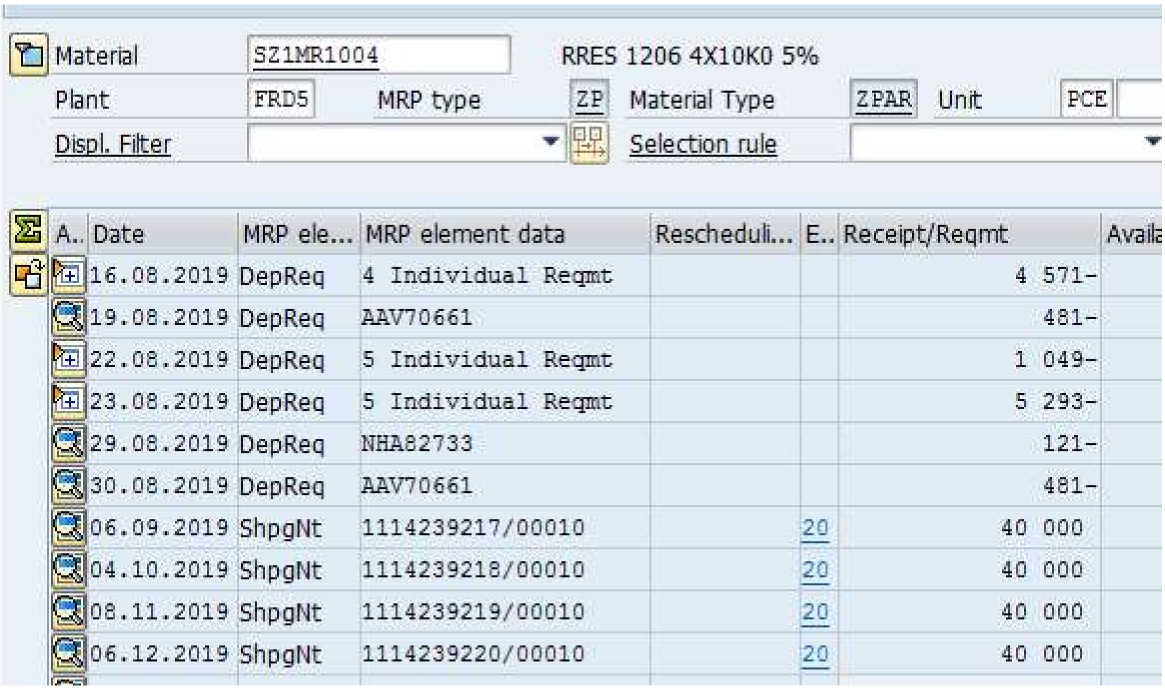
For the same reason, a great attention is also paid to the supermarket existing between the PCB sector and the one in charge of assembling finished products. It should, indeed, be able to decouple the two production phases making them independent of each other. Even if raw materials are not available, modules should continue to be assembled starting from the PCBA that are already prepared and stocked in the supermarket. This permit, on the one hand, to continue to respond to customers' needs and, on the other hand, to wait for the missing part to be received again and go back to a normal situation.

When upstream strategies are not sufficient, and shortage impacts the final customer, additional solutions should be investigated and implemented between Carros plant and the Distribution centre in Lyon in order to prioritise receipts and shipments toward customers. One of the simplest but also effective solutions implemented is the placement of labels on the carton with a red message "SHORTAGE". The main aim is to make these parts more visible than the rest when they arrive at the distribution centre. In this way, people working inside the warehouse know that they should be treated as a priority: placed in storage and then shipped towards the end user.

4.3.3 Solutions analysis: main drawbacks

All the solutions adopted have the aim to increase the company flexibility and to limit that the shortage impacts production at most. However, even if solutions can, often, seem effective they can generate additional problems, due to the fact that informatic tools were not adapted to new requirements, or simply because they generate an extra cost that should be kept under control.

