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Application of lean manufacturing techniques for the optimization of purchasing processes. The Schnell Monteprandone S.r.l. case.

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Alla mia famiglia,

Roberto, Beatrice e Michela

Da sempre miei esempi di vita.

INTRODUCTION

In an increasingly globalized world and in times of crisis such as the one we have been experiencing since the early 2020s, organizations are progressively obliged to become lean and agile in order to adapt quickly to changing socio-economic conditions.

Procurement can be an integral and fully-fledged part of this strategy because it can provide considerable support to the entire organization. The introduction of Lean methods for continuous process improvement enables a reduction of time along the decision chain between different parties. These objectives can be achieved using methods and tools, which eliminate waste, reduce process times and simplify operations. Good procurement management can also contribute to the definition and implementation of corporate strategies by bringing knowledge of market potential in-house and implementing it by searching for and selecting the best opportunities.

The following paper discusses how Schnell Monteprandone srl, a subsidiary of Schnell spa, a world leader in automotive iron-working machinery, implements activities and projects aimed at the continuous improvement of its purchasing department using lean manufacturing and supply chain management techniques.

The choice of this activity was the result of a discussion with Ing. Mirko Bartolucci, head of the purchasing department, who pointed out the need to optimize the purchasing processes also by downsizing the total number of suppliers. The implementation of this project follows the structure of the DMAIC method which allows, with the help of appropriate tools to measure, analyze and improve processes.

In particular, the analysis was made on the product category 'Special mechanical parts', chosen as the most significant category in Schnell Monteprandone's portfolio. It will in turn be divided into product types and all suppliers of each type will be analyzed to finally choose the best ones with whom to establish a long-term relationship. In this paper, the product type 'Bushing' will be analyzed.

The thesis is divided into four chapters: in the first, the concepts of lean manufacturing and lean six sigma are introduced, which are necessary for understanding the structure and objectives of the paper. The second will illustrate how the procurement function has evolved from a purely administrative function to a strategic role. In addition, it will be mentioned how some lean manufacturing techniques can be applied within the procurement department and how some experts see the procurement function in the near future. The third chapter will introduce the project implemented with Schnell for the continuous improvement of the purchasing department and the subsequent application of the DMAIC method and the PDCA cycle for the optimization of purchasing processes. The fourth chapter will introduce the topic of 'Forecasting with time series' and the various models available for performing time series forecast analyses. Schnell's orders via Rstudios will then be analyzed to see which model for forecasting purchase turnover may be the most compliant.

Chapter 1 - LEAN PRODUCTION, LEAN MANUFACTURING AND TOOLS

In the first chapter of this thesis, we will illustrate from a theoretical point of view what the literature has to say about the Lean philosophy, the six-sigma concept and related tools. Will be presented those that will then be used in the last chapter for the execution of the project and the achievement of the aim of the thesis.

1.1 Lean Production

Lean Thinking is a mental approach in which everything is designed and implemented with the aim of being effective and efficient. The work is well distributed among all those who belong to the system under consideration, and everyone feels part of a common project.[1]

Its main aims are the elimination of waste and the value created by each individual activity constituting the processes on which it is applied, based on what the customer wants, all while trying to minimize the resources used and costs incurred in its implementation.

It has already been applied in many realities, such as industries, hospitals, offices, etc., but the area in which it is most developed, and from which it originated, is production, hence the name Lean Production.

[1] Womack, Jones: "Lean Thinking. Banish Waste and Create Wealth in your organization.", 1997

1.1.1 *The origins*

At the beginning of the 20th century, following the industrial revolution, Henry Ford gave rise to a new idea of production, the assembly line, which gave rise to an era of mass production, in which supply was put before demand; the focus was therefore more on how much had to be produced rather than on how much and what the customer really wanted to buy, inducing him to buy what the market offered and not what he really wanted to buy. In this regard, his statement regarding the Ford T car model is famous: "*They will have the car they want, the color they want, as long as it is black*" (Henry Ford, 1922).

However, this model did not consider the human side of production, standardizing the activities and inducing the workers to perform repetitive and monotonous actions. Moreover, it neglected quality, price and customer service.

It was only in the second half of the 20th century that there was a change in thinking, oriented less towards mass production and more towards flexibility, while still trying not to undermine productivity. The crisis caused by the Second World War also had negative effects in the industrial world, giving rise to the need to reduce production costs.

Japan was the first to concern itself with introducing more flexibility while keeping costs under control: it all started precisely in the Toyota Motor Corporation. At the time, the company was headed by Taiichi Ōhno, who managed to introduce a new industrial model that encompassed all the requirements that the crisis demanded, i.e., greater flexibility and productivity, but at lower costs.

This model took the name Toyota Production System (TPS), an innovative methodology focused on the continuous search for waste and the importance of the involvement of all personnel within the company.

Taiichi Ōhno tried to introduce 'levelled production', i.e., he tried to achieve a balanced output throughout the working day, so that a constant and continuous flow of production was maintained[2].

To create such a production model, it was necessary to divide the monthly demand by the working hours; by doing so, it was possible to obtain the quantity to be produced per hour.

In any case, this mathematical operation is not the only one capable of satisfying the customer's demands by achieving better performance, but it is necessary to implement a series of interventions such that the entire procurement process must be capable of supporting such a structured production system.

As a result of the introduction of this model, the concept Lean Production was born. This term was coined at the end of the 1980s and was first used in the book 'The Machine that changed the World', written in 1991 by James P. Womack, Daniel T. Jones and Daniel Roos as a result of a study carried out as part of the International Motor Vehicle Program (IMVP), developed at the Massachusetts Institute of Technology (MIT) in Boston. The focus of the text was on the comparison between the still strongly Fordist western production and the oriental production, especially the Japanese one, demonstrating that the former, despite continuous refinements, was now

[2] Taiichi Ohno, “Lo spirito Toyota: il modello giapponese della qualità totale”.

outdated in favour of the latter, capable of providing quality products at reduced times and costs[3].

1.1.2 *The tools*

Lean production represents one of the most valid production management models applied in recent years in companies. The Lean model, using appropriate principles at management and organizational level, makes it possible to achieve a structure in which the main objective is to optimize the production system, all in terms of eliminating waste and speeding up processes.[4]

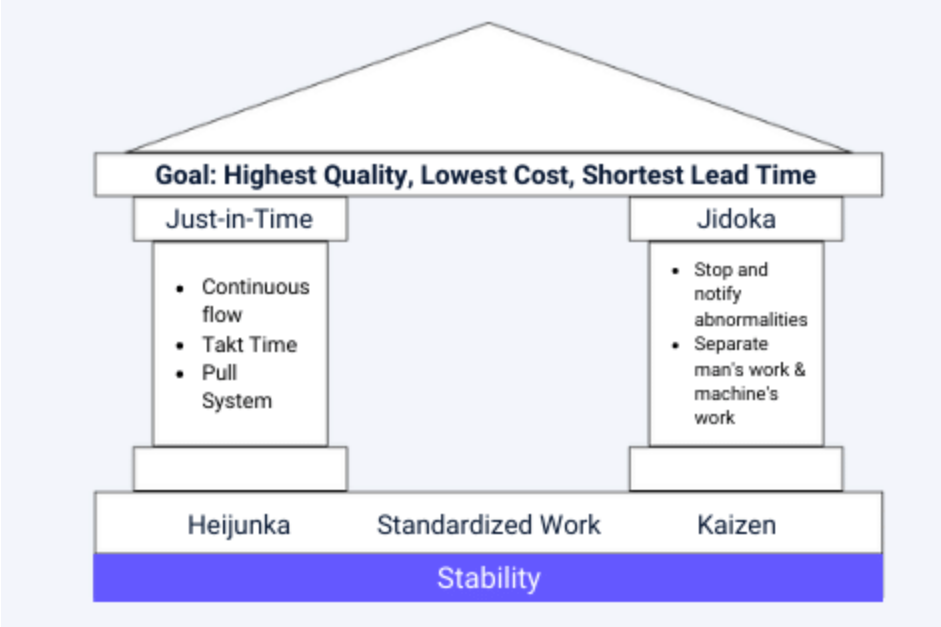
This is only possible with the involvement of people motivated for continuous improvement. It involves everything related to production that can be improved through a lean approach: production processes, management systems, the way information is circulated, resource optimization and, as in the case of this thesis, procurement processes.

Essentially, it aims to maintain only those activities that generate value for the customer and involves an in-depth study of production processes, which must be progressively improved over the life of the company.

All the elements used and applied with the aim of achieving continuous improvement by reducing as many elements as possible, such as costs, resources, waste, etc., can be summarized in a chart called the 'House of Lean', in which each constituent element of the house represents a foundation on which lean thinking, and lean production, is based.

[3] Womack, Jones: "Lean Thinking. Banish Waste and Create Wealth in your organization.", 1997
[4] Aggogeri Francesco, Gentili Enzo: "Lean Six Sigma: la nuova frontiera per la qualità", 2015

The Lean House is also called the Toyota Production System House because the principles on which Lean thinking is based are the same as those introduced by the Toyota Production System.



Pic. 1.1: The house of lean https://fomir.it/wp-content/uploads/2017/11/Approfondimenti-sulla-Lean_Production.pdf

With this diagram, we can see the key actions to achieve a **high-quality**, **low-cost**, **low-lead time** product, represented by the roof of the house.

The house is founded on two major pillars that support all lean thinking and whose main objective is to reduce and eliminate waste and defects. They are:

- **Just in time**: it is a stock management policy that uses methods aimed at improving the production process, seeking to optimize not so much the

production as the upstream stages, to reduce stocks of raw materials and semi-finished products necessary for production as much as possible. Just in Time combines elements such as reliability, stock reduction and lead time, with an increase in quality and customer service. This greatly reduces storage, management, loading and unloading costs.[5]

- **Jidoka**: it is a Japanese word translated as 'automation'. "*Stop production so that production never stops*". It is precisely in this phrase that the meaning of automation is inherent, in fact this principle indicates the need for a machine stop during production if a defect or error is found. Precisely, it means equipping each machine with a special system and training each worker so that the production process can be stopped at the first sign of any abnormal condition. If a defect or malfunction is discovered, the machinery must stop automatically and individual operators must immediately correct the problem, interrupting the production flow. This *modus operandi* allows us to "build-in quality" at each stage of our process by separating man and machine to achieve more efficient work from both.[6]

[5] "Just In Time (JIT)", https://www.lean-manufacturing.it/just-in-time/

[6] Keffrey K. Liker: "The Toyota way: 14 Management Principles from World's Greatest Manufacturer".

On the basis of the two pillars just mentioned, there are three other concepts of the Lean philosophy that form the foundation of the house, namely:

- *Heijunka*: is a Lean method for reducing irregularity in a production process and with it the possibility of overloading. The term *Heijunka* literally means 'levelling' and can help a company react to changes in demand and utilize capacity in the best possible way. It is recommended to perform certain actions to enable its application as production levelling by volume and by product mix. With the former, the average demand is calculated to define the minimum production batch, with a minimum stock to cover any peaks. The advantage is that both average demand and initial stock are monitored, so that production can be levelled out. With the second, the game becomes more complicated, but not excessively so: there is a tendency to co-ordinate the production of the various products into a single whole and to organize batches and minimum stocks according to the reference mix.[7]

- Standardized Work, i.e. that set of operational procedures drawn up by all company personnel and involving machines and materials aimed at maximizing the quality and efficiency of processes, while ensuring a high degree of predictability and safety of work.

- *Kaizen*, the Japanese term is the union of two words: KAI meaning change, and ZEN meaning better: hence the meaning of continuous improvement. It is a fundamental concept in Japanese culture, and one that we therefore also find in the lean

house. The *Kaizen* business strategy involves everyone in an organization working together to make improvements without large capital investments. Through this system, the productivity of the company can be improved, especially through quality improvement, cost reduction, reduction of delivery times, improved stock control, and increased safety.[8] Innovation can be realized in the traditional way and using KAIZEN. The difference between traditional productivity improvement and kaizen are that the former requires the introduction of new machinery with large investments while the latter is based on the improvement of current machinery and systems through small investments.

[7] Steffan, F. (2016), "HEIJUNKE: livellamento della produzione JustInTime", website: https://www.makeitlean.it/lean-production-blog/heijunka-livellamento-della-produzionejust-in-time
[8] Sándor Dobi : "The KAIZEN and the Japanese Company Culture."

1.2 Over the lean: Lean Six-Sigma

The technique defined as 'Lean Six Sigma' is an orderly method of problem solving, born from the synergy between the Lean technique and the Six Sigma methodology, which enables significant changes in the way companies operate and the results they achieve, through a management and operational philosophy of production and organizational activities.

1.2.1 *What is Six Sigma?*

Six Sigma is a highly disciplined continuous business improvement approach aimed at customer satisfaction[9]. The methodology bases its development and effectiveness on the collection of data and information relating to customer requirements and expectations, integrating them directly into the corporate structure. The underlying principle is the measurability of each process, which allows an analysis to be conducted following a rigorous structure, in which appropriate statistical tools are used. This analysis is aimed at improving the performance of the process, associating a decrease in variability[10].

In a more global view, the six sigma is[11]:

- A valid Management System to compete in the marketplace, optimizing the satisfaction of customer needs.

- A method focused on customer satisfaction.

[9] T. Pyzdek: "Six sigma hand-book", McGraw-hill, Inc. New York, 3-4, 2001

[10] Francesco Aggogeri, Enzo Gentili: "Lean Six sigma: la nuova frontiera per la qualità" pp. 33-34

- A discipline that minimizes defects by studying the variability of a system.

- A measure of variability and defects.

- A standard for defining the capability of each process.

Applying Six Sigma also means determining how well a system, process or activity can meet specified standards. The methodology aims to increase the capability of a process through an ordered variability reduction strategy. Sigma (σ) is, in fact, a letter of the Greek alphabet used in statistics to describe the variability of a phenomenon through dispersion. Assuming that a set of values of a quality characteristic can be represented with a normal distribution, the shape of the curve and the positioning of the curve with respect to the target and company tolerances provide objective indications of the "capability" of the output. Performance indications are defined by the Sigma level, which characterizes a process, calculated through an evaluation between the standard deviation of the phenomenon of interest and the number of times the latter can be contained within the tolerance interval. Sigma is therefore an index to identify the dispersion with respect to the mean value of the elements of a system and reaching 6 sigma means achieving process control such that there are only 3.4 defective parts per million[12].

