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# Furniture supply chain analysis with a simulation tool: the Natuzzi S.p.A. case

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# Abstract

Effective supply chain management is critical to the success and competitiveness of businesses in today's global economic landscape. Specifically, it allows companies to reduce operating costs, improve the quality of the products and services they offer, and maintain a competitive edge.

This thesis is a company case study on a simulation tool for the analysis and possible improvement of the efficiency of a supply chain. Specifically, it examines the context of the company Natuzzi S.p.A., operating in the furniture sector. The scope is limited to the analysis of the production system of a single product, the upholstered sofa in different variants, with focus on demand satisfaction and procurement of its components.

The study is conducted by comparing different scenarios of procurement process management, with particular attention to reordering policies and choice of suppliers. The key outputs of interest are stock level, service level, delivery lead time, inventory cost and order cost.

The aim is to make a comparison and evaluate trade-offs between the cost-effectiveness of logistics chains and the lead time in serving the customer in the scenarios analyzed, a comparison that allows to elaborate considerations on the goodness of tactical and operational processes and suggestions on what could be implemented in the future.

The work can be divided into phases: study of the literature, analysis, and identification of the fundamental elements to be considered in the subsequent phases, construction of the model in the anyLogistix language, analysis of the outputs, prior sensitivity analysis to verify the robustness of the results obtained.

# 1. Introduction

Managing supply chain means continuously seeking improvements and taking on new challenges. Solutions can span different areas of expertise and come from operational, tactical, or strategic management levels.

Challenges related to supply chain design, inventory and transportation policies, production planning, and risk management include:

- Where to locate new facilities: distribution centers or factories?
- How would the supply chain withstand a strike or the loss of a supplier?
- What inventory policies should be used to balance costs and service levels?
- How much product to ship each month?
- How would the supply chain change with the introduction of a new product?
- What level of service is provided to customers?
- What should the capacity of the new production facility be?
- Should transportation be handled internally or through third parties?

Essentially, each issue requires a level of detail appropriate to the system in question. It is possible to have an overview by considering the essentials, but understanding complex issues requires examining multiple factors.

However, the challenge lies in balancing the complexity: some issues are too vast to go into every detail in a reasonable amount of time. Success comes from finding the optimal level of detail that meets the needs of the situation. The more details considered, the more opportunities there are for improvement, including more decision variables to improve and more variants to test.

A mathematical model of the supply chain provides a risk-free space to conduct experiments and test "what-if" scenarios before introducing an innovation. Only after you have carefully examined the effects of innovation in your model should you begin to implement it in your actual business system.

To address mid- and low-level abstraction supply chain problems, supply chain leaders around the world leverage analytical optimization and dynamic simulation.

For analytical optimization, the model undergoes a transformation into a series of linear equations, creating an integer mixed linear programming challenge. These equations are then solved using optimization engines. Analytical models excel at tackling large-scale, data-rich problems. They are able to streamline supply chains with numerous sites and product categories, offering a significant advantage in this regard.

However, analytical models are unable to capture the intricate workings of real-world supply chains, such as operational logic, resource availability, randomness, and time-dependent dynamics. As a result, there is always an uncertainty as to whether the result obtained is truly optimal. Analytical models shine when it comes to network-wide supply chain dilemmas, where operational complexities, randomness, and time dynamics are not critical. If the problem requires consideration of these factors, analytical optimization can still provide an initial approximation of the solution. It is then possible to prepare a detailed analysis using dynamic simulation modeling, i.e., a situation in which a particular set of conditions is artificially created to study or experiment with something that might exist. A dynamic simulation model works so that you can run it, allowing you to observe the behavior of the system over time. Essentially, it serves as the digital twin of the supply chain.

Dynamic simulation becomes particularly useful when the inner workings of operations have a significant impact on financial efficiency and must be taken into account during supply chain design. With dynamic simulation, it is possible to model operational logic and analyze real-world dynamics.

The simulation can handle stochastic models, where random inputs lead to random outputs. Instead of optimizing, simulation focuses on modeling various scenarios by observing their results to drive business decisions.

Analytical models typically focus on a single key performance indicator (KPI) of the supply chain, such as cost or profit. On the other hand, in a dynamic simulation model, many different parameters can be measured at the same time. Costs, capacity utilization in distribution centers, service levels, fleet utilization rates, and whip can be calculated within the same model. Analysts take advantage of this feature to test how changes to model parameters affect different KPIs. This allows to experiment different inventory policies and analyze their impact on costs and service levels.

It's important to note that simulation doesn't produce an optimal solution from multiple combinations, but it does allow analysts to thoroughly examine specific dynamic scenarios and supply chain interdependencies. While there is simulation-based optimization, it differs fundamentally from analytical or mathematical optimization. In simulation, the optimization engine operates separately from the simulation model. The optimizer evaluates the model's output and generates new input parameters based on this data to better achieve optimization goals. As a result, more iterations of the what-if model are needed to achieve the best possible outcome. Advances in cloud technologies are addressing the existing time and machine power constraints by moving the simulation model execution to the cloud. Therefore, dynamic simulation is best suited for supply chains that are heavily influenced by uncertainties, internal site logic, and processes, and that require the consideration of numerous details. It stands as the only technology that can address these challenges.

To achieve efficiency, it is useful to combine these techniques: simulate the supply chain to obtain detailed information on the dynamics of the system, starting from the scenarios obtained through analytical optimization.

AnyLogistix™ (ALX™) software integrates powerful analytical optimization approaches with innovative dynamic simulation technologies, providing supply chain experts with a comprehensive toolkit for end-to-end network analysis.