Concerning logistics point of view, the main issues that are recorded are linked to order anticipation. As explained in the previous chapter, when passing orders to secure procurements, many of them had a requested date that fell beyond the planning horizon. Therefore, no forecast is uploaded in the system and needed quantities have to be calculated on the base of the average monthly usage. Due to forecasts' absence, all the orders that are placed for this period appear with an exception message asking the planner to cancel them. For the MRP system, indeed, no quantity is required and, therefore, no purchase order would be needed. As you can see looking at the Figure 24, every order placed on period with zero forecasts, beyond 15 months, are to be cancelled.



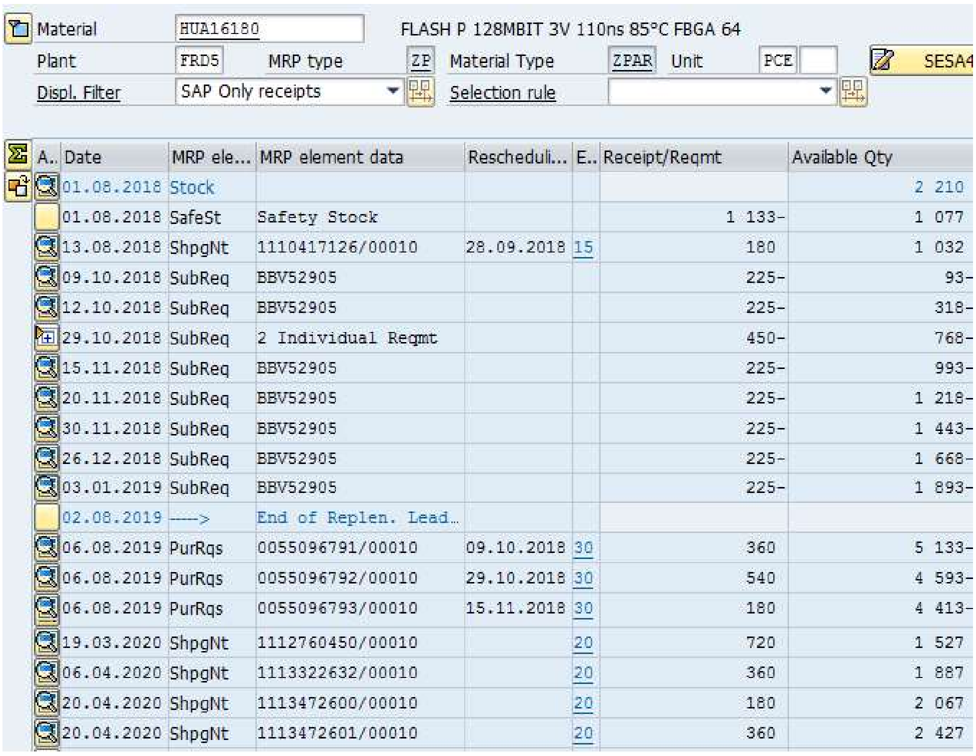
A..	Date	MRP ele...	MRP element data	Rescheduli...	E..	Receipt/Reqmt	Availa
	16.08.2019	DepReq	4 Individual Reqmt			4 571-	
	19.08.2019	DepReq	AAV70661			481-	
	22.08.2019	DepReq	5 Individual Reqmt			1 049-	
	23.08.2019	DepReq	5 Individual Reqmt			5 293-	
	29.08.2019	DepReq	NHA82733			121-	
	30.08.2019	DepReq	AAV70661			481-	
	06.09.2019	ShpgNt	1114239217/00010		20	40 000	
	04.10.2019	ShpgNt	1114239218/00010		20	40 000	
	08.11.2019	ShpgNt	1114239219/00010		20	40 000	
	06.12.2019	ShpgNt	1114239220/00010		20	40 000	

Figure 26: Example of annulation messages – SAP view

The same problem can be recorded for all allocated parts. Given that no order confirmation is possible before pieces are received by the distributor and allocated to the specific customer, distributors, cannot confirm orders placed by their customer. Therefore, they commit on a date which is very far and that falls beyond the planning horizon, like for instance January 2020, to commit on a more realistic date just after, once they would receive manufacturer's confirmation. As before, all these orders have an exception message of annulation. In this case, however, the system asks the planner to release new orders to cover the gap that is generated by orders confirmed so late.