Lean six sigma employs the six-sigma capability to identify critical customer requirements and turn them into those critical features of the production flow and

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[11] Pande P., Holpp L.: "What is Six sigma?", McGraw-hill, Inc. New York, 6-14, 2002

product, which have an immediate impact on customer satisfaction. At the same time, it applies the lean model to reduce non-value-adding activities, streamlining processes and attacking costs generated by working capital. Lean Six Sigma is based on a rigorous method of problem solving that allows business problems to be defined and quantified in order to analyze and improve them: the DMAIC method.

1.2.2 *The DMAIC method*

DMAIC is a management tool used to improve, optimize and stabilize processes and in an organization, it can be used for improvement activities in a particular process.

DMAIC provides a cyclic path, as visible in figure 1.2, integrating and exploiting all the information gathered, in order to achieve a significant improvement in the performance of a system. In fact, the representation of the DMAIC method is not a chain of five links but a continuous five-step cycle.

Fig. 1.2: The 5 phases of DMAIC method

https://greenboxinstitute.com/2021/09/que-es-lean-six-sigma/

[12] Ciappei Cristiano, Citti Paolo, Bacci Niccolò, Campatelli Gianni (2007): "La metodologia sei sigma nei servizi" pp. 21-23

The word DMAIC is an acronym, with each letter representing a step in the methodology: Define, Measure, Analyze, Improve and Control.

a) Define

The first phase is obviously to define the problem: this allows a clear vision of the improvements to be made and the objectives to be achieved. In the Define phase, will be defined the "reference scenario" of a project in which it will be necessary to specify:

- The problem to be analyzed.
- The objectives to be pursued with the project.
- Voice of customer.
- Process indicators to be measured.
- The resources required and the time frame for completion.
- The project charter.

We also have to say that, in order to apply the DMAIC method, first of all, it is necessary to develop leadership at every organizational level, first and foremost at company management level, that is able to manage a complex and important project to be managed, which, if correctly completed, can lead to considerable successes, but also to costly failures if the project is not correctly learnt by all those who are called upon to make their contribution.

The implementation of the six-sigma program passes through the training of specific professionals[13]:

- *Champion*: the role of the champion in six sigma projects is to select projects, define the cost-benefit analysis, coordinate the various projects and act as an interface with management. A champion will devote no more than 10-15% of his or her daily time to this role.

- *Black belt*: the role of the black belt is to manage working groups (teamwork) dedicated to specific programs that require advanced techniques. A black belt can follow several projects, even full-time. The black belt is very familiar with problem solving and continuous process improvement techniques.

- *Green belt*: the role of the green belt is similar to that of the black belt, but will be dedicated to simpler projects that do not require a full-time commitment.

Once the team has been created, we proceed by listening to the most important voice, the Voc (Voice of the Customer). The VOC represents the set of requests for a given output and aims to bring out the CTCs (Critical to Customer), the fundamental characteristics for an immediate impact on customer satisfaction. By working directly on CTCs, one can create priorities for improvement. That is, one chooses the aspects that are most important to the customer to take action on them and consequently achieve a significant increase in customer satisfaction in the short term. The identification of CTCs is the task of team members who interface directly with the customer, such as a

[13] R. Tartari R. (2008): "Manuale del Six Sigma", FrancoAngeli Editore, Milano.

customer service representative for external customers or a department manager for internal customers. department manager for internal customers. The identification of CTCs must be accompanied by a careful analysis of business performance, expressed through VOP (Voice of the Process).

In the development of a project, it is very important to be able to define the starting company performance level, as a useful comparison in the development of improvement activities. From the very first meetings it may emerge, based on the defined objectives, which processes are involved in the project. It is therefore useful to develop a general mapping of the production flow, and then go into detail in particularly critical areas. The mapping of a production flow can be developed at different levels of detail. The choice of how go into depth depends on the characteristics of the project.

The best technique for tracking, sharing and understanding the value stream is the Value Stream Map (VSM). The VSM is a fundamental quality tool with benefits:

- It integrates individual processes as elements of a macro flow.
- Facilitates the highlighting and prioritization by importance of causes of waste.
- It integrates and makes consistent the application of Lean techniques and tools with respect to a future flow (future state), to be achieved from the current flow of materials and information (current state).

b) Measure

In the measure phase, the performance of the AS-IS process will be analyzed the characteristics of the existing process will be measured, and critical areas will be monitored where improvements will be made. The goal of the Measure phase is to better understand the problem in order to better focus interventions. The Measure phase is necessary for the subsequent Analyze phase to function properly, because it provides the data that will then be analyzed.

The activities performed are typically as follows:

- Planning of data collection, necessary for understanding the problem.
- Validation of the measurement system.
- Performance and process capability analysis.

In this phase, a structured data collection plan will be created to

- Distinguish what is really happening from what we think is happening.
- Confirm or refute ideas, preconceptions and theories.
- Establish a baseline level of performance.
- Identify and understand relationships that might help explain variability.

One of the tools used in this phase is the **Pareto Diagram**. A Pareto chart helps the organization get a clear picture of where the greatest contribution can be made.

The principle suggests that a few problem categories, approximately 20%, will present the most opportunity for improvement, approximately 80%. it prioritizes problems so that the major problem can be identified. The pareto diagram is a bar chart in which the plotted values are arranged in descending order, the highest bar representing the largest problem.

Another tool is the **graphical summary** that is a representation model of the collected and processed data, which is clear and easily understood by all those working on the project. It consists of histogram, box plot, confidence interval calculation, normality test and calculation of statistical indicators.

c) Analyze

In the Analyses Phase, the few significant causes leading to defects or non-conformities are identified. This analysis will be performed using management and statistical tools. The objective of the Analyze Phase is to identify the causes of the problem and to quantify their influence on the Critical To Quality (CTQ) values, i.e. the core elements on which to work to improve the quality of a service/product.

One tool used to understand the root causes of a given problem is the 5 whys. The 5 whys is a technique for getting to the root cause of the problem and involves asking five or more times why the problem occurred and getting to its root cause. Each time an answer is given, you ask why that a particular condition occurred.[14]

d) Improve

In the Improve phase, corrective solutions are selected and implemented to ensure defect reduction, strategic effectiveness and management efficiency. It is now necessary to generate improvement opportunities, develop and implement corrective solutions and plan a 'pilot test', i.e., a prototype to monitor the effectiveness of the solutions in the short to medium term.

An important tool in the improve phase is the **PDCA cycle** that is a very useful for improving processes and implementing chosen solutions.[15]

It consists of four phases:

- P (Plan): In this phase, the problem is carefully assessed and possible corrective actions are planned;
- D (Do): The corrections are applied and the corrected processes are monitored with a data collection system;
- C (Check): Collected data are checked, process improvements are applied and new solutions are sought for what is not working;
- A (Act): All new solutions are applied and a new start is made from step 1, to trigger a process of continuous improvement.

[14] Frank Voehl (2016): "The innovation tools handbook."
[15] Sarah Isniah: "Plan do check action (PDCA) method: literature review and research issues"

More than a quality tool, the PDCA cycle is a fundamental concept of continuous improvement processes embedded in the organization's culture. It is simple to apply and should be used by most of the people in the company. The most important phase of PDCA is the 'action' phase after the completion of a project, when the cycle starts again for further improvement.

The **5S** methodology is based on the idea that a tidy and clean working environment is necessary to promote continuous improvement and productivity. The expression 5S method originates from the initials of the five Japanese words that summarize the five steps of the methodology[16]:

- SEIRI: simplify, select and separate, i.e., classify the equipment and tools in a workstation by eliminating what is not strictly necessary.
- SEITON: arranging, sorting and organizing, i.e., placing what is needed in the right place so that it can be easily identified, accessed and stored.
- SEISO: shine, clean, i.e. to keep the workplace clean and in a previously constituted state of order.
- SEIKETSU: stabilize and standardize, i.e. create standardized principles to keep the area in order by repeating the previous three steps and make these principles visible and applicable for all.

[16] Michalska, D. Szewieczek: "The 5S methodology as a tool for improving the organisation"

- SHITSUKE: sustain over time, i.e. make the standard of the 5S method a habit and part of daily work by sustaining the appropriate discipline and rigor for continuation.

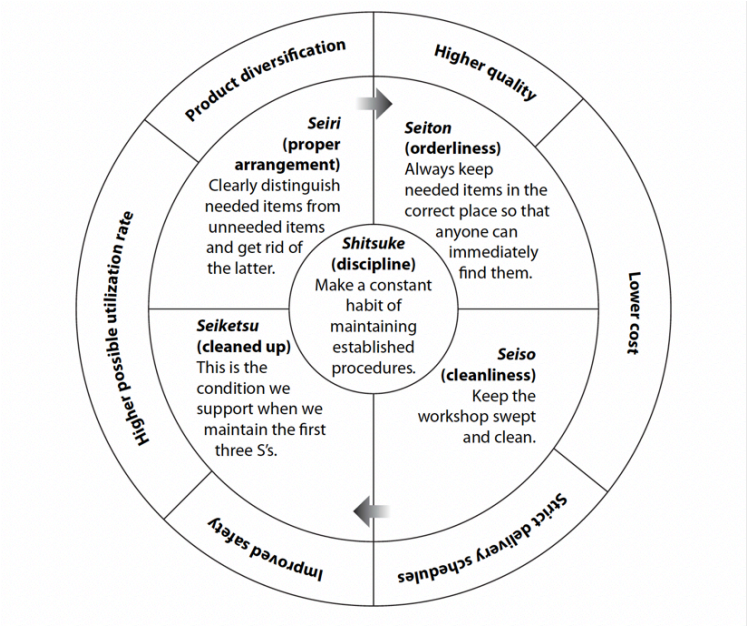

Fig. 1.3: 5S Methodology, https://www.5stoday.com/what-is-5s/

e) Control

The objective of the Control phase is to verify the efficiency of the implemented solutions, to analyze the performance of the improved processes and to ensure that the project objectives are achieved.

In this phase, processes will also be standardized, i.e. the working method will be defined and finalized on paper. All variables, specifications and actions will be

documented and shared, in order to make processes more effective and to simplify the work for staff, who will thus become more productive.

Chapter 2 - THE EVOLUTION OF PROCUREMENT: MOVING FROM A PURELY ADMINISTRATIVE FUNCTION TO A STRATEGIC ROLE

2.1 Procurement

Thinking about the key functions within an organization, often only those departments hand - in - hand with the end customer are considered, such as: sales, marketing, product development and, after the digital revolution, ICT. Procurement, on the other hand, which is more distant and less involved in the strategic vision of the company, is often considered a commodity, remaining in the shadow of the other functions[17].

Going back to the academic literature in the field of procurement, the main purpose of the function is defined as: to provide inputs of the right quality, in the right quantity, at the right price and with the right timing. In the past, procurement was often limited to pure transaction management, but in recent years, many companies have recognised that investing in a more controlled and centralised procurement management is necessary to optimise external spend and have more leverage in negotiating and contracting with suppliers. Today, the role of procurement is evolving rapidly, extending its scope to vendor management, strategic sourcing, demand forecasting, logistics, product development. Precisely for this reason, in the light of the emerging potential of the function, it is necessary to question the value that it can bring to the entire organization and the advantages that a more strategic vision of procurement can bring.[18]

[17] Niccolò Mazzoni (2017):" Procurement una funzione sottovalutata"
[18] Lysons Kenneth (2016): "Procurement and Supply Chain Management"

2.1.1 *Definition and functions*

The procurement process covers all production factors required by the company to carry out its activities. These include simple factors, repeated-use factors and labor factors such as, for example, raw materials and components for the manufacture of products, consumables, energy, fuel, maintenance services, external processing, etc.

The procurement process encompasses all activities ranging from the definition and planning of prospects for the purchase of goods and services, to the actual procurement of these goods, to the regulation of the administrative and financial relationship with suppliers.[19] The size of a purchasing department depends, of course, on the size of the company: it ranges from needing only one person for procurement for small companies to needing a full-fledged team for gathering input from different business groups. However, it is important to consider that procurement is an ongoing process, not just a series of isolated acts. For example, companies generally aim to establish relationships with key suppliers to achieve higher profit margins, i.e., the best service at the lowest cost. Companies may also need regular quality control and performance reviews to ensure that suppliers consistently meet expectations. As we will see in chapter three, the company on which the project will be carried out monitors monthly some kpi, in particular the lead time and the delay time. Visual management it is also used to monitor lead time trends to quickly assess the performance of each supplier.

[19] Marchi Luciano (2009): "Introduzione all'economia aziendale" p.232

Procurement processes vary widely depending on the structure and needs of each company, but generally comprise the following nine basic steps[20]:

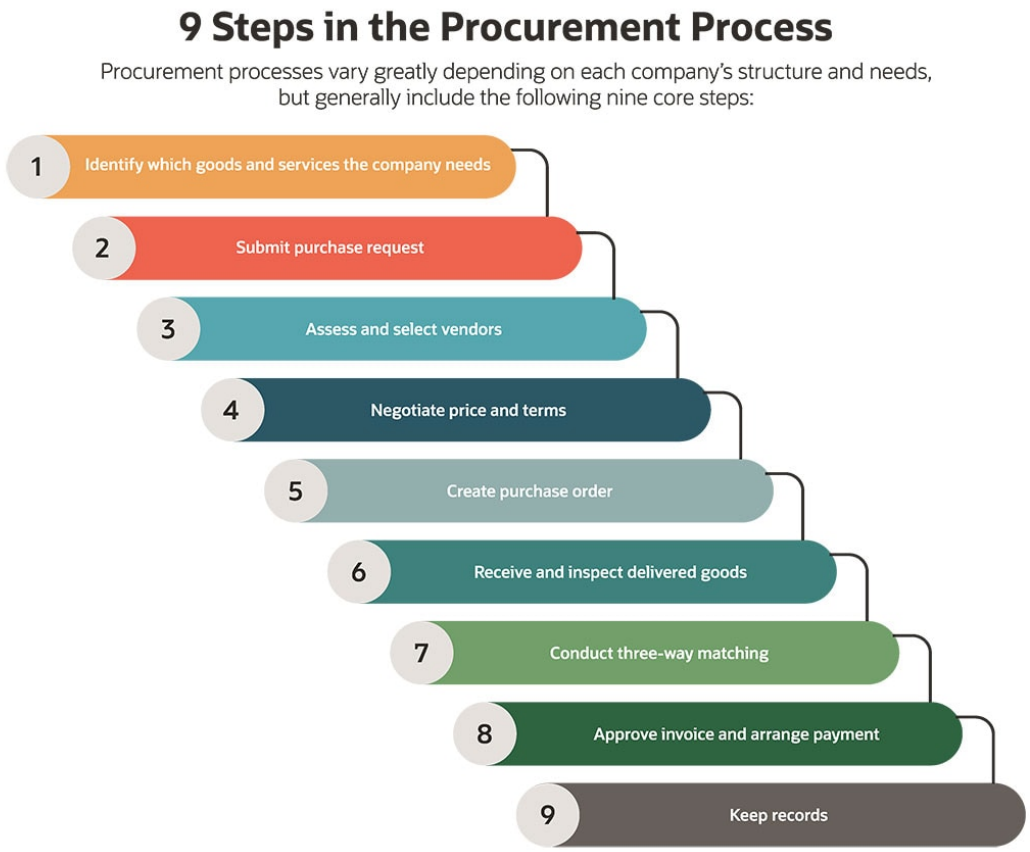

Fig. 2.1: 9 steps in the procurement process

[20] Abby Jenkins (2021): "What is procurement? Types, Processes & Technology", Website: https://www.netsuite.com/portal/resource/articles/accounting/procurement.shtml

1) Identify which goods and services the company needs

This phase consists of understanding specifically what the company needs, technical specifications, materials, part numbers or service features. At this stage it is necessary to consult all company departments involved in the purchasing decision, to ensure that the items purchased reflect accurately the needs of each department.