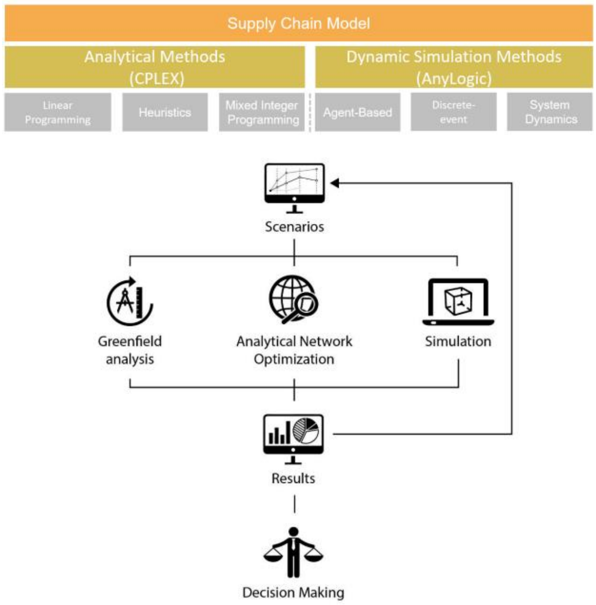


*Figure 1. Analytical and Simulation methods in anyLogistix*

Among the problems mentioned above, the evaluations of the following thesis will focus on the topics of supplier selection and warehouse management. The warehouse is an integral part of the logistics process, and understanding the inefficiencies within a warehouse can be tricky but crucial for business owners looking to effectively manage their inventory. Small and medium-sized companies often underestimate the importance of effective inventory and order organization, an automation that saves money and time. First, it's important to evaluate current practices and processes, review inventory systems, and look for improvement areas. Speaking of warehouse organization, we come across a wide range of aspects, from the reduction of the space occupied by the goods if they occupy more than necessary due to packaging, to the simplification of the packaging or receiving process itself, to the arrangement of the loading units to make those to be picked up more frequently more easily accessible, and also the automatic stock control in the manual warehouse to control the stock level and the picking of orders through processes managed in real time, reliable and accurate.

The thesis work is configured as a contribution to a project in which the Politecnico di Torino collaborates as a partner of Made in Italy Circolare e Sostenibile (MICS), an Extended Partnership funded by the MUR (Ministry of University and Research) thanks to the funds made available by the European Union under the NextGenerationEU program. Specifically, it will focus on improving the efficiency of the supply chain dynamics of the Natuzzi S.p.A. company.

The present work will make evaluations that will focus on reorder points and quantities, storage costs and availability of goods as well as discussing the possibility of abandoning relationships with some suppliers and reinforcing those with others, also in light of the differences in the unit costs of the items themselves, depending on the origin, a variable that is included in the resulting trade-offs.

The aim of this specific project is, from a more practical point of view, to understand the origin of the inefficiencies that prevent the customer from providing a certain and contained delivery time, as well as to understand if it is possible in the context studied to help management through this tool.

The following concept map shows a standard design of a supply chain, its interdependencies, all parameters that are part of our model as input data or as simulation variables.

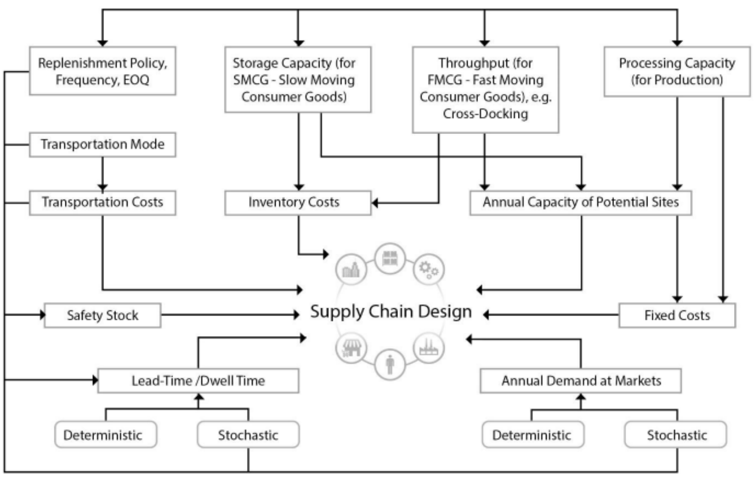


*Figure 2. Supply chain design analysis framework*

This study stems from the desire to combine a simulation tool with the study of the supply chain of a specific business reality.

A preliminary analysis of the literature was carried out, useful to have a relatively complete picture of the research and publications pertinent to the topic addressed. By collecting, synthesizing and reporting the main articles concerning the theoretical and methodological context in which the present research is inserted, the main concepts that it deals with and those on which it does not dwell are established. The literature review is presented in subchapters, according to a conceptual structure that refers to the structure of the thesis.

With the greater theoretical awareness and a clearer idea of the methodology to be followed provided by the study of the literature, the industrial and economic context of reference is examined. A wide-ranging analysis of the furniture industry is then prepared, necessary to contextualize the specific business case and to understand the main aspects to be considered when analyzing this type of supply chain. An in-depth study is dedicated to the structure of the sector in Italy, to the history of Italian districts and to the Apulian district in which the company taken as a case study is located.

The company, Natuzzi S.p.A., is then introduced. Its structures and divisions are explained, considering that reference will be made in subsequent analyses to the Divani&Divani® division. Key success factors and innovations adopted by the company are summarized, some of which are described in more detail in the subchapter dedicated to the production cycle of the Natuzzi sofa. The production cycle was implemented in the virtual model in a "digital twin" inspiration. Some specificities are not formalized in the model, but they might be introduced and exploited in potential future analyses some aspects of the model used in this case study were simplified.

Following the information received and the inquiries performed with supply-chain professionals from Natuzzi, we identified the main difficulties and criticalities encountered by the company in the effective management of the Divani&Divani® supply chain.

Parallel to these studies and information/data collection activities, there was research on how to use and leverage the anyLogistix software, considered adapt to perform the simulation.

With the company's proprietary data in hand, we move on to populate the model with the required input parameters and set all possible settings to make it functional, valid and verified. Chapter 4 is dedicated to the definition of the model and reports the anyLogistix tools used, as well as the assumptions and simplification choices.

A sensitivity analysis is then carried out to ensure that a robust model is used and then the experiments are designed, with the choice of the scenarios to be simulated.

In the discussion of the results, a reading of what was returned by the simulations was proposed. The results are presented as a tradeoff between a cost function and Lead Time to be minimized.

The output is a "winning" scenario that, although not optimal, is the best among the tested ones. The scope, assumptions, limitations and results are discussed in the Conclusions chapter.