The problem is that even if new orders were placed and old ones cancelled, the same committed date would be confirmed by the supplier, without changing the situation. In addition, the issue of planned orders that should be released to cover for the purchase orders that the system wants to delete, generates another subsequent problem. As a matter of fact, to reduce the number of planned orders a planner has to release manually, on many components an automatic flag has been put, in order to allow the MRP system to release the orders without planner intervention, on the base of the replenishment lead time and requirements.

However, since many orders have been anticipated and the majority of them have been confirmed very far away compared to the requested date, automatic flags have been removed, forcing the planner to daily analyse fixed receipts and forecasts and decide whether to place or not the purchase order. The system would, otherwise, automatically release orders that are not needed since forecasted demand is covered by already placed orders that just need to be rescheduled, in the light of manufacturers' commitment and needs' evolution. Hence, most of the exception messages generated by the MRP system on such parts are false and, instead of helping the planner in its daily activities, force him to double his attention and efforts. Benefits generated by an automatic MRP, therefore, are eliminated by the crisis and the solutions that have been adopted.



Material HUA16180 FLASH P 128MBIT 3V 110ns 85°C FBGA 64
Plant FRD5 MRP type ZP Material Type ZPAR Unit PCE SESA4
Displ. Filter SAP Only receipts Selection rule

A..	Date	MRP ele...	MRP element data	Rescheduli...	E..	Receipt/Reqmt	Available Qty
	01.08.2018	Stock					2 210
	01.08.2018	SafeSt	Safety Stock			1 133-	1 077
	13.08.2018	ShpgNt	1110417126/00010	28.09.2018	15	180	1 032
	09.10.2018	SubReq	BBV52905			225-	93-
	12.10.2018	SubReq	BBV52905			225-	318-
	29.10.2018	SubReq	2 Individual Reqmt			450-	768-
	15.11.2018	SubReq	BBV52905			225-	993-
	20.11.2018	SubReq	BBV52905			225-	1 218-
	30.11.2018	SubReq	BBV52905			225-	1 443-
	26.12.2018	SubReq	BBV52905			225-	1 668-
	03.01.2019	SubReq	BBV52905			225-	1 893-
	02.08.2019	---->	End of Replen. Lead...				
	06.08.2019	PurRqs	0055096791/00010	09.10.2018	30	360	5 133-
	06.08.2019	PurRqs	0055096792/00010	29.10.2018	30	540	4 593-
	06.08.2019	PurRqs	0055096793/00010	15.11.2018	30	180	4 413-
	19.03.2020	ShpgNt	1112760450/00010		20	720	1 527
	06.04.2020	ShpgNt	1113322632/00010		20	360	1 887
	20.04.2020	ShpgNt	1113472600/00010		20	180	2 067
	20.04.2020	ShpgNt	1113472601/00010		20	360	2 427

Figure 27: Example of annulation messages for allocated parts – SAP view

The choice of anticipating the orders for a portion or all 2019 has an impact not only on logistics department and its daily tasks but also on the negotiations that are done by buyers at the end of the year to define which distributor is awarded as well as the price. In normal market conditions, very few orders are placed for the following year, before negotiations end. On July, forecasts on all electronic parts, coming from all the group's factories, are collected and then shared, through a global file, with buyers. In this way, requirements are cumulated on every part and all valid sources are consulted to negotiate prices and minimum order quantities either with the vendor or the distributor. Once the agreement is reached, the chosen supplier receives the information that it has been awarded and further discussions are done on minimum order quantities and lead times.