2) Submit purchase request

Once the material to be supplied has been identified, the employee or a company group must submit a formal purchase request to the appropriate office, which will proceed to the next step.

3) Assess and select vendors

Once the purchase request has been made, it is time to find the best supplier and submit a request for a quote. The evaluation of suppliers should focus on cost, reputation, speed, quality and reliability. Many companies also consider ethics and social responsibility, as purchasing is often linked to corporate identity.

4) Negotiate price and terms

A common good practice is to obtain at least three quotes from suppliers before deciding, review them and if possible, negotiate. Once the conditions have been finalized, everything should be put in writing.

5) Create purchase order

The order must now be filled out in detail and sent to the supplier.

6) Receive and inspect the delivered goods

Once the material has been delivered, it must be examined for errors or damage and whether the quantity received reflects the quantity ordered.

7) Conduct three-way matching

Accounts Payable will perform a triple-check, checking and comparing the purchase order, order receipt and invoice to ensure that the goods or services received correspond to the purchase order and prevent inaccurate invoices from being paid. If there are anomalies between the three documents, they must be resolved before payment is organized.

8) Approve the invoice and arrange payment

The invoice will be paid once the correspondence of the three documents has been approved. The invoice payment process should be consistent through verification of payments by the purchasing department employees. A standardized process can help ensure that invoices are always paid on time, thus avoiding late fees and creating good relationships with suppliers.

9) Recordkeeping

The archiving of procurement records is a crucial step as they can help the company reorder products at the right price in the future and base analyses on which future orders can be relied upon, optimizing purchasing processes. Clear and accurate records are essential to defend against disputes.

An effective procurement process can help a company succeed by containing costs and ensuring that supplies arrive when the company needs them. A well-designed and methodical process helps promote accuracy and timeliness, because each person involved knows exactly what they need to do and how much time they have for a given task. In contrast, a disorganized procurement process causes inefficiencies and potentially costly errors. Overpayments, for example, can have an impact on the budget, or late payments negatively affect relationships with suppliers.[21]

[21] Georgia Wilson (2021): "A guide to understanding the procurement function" website: https://procurementmag.com/procurement-strategy/guide-understanding-procurement-function

2.1.2 *Where procurement can generate value?*

According to Marcello Sala, CPO[22] of Samsung Electronics Italy at the time of the interview quoted below and current CPO of Yoox, there is still a widespread opinion that the value of procurement consists only in reducing the cost of a good or service. If one analyses the procurement value chain, it is easy to realize that the value provided is much broader. The Procurement, by its mission, should not aim only at pursuing efficiency in procurement, by affecting costs, but should above all improve the effectiveness of its own business, qualifying itself as an enabler as an enabler capable of ensuring through the supply of goods and services, business-supporting quality and safeguards to your company. There are many points where procurement can leverage to generate value, and in this section, we will focus on three in particular: Cost management, quality and service level and reputation, transparency and credibility.

Regarding the **cost management**, there are other ways to generate value besides negotiation[23]:

> Cost avoidance: cost reduction, through negotiation, in a situation of potential variation in expenditure compared to the historical benchmark.
>
> Total cost of ownership: analyzing whether it is more convenient and strategic for the company to outsource certain processes (make or buy decision), looking at Total Cost of Ownership.

[22] Chief Procurement Officier
[23] Marcello Sala interview (2017): "Procurement tra sfide e obiettivi", The Procurement Magazine year 5, p. 67

Changing the purchase method: switching from a variable cost model to a fixed cost model, or the opposite, looking at the characteristics of the business.

Demand management: manage internal customers, trying to better grasp their needs and the specifics of their spend requirements. In this way, the function can better control the purchase volume and the specificity of the product in question, without forgetting to always look at the possibilities that the market can offer externally.

After savings, the first factor that is usually associated with procurement is the **quality of the product/service offered**. By meeting the needs of each business line, and ideally exceeding them, the function can benefit the quality of the end product and have a positive impact on its performance. In order to increase the quality of supply, it will be necessary to adequately select and stimulate one's network of suppliers by checking their suitability before and after the service. Following a logic of continuous improvement, one tool in line for this purpose is the monitoring of specific KPIs.[24]

Considering the **transparency** of the company in relation to the market, this can be a competitive advantage by increasing the credibility of a company in the eyes of possible suppliers. Procurement is the only department that can provide transparency, traceability and clarity to the entire purchasing process: from giving equal opportunities to suppliers

[24] Benjamin Shute (2017): The Academy of Procurement: "The Importance of Being Earnest About SLAs and KPIs"

involved in the selection process to dealing only with companies that are responsible towards society and the environment.[25]

2.1.3 *New frontiers of value generation for the procurement function: sustainability and innovation*

Nowadays, the issue of sustainability no longer simply involves the preservation of the natural heritage, but also concerns corporate strategies and policies aimed at innovation. In this sense, the adoption of green practices must take into account the fact that in minimizing one's own environmental impact, it will no longer be sufficient to innovate and improve one's own environmental policies if all stakeholders, including procurement, are not involved.

In recent years, the topic of sustainable procurement in innovation and development policy has been much discussed and supported at European level.

By integrating environmental preferences into the procurement of products, works and services, both public and private organizations can improve their environmental performance and at the same time influence their suppliers to improve the environmental performance of their products and production processes. For public organizations, green procurement can function as a market-like incentive to improve green initiatives in the private sector.[26]

[25] Impact ROI: Website http://www.impactroiglobal.com/about-us/#About-impact-ROI

[26] Annika Varnas: "Environmental consideration in procurement of construction contracts: current practice, problems and opportunities in green procurement in the Swedish construction industry"

Green Public Procurement (GPP) is the approach by which public administrations use environmental criteria in their procurement processes, promoting the spread of more sustainable practices and developing green products, seeking solutions that have a low environmental impact. The theme of sustainability, therefore, refers to a process of change that consists not only in the exploitation of renewable resources, but also in investment plans and technological developments, thanks to which current and future potential can be exploited.[27]

As far as the corporate sector is concerned, IKEA provides a clear example of how a company can adapt and evolve its business model, following sustainable development, in such a way as to create the prerequisites for a lasting competitive advantage. The Swedish company's green approach has been instrumental over the years in stimulating revenue growth, reducing risk, securing raw material supplies and meeting stakeholder expectations.

Despite the growth in sales, the company decided to completely revolutionize its business model, aiming at circular production with closed-loop solutions. To achieve this ambitious goal, Ikea's purchasing function played a key role in adapting the current supply chain business model towards a circular economy approach, reducing the company's environmental impact as much as possible.[28]

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[27] Wenjuan Cheng, Andrea Appolloni (2018): "Green Public Procurement, missing concepts and future trends – A critical review"

[28] Michael Holder (2016): "IKEA argues for businesses to go all-in on sustainability" Website: https://www.greenbiz.com/article/ikea-argues-businesses-go-all-sustainability#:~:text=So%2C%20by%202020%2C%20not%20only,it%20is%20entirely%20energy%20independent.

According to Steve Howard, former sustainability manager of Ikea UK, evolving the business model and becoming sustainable is necessary even if the current model is still successful: "*A linear system has made us the largest furniture retailer in the world with more than 175,000 employees, so you may ask why we want to change it. Quite simply, we want to maintain this position for another 75 years*".

However, implementing this circular economy model requires various changes within a company such as:

- new product design, so that raw materials can be recycled, remanufactured or repaired.
- the involvement of suppliers to develop new skills related to the needs of circular production.
- a restructuring of the supply chain to have new sources of recycled materials.

Such a project is only feasible by recognizing how suppliers are the key to its realization. Ikea has established a long-lasting partnership with its suppliers with an average contractual relationship of nine years.

2.2 Lean methodology in the purchasing

Lean Manufacturing in supply chain management is defined as 'achieving more with less'. The whole process is perceived differently by companies and procurement professionals. For example, some companies try to reduce staff. Others do it by reducing inventories. Lean procurement is a systematic approach that defines what adds value within a production system and it reduces everything that does not.

2.2.1 *The evolution of procurement*

It is well known that companies today are confronted with global competition, new market trends and business models, pressure to save, price volatility, scarcity of raw materials and increasingly climate change risks. To survive and remain competitive, they must necessarily cut costs, open to new markets or seek strategic alliances and partnerships. In addition, the ever-changing market dynamics require an increasingly proactive approach that enables companies to decrease time to market by fulfilling or anticipating consumer needs.

All these needs also affect the work of the procurement function, which thus finds itself influencing not only costs but the entire business performance. Looking at the evolution of procurement over the past decades, we can observe how its role has progressively acquired more and more strategic relevance.

In the early 1980s, the function experienced a transformation from Transactional Purchasing to Supply Management, when companies realized the importance of

establishing different strategic relationships for different types of suppliers and product categories by following models such as Kraljic's matrix.[29]

In the 1990s, however, the rise of the outsourcing and global sourcing trend further changed the focus of the function towards optimizing the entire purchasing process. Many companies began to think in terms of Total Cost of Ownership, implementing collaborations between purchasing and other business areas. Procurement thus began to take on a more strategic role, affecting not only price reduction but above all Total Lifecycle Cost optimization.

The next step towards the modern role of the purchasing function materialized in recognizing collaboration with suppliers as a possible source of value through innovation, time to market, value engineering. Getting the best price was not the only competitive advantage, leading many companies to outsource most non-core activities.

Where the spend managed by purchasing accounts for between 50% and 80% of the total cost of the product, the importance and focus on suppliers has become fundamental in the company not only in financial terms but also in terms of innovation, supply security and sustainability. However, to make this exchange of value possible, it was necessary to change the relationship with suppliers from a perspective of close collaboration and mutual trust.

Subsequently, at the beginning of the new millennium, the focus shifted to supplier risk assessment not only from a financial but also from a reputational point of view and

[29] According to the scheme proposed by Kralijc, a company's purchases are divided into four classes, based on the complexity of the supply market and the importance of the purchases. This division allows the company to define the optimal purchasing strategies for each of the four component types/classes identified by the matrix, with the objective of maximising the company's bottom line

another trend that greatly influenced the role of procurement was the topic of sustainability and corporate social responsibility.

Although many companies are still reluctant to take a strategic view of procurement, numerous studies show that the degree of maturity of the procurement function is positively correlated with corporate performance.

2.2.2 *Lean techniques in a purchasing department*

In times of crisis, organizations are increasingly working to become leaner and more agile in order to adapt quickly to changing socio-economic conditions. Procurement can be an integral and fully-fledged part of this strategy because it can provide considerable support to the entire organization. The introduction of process improvement methods enables a reduction of time along the decision-making chain between different actors. These objectives can be achieved using methods and tools, which eliminate waste, reduce process times and simplify operations.

As mentioned in the first chapter, lean is an operational methodology aimed at improving processes and organizations for the effective achievement of strategic goals. Since this approach has been proven as an effective tool for supply chain management, in this section we will attempt to establish its use within the purchasing function.

Therefore, to summarize, the Lean methodology, by acting primarily on costs, reducing them through the elimination of activities that are not perceived to be of value to the end consumer, succeeds in guaranteeing a profit for the company.

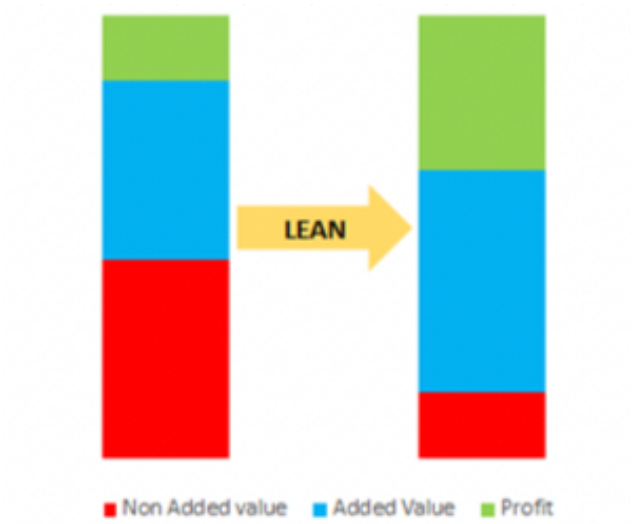


Fig. 2.2: Lean process, from "The Procurement Magazine"

Applying it to procurement, the lean methodology has, as opposed to other functions including operations, a dual application and therefore a dual benefit. A first application of Lean techniques can be aimed at **optimizing the procurement process** and therefore a predominantly internal activity within the company. The second, on the other hand, is to apply Lean techniques and tools to **reduce the Total Cost of Ownership** of the product or good purchased and therefore an activity involving suppliers.