# 2. Literature review

This literature review examines key research projects and articles that explore particularities of the supply-chain in the context of the furniture industry, covering the topics of outsourcing and the local reality of the Apulian district for upholstered furniture. The focus is then shifted to the topic of simulation modeling applications in the context of supply chain scenarios, with a limited reference to anyLogistix software previous usage in other similar research projects.

## 2.1. Introduction to supply chain

Supply chain management plays a critical role in the success of contemporary businesses, and simulation modeling has emerged as a powerful tool for optimizing and analyzing supply chain processes. The two key success factors for companies, which are often conflicting and require dynamic trade-off models are procurement costs and lead time. In recent years, several major events posed threats to the correct functioning of the global supply chain such as Covid-19 crisis and the war in Ukraine.

Regarding the topic of uncertainty and resilience towards disaster events, *N. Sahebjamnia (2018)* studied the decreasing performance of supply chain in case of disaster events around the world and proposed some methods to mitigate these risks. In this research paper, a mathematical model was designed and applied to a real example in the furniture industry, with the objective to minimize costs while increasing the resilience of the supply chain. The results from the empirical valuation confirmed the applicability and value of the proposed mathematical model, that mainly aimed at optimizing supplier selection and order allocation in a dynamic multi-period, multi-sourcing and multi-item supply chain. The supplier selection, alongside direct costs, determined a Resilience Weight variable (RW) for each supplier. It was computed based on surveys that evaluated historical data and current risk factors, and incorporated it into the model. This approach can lead to a change of procurement practices (supplier and order decisions) based on the resilience of suppliers and their risk against possible tragical events.

*S. Hosseini et al (2019)* also contributed to the literature on supply-chain resilience, performing a meta-analysis and conceptualization on the state of the art of the use of quantitative methods on studies of supply chain resilience, providing insightful recommendations as to which quantitative methods can be used at different levels of capacity resilience, as well as shedding a light over the current gaps and limitations on the topic.

*M. Sellitto (2018)* wrote a research paper with the purpose to present a method for calculating inventory, lead time and safety stock in job shop MTO manufacturing, from the application on an empirical case in the furniture sector. The proposed computation methods he used appeared to be a good estimate, failing however on WIP computation: the unbalanced and variable flows of materials in and out the production cycle lead to structural excessive levels of WIP.

Another contribution to the existing literature on furniture manufacturing, with a focus on the case of upholstered furniture in Italy, came from *R. Dangelico et al (2013)* that studied the importance of sustainability in the sector and the importance of companies "Going Green". It is important also to consider the sustainability impact of decisions whenever dealing with procurement in the upholstered furniture manufacturing.

## 2.2. Outsourcing in the furniture industry

As in recent years the role of outsourcing has become crucial for the manufacturing of western companies, the role of supply-chain decisions related to outsourcing have also increased in importance. *B. Eksioglu et al (2010)* have studied the impact of outsourcing decisions and supply-chain policies for US based firms operating in the upholstered furniture industry in Asia. They used a simulation model on a real-case scenario for a company based in Mississipi, and after comparing different scenarios they concluded that outsourcing is not always the best option, as it reduces local capacity, thus flexibility and profitability. According to their study, it is sensible and profitable to outsource in the upholstered furniture business based on the product types. In general outsourcing labor-intensive, slow-moving, and easy-to-transport items makes sense.

When it comes to outsourcing, western Europe is reliant on several different countries. Many companies decide to outsource part of their production within the continent, shifting to Eastern European countries. Particularly relevant to the scope of this research paper is the case of Romania, where Natuzzi also has a production plant. *E. Ciupan et al (2018)* studied ways to enhance sustainability in the upholstered furniture industry procurement in Romania, with a focus on the wood production. This paper addresses both environmental and economic sustainability of the industry, showing how changing wood with composite materials based on natural fibers obtained from fast-growing renewable crops (hemp, willow, flax, etc.) could significantly improve both the quality and externalities of the production. Consistently with the results of the study from *R. Dangelico et al (2013),* it is key to enhance the sustainability of operations in the upholstered furniture industry to achieve long-term growth and success, even when it comes to outsourcing decisions.

Outside of Europe, consistently with the US-based case study, the main outsourcing country is China. Whereas decades ago, Chinese manufacturers were not considered as reliable as others in terms of product quality and procurement reliability, they have developed much better capabilities in recent years, specifically in terms of supply-chain optimization *D.J. Robb et al (2008).*

More recent contributions, incorporating the events happened in the latest years came from *H. Østbø Haugen et al. (2024)*, that conducted a study in developing countries importing from China, the impact of the pandemic on the global supply chain has raised questions over whether a higher share of locally produced goods could prevent major impacts. After a case study regarding furniture makers in Ghana, their conclusions confirmed the hypothesis that a higher share of locally performed processes can be beneficial for the availability and cost of products in case of systematic disruptions, however a complete decoupling from China is neither possible or desirable, as raw materials and several layers of processed products were not easily sourceable elsewhere. Although the scope of this research paper was limited to Ghana, it is not implausible to suppose that the results are applicable in many developed countries as well, that are also strongly intertwined with global supply chain relationships. The results are thus important to keep in mind when analyzing sourcing and supplier management in the context of the furniture industry.

## 2.3. The Apulian district

Natuzzi is a market segment leader operating in a local context in southern Italy. The Apulian district is regarded as prestigious for the upholstered furniture industry, and as in many local local industrial districts some dynamics are common and do not correspond to usual free competitive market dynamics. “Trust is a major governance mechanism in industrial district supply chains and has been credited of every sort of advantage in previous literature.” according to *A. Capaldo et al (2012)* who specifically studied the dynamics of the upholstered furniture supply chain in the Apulian district, with a focus on Natuzzi. They applied complex systems’ theory methodology to quantify the impact on economic performance of trust within the local supply-chain.

*G. Belgiojoso et al (2009)* also analyzed the context of Natuzzi as a case study of internationalization within a traditional industry in a local context, adding valuable contribution to the context of the company that is precious for this thesis.