However, nowadays, lead times extension and components scarcity have forced the company to commit for orders on a longer horizon. The result is that buyers do not negotiate on forecasted quantities anymore, but on something that has already been ordered, which reduces their bargaining power. In addition, prices continue to increase, which is out of the ordinary situation. As a matter of fact, in the past, when a specific tariff had been negotiated, no change was made during the year. Today, however, given the difficulties of manufacturers and the investments they are doing to boost their capacity, they are forced to increase prices in order to cover their higher production cost, and clients are forced to accept prices' evolution. This generates an increased workload for both planners and buyers. As a matter of fact, to prevent that invoices are blocked by the accounting team, planners should update the order prices. Nevertheless, if the information is received once pieces have already been put in stock, the order price cannot be modified, and buyers are responsible for verifying the information and unlock the invoice. If this operation is not completed quickly or price verification requires time, invoices suppliers are not paid, and they can decide to cancel orders or wait for invoices payment before proceeding with new shipments. This problem is especially recorded for passive components, which are the most critical parts, to this day.

The amount of invoice litigation has, therefore, dramatically increased, reaching its highest level since 2010. Last analysis show that the number of invoice problems got to almost 11500 at the end of July, recording a 17% increase compared to end of June. When looking at the situation in 2017 and 2018, in the graphs below, it is evident that the biggest increase can be seen for all the invoices connected with production, invoices that are issued by the suppliers after products' shipments. As explained in the previous paragraph, all these issues are linked to price rise and the increase in the workload for supply chain and purchasing teams. However, despite the negative KPIs generated by the laying around payments, the biggest issue is connected to the vendor account locking inside the MRP system. Due to that, no additional PO can be placed, shipments are blocked and payments' receipts should be provided in order to unlock the account and come back to the normal situation.

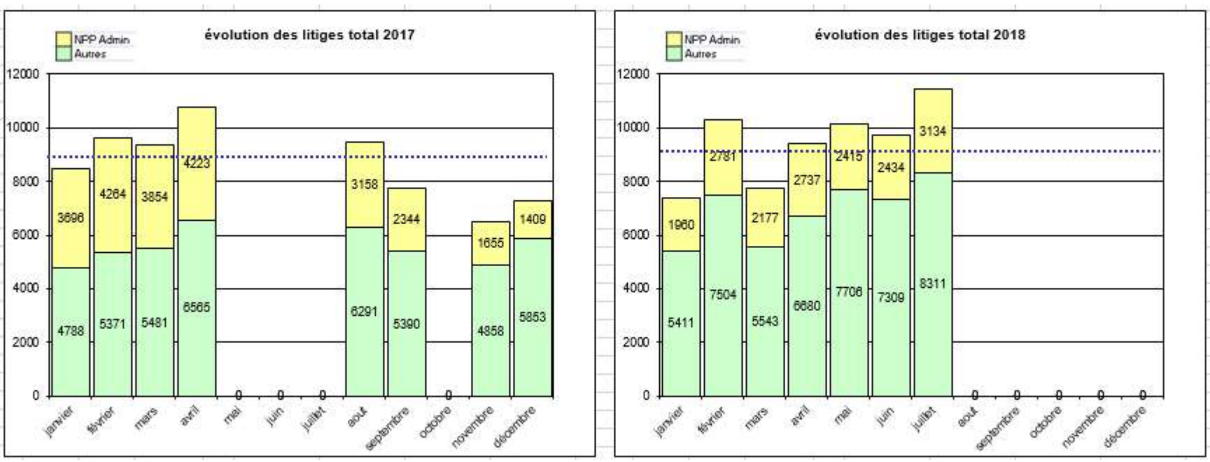


Figure 28: Invoice litigations follow-up

Concerning negotiation, therefore, buyers are forced to look for other leverages to focus on. As explained before, it can happen that pull in are refused or that shipments are delayed due to capacity problems. Alternative solutions are, therefore, searched to avoid shortage. This means that additional quantities are purchased and that on certain parts that are either at the end of their life cycle or on which consumptions are very low, parts purchased from the usual supplier become unnecessary. Moreover, every time that parts are bought from other sources an extra cost should be considered since the proposed price is generally higher than the usual one. As it is becoming bigger and bigger it is budgeted and its amount is monitored every month. As you can see in the table below, the average extra cost per month recorded this year from January to June has increased by 30%, compared to the global one of 2017, when the crisis had just begun.