In both cases, procurement has a difficult task: to identify non-value-added activities throughout the process, to minimize the Total Cost of Ownership while guaranteeing the highest level of service, product or service quality and continuity of supply. As far as procurement is concerned, one element that does not add value is the long waiting times for the approval of purchase orders.

In manufacturing, for the supply of materials and/or services, it is imperative to maintain a constant, real-time flow of data and information to ensure continuity in

production or even proactively intervene to mitigate or eliminate manufacturing process defaults.[30]

Following the Lean principles and remaining in manufacturing, another major challenge is the elimination or at least a significant reduction of raw material and component inventories. To this end, the manager should redefine the entire relationship with his suppliers: quantities to be ordered, timing and frequency of delivery. All this in a context of redefining the supply contract conditions. The interaction between the parties must be reviewed from a perspective that is not only of greater benefit to the customer but to both parties: a win-to-win situation. A useful tool that helps the manager to find the right compromise is to look not only at the purchase price of the product but to look at the overall price of the supply, i.e., the so-called Total Cost of Ownership.

Buying at the lowest TCO means finding the right combination of unit price, financial cost of supply, transport, logistics, lot size and delivery frequency.

The CPO[31]'s approach to the use and calculation of TCO in the choice of supplier and procurement methods, facilitates the company to enter into a partnership relationship with the chosen supplier, who is at this point more predisposed to collaborate with its customer to seek solutions that will see, in a long-term relationship, a reduction of its internal costs while safeguarding the right profit.

The advantage for the supplier is undoubtedly twofold: on the one hand to secure a long-term relationship with the customer, on the other hand to act on costs and not on margins to meet the customer's demand for savings.

[30] The procurement S.r.l. (2019) : “L’evoluzione del procurement” p. 79
[31] CPO: chief procurement officier

The requirement for the success of such an approach is a supply characterized by high volumes, long-term planning, repetitive products. Less effective is the application of Lean techniques at suppliers in the case of purchases of services and indirect materials.

Lean techniques applied to suppliers have enormous value for procurement when suppliers are in fact business partners. We speak in this case of a "profit pooling"[32] approach i.e. when the customer achieves its savings target by reducing the supplier's costs without affecting the supplier's profits.

The idea is to identify among the strategic suppliers those where volumes are high and the impact on product cost is prevalent. The evaluation usually takes place using the Kraljic matrix tool. Once this is completed and the supplier is contacted, a medium-long term contract is proposed in which the transparency and partnership requirements of the project are also defined.

Once the diagnosis is complete, operational objectives and corrective actions are established by applying the Lean methodology. The sharing between customer and supplier of cost reduction is undoubtedly a manifestation of real partnership and strategic alliance. The main objective is to produce benefits for both parties, in terms of sales and profits, through the reduction of all unnecessary costs along the value creation chain.

According to Jon Hansen, companies and CPOs need to be clear in their own minds that their goal of reducing costs does not translate directly into a demand for price reductions

[32] strategy model that can be used to help managers or companies focus on profits, rather than on revenue growth

from their suppliers, dangerously neglecting the fact that with such an approach comes an increased risk of financial stability for the supplier.[33]

Experiences have shown that when the initiative was only from procurement, other supporting departments, not being aligned with the same objectives, did not cooperate adequately, leading such initiatives to failure and sometimes to a deterioration of the relationship with suppliers.

In summary, there is, on the one hand, an awareness of benefits, greater than those derived from mere negotiation, in implementing the Lean methodology but, on the other hand, that without a commitment from top management to stimulate change, there is a lack of effective coordination and involvement by all in the project and thus a high risk of failure.

A possible solution to this problem could be a results-based project analysis, rigorously documented step by step, which makes the objectives for each party involved explicit. Some of the KPIs that can show the effectiveness of the Lean approach are: reduction of product cost, reduction of purchasing and logistics costs, on-time delivery, inventory reduction, faster delivery and higher quality.

[33] Jon Hansen, The Procurement Magazine (2019): "How smart is your lean and agile procurement practice?"

2.3 The future of procurement

The future of procurement is an ongoing construction site. In recent years, many opportunities have emerged for the function that, if seized appropriately, could elevate it to a strategic level for the company. In spite of this, through the testimonies of professionals in the sector, it has emerged that the procurement function in many companies has not yet managed to redefine itself, making full use of its new potential.

Thanks to 'The Procurement' magazine we can see various points of view regarding the future of procurement as seen by experts in the field.[34]

According to Rosanna Lippolis, Head of Global Category Management, "*With artificial intelligence and the internet of things, the function will evolve, albeit in different ways according to sectors and business realities. The human mind, however, to handle new situations such as covid, can never be completely replaced. Rather, it will have to be capable of interpreting and translating the large amount of available data into new strategic scenarios […]. So, we will move towards a conspicuous use of technology, but it is not enough in itself to evolve*."

Fabio Zucchi, Chief procurement officer of Gnutti Carlo, regarding the future of the procurement said: "*We are trying to automate certain procedures in order to achieve greater synergies and leave room for people to play a more strategic role. In my opinion, the aspect that will not go away is the personal relationships with suppliers, which generate relationships and create systems*."

[34] "La parola al procurement: trend e sfide dalle voci dei protagonisti degli acquisti", anno 6, n°3

Giovanni Berra, supply chain director of Ferretti, on the other hand, sees the procurement function as increasingly central, "*[...] a veritable hub around which the other operations functions can revolve"* only if the other companies know how to attract, select, train and retain capable and motivated young people. "*Today more than ever, the difference is made by the people*" says Berra, adding that in the past, the least brilliant profiles were hired in the procurement department, thus creating major damage. Nowadays it is no longer a question of receiving a request and issuing the order but of understanding the needs of the internal stakeholder, finding out what the market has to offer and going a step further than just buying.

According to these three experts, in the future we will move more and more towards an automated version of purchasing. In spite of this, what can certainly not be replaced is the humanity with which one contracts, i.e. the relationship with suppliers, and the strategic function of human resources increasingly predisposed to innovation and continuous improvement.

CHAPTER 3 - CASE STUDY: SCHNELL MONTEPRANDONE SRL

3.1 Presentation of Schenll spa

Schnell S.p.A. was founded in August 1962 by Alessandro Rupoli and was initially involved in the production of iron-working machines for reinforced concrete. In order to speed up the iron-tying business, its founders introduced an innovative solution that allowed them to significantly reduce the time required, immediately highlighting the company's proactive nature.

Fig. 3.1: Schnell S.p.a, Colli al Metauro, from www.schnell.it

The positive impact of the implementation of this solution combined with its German origin led Rupoli and partners to name the company 'SCHNELL', which in German means “quick”, “fast”.

In the following years, the company expanded its business by also starting to deal with the production of construction machinery for cutting and bending reinforcing bars, adding this activity to its original production.

The company continued this activity until 1987, when it decided to take a further step by entering the automatic machine sector, immediately succeeding in differentiating itself with the introduction of a machine for the production of cylindrical cages, a revolutionary product for those years.

In 1989 the company introduced electric servomotors and developed the first graphic computer, which enabled it to make an important leap in quality, considerably widening the gap with other companies in the sector.

By adopting this tool and continuing to operate with a view to continuous improvement, Schnell created a new range of machines capable of performing functions and responding to needs previously left unmet. This innovative idea has significantly boosted Schnell's image around the world, establishing it as a cutting-edge, modern company capable of responding appropriately to the changes affecting the market.

Robomaster, patented by Schnell in 1991, is the first plant capable of performing the bending operation in all directions with the ability to produce any type of shaped product automatically.

Schnell operates from a strategic customer-oriented perspective and strives to fully meet customer needs, seeking to develop machines that are innovative in terms of software and capable of optimising time while minimising costs.

The company offers a range of machinery that is very attractive on the market due to its quantitative-qualitative characteristics, and this allows it to grow considerably and establish itself as an innovative company in the sector. Aware of the validity of the products offered and strengthened by the results achieved on the market, in 1996 it decided to set up Schnell Japan, an after-sales center for troubleshooting, installation and sales of new machines.

Once a positive response to machine automation combined with software development had been verified, the company began to adopt this logic to produce other machines, also experiencing a positive sales result.

In 2001, Schnell, always working according to a logic of continuous improvement, increased research and development of software to make the machines more and more efficient and developed Graphico, a flexible, powerful and user-friendly system for developing irons.

Designed for civil houses and public works, Graphico has found an immediate positive response by developing worldwide. This continuous growth and the need to be closer to customers in order to offer adequate support services, led the company to establish Schnell Parts & Services Inc. in the USA, Schnell Brasil and Schnell Gulf established later in Hamriya Free Zone, Sharjah, UAE, state-of-the-art centers capable of responding to every need.

The development of ever more advanced software to meet increasingly complex requirements can lead the company to produce machinery that is efficient but difficult to use. To overcome this problem, the company introduced Sapiens, the technology

capable of integrating the innovation of mechanics with a simpler interface with even less experienced operators.

The ability to offer fully automatic machines capable of picking, counting and loading the cutting table brings benefits both in terms of increased production and safety, and in terms of cost reduction and increased flexibility.

The MegaGenius automatic loader represents the centerpiece of the technological innovation developed at Schnell and has absolutely new features that bring numerous benefits. Schnell's focus on the continuous improvement of the organizational process, quality and reliability of its products led the company to obtain quality system certification to ISO 9001 at the end of 2007, from the prestigious TUV Italia certification body.

Continuous innovation led Schnell to enter the unexplored mesh processing sector in 2008 with the presentation of the Multi Assembler machine. Also in this sector, the company adopts an approach geared towards innovation and continuous improvement, which allows it to win the 'Matexpo Innovation Award' at the Brussels International Fair in 2009 with its latest innovative Spirex machine.

This recognition is the result of the numerous investments in research and development in which Schnell has always believed and which has led it to be an important player in the market in which it operates.

In the same year, the company also received the '2009 Environmentally Friendly Innovation Award' from Legambiente for introducing innovations in accordance with Green Economy policies. This testifies that Schnell is indeed a company that aims for

success and continuous expansion but does not forget the importance of adopting a production style that is as sustainable and environmentally friendly as possible. Continuing its growth in size and needing to increase its proximity to emerging markets such as India, Schnell India Machinery was founded at Borivali West in Mumbai, India. In addition, in order to profitably interact with all Eastern European markets, Schnell Rus was founded in 2015 in Moscow, Russia, so as to better understand the needs of local customers and be able to offer a type of machinery with characteristics that meet these needs and better develop an important role in the local market.

Also during these years, the company obtained a further important certification from the Authorized Economic Operator Full (AEOF), which certifies the company's reliability towards customs authorities by supporting them in their control activities in international trade. The advantages of becoming an AEOF operator

concerns the possibility of having easier access to customs simplifications with a reduction in controls and the acquisition of a status of reliability and security with unlimited validity.

3.2 The project

3.2.1 *Introduction*

This project is the result of my experience in the purchasing department of Schnell spa, a company that gave me the opportunity to do my curricular internship and write my thesis project at their headquarter.

Schnell offers its customers highly customized machines, adapted to the most specific operating and construction conditions, therefore, this requires an efficient supply chain and effective control and management tools.

A preliminary analysis of the supply chain of Schnell Monteprandone, a subsidiary of Schnell spa based in the province of Ascoli Piceno, reveals long delivery times, delays and, in some cases, a low level of service. The latter is a factor of great impact not only on the loss of value offered to the end customer, but also on the company's performance. In order to successfully manage the entire supply chain, the company must set itself the overall objective of improving its economic and operational results, also through the strategic use of its suppliers. To this end, also thanks to lean manufacturing and lean six sigma techniques, Schnell Monteprandone is committed to optimizing and improving its purchasing processes by evaluating and monitoring performance and developing relationships with its suppliers. An excellent procurement management therefore contributes to the definition and implementation of corporate strategies by bringing in-house knowledge of market potential and implementing it by searching for and selecting the best opportunities. However, it is excessively burdensome to maintain consolidated supply relationships with a large number of suppliers.

To this end, the strategic management of suppliers includes, in addition to the establishment of partnerships with the best suppliers, a rationalization of the supplier base, which broadly speaking consists of the elimination by product category of the less performing suppliers. The objective of strategic supplier management is to implement an optimization of the number of suppliers. Consequently, the corresponding strategies aim to stimulate competition within the company, identifying a small number of suppliers with quality, reliability and service level characteristics appropriate to the organization's needs, and using management and purchasing methods that encourage competition.

The project aims to implement continuous performance improvement actions in the purchasing department for the Schnell Monteprandone supply chain, thanks to the use of lean and six sigma techniques, such as kaizen, the 5S method, the DMAIC model and the PDCA cycle.

The main results achieved are:

- Improved performance for the product category "Bushings".
- Rationalization of the supplier pool.
- Implementation of partnerships with the best-performing suppliers.

3.2.2 *Application of the DMAIC method to support continuous improvement in the purchasing department of Schnell Monteprandone.*

As analyzed in the first chapter, the DMAIC model is a six-sigma model that guides step by step the improvement of performance and the increase of business process results. In our case, we applied it with the aim of improving purchasing processes within Schnell Monteprandone srl.

The word DMAIC is an acronym, with each letter representing a step in the methodology: Define, Measure, Analyze, Improve and Control

a) Define

PROBLEM STATEMENT

Based on pressing market demands in terms of reducing costs and increasing quality performance, it was deemed necessary to implement purchasing process improvement actions within the Schnell Monteprandone subsidiary. Through a Lean Manufacturing and Six Sigma approach, a project was developed to streamline and optimize purchasing processes and enhance suppliers by category and product type.

BUSINESS CASE

In view of the necessary optimization of efficiencies in the field of operations, the current purchasing portfolio and suppliers of the subsidiary Schnell Monteprandone were analyzed. In order to be able to define an increase in the quality value of the

processes, it was considered essential to stratify the purchasing portfolio both by product category and component type.

PROJECT GOALS

The main objective of the project is the optimization of purchasing processes, more specifically:

- Selection of the most competent suppliers
- Reduction of lead time
- Improvement of supply quality
- Reduction of direct and indirect costs

RING DEFINITION

IN SCOPE	OUT OF SCOPE
All suppliers participating in the Schnell Monteprandone portfolio between January 2021 and July 2022	All suppliers with orders outside the defined time frame.
Orders with the initials OAM (Ordine di Acquisto Monteprandone)	Orders with other initial (OLM, OEM, ...)