## 2.4. Introduction to simulation modelling

Simulation modeling has gained prominence as an effective approach for evaluating and improving supply chain performance. The work of *H. Min et al. (2002)* is a good starting point to understand the world of supply chain modelling. The paper, although now considered dated as it was published more than 20 years ago, gives a good perspective on how supply chain modelling worked during the last century, of its evolutions in the early 2000s and of the expectations that existed at the time. The researchers divided the existing models into 4 different categories: deterministic, stochastic, hybrid and IT-driven models. All models had to deal with trade-offs of reducing costs and reducing delivery time considering inbound transportation, production, and outbound transportation. Deterministic models were the oldest and less complex ones, that could lead to directionally correct results even with scarce data and low resources, but often were too theoretical and missed empirical evidence and input, whereas stochastic models required more effort and time to be built and functioning. Hybrid models tried to combine the two only introducing stochastic variables where really needed (for instance in demand planning). These models were very useful and sufficiently accurate but could be used at the time only for single-product problems with no capacity constraints. IT-driven models, such as WMS, ERP, and GIS were in very high demand at the time because significantly reduced costs and risk of errors when estimating costs and times, however back in 2002 IT-driven models were still in their infancy. Particularly interesting are the remarks over the scarcity of analytical tools to properly address the mathematical models already developed at the time, and on the unavailability or low quality of data. Considering the evolution of technology in the last 22 years, with particular focus on analytical tools and data mining, it is clear how they predicted very well the events in the year after their paper was published, and how now it is possible to achieve, thanks to technology what was only imagined in 2002.

Just two years before, *G. Cachon et al (2000)* shed a light on the importance of sharing information within the supply chain. Until a few years prior only minimal information was shared within the supply chains was shared: purchase orders. During the '90s, more information could be shared and analyzed by the existing computers, such as inventory levels and demand. To identify the potential benefits of sharing with suppliers more information on inventory levels and demand, they performed both a numerical study and simulation-based model. According to the results, 2.2%-3.4% lower costs on average, with peaks of 12.1%-13.8%, could be achieved by simply sharing more information with suppliers, that helped them properly prioritize the existing orders.

Acknowledged the strategic importance of the topic, just 3 years later, *M. Fayez et al. (2005)* developed an ontology for supply chain simulation modelling. That was a time in which modelling was becoming crucial for all firms, however not all of them were able to exploit the full potential of it because each model has its own objectives, scope, level of details, and assumptions. Supply-chain managers often tried to imply causations or broad the scope of the results of existing models, rather than spending on a new one for an updated environment. By doing so, they do not capture the fact that supply chains are rarely static and most often extremely dynamic. This research paper tried to give some guidelines on how to approach modelling and shed light on some mistakes to avoid.

*J. Brito Oliveira et al. (2016),* performed a meta-analysis and systemic literature review on existing research projects on simulation modelling in supply-chain models. This comprehensive paper puts together many existing projects with limited scope in terms of projects, industries, or countries to try give a state-of-the-art view over the topic. The key insights from this research were the increasing scientific interest in the topic as year over year the number of articles and citations on Supply Chain Management and Supply Chain Simulation, alongside with higher interest into combination of optimization methods with agent-based simulation, focus on better integration and more sophistications of the models and more empirical studies than before.

Supply chain modelling has proven to be pivotal in the recovery and post-disruption periods for supply chain. *D. Ivanov (2019)* used anyLogistix Software to study Disruption tails and revival policies in production-ordering systems, adding valuable scientific literature on how simulation tools and modelling can be used to mitigate the risks identified in the introduction to supply-chain section regarding resilience and variability generated by disruptive events.

## 2.5. The concept of a Digital Twin

Alongside the concept of simulation modelling, it is important to highlight the technique of "Digital Twins" in the context of simulation modelling. Digital twins refer to virtual representations of physical assets, processes or systems that can be used to model and simulate their real-world counterparts according to *S.S. Kamble et al (2022).* In the supply chain context, digital twins allow organizations to create virtual replicas of their supply chain networks, facilities, products and processes.

The concept of digital twins was invented in the early 2000s, consistently with the literature on opportunities for SCM improvement with Digital Supply Chains, and consists in replicating the physical Supply Chain on digital tools to better analyze it and study the impact of possible improvements.

*C. Piancastrelli et al (2020)* analyzed the state-of-the art of the development and application of digital twins in the context of logistics. They noted the higher advancement of DTs in production, and tried to derive some insights and requirements necessary to expand the applications in SCM.

*H. van der Valk et al. (2022)* built a comprehensive review on the literature about Digital Twins in supply-chain modelling, highlighting use cases, purposes and the level of technological readiness. They confirmed the previous literature on different advancement status of DTs between production systems and logistical chains. Whereas in the production context the development stage is really advanced, with digital twins on the way to fully automatize and autonomously control the physical twin, in the logistic context are not yet focused on autonomously controlling the system.

Some important academic contribution on how supply-chain management can leverage on the concept of Digital Twins with concrete examples has been provided by *E. Badakhshan et al. (2022)* who studied how Digital Twins alongside Machine Learning can be used to improve inventory and cash management in supply chains. Specifically, they found out how digital twins can help mitigate the bullwhip effect and minimize the cash-conversion cycle, especially for the upstream members of the chain.

In summary, digital twins offer a way to digitally replicate physical supply chains with real-time data synchronization and enable companies to test scenarios, measure impacts and support decision making without disrupting live operations. There is still room from improvement and possibilities to learn from the advancement in production, where digital twins are widespread and optimized.

## 2.6. Simulation tools

*S. Agrawal et al. (2023)* performed a comprehensive literature review from over 194 research articles published between 2009 and 2022 – with a trend increase from 2019 to 2022 – to understand whether Industry 5.0 and a stronger cooperation between humans and tools of automation and Artificial Intelligence can help offset the negative effects arising from 3 different types of events on global supply chains: pandemics, wars, and climate change. They concluded that with the integration of the Industry 5.0 framework into business, it is possible to achieve a partial shift to a “digital supply chain” and have better results in terms of agility, operational efficiency, customer service and innovation even against the most advanced tools used until I5.0 (ie. JIT philosophy, minimum stock management, outsourcing). The topic of this comprehensive research shows that the sapient use of tools such as supply-chain simulators among other technologies can be beneficial to firms that wish to optimize their supply chain cost and operating structures.