EXTRA COST FOLLOW UP	
January	5 000.00 €
February	23 000.00 €
March	39 000.00 €
April	30 000.00 €
May	13 000.00 €
June	7 000.00 €
Total 2018	**117 000.00 €**

Total 2017	**88 600.00 €**

In the recurring analysis made by buyers, many information can be found not only about costs, but especially about more and less reliable suppliers and distributors, about their flexibility and ability to respond to demand variation. All these elements, as well as their willingness to cancel orders when they are not needed anymore, are used during negotiations in order to obtain more favourable terms.

But the solution of buying pieces from other sources does not only have an impact on costs. As a matter of fact, when planners need additional parts they investigate and consult suppliers for all the parts they are authorised to buy, including the ones that are in Restricted Use. For all these components a deviation request should be submitted to the quality and R&D teams and an analysis should be performed in to be sure that new manufacturer part number does not have any negative impact on products that are manufactured in Carros. The alternative sources database, indeed, is used and valid for all Schneider production sites, therefore information should be analysed attentively. As you can imagine this operation can be time consuming and responses can arrive too late, when the available stock found has already been consumed by other customers.

One of the first strategies that were adopted in order to be covered from suppliers' decommitments was to increase the amount of products stocked. If, on the one hand, the strategy gave the possibility to cover and anticipate shortages on several components, it created, on the other hand, a serious problem inside company's warehouse. As a matter of fact, several problems have occurred due to the lack of available storage locations or the excess fixed asset value. The supply chain team, indeed, is challenged on inventory value and of course should try to optimise deliveries and product placement inside the warehouse.

One of the solutions adopted was, therefore, to transfer a selected list of parts from the central inventory to the off-set one at Transcan. The decision has been taken on the base of part consumption made by the manufacturing service and its volume. As a matter of fact, every component for which consumption is low or not too frequent and that are characterised by a high volume, the transfer has been decided, in order to free up space. However, it results in a longer time required to replenish the intermediary inventory that are located next to the production lines, since three – maximum four shuttles are set up between the decentralised warehouse and the factory. The main problem is, indeed, the fact that the same driver is not only responsible for parts transfer but for also for components deliveries to subcontractors that are located in the way between the manufacturing plant and the warehouse.

As it can easily be understood, the shortage as well as the problems generated by the solutions adopted are impacting not only the logistics and purchasing department but production too, since it is the function for which components are purchased. Missing parts make it even more complicated for production managers to adapt capacity to customers' requirements and schedule operators' shifts in order to keep the waiting queue around the agreed five days. When situation is really critical and the accumulated delay too high, the possibility to create an extra-shift is explored, both for the creation of third shift after 10pm or on Saturday.

It generates, of course an additional cost and volunteers should be found. In addition, reasons, duration of the extra-shift and the names of people that volunteered should be provided to the works committee that should decide whether to accept or refuse the proposal.

4.3.4 Solution analysis: further suggestions

Solutions adopted are helping the group to reduce the impact of components' shortage on production and customers, but many drawbacks and criticalities are still present. As a matter of fact, components' shortage has forced companies to look for solutions to secure production and continue to serve cutomers, but informatic tools were not completely adapted to new requirements and, sometimes, consequences were not too deeply analysed. This has led to the creation of new issues that have to be adressed and tackled, without considering the fact that additional workload in several departments should be managed.

Since the crisis is not over, and that figures for 2019 are far from being encouraging, it is important to continue to work closely with usual suppliers and distributors, as well as with clients, to share the largest amount of information and to try to simplify all the tasks that can be simplified. In other words, one of the main element on which companies should focus today in order to deal with supply chain complexity and, in this case, shortage, is collaboration with and between the several actors that are part of the network.

On this subject, several Schneider sites around the world, have decided to join forces and develop an application, based on a cloud platform on which orders that are placed via the MRP system are automatically uploaded on the platform and suppliers are requested to commit on delivery dates directly on the Schneider Supplier Portal - SSP.