RESOURCES NEEDED

The resources required for this type of project include a purchasing department with strategic buyers with previous experience with current suppliers and a chief purchasing officer to monitor results.

PROJECT CHARTER

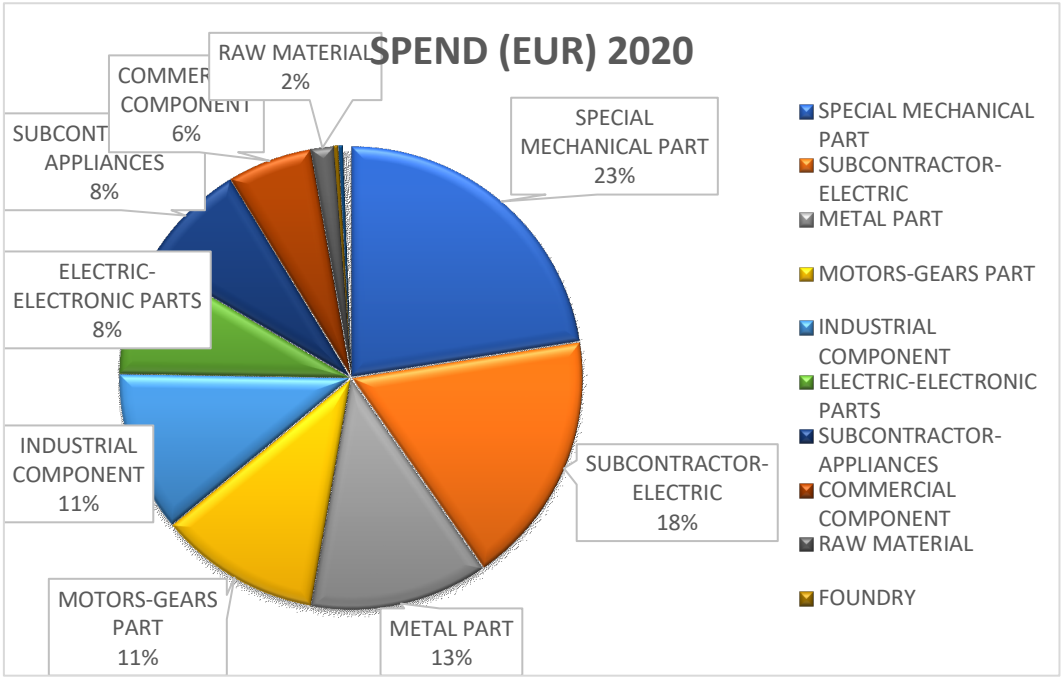
TEAM	NAME/SURNAME/ ROLE
PROJECT LEADER	STRATEGIC BUYER
SPONSOR	PLANT MANAGER
TEAM MEMBER	ELENA SANTEUSANIO
TEAM MEMBER	STRATEGIC BUYER 2
MBB/COACH	MIRKO BARTOLUCCI

b) Measure

In order to carry out a supply performance analysis, it is necessary to segment the entire purchasing portfolio in order to subsequently associate differentiated purchasing policies for each category.

Efficiency actions will be defined starting with the categories with a high impact on total purchasing turnover. In a second step, corrective actions on the other categories will be outlined, in line with the strategies used previously.

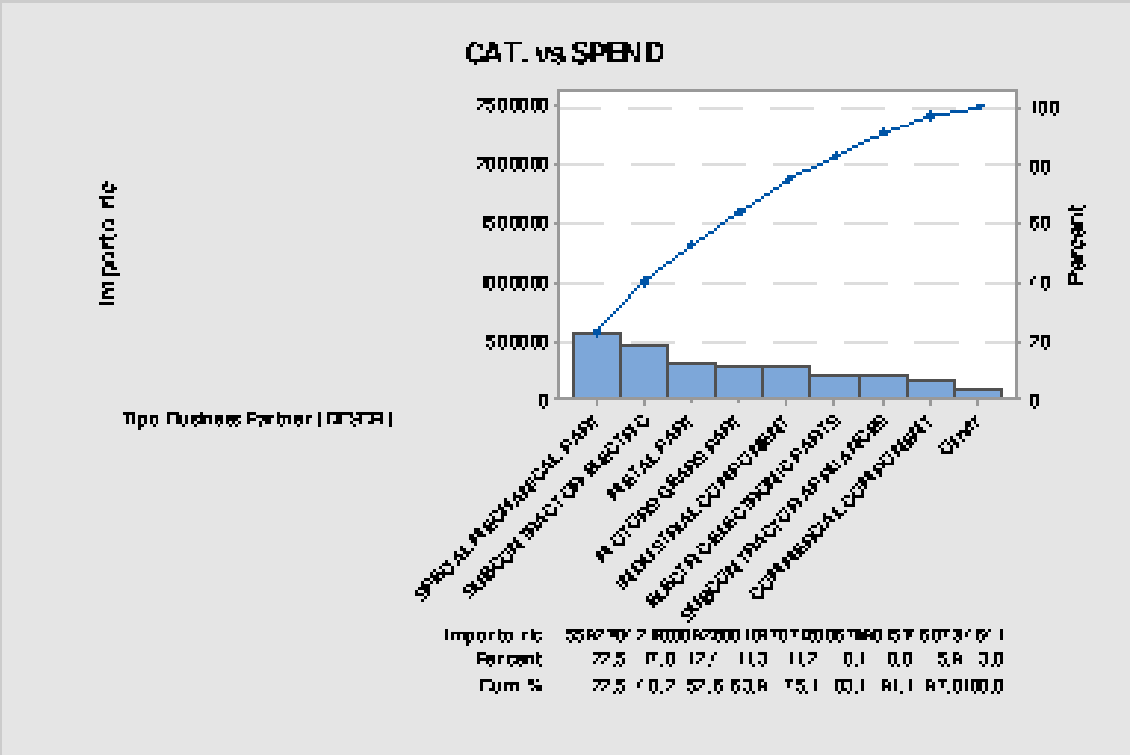
In order to identify which category has the greatest impact on purchasing turnover, we add up the purchasing turnovers of the individual suppliers belonging to each of these categories and then see how much they account for as a percentage of total turnover.



Graph. 3.1: Calculation of % of total 2020 turnover of each macro category

The following figure graphically illustrates the Pareto analysis of the product categories, shown on the x-axis. The histogram shows the percentage of the purchasing turnover of each category in relation to the total turnover, while the respective cumulative percentage is plotted with the respective Lorenz curve.

A Pareto chart helps the organization get a clear picture of where the greatest contribution can be made. The principle suggests that a few problem categories, approximately 20%, will present the most opportunity for improvement, approximately 80%. It prioritizes problems so that the major problem can be identified.



Graph. 3.2: Pareto Chart of macro-categories

By stratifying the portfolio, we can see that it is divided into eleven product categories, which in turn are divided into product types.

As mentioned above, we are going to analyze the category that has the greatest impact on turnover, namely the Special Mechanical parts category, which accounts for 23% of Schnell Monteprandone's purchasing portfolio.

This category includes: Bushings, Shafts, Wheels, Pivots, Screws, Discs, Blocks, etc..

In particular, we analysed the purchases and suppliers of the Bushing type[35].

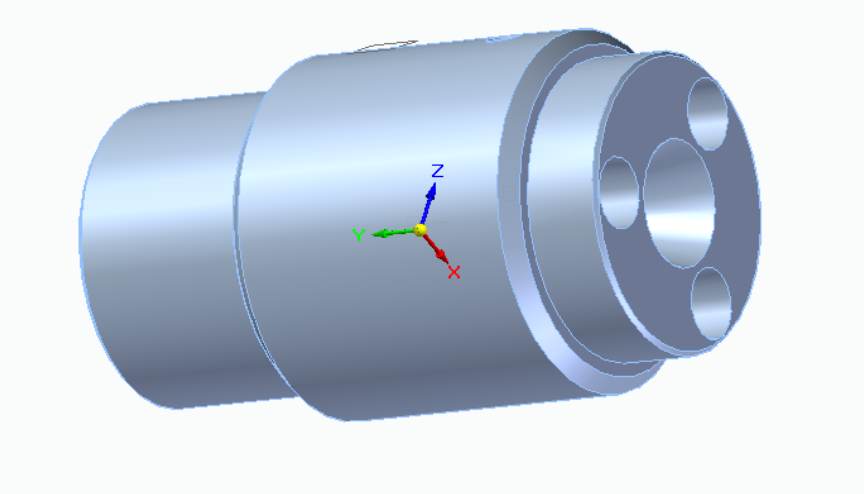


Fig. 3.2: bushing technical drawing, source: schnell spa purchasing office

[35] Defined in mechanics as a cylindrical ring with a through-hole that acts as a support for a shaft pin. Its purpose is to support the pin and allow it to rotate or translate within its housing; the bushing is generally made of bronze or other materials with a low coefficient of friction.

ANALYSIS AS-IS

As a first analysis, we will describe the situation prior to the implementation of the project, i.e. how many and which suppliers we relied on for the Busching type in the year 2021 and their data regarding average lead time and spend.

SUPPLIERS	SPEND (EUR)	Average L.T.(days) RACC
SUPPLIER 1	74.413 €	39,19
SUPPLIER 2	154 €	98,22
SUPPLIER 3	42 €	119,9
SUPPLIER 4	5.562 €	80,06
SUPPLIER 5	9.713 €	73,57
SUPPLIER 6	1.221 €	59,22
SUPPLIER 7	8.015 €	22,01
Total amount	99.119 €	57,62

Tab 3.1: 2021 supplier list for the bushings product category with average lead time values and total spend

From the as-is analysis, it can immediately be seen that for the bushings category, the supplier pool is very broad with different values in terms of lead time and spend. As we can see from the table, some suppliers were contacted only for small orders, some of which were placed out of 'fear' of not receiving the material ordered by the other suppliers on time or for specific parts not contracted between the parties. As far as lead time is concerned, some suppliers such as, for example, number 3 is outside the range for the preparation of a bushing.

Anderson-Darling Normality Test	
A-Squared	2,73
P-Value	<0,005
Mean	57,619
StDev	43,991
Variance	1935,188
Skewness	0,814865
Kurtosis	-0,313780
N	81
Minimum	0,010
1st Quartile	21,940
Median	40,262
3rd Quartile	91,867
Maximum	167,954
95% Confidence Interval for Mean	
47,892	67,346
95% Confidence Interval for Median	
32,310	66,607
95% Confidence Interval for StDev	
38,104	52,046

Fig.3.3: statistical analysis and confidence intervals lead time

By means of a statistical analysis, we can prove with a 95% confidence interval that if we do not carry out any kind of intervention/improvement action, the lead time of our deliveries will be between a minimum of 47.89 days and a maximum of 67.346. Through the table we can verify that the average of the 81 deliveries stands at a value of 57.619 days where 25% of the deliveries fall at a lead time of 21.940 and over 75% of the deliveries exceed 91.867 days lead time.

c) Analyze

After analyzing the AS-IS phase and noting the unevenness of orders on suppliers, it was deemed necessary to introduce a selection method to define to whom to entrust the supply of the component.

A careful analysis will be carried out among existing suppliers to select whom to entrust all or most of the bushing supply. How to know who to choose from the list of suppliers?

The first thing to be checked periodically is the **Chamber of Commerce certificate**, balance sheet and "DURC"[36] (Documento Unico di Regolatità Contributiva) of each supplier, in order to ensure the correctness and reliability of each one.

Then we move on **"Spend",** in other word, turnover of the year 2021, considering those who contributed most to the supply during the year as preferential.

We then focus on quantitative and measurable KPIs for each individual supplier, such as Procurement **Lead Time** and **Delay Time**.

To meet one of the cardinal principles of lean manufacturing, namely the elimination of "muda", it is necessary and essential to optimize the lead time. A low lead time can be translated as: offering a better service (in the case of emergencies it provides me with a material immediately), being flexible, greater efficiency in time to market, a reduction in stock in the warehouse, an increase in the stock rotation index.

The time estimated by the suppliers is around 35 days, considering the following steps:

- Sending order to supplier
- Receiving the order
- Purchase of raw materials for manufacture
- Mechanical processing
- Surface coating or heat treatment

[36] certification of the regularity of payments to INPS, INAIL and Cassa Edile.

- Grinding (if any)

- Quality control by supplier

- Packaging

- Shipment

- Reception central warehouse schnell Monteprandone

Another index we considered when selecting suppliers is **On Time Delivery**, specifically the percentage of orders delivered "on time" by each supplier. The analysis was carried out considering all orders of all material categories for each of the seven suppliers in the period January 2021 - March 2022.

Schnell uses both pull production approaches, with “inlining”[37] contracts, and push production approaches, with custom order[38]. With regard to bushings, orders will only be placed for the latter, as for the production of machines with “inlining” contracts, orders will be placed for assembled units where the bushing is already incorporated.

Once we had calculated the delay time of each order, i.e., the difference between the delivery date confirmed by the supplier and the actual delivery date, we gave each order an index, 1 or 0, where 1 indicates that the order was received between five days in advance and five days after the planned delivery date, and 0 all others, i.e., more than five days late or more than five days early in delivery. [39]

[37] By 'inlining' production, Schnell means all those machining operations where there is a kanban for supply and an assembly line production to make the machine. Here, unlike in contract manufacturing, the tolerance for delivery of materials is 1-2 days.

[38] by custom order we mean all those machine orders that are made to order for the customer. As each machine is different from the others, the production steps are different for each machine, making 'assembly line' production for this type of machine not possible.

[39] The time interval of five days was calculated on the basis of the efficiency of production on order as production delivers the machine to the salesman with a reliability of eight days. By doing so, we can see

		Number of orders	
SUPPLIER 1		**1454**	
	0	580	40%
	1	874	60%
SUPPLIER 2		**561**	
	0	250	45%
	1	311	55%
SUPPLIER 3		**206**	
	0	164	80%
	1	42	20%
SUPPLIER 4		**231**	
	0	66	29%
	1	165	71%
SUPPLIER 5		**1256**	
	0	834	66%
	1	422	34%
SUPPLIER 6		**141**	
	0	80	57%
	1	61	43%
SUPPLIER 7		**169**	
	0	26	15%
	1	143	85%

0: order considered 'overdue', more than five days late or more than five days early.