A common thread from existing literature on the topic, is the extreme dynamism of supply chains, and the importance of analytical tools into the simulation modelling. This was a theme back in 2002 when the first IT-driven models started growing and it is still now with the new Industry 5.0 paradigm and the existing automation and Artificial Intelligence tools, that easy the treatment of stochastic process and variables.

Within this framework, this research project will focus on anyLogistix, which is a versatile simulation software, that has been adopted by many firms and institutions for modeling and analyzing supply chain systems.

One noteworthy application of anyLogistix in supply-chain management is exemplified in e-commerce in Brazil, as studied by *L. Ramon dos Santos Hermogenesa et al. (2022)* in the case of "Marinna Acessorios". Facing a lack of demand data, the company aimed to strategically target cities for sales optimization. Employing a population density approach, they simulated demands across various scenarios to enhance financial returns. Similarly, *L. Vitorino et al. (2023)* utilized anyLogistix in the case of "Uvas do Vale", a Brazilian company analyzing a food distribution network. Without historical demand data, they employed the software to assess potential Distribution Center locations across the 100 largest Brazilian cities, generating three distinct scenarios for strategic evaluation.

This literature review provides a comprehensive overview of the existing research on simulation modeling in supply chain scenarios, specifically within the furniture industry using anyLogistix software. The synthesis of these studies lays the groundwork for the thesis's exploration of the application of simulation modeling to optimize the supply chain processes in a furniture company context.

# 3. The industry and company context

## 3.1. Furniture industry

Furniture industry consist of the production of all the furniture in the house and beyond, including furnishing objects for the purpose of support and storage of objects, for the relaxation of the person, with decorative purposes or with that of making a room comfortable for living.

The chart, produced by Statista in January 2024, is a global overview of revenues in billions of euros by product segment.

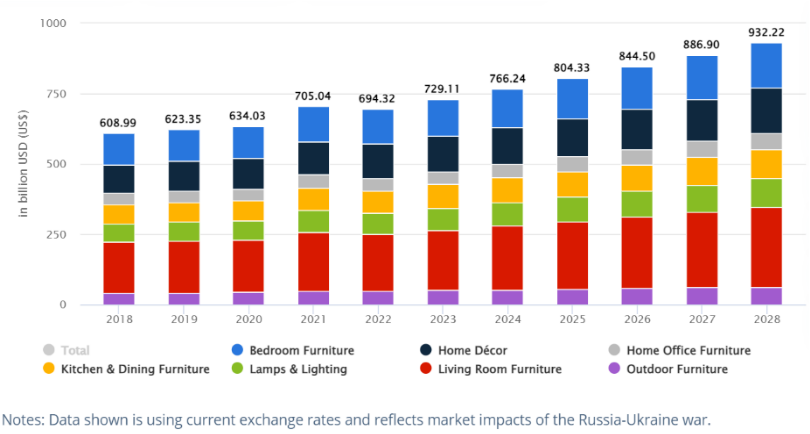


*Figure 3. Global overview of revenues in billions of euros by product segment*

If we limit the analysis to the Italian market, it is not surprising to note that among the items that fall within the scope of supplies, those for the kitchen and those for the bedroom have a greater weight than the global segmentation. The largest among the market segments is living room furniture.

Looking at global furniture production to date, the sector is dominated by China, which produces 180 billion dollars of products per year, followed by the United States and Germany.

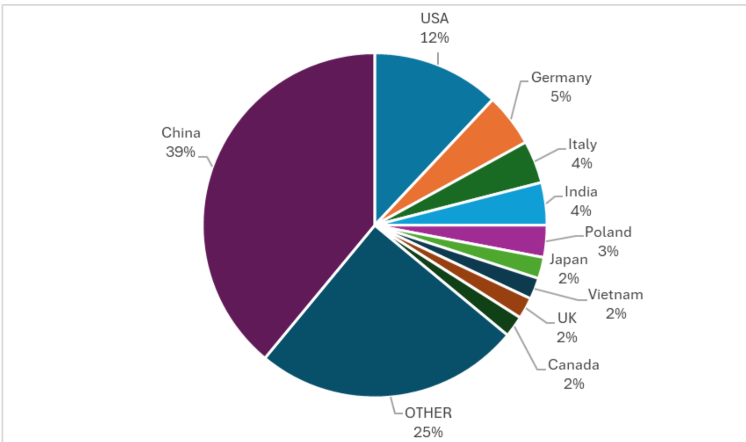


*Figure 4. Global market share by Country (bn€)*

Until 2006, Italy was one of the world's largest exporters of furniture. Among the main export destinations are France, Germany, the United Kingdom, Russia, the United States, Switzerland, China and Saudi Arabia. In the last decade, Italian furniture has begun to regain its foothold to rank 4th in the world. The record for exports is also held by China, followed by Germany and Poland. Germany, the largest exporter in the EU, accounts for a third of the total exports of wooden furniture for kitchens, and Italy also is well positioned in this segment. The Polish furniture industry is specialized in exports: since the domestic demand is relatively small compared to the production potential of the companies, most of the production is sold in foreign markets.

Dataset Statista provides us a list of the most important players of the sector in the world:

in billion USD (US$)

| | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|
| Ashley Furniture Industries Inc | 4.70 | 5.70 | 6.40 | 6.60 | 10.30 |
| Inter Ikea Holding B.V. | 30.15 | 28.20 | 25.80 | 28.37 | 30.55 |
| Nitori Holdings | 5.51 | 5.89 | 6.71 | 7.40 | |
| Oppein Home Group | 1.72 | 2.13 | 2.96 | | |
| Rh | 2.51 | 2.65 | 2.85 | 3.76 | 3.59 |
| Rooms To Go Inc | 2.30 | 2.50 | 2.50 | 2.70 | 3.80 |
| Wayfair | 6.78 | 9.13 | 14.15 | 13.71 | 12.22 |
| Williams Sonoma | 5.67 | 5.90 | 6.78 | 8.25 | 8.67 |

*Figure 5. Top Company Revenues (Worldwide & Consolidated)*

### *3.1.1. The players in the supply chain*

The first level of this chain is customers or retailers who sell the final products to customers. The second level, that might not be present, is composed of distributors who distribute final products to retailers. The third level is producers, that convert raw materials into final products and sell them to distributors, or to retailers.