Figure 29: SSP scheme

In addition, everytime the requested date for a purchase order is changed inside the company ERP, the supplier will auomatically receive an e-mail, informing him about the change and a new confirmaton will be requested. This new solution, which is being implemented for different Schneider sites all over the world, and for the majority of suppliers, has several benefits. On the one hand, the tool is common to all Schneider sites, which gives the suppliers working with more than one plant, the possibility to interact on a standardised device, requiring the same operations and handlings. In addition, suppliers have access to real time information, and can communicate on order changes and possible issues as soon as they have the information. On the other hand, it reduces the workload planners have to deal with, since order acknowledgments and orders' change are updated directly by the system without any other intervention. Moreover, everytime suppliers' commited dates differ from the buyers' requested date, an alert is sent to the planner on a weekly basis, so that verifications can be carried out and corrective actions are taken if needed.

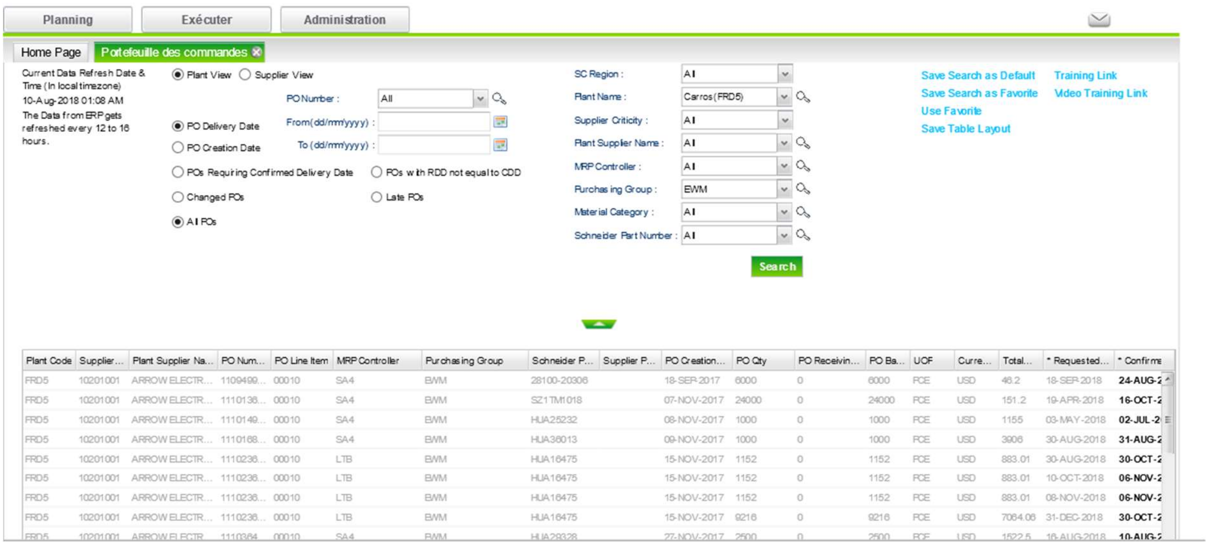


Figure 30: SSP Platform

This tool perfectly fits with the new needs generated by the components' shortage, since it allows a more efficient and rapid information exchange between supply chain actors and, at the same time, it reduces the number of tasks planners are forced to do, permitting them to focus on more important and useful activities. As a matter of fact, one of the many issues electronics components' buyers have to deal with today is the lack of time they are experiencing, due to market complexity and the additional tasks and problems that they have to tackle. This is consequently reducing the time they can dedicate to all the activities connected to analysis and flux optimisation.

For instance, when new forecasts are uploaded or customers' orders are placed or modified, the MRP system is updated and exception messages appears for all the production orders or replenishment orders between the production site and the external distribution center. Since an MRP works with products characterised by a dependent demand, every chage in the requirements for the finished products have a direct impact on the needs for the subcomponentsand parts they are composed of. If planners do not dedicate time to the treatment and analysis of system's suggestions at a downstream level, the messages that are generated for raw materials and subasssemblies do not represent the real situation and shortage on a specific part since they could be caused by a false need on the finished product.