1: order considered ‘ontime’, delivery between five days in advance and five days late

Green square: the three suppliers selected based on best performance.

One thing to specify is that shipping in Italy, as well as all over the world in this historical period, is undergoing a severe crisis and consequently delays in production are now a certainty.

on average which suppliers are most reliable in terms of on-time delivery, an indispensable element when assessing the reliability of a supplier.

The list of raw materials that cannot be delivered in a reasonable time is getting longer and longer, and if they are available, they have an exaggerated price increase, which is also why the percentages of on-time deliveries of orders are medium to low. In spite of this, we considered the companies with the highest percentage of on-time orders, i.e. supplier 1, 4 and 7.

Another index that is taken into consideration is the **non-conformity** of the supply with respect to the order. The purpose of this index is to assess the supplier's performance, with errors (if repeated over time) representing a symptom of "superficiality", lack of attention or perhaps a lack of equipment and machinery appropriate to the requirements made by Schnell.

Another non-quantitative index is the **response time** of each supplier, which is determined by the time that elapses between sending an order request and confirmation. This information was given by each strategic buyer where experience with suppliers enabled them to promptly assess the quality of the supplier.

Another factor is the average **physical distance** of the supplier's production facility from that of the customer. Naturally, it is used to emphasize the possible implementation of transport optimization strategies. In addition, preference is given to suppliers belonging to the same geographical district in order to allow Schnell Monteprandone personnel to make frequent visits and meetings with it, with a view to collaboration and prevention.

d) Improve

In the Improve phase, corrective solutions are selected and implemented to ensure defect reduction, strategic effectiveness and management efficiency. The ultimate aim is to obtain a new supplier list, smaller in number than the initial one, and in which the inclusion of suppliers is conditioned by a phase of verification of their characteristics, and permanence by the level of performance in the course of supplies made. Suppliers with a low level of performance in one or more purchasing categories will instead be eliminated from the supplier list and their codes will be reallocated to preferred suppliers, with whom the organization will establish long-term partnerships.

At this stage, the PDCA cycle will help us in the implementation of a continuous cycle of process improvement in purchasing.

The PDCA cycle, as explained in the previous chapters, is a very useful tool for improving processes and implementing chosen solutions. It consists of four phases:

1. P (Plan): In this phase, the problem is carefully assessed and possible corrective actions are planned;

Based on pressing market demands in terms of reducing costs and increasing quality performance, it was deemed necessary to implement purchasing process improvement actions within the Schnell Monteprandone subsidiary. After a detailed analysis of purchases, it was realized that there was an excess number of suppliers for individual product types, thus giving rise to the need to include a more competent supplier selection model.

After listing the necessary characteristics of a good supplier, concrete actions must be defined to achieve lead time reduction, quality improvement and elimination of critical suppliers. These actions are generally classified as follows:

- Kaizen, aimed at negotiating costs, delivery methods and times, packaging, etc., which are classified into the following types:

- Open contracts (general purchasing conditions, specific agreements and contracts and lead time reduction)
- Ordering procedures (conclusion of Kan Ban contracts and delivery schedules)
- Bonus/ malus (bonuses or penalties for reaching certain turnover values, quality levels or service levels)

- Elimination of the most critical suppliers for the category in question and subsequent reallocation of all previously purchased codes to emerging suppliers, in order to increase their overall performance, favoring them in the categories where they perform best.

2. D (Do): Corrections are applied and corrected processes are monitored with a data collection system;

Once the current situation had been observed thanks to the as-is analysis, we started to evaluate which of the seven suppliers were the preferred ones.

As a first step, those suppliers were "eliminated" who were considered not to meet the requirements that the company defined as sustainable for the project. Next, those with the highest spend and those with a low average lead time and a high percentage of

orders delivered on time were considered. The other factors were then considered, namely, distance, reliability and responsiveness.

Once the preferred potentials were identified, open contracts were made to establish a stable annual supply relationship in order to provide continuity of supply within the required lead time. Here, annual consumption quantities and supply lead times are established. With the open order, part of the stock is entrusted directly to the supplier, thus reducing inventory costs.

Two open supply contracts were entered into, one with supplier 4 and the other with supplier 7. Supplier 4 was considered strategic for certain types of bushings as it was the only one to be entrusted with the coating of plastic material on iron.

In the case of supplier 1, there was already an open contract.

3. C (check): Collected data are checked, process improvements are applied and new solutions are sought for what is not working;

From 2019, Schnell activated a system for monitoring Punctuality/Delivery Times related to the supply chain with reference to the company's main suppliers in terms of turnover. To compensate for the lack of a valid vendor rating model, these tools were designed and implemented to make the process of monitoring and analyzing supply performance effective and efficient. This activity is carried out by a person from the purchasing department, who, after extracting and processing the data, will be able to make an assessment of the performance of the three preferred suppliers after the implementation of corrective actions. In particular, if the current figure has increased in

comparison to the previous time period, this means that there has been a worsening, as the number of days relating to Lead Time or Delay Time have increased, conversely, a decrease in comparison to the previous period indicates an improvement. Once a month, therefore, a check will be made to see whether there has indeed been an improvement in the average lead time between suppliers.

Below are graphs of how the deterioration and improvement is depicted in the company's management system.

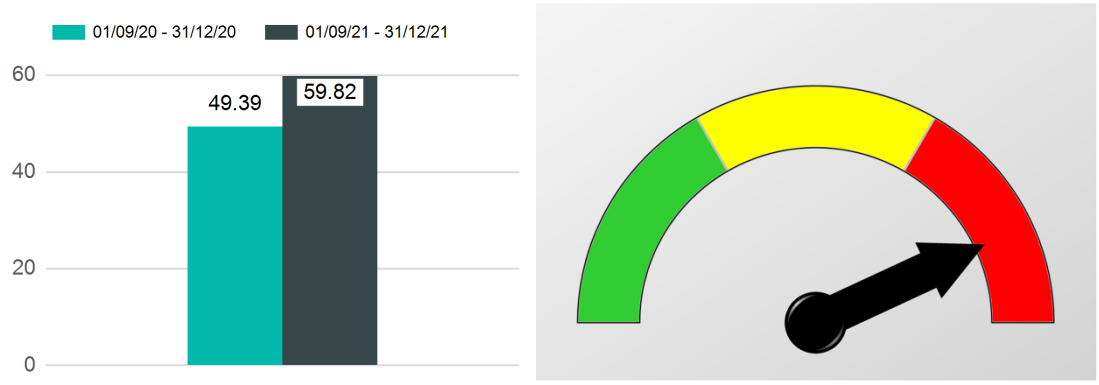


Fig.3.4: negative effect in the average of lead time for the supplier X

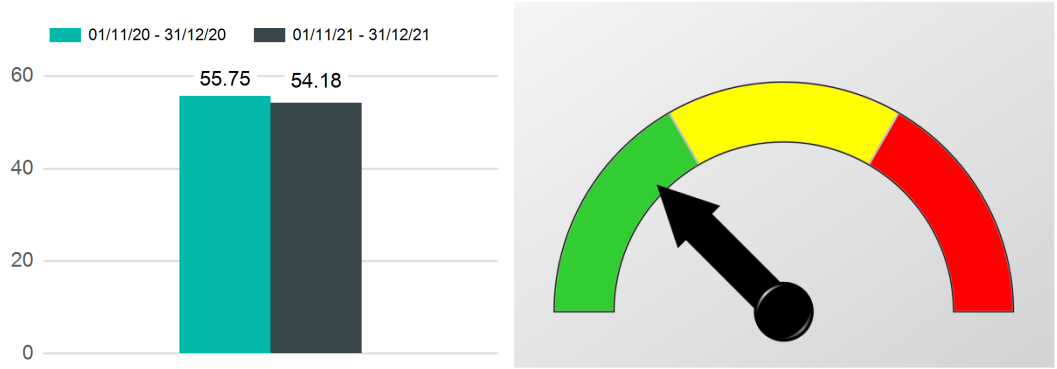


Fig.3.5: positive effect in the average of lead time for the supplier X

This data, whether positive or negative, is sent to the supplier by means of an e-mail containing a description of the activity carried out, to which the operator attaches the relevant tables and graphs and asks the supplier to analyze them. This service was created precisely to ensure that a common, shared language is created between Schnell and its suppliers to bring benefits to both, with a view to continuous improvement.

4. A (act): Apply all new solutions and start again from step 1, to trigger a process of continuous improvement.

The three favorites were selected from the previous seven, thus focusing supply requests on a smaller number of suppliers. Corrective actions were applied to decrease lead time and delay time. Over the course of the months, the KPI will be monitored to see if the expected improvement will occur. Once monitored, we will then start again from point one to trigger a process of continuous improvement.

e) Control

The objective of the Control phase is to verify the efficiency of the implemented solutions, to analyze the performance of the improved processes and to ensure that the project objectives are achieved.

In particular, we will compare the period March-July 2021 with the same period the following year, so as to have a fair comparison.

Suppliers	SPEND (€)	Average LEAD TIME (days)
SUPPLIER 1	29120	41
SUPPLIER 2	57	31
SUPPLIER 3	926	60
SUPPLIER 4	2612	19
SUPPLIER 5	6200	26
SUPPLIER 6	82	33
SUPPLIER 7	3928	50
Total	42923	40

Tab. 1: bushing supplier situation from March 2021 to July 2021

Suppliers	SPEND (€)	Average LEAD TIME (days)
SUPPLIER 1	35141	22
SUPPLIER 4	2612	18
SUPPLIER 7	5102	22
Total	42855	21

Tab.2: bushing supplier situation from March 2022 to July 2022

As can be seen from the tables, the average lead time halved from 40 to 20 days.

This data was obtained from the list of bushing purchases for the above-mentioned periods. A pivot table was used to group and analyze each individual supplier, thus obtaining the results needed to assess the success of the project.

We can conclude by saying that thanks to the analysis just carried out, the number of suppliers for the 'bushings' category was reduced, identifying the most strategic ones among them. Medium- to long-term contracts were opened with them to have a win-win situation and a considerable reduction in lead time and delay time. Once this analysis is complete, we will move on to all the other product types for the 'Special Machinal Parts' category to have a general optimization of the purchasing processes.

Chapter 4 - TIME SERIES FORECAST ANALYSIS OF SCHNELL SPA'S PURCHASES

4.1 Forecasting with time series

Forecasting means predicting and thanks to this analysis we will be able to predict observation that we don't have available. [40]

A forecasting analysis can be useful in various situations of an economic and non-economic nature. For instance, deciding whether to build a new power plant in the next few years requires forecasting future demand; scheduling the number of employees for a call center for the next week requires forecasts on the volume of calls; stocking an inventory requires forecasts on inventory requirements. Forecasts can be required either several years in advance, as in the case of capital investments, or a few minutes before, as for telecommunications routing.

Regardless of circumstances or time horizons, forecasts are an important aid to effective and efficient planning.

The predictability of an event or a quantity depends on several factors including:

- how well we understand the factors that contribute to it;
- the amount of data available;
- whether the forecasts can affect the thing we are trying to forecast.

Often in forecasting, a key step is to know when something can be accurately predicted and when forecasts are completely random. A good forecast catches genuine patterns

[40] Rob J. Hyndman, George Athanasopoulos: "Forecasting Principles and Practice"

and relationships that exist in historical data, but do not replicate past events that will not be repeated.

Every environment is constantly in evolution and a good forecasting model is able to capture the way things are changing. Forecasting rarely assumes that the environment is immutable. It usually assumes that the way the environment is changing will continue into the future.

For instance, a highly volatile environment will continue to be highly volatile and a business with fluctuating sales will continue to have fluctuating sales. A forecasting model is intended to capture the way things move, not just where things are. Forecasting is a common statistical task in business, as part of the decision-making activities of management. Given all the information available the goal is predicting the future as accurately as possible, also considering the historical data and knowledge of the future event that might impact.

Depending on the available data we can perform two types of forecasts:

- Qualitative forecasts, if there are no data available or if the data available are not relevant to the forecast.
- Quantitative forecast, if numerical information about the past is available and it is reasonable to assume that some features of the past will continue.

The time series data has to be regular, this mean that has to be collected at regular intervals in time like days, weeks and months.

4.1.1 *Time Patterns*

In describing time series, we will use words such as “trend” and “seasonal” and “cycle” which need to be defined more carefully.

We have a **trend** when there is a long-term increase or decrease in our data. It does not have to be linear. Sometimes we refer to a trend as a 'change of direction', when we go from an increasing trend to a decreasing one.

A **seasonal** pattern occurs when a time series is affected by seasonal factors such as the time of day, the week or the year. Seasonality has always a fixed and known frequency.

A cycle occurs when the data exhibit rises and falls that are not of a fixed frequency. These fluctuations are usually due to economic conditions, and are often related to the “business cycle”. The duration of these fluctuations is usually at least 2 years.

A **cycle** occurs when data show increases and decreases that do not have a fixed frequency. These fluctuations are usually caused by economic conditions and are often linked to the 'business cycle'.

4.1.2 *Simple forecasting methods*

Forecasting situations vary widely depending on time horizons, factors determining actual outcomes, types of data models and many other aspects. [41]

Some forecasting methods are extremely simple and surprisingly effective, for example:

[41] Academic material of “Big Data Analytics for Business” course A.A 2021/2022, Prof. Claudia Pigini

Average method: the forecasts of all future values are equal to the average of the available data.

$$\hat{y}_{T+h|T} = \frac{y_1 + y_2 + \ldots + y_T}{T}. \quad (1)$$

Naïve method: the forecasts of all future values are equal to the value of the last observation.

$$\hat{y}_{T+h|T} = y_T. \quad (2)$$

Seasonal naïve method: each forecast is equal to the last observed value from the same season of the year, that is:

$$\hat{y}_{T+h|T} = y_{T+h-m}, \quad (3)$$

Drift method: allows the forecasts to increase or decrease over time. The drift (change over time) is the average change seen in the historical data.

$$\hat{y}_{T+h|T} = y_T = h\frac{y_T - y_1}{T-1}, \quad (4)$$

is equivalent to drawing a line between the first and last observations.