In this type of supply chain where dimensions of products handled are often substantial, usually no stock is held at retailers' premises, unless for demonstration purposes, and drop shipping policy is enabled. This means that manufacturer directly send final products to customers.

The fourth level consists of suppliers who provide raw materials and send them to producers through different ways of transportation.

Between the different players in the supply chain, there are three main types of flow, namely material, financial, and information flows (represented in *Figure 6. Supply chain's flows*). The latter involves exchanging product data, electronic catalogues and orders, with the information seamlessly exchanged between parties, giving the customer better choices, by offering high customization.

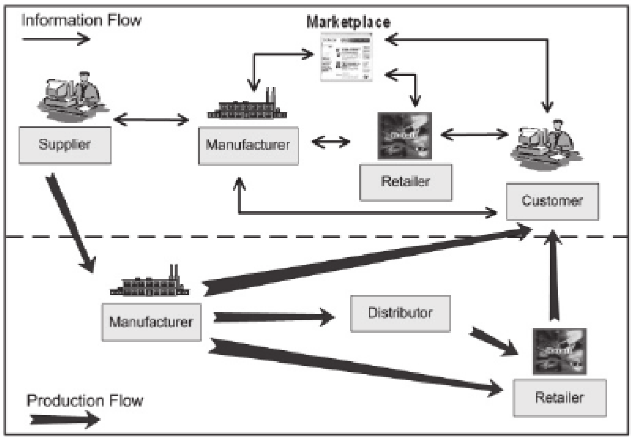


*Figure 6. Supply chain's flows*

Some companies that sell branded products, for example, only play a commercial and logistical role and outsource all of production. With their own warehouses, they can serve the customer directly at home, without going through the stores where the purchase takes place. For example, Mondo Convenienza relies on a group of manufacturers (80% of whom are Italian) and only retails products with its brand.

### *3.1.2. Flows and main issues of the furniture supply chain*

As the flow chart shows, the network of interlocking processes is complex, even though the product is relatively simple. The management of these flows of operation is the Supply Chain Management and to achieve competitiveness every aspect from sourcing to fulfillment is crucial. Some peculiar aspects need to be considered when dealing with the supply chain in the furniture industry specifically.

Wood, metal, fabric and foam are the building blocks of furniture and ensuring high quality materials is a priority for manufacturers.

Then, keeping quality high until the product is delivered is essential since even minor defects can lead to costly returns and negative repercussions on brand's reputation. Stringent quality control processes secure that problems are promptly solved but also reinforce the bond between manufacturers and suppliers. An efficient product storage and packaging can help as it safeguards against potential damages and the retailer choosing to keep its own warehouse may be dictated by greater protection in this sense.

Inventory management plays a crucial role in this type of supply chain where customers demand and command. While in other industries products are standardized, furniture production is complex, due to the different customers' personal tastes and choices. Their preferences evolve continuously. The sector is also subject to seasonal fluctuations in demand. Furniture sales often increase during holidays and mid-seasons. Fluctuations require careful planning of production and inventory management.

Many companies develop strategies that aim at reducing physical inventories embracing the practices of Just-In-Time inventory systems, which mean producing and delivering items as they are ordered. This approach minimizes storage costs, but the implications of this principles on the transportation costs must be considered. The shipping charges from suppliers to manufacturer and from wholesalers to retailers are a significant part of the overall costs, so reducing logistic costs is crucial.

Customer Service is a key success factor. The expectation is to grant timely and damage free deliveries, for all different options: in-home delivery, curbside delivery, or DIY assembly kits.

The main drivers of optimization are, in conclusion, the cost of transportations and the speed of delivery.

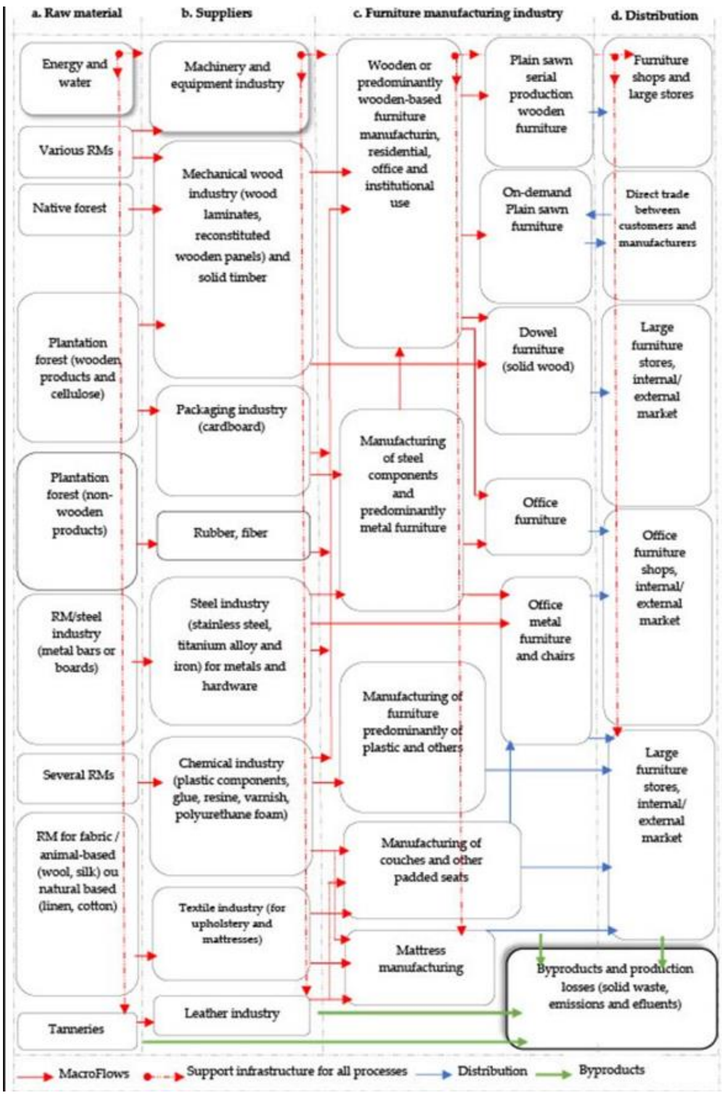


*Figure 7. Furniture supply chain's flow chart*

Italian furniture industry is still late in the adoption of circular economy (CE) strategies even though this is considered as one of major competitive success factor. Furniture waste disposal has negative externalities on the environment and economy. In 2017, 10.78 million tons of wastes were generated in EU Member States, the majority of which is destined for landfill or incineration, with a recycling rate lower than 10%, according to the Report 2017 on the Circular Economy Opportunities in the Furniture Sector.