For instance if a customer's order is deleted or postponed the replenisment order that would allow to serve that specific order could be postponed too or even cancelled. If the message is not analysed by planners, it will pull requirements on the parts it is composed of even if they are not necessary for that date. The treatment of exception messages at every level of the Bill of Materials is, therefore, extremely important, especially in a period in which raw materials' are so difficultly supplied.

As explained in the previous chapter, capacity management is another of the main issues generated by components' shortage, in particular, due to the high level of flexibility which is required to workers on the production lines. Generally, capacity commitments are established by production department on the base of the MPP – Master Production Plan – which is prepared by the logistics team. Nevertheless, the quantities required are calculated on the base of fixed orders and forecasted demand, without taking into consideration raw materials' and subassemblies' availability. Therefore, production team does not have any visibility on the percentage of the required quantity which is actually manufacturable. For instance, if a closer look is given to the picture below, in week 24, a demand for 146 products had been planned and production had committed on a quantity of 140 products. However, the actual amount of products that were assembled and sent to the distribution centre was 3. If technical problems on the line are excluded, the reason of this low production level is missing parts, components and parts which are not available to start the assembly process on the finished product. However, operators and a planning to respect the commitment of 140 products on that line were found and established, people that should be moved to other production lines, where a higher capacity is required.

**Note DT = design time OT = operating time lib.		**Regroupement prd sch 121/122, 116/126, 123/125/135 et 142/143	Retard QTE	JUIN	JUIN	JUIN	JUIN	JUILLET	JUILLET	JUILLET	JUILLET	AOÛT	AOÛT	AOÛT	AOÛT
				23	24	25	26	27	28	29	30	31	32	33	34
				5	5	5	5	5	5	5	5	5	5	5	5
SEPAM 10	144	charge qté	113	56	146	171	248	307	40	42	36	48	54	30	42
	144	Réalisé qté		0	3	3	0								
	144	capa qté		140	140	140	140	140	140	140	140	140	140	140	140
	144	charge H DT													
	144	KE		84,80	85,80	86,80	87,80	88,80	89,80	90,80	91,80	92,80	93,80	94,80	95,80
	144	delta (capa-charge)						-167,0	-67,0	31,0	135,0	227,0	313,0	423,0	521,0
	144	Jours de FA						11	7	4	0	-3	-6	-10	-14

Figure 31: Example of the MPP for a specific product range

Even if it could appear as a secondary issue, compared to all the major problems linked to customers shortage and penalties the company has to pay when products are delivered later that promised, a more accurate and precise capacity planning, based not only on forecasts but on the actual quantity which can be produced, could help a more efficient work planning and reduce all the wastes connected to operator relocation and training. Whenever the amount of manufacturable products is low, and waiting for the missing parts to be received, shifts could be reorganised and operators needing to be trained on a specific product range could be instructed before being already working on the line.

Always reasoning at an internal level, another way to reduce the impact of components' lack, would be a more controlled use and management of available resources and stocks. As a matter of fact, it can sometimes happen that for several reasons[31] all or part of the resources that result available for production in the ERP are not physically there. Production is then forced to declare a shortfall and ask Supply Chain team to look for stock available in order to cover for the missing quantity. However, today, the electronic components' market has lost the flexibility to rapidly react to customers' demand variation. Given capacity lack, the high demand level and the several difficulties recorded in serving already placed and forecasted orders, manufacturers

[31] Components can be used, rejected, sent to subcontractors but information are not updated in the ERP. Sometimes when they are used on production lines and then brought back to the warehouse they could be misplaced.

hardly have available stock to respond to sudden companies' needs. The situation, in this case, is, if possible, even more critical.

\Generally speaking, before releasing a Fabrication Order a simulation to check components' availability is made and several product ranges are grouped based on similarities in the assembly process. If resources are informatically available, setups start to be prepared and programs are uploaded on automatic machines according to the series that is supposed to be manufactured. Whenever a shortfall is recorded, and suppliers are not able to provide additional parts, no other solution exists than unmount setups and move to the production of another batch. Of course, this operation is time consuming and delays all the following steps in the production process. That is the reason why a more attentive and precise management of stock levels and components' consumption would help reducing the pressure on Supply Chain and avoid delays accumulation, in a period in which shortages are already frequent.