Sometimes one of these simple methods will be the best forecasting method available; but in many cases, these methods will serve as a benchmark rather than a method of choice. In other words, all forecasting methods we develop will be compared with these

simple methods to ensure that the new method is better than these simple alternatives. Otherwise, the new method is not worth considering.[42]

4.1.3 *Evaluating the forecasting accuracy*

The accuracy of predictions can only be determined by considering the performance of a model on new data that were not used when the model was adapted. When choosing models, it is common practice to separate the available data into two parts, training data and test data, where training data are used to estimate the parameters of a prediction method and test data are used to assess its accuracy. Since test data will not be used to determine predictions, it should provide a reliable indication of how well the model is able to make predictions.

Fig 4.1: Training and test data, from the book "Forecasting Principles and Practice"

The size of the test set is generally about 20 per cent of the total sample, although this value depends on the length of the sample and the anticipation with which the prediction is to be made.

A prediction 'error' is the difference between an observed value and its prediction and can be written as:

$$e_{T+h} = \hat{y}_{T+h|T} - y_{T+h}, \tag{5}$$

[42] Rob J. Hyndman, George Athanasopoulos: "Forecasting Principles and Practice"

where the training data is {y1, . . ., yT } and the test data is {yT+1, yT+2, . . .}

4.1.4 *Forecasting with time series decomposition*

Time series data can show a variety of patterns and it is often useful to divide a time series into several components, each representing an underlying pattern category.

When we decompose a time series into components, we usually combine the trend and the cycle into a single trend-cycle component. Therefore, we think of a time series as having three components: a trend-cycle component, a seasonal component and a residual component.

We assume an **additive decomposition**, wrote as:

$$y_t = S_t + T_t + R_t, \tag{6}$$

where yt is the data, St is the seasonal component, Tt is the trend-cycle component, and Rt is the remainder component, all at period t.

The first step in a classical decomposition is to use a **moving average** method to estimate the trend cycle.

A moving average of order n is:

$$\hat{T}_t = \frac{1}{n} \sum_{j=-k}^{k} y_{t+j}, \tag{7}$$

where n=2k+1.

The trend-cycle estimate at time t is obtained by averaging the values of the time series within k periods from t. Observations that are close in time are also likely to be close in value, therefore, averaging eliminates some of the randomness in the data, leaving a smooth trend-cycle component.

Once the trend-cycle (7) is computed, we will calculate the detrended series that is equal to:

$$y_t - \hat{T}_t \quad (8)$$

For each season, we have to compute the seasonal component Ŝt averaging the detrended value for that season, and the sequence is then replicated for each year of the data (Example: With monthly data, the seasonal component for March is the average of all the detrended March values in the data). The values are adjusted to ensure that they add to zero.

The remainder component is calculated by subtracting the estimated seasonal and trend-cycle components:

$$\hat{R}_t = y_t - \hat{T}_t - \hat{S}_t \quad (9)$$

Although decomposition is primarily useful for studying time series data and exploring historical changes over time, it can also be used for forecasting.

To forecast a decomposed time series, the seasonal component and the seasonally adjusted component are forecast separately. It is usually assumed that the seasonal

component is immutable or changes very slowly, so it is predicted simply by taking the last year of the estimated component.

4.1.5 *Forecasting tasks*

To perform a forecasting analysis, the following steps must be followed:

1) **Problem definition:**

First thing, we need to know what we need to forecast, it requires an understanding of the way the forecasts will be used and how the forecasting function fits within the organization requiring it.

2) **Gathering information**

Statistical data and the expertise of the people who collect the data, perform and use the forecasts.

3) **Exploratory analysis:**

Detecting patterns, such as trends, seasonality, evidence for business cycles…

Examples should be: trend (a long term increase or decrease in the data), seasonality (the time series is affected by seasonal factors), cycle (rises and fall are not of a fixed frequency and the fluctuation are usually due to economic conditions, often related to the business cycle)

4) **Choosing and fitting model:**

Once we have detected what the patterns are, we need to choose and fit the forecasting model. It is common to compare two or three potential models. Each model is an artificial construct based on a set of assumptions and one of more parameters which must be estimated using the known historical data.

5) **Evaluating a forecasting model:**

The performance of the model can only be properly evaluated after the data for the forecasts period have become available. Several methods have been developed to help in assessing the accuracy of forecasts.

4.2 Turnover forecast analysis of the Schnell spa's purchasing department

1) PROBLEM DEFINITION

In this part, we will first analyse the supplier turnover trend for the period 2018 - 2021, considering turnover as the amount in euros of all the orders placed each month by the company's purchasing department. Then, after making some forecasts, we will choose the best model and see if they match the actual figures for the first months of 2022.

2) GATHERING INFORMATION

The initial dataset was taken from the company's management system where all the orders placed are updated daily. The excel sheet consisted of the order date, order code, supplier name and code and the amount of turnover for each order. After cleaning and

sorting the dataset, I inserted a pivot table and obtained the total monthly turnover for each year and then analyzed it in Rstudio.

3) EXPLORATORY ANALYSIS

The most important part of the exploratory analysis is to visualize the time series and be able to detect patterns (trends, seasonality behavior and cyclical behavior) or understand if there is not a systematic behavior at all.

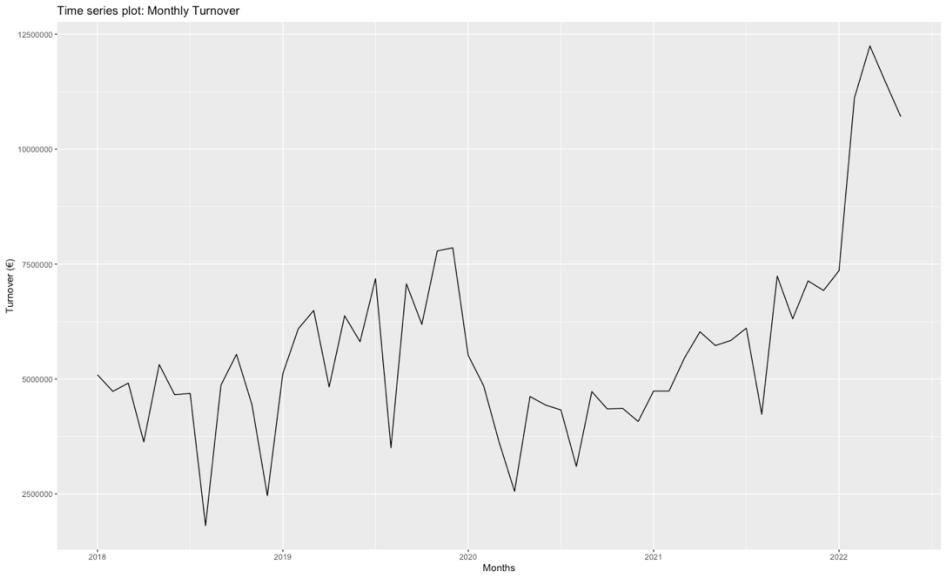


Fig 4.2: Monthly turnover of schnell spa purchasing department

Thanks to the **time series plot** we can immediately see that, prior to 2020, the trend in turnover was increasing and with the presence of seasonality.

With the arrival of Covid 19 in early 2020, which brought not a few disruptions, many companies were closed, including some suppliers, and this is the cause of the collapse and the downward trend that we see starting already in the first months of the year.

From mid-2021 onwards, we can see that values are back to the same level as in 2019, while from 2022 onwards there is an abnormal upward spike due to high demand but also to other factors outside the company's control.

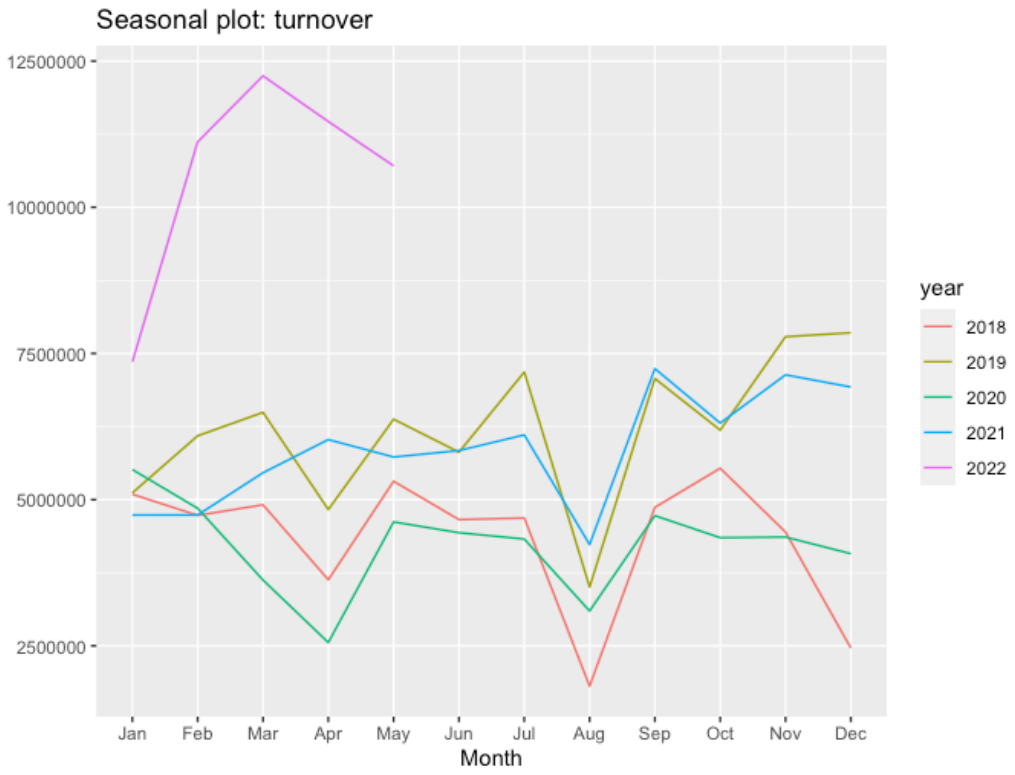


Fig 4.3: Seasonal plot of monthly turnover of Schnell spa purchasing department

With the **seasonal plot** we can detect seasonality behaviors across the years. As we can see, in each year we have a downward peak in august, which corresponds to the company's closure in the summer period, and in April, which corresponds to the Easter holiday (we've assumed).

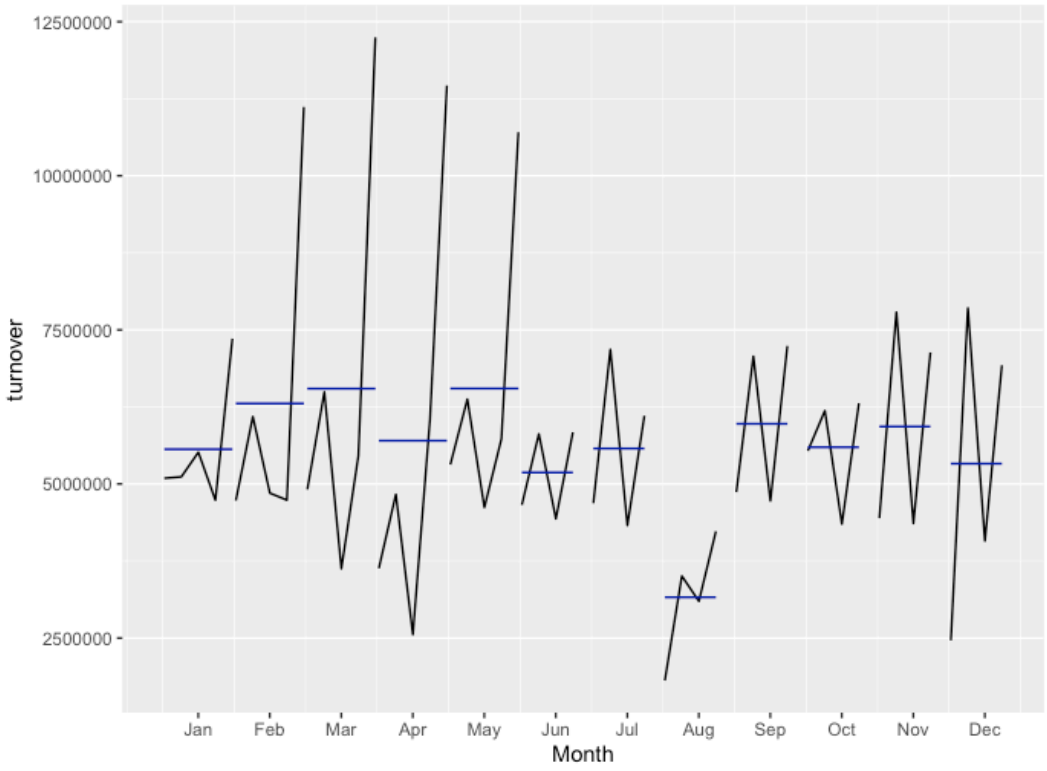


Fig 4.4: Seasonal subseries plot of turnover of Schnell spa purchasing department

With the subseries plot we can see that on average, by taking all the years, the turnover in August is lower with respect to the rest of the year and downward peaks in each month are due to low 2020 values and the high levels in the first months of 2022.

4) CHOOSING AND FITTING MODELS

Before we look at our forecasts, it must be said that the result will not be accurate and realistic as it will not consider external factors that are affecting the markets, especially in recent months, such as trends in demand and markets, but above all the general increase in raw material prices.