The approach of "eco-design", that is using eco-friendly materials as soon as at the design stage, should be widely shared and approved. The goal is a continuous cycle of use and reuse of materials without the production of waste, or that the materials used could biodegrade 100%, returning to a natural cycle. The most important benefit of eco-design is precisely the planning of all the future "lives" of the object and embracing the model is the first step to be taken to talk about circular economy.

### *3.1.3. Information systems and flows for an integrated supply chain.*

To address all these challenges, companies in the furniture sector should be able to adopt structures, business models, management approaches able to withstand multiple sources of complexity.

Especially during the 2020-2022 period, the stress on the furniture industry caused by the pandemic induced demand on home goods, manufacturers had to improve their procurement systems.

To properly manage every aspect of the supply chain, it is first necessary to have complete visibility on both incoming and outgoing physical flows, which can only be achieved through the digitization of all processes from the planning stage, then an integration of the software used throughout the supply chain. This confirms the increasing needs for improvement on digital twin methods on supply-chain management systems. Having effective and integrated solutions for digital data management is an even more urgent result given that, on the customer side, online sales are becoming increasingly popular.

In the graph below, the furniture industry e-commerce sales trend worldwide. In Italy, according to Statista, by 2027 online sales will account for 25% of total furniture sales.

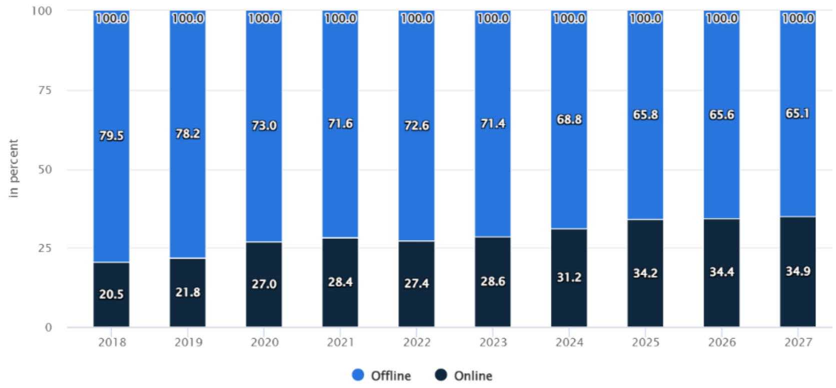


*Figure 8. E-commerce sales increasing trend as a percentage of the total*

Actors already communicate within any supply-chain, however the amount and quality of shared information should be increased to grant better leverage of the existing planning and simulation systems. Digitalization combined with the standardization of procedures is essential to achieve this goal and guarantees fast, efficient, reliable, and transparent information flows.

For companies with multiple production and logistic facilities, broad visibility that includes all nodes in the network and efficient sharing of information between them is even more important. In these cases, treating the various production plants (or warehouses) in an interconnected way allows for good flexibility performance. It means, for example, optimally managing the production capacities of plants, moving human resources where they are needed most in a timely manner, or making horizontal transfers of raw materials from one plant to another or finished products from one store/warehouse to another. Integrated inventory management, in fact, makes it possible to significantly reduce the safety stock. That's why management software absolutely must be integrated, at least at the company level.

It is pivotal to exchange information specifically on the quality of goods. As previously mentioned, the treated products cannot accept any type of non-conformity, if this does not belong to hidden parts of the product. The company's reputation is worth it, given the enormous sensitivity that the customer has for the integrity of the finished product. Promptly communicating problems found in the material arrived from the supplier is necessary for the rapid replacement of the batch and for a smooth continuation of the processes. Communication delays mean having to wait much longer for the new delivery and the greater the chances of having to suspend the production process. In addition, If the supplier obtains information of a non-conformity in the delivered material in time, they can stop the production of the batch in time and trace the cause of the defect, preventing the error from spreading to following pieces. This implies carrying out constant conformity checks on incoming goods.

An integrated supply chain consists precisely in the sharing of information between each of the links in the chain and promotes the traceability of goods, i.e., the monitoring of the inventory position in real time as well as the condition of each raw material, article, semi-finished or final product, and its history. It means knowing what operations it has been subjected to, where and by whom.

In this context, the world of Blockchain takes on enormous potential as it guarantees traceability. With its pillars of traceability, transparency, and decentralization, the Blockchain could be defined as a shared and immutable repository of information grouped into blocks connected to each other in a chain. Blocks are a set of data recorded at a given point in time and cannot be changed by subsequent transactions or actors. The result is a coherent structure of information chained in chronological order, the integrity of which is guaranteed by the protocols used, which facilitates the process of recording transactions and the traceability of goods in a commercial network. From this derive the advantages of Blockchain which take the form of greater trust, greater security, greater efficiency. Initially widespread in the financial and cryptocurrency sectors, it is now also widely used in the supply chain, for sharing information on the origin of products.

An increased use of Blockchain would greatly contribute to the cause of sustainability. You have clear visibility of what's happening beyond your company's boundaries, and that information is certified.

In terms of output, it would be useful to communicate the resources that have been exploited during the production and logistics phases in the Life Cycle Assessment modalities, with a view to contributing to the assessment of the environmental impact of the product throughout its entire life cycle.

They are therefore excellent tools for monitoring the sustainability performance of the Supply Chain to identify critical points more easily in the chain. This would have the effect of stimulating sustainable behavior of the actors involved.

### 3.1.4. Main trends

Since eCommerce is gaining a more and more crucial role in the growth of furniture industry, Wayfair, one of the largest online-only home goods retailers must be mentioned, according to Statista, as one of the companies with major potential for its future business.

According to Statista, the following trends are arising: augmented reality apps, multifunctional furniture designs, integrated technology. From 3D-printed furniture to smart lightening, the furniture market has been shaped by innovations in design, production, and material.