As already stated in the previous chapters, one of the solutions adopted by electronic components' manufacturers when dealing with very critical parts is allocation, meaning that a limited quantity of raw materials is reserved for each specific customer every year, according to the client's forecasts and manufacturer's capacity. The same strategy could be adopted from the organisation which is in charge of manufacturing the finished product. Starting from sales forecasts coming from the Distribution Centres, that should previously be confirmed by each national commercial office and mixing the information with capacity on that product range, the production plant could decide to prioritise customers and commit on a limited amount of products to be delivered. Nevertheless, the solution can be considered effective on the short term, waiting for the situation to come back to a normal status. On the one hand, production is planned according to parts' arrivals and limited to a maximum quantity, which protects manufacturing companies towards end users. On the other hand, allocation forces buyers to look for missing quantities available from other suppliers, which can, on the long term, convince them to definitely move to another supplying source.

One last suggestion could, instead, be linked to product evolution and design. As a matter of fact, on some parts, especially passive ones, the situation is more critical and components are almost impossible to be found neither from authorized distributors nor brokers. Several parts are, indeed, considered unprofitable by manufacturers who decide to reduce the production to very low volumes or to completely stop it. Therefore, to avoid or, at least reduce, the impact of shortage on finished product assembly and on the end users, the solution could be the redesign or adaptation of the Printed Circuit Board to the characteristics of components which can more easily be supplied. However, this last solution requires the joint work and collaboration of R&D, quality, purchasing and production departments and it is highly time consuming. First of all, new parts having the same technical characteristics as the old and critical ones have to be sourced. The design of the PCB should, then be adapted to the shape and features of the new part, to avoid the component's shift during the automatic assembly phases. Consequently, tests and functional trials should be made on the PCBA as well as on the finished PCL, to be sure that component change and the redesign of the printed circuit board do not have any impact on the functioning and safety of the end product. Given the cost, efforts and time required, the solution would be effective if adopted and implemented when previous attempts of solving the problem had failed and no other possibility seems to be effective. In this case, the collaboration with raw materials' suppliers becomes essential in order to reduce the time needed to come up with a functioning and ready to be used solution. The possibility to access the largest number of technical information on components' features, as well as the chance to receive samples of them to be assembled on virgin PCB, would help the user to reduce the time needed to adapt the board to the new component.

CONCLUSION

No later than two years ago, when the first signals of a possible electronic components' shortage started to show up in statistics and sales forecasts, no OEM would have thought that they had to prepare for a "perfect storm", with no planned end date. The rapid changes modern society is living today, mixed with the effects left by the previous economic crisis are forcing companies to look for new ways to deal with procurements, in order to reduce the impact of parts' lack. However, the panic triggered by first information on the topic and by previous experiences, and the rapidity with which companies have been asked to react to this situation, have often lead to the adoption of strategies that contributed to the deterioration of an already critical situation. As a matter of fact, many solutions were implemented inside organisations with the aim of protecting and securing their own procurements and business; impacts and consequences of certain decisions on the other actors of the Supply Chain were not excessively analysed. In other words, many companies in the industry forgot the fact that they were part of a wider network, composed of several organisations, and that every action necessarily has a consequence on the entire system.

Collaboration, information exchange, and the concept that the integration of actors inside the supply chain and their cooperation are fundamental in the achievement of every actor common goal: customer satisfaction.

Since the main issues characterising the electronic components' market are far away from being solved, and that, on the contrary, figures show that the crisis will possibly worsen or at least continue as it is today, for the following years, more durable strategies should be elaborated. The rapprochement and deep understanding of customers', suppliers', transporters' needs and problems becomes, indeed, essential to reach a win-win situation and, most importantly, to break the vicious cycle which is today fuelling the "perfect storm".

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