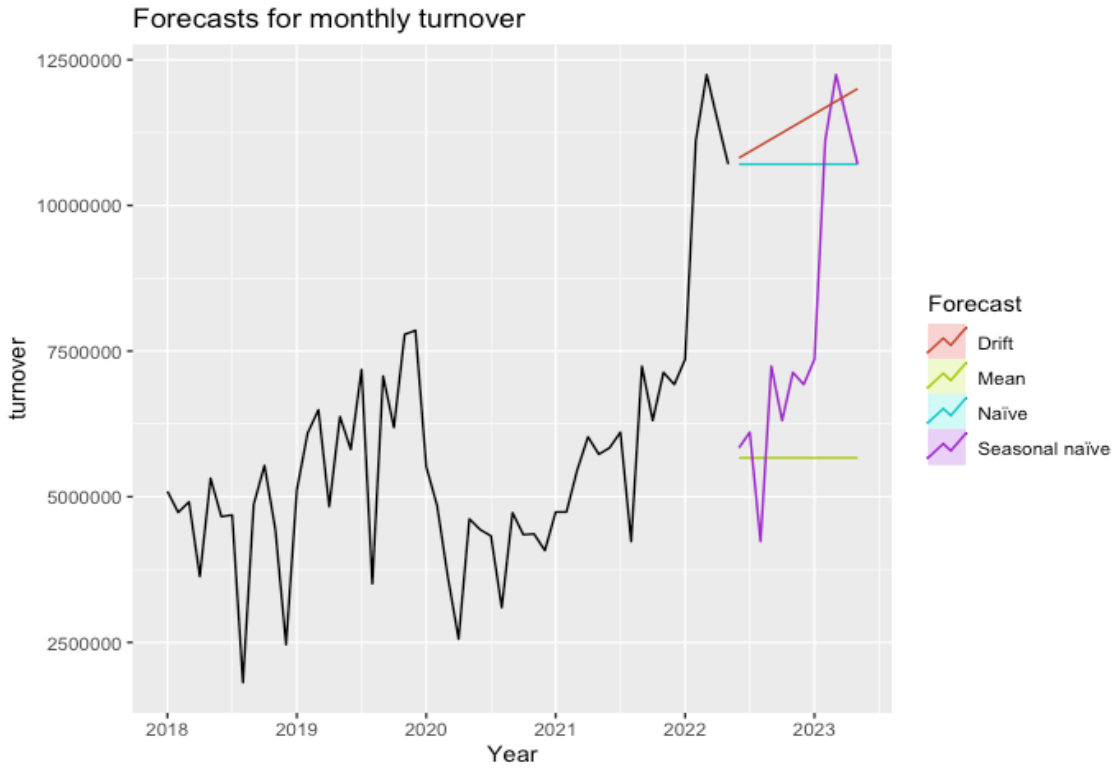


Fig 4.5: Forecasts of turnover of Schnell spa purchasing department

After making all the simple predictions (Dift, Mean, Naïve and Seasonal Naïve method) we can look at the residuals to assess their accuracy.

As we expected, looking also at the forecast errors of the various methods, these do not provide us with an accurate prediction.

As the previous methods are not very accurate, we need a more sophisticated method.

We can start by doing the classical decomposition:

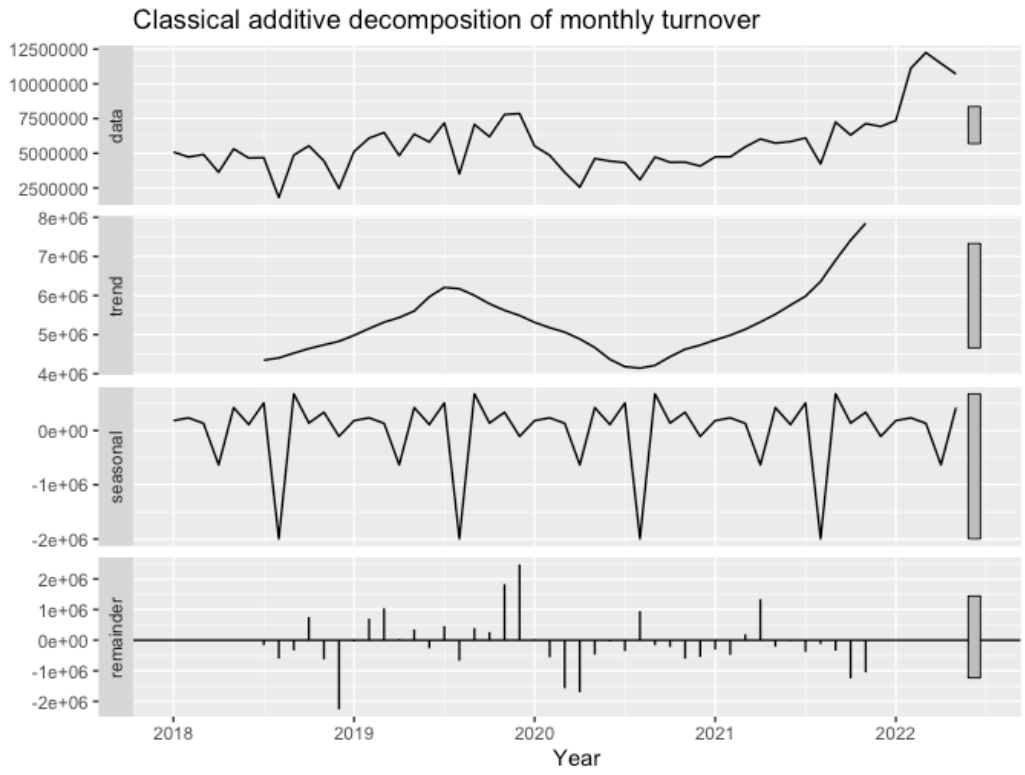


Fig 4.5: Classical additive decomposition of monthly turnover

With the classical addictive decomposition, we separately performed a moving average (to estimate the trend cycle components) and we estimated seasonal components (that are constant over the time and repeated itself).

The decomposition look fine as the remainder doesn't have a clear pattern.

By performing the different prediction methods and comparing the accuracy with the error calculation, the **best model** turns out to be the STL decomposition[43].

[43]STL is a versatile and robust method for decomposing time series. STL is an acronym for "Seasonal and Trend decomposition using Loess", while Loess is a method for estimating nonlinear relationships.

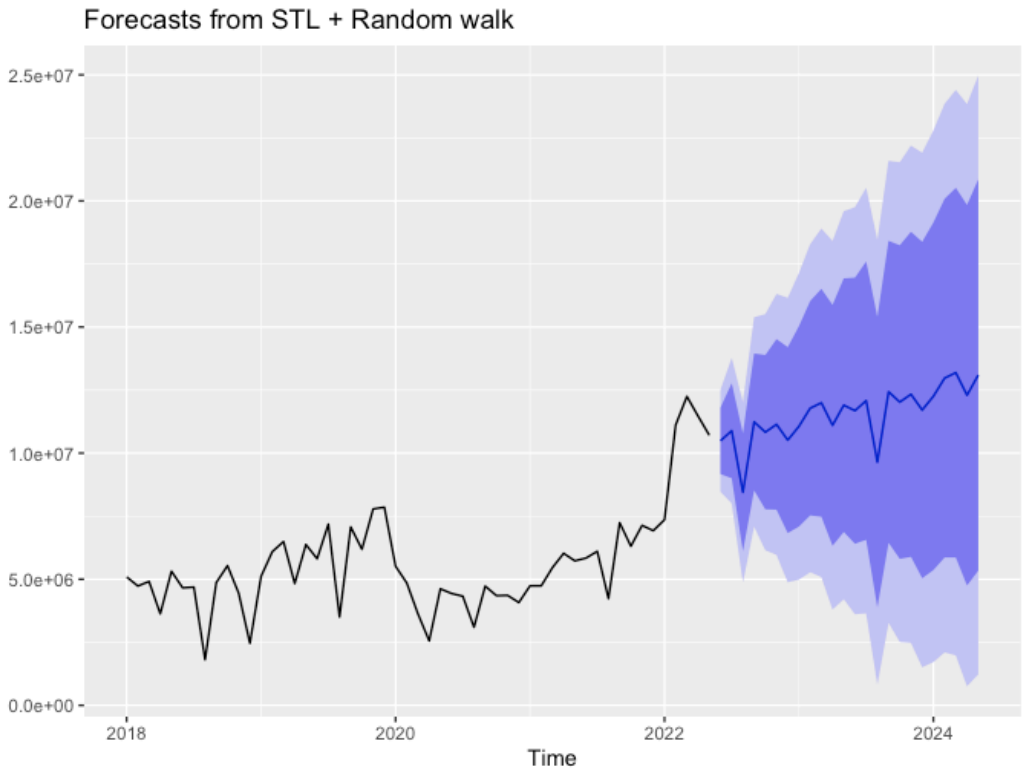


Fig4.6: Final forecast

We have performed an STL decomposition, so the total forecast is the sum of the prediction of the trend cycle and the seasonality.

Thanks to this method we catch both the seasonal periodicity and the upward trend.

CONCLUSION

In view of the necessary optimization of efficiencies in the field of operations, Schnell Monteprandone's current purchasing package was analyzed, revealing a high number of suppliers for the same type of product. The implementation of actions aimed at the continuous improvement of purchasing will allow the optimization of purchasing processes by entrusting orders to a limited number of suppliers with whom a long-term relationship will be established.

With my experience within Schnell, I was only able to be part of a small part of the entire project, as only one product type was analyzed out of the hundreds in the company's portfolio. However, the analysis of the other product types will be carried out with the same method used in this paper, again focusing on the elimination of activities that do not add value, which is the cardinal principle of lean manufacturing.

Using the DMAIC method and the PDCA cycle, the supplier base will be rationalized, allowing more volume to be offered to the remaining suppliers, costs to be reduced, and other performance improvements to be triggered. Preferred suppliers will be periodically monitored for their performance in lead time and delay time. In addition, they will have the ability to offer full service and often better benefits in the form of engineering, design, testing, manufacturing and tooling capabilities.

It can be concluded that the optimization of Schnell Monteprandone's supplier base leads to a significant improvement in total cost, quality, average lead time, on-time delivery and technical support.

R CODES

```
rm(list=ls())
# Set working directory
setwd("/Users/elenasanteusanio/Desktop/INTERNATIONAL ECONOMICS AND COMMERCE/BIG DATA ANALYTICS FOR BUSINESS/TIME SERIES")
library(fpp2)

data = read.csv("2022.csv", head=TRUE, stringsAsFactors = TRUE )
head(data)



# Set time series data
data = ts(data, frequency=12, start=c(2018,1))
autoplot(data, facets=TRUE)

turnover = data[,2]
autoplot(turnover) +
  xlab("Months") + ylab("Turnover (€)") +
  ggtitle("Time series plot: Monthly Turnover")

# Inspect seasonality
ggseasonplot(turnover)
ggsubseriesplot(turnover)

# Autocorrelation
ggAcf(turnover)

autoplot(diff(turnover))
ggAcf(diff(turnover))

#AVEAGE METHOD
meanf(turnover, h=1)
meanf(turnover, h=12)
```

```
#NAIVE METHOD
naive(turnover, h=1)

#SEASONAL NAIVE METHOD
snaive(turnover, h=12)

#DRIFT METHOD
rwf(turnover, h=12, drift=T)

# Plot basic forecasts
autoplot(turnover) + autolayer(meanf(turnover, h=12),
                        series="Mean", PI=FALSE) +
  autolayer(naive(turnover, h=12),
          series="Naïve", PI=FALSE) +
  autolayer(snaive(turnover, h=12),
          series="Seasonal naïve", PI=FALSE) +
  autolayer(rwf(turnover, h=12, drift=TRUE),
          series="Drift", PI=FALSE) +
  ggtitle("Forecasts for monthly turnover") +
  xlab("Year")  + guides(colour=guide_legend(title="Forecast"))


#RESIDUALS
autoplot(turnover)

res = residuals(snaive(turnover))
autoplot(res) + xlab("month") + ylab("") +
  ggtitle("Residuals from seasonal naïve method")

checkresiduals(snaive(turnover), 24)
checkresiduals(rwf(turnover), 10)
checkresiduals(meanf(turnover), 10)

# Check forecast accuracy
# Select the training set (window function)
turnover2 = window(turnover,start=2018,end=c(2021,12))
```

```
retfit1 = meanf(turnover2, h = 12)
retfit2 = rwf(turnover2, h = 12)
retfit3 = snaive(turnover2, h = 12)
retfit4 = rwf(turnover2, h = 12, drift=TRUE)

# Forecasts
autoplot(window(turnover)) +
  autolayer(retfit1, series="Mean", PI=FALSE) +
  autolayer(retfit2, series="Naïve", PI=FALSE) +
  autolayer(retfit3, series="Seasonal naïve", PI=FALSE) +
  autolayer(retfit4, series="Drift", PI=FALSE) +
  xlab("Year") + ylab("") +
  ggtitle("Forecasts for monthly turnover") +
  guides(colour=guide_legend(title="Forecast"))

accuracy(retfit1)
accuracy(retfit2)
accuracy(retfit3)
accuracy(retfit4)

#-------DECOMPOSITIONS

# Moving average
autoplot(turnover) + ggtitle("Monthly turnover") + ylab("") + xlab("Year")
ma(turnover, 4, centre = FALSE)

autoplot(turnover,  series="Data") +
  autolayer(ma(turnover, 4, centre = FALSE), series = "4 - MA")  +
  ggtitle("Monthly turnover") + ylab("") + xlab("Year")


autoplot(turnover,  series="Data") +
  autolayer(ma(turnover, 4, centre = FALSE), series = "4 - MA")  +
  autolayer(ma(turnover, 6, centre = FALSE), series = "6 - MA")  +
  autolayer(ma(turnover, 12, centre = FALSE), series = "12 - MA")  +
  ggtitle("Monthly turnover") + ylab("") + xlab("Year")
```

```
# Centered MA
autoplot(turnover,  series="Data") +
  autolayer(ma(turnover, 4, centre = FALSE), series = "4 - MA")  +
  autolayer(ma(turnover, 4, centre = TRUE), series = "2 x 4 - MA")  +
  ggtitle("Monthly turnover") + ylab("") + xlab("Year")

# Classical decomposition
autoplot(decompose(turnover, type="additive")) +
  ggtitle("Classical additive decomposition of monthly turnover") + xlab("Year")

autoplot(decompose(turnover, type="multiplicative")) +
  ggtitle("Classical multiplicative decomposition of monthly retail sales") +
xlab("Year")


# Forecasting with decompositions
fit = stl(turnover, s.window="periodic")

# Random walk  forecasts of seasonally adjusted data
autoplot(seasadj(fit)) +
  autolayer(rwf(seasadj(fit), h = 12, drift=TRUE)) + ylab("  ") +
  ggtitle("Random walk forecasts of seasonally adjusted data")


# Complete forecasts, STL + naive
autoplot(turnover) +
  autolayer(forecast(fit, method="naive")) + ylab("  ") +
  ggtitle("Forecasts from STL + naive")

# Complete forecasts, STL + random walk with drift
autoplot(turnover) +
  autolayer(forecast(fit, method="rwdrift")) + ylab("  ") +
  ggtitle("Forecasts from STL + Random walk")

accuracy(forecast(fit, method="rwdrift"))
accuracy(forecast(fit, method="naive"))
```

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