Customers are starting to take advantage of virtual showrooms where they can explore collections in interactive 3D environments without having to go to the store, as well as applications that allow them to virtually view the furniture in their homes before making a purchase. IoT is gaining an important role in this sector, enabling the creation of smart furniture with smart device integration and data sensing capabilities for health and comfort monitoring, for example.

As told, strategies for a "Green Supply Chain", including eco-design product, green procurement, green manufacturing, green logistics and reverse logistics are being developed in this industry as in others, to improve economic and environmental sustainability.


*Figure 9. Top ten trends in furniture industry for 2024*

## 3.2. Made in Italy furniture

The Made in Italy furniture industry was born and established in the post-war period. It is now worth over 41b€ and it employs over 320,000 workers.

The furniture sector makes up 64% of the Italian wood-furniture supply chain. The wood-furniture supply chain ranges from the import or production of semi-finished products (for example, wood panels or other composite materials), to the production of furniture for different environments, up to their marketing, wholesale, or retail. The furniture sector can be divided in the following types:

- Commercial Furniture & Furnishings ( > 32% of the market)
- Bedrooms ( > 16% of the market)
- Upholstered ( > 16% of the market)
- Kitchens ( > 12% of the market)
- Area living
- Chairs
- Home Office
- Mattresses
- Furnishing accessories

In addition, the country is the world's leading exporter of high-end sofas and armchairs. The 286 largest Italian companies in this sector recorded an aggregate turnover of €14 billion in 2021, more than half of which came from exports.

The furniture supply chain on Italian soil has historically been very fragmented. Most of the companies operating there are small and medium-sized. In the Italian scenario, there are about 29 thousand companies and there are only about 80 manufacturing companies that have revenues of more than 50 million euros.

- 80% are micro-enterprises
- 17% Small Businesses
- 3% Medium and large companies

Distribution in Italy is widespread. Organized distribution (chains, franchises) is almost non-existent. The few groups present, about ten in all, manage only 3% of total sales. Distribution is almost exclusively entrusted to individual stores (about 25300). These outlets are typically small in terms of physical size, revenues and are often family-owned.

One fourth of the supply chain is represented by industrial districts, whose traditional ties have in fact determined the success of local production systems in the past. Not all districts have survived the advent of foreign competition: the most resilient were the ones with autonomous sub-contracting firms, propensity to invest and innovate, and the presence of leading firms.

To remain competitive on the global furniture market, Italian companies focus on some key success factors:

- diversification of suppliers, with a shortening of supply chains, to mitigate the disruption risks.
- human capital, with investments in training and welfare for the employee
- particular attention to ESG issues and eco-sustainable strategies
- digitalization

Italian firms have to consider that Global demand is progressively polarizing towards either price competition on standard items or higher value and high customization.

Below is a list of internationally managed companies, with a strong presence in Italy, that have the greatest relevance in terms of distribution network, branding strategy and product diversification.

**IKEA** Globally, the biggest player in terms of market share, is the Swedish company IKEA. With sales above $45 billion, IKEA leads the industry by a significant margin in terms of revenue. Already in 2022, the world's most prominent furniture retailer, Ikea has a worldwide retail network, and Italy is one of the leading five selling countries for IKEA products as share of sales in 2023. Ikea's position in Italy is now well-established and makes it the largest economic player in the country in terms of market share in the furniture sector, acting as a manufacturer and as a retailer.

IKEA's success derives from the consistency of the strategies adopted to offer a value proposition that is unique in the world. The "democratic design" of Ikea products, in which design, functionality, sustainability, quality and low price coexist, is the element that has always distinguished it. Affordability and minimalist style, as well as a particular focus on sustainability, are the factors that make it more attractive to the young part of the population. Its wide assortment in terms of product categories also makes it convenient as, in one store you can potentially make your home functional and habitable. Branding strategies, a series of additional services, commercial policies, and measures are all linked by the common thread of strategic coherence and establish the company's worldwide success.

To get an idea of Ikea's presence in Italy, we report the market shares in 2020 of the companies producing seating furniture that record the highest revenues in Italy.

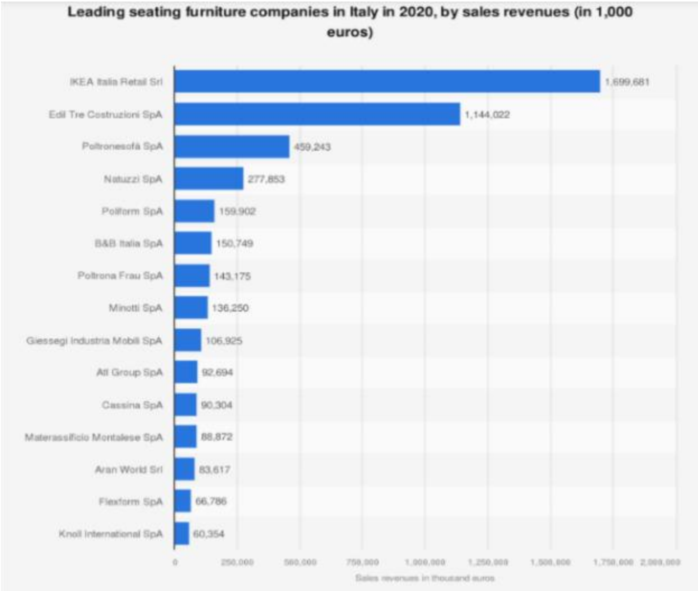


*Figure 10. Leading seating furniture companies in Italy in 2020, by sales revenues*

**Mondo Convenienza** A company that, like Ikea, leverages the volumes it obtains by guaranteeing very low prices. In addition, the financing possibilities offered by these companies, such as payment in installments, contribute to their popularity among the Italian population. However, Mondo Convenienza's strategy is very far from that of Ikea, but equally successful. If Ikea has the strength of the brand, Mondo Convenienza is chosen by customers because of its usefulness in terms of quality of assembly service, which is almost absent in Ikea (cash and carry, self-assembly).

**Leroy Merlin** French Leroy Merlin has a strong presence in the Italian market with numerous points of sale throughout the country. It offers a wide range of products for home décor (as well as DIY).

**Scavolini** It is one of the leading kitchen manufacturers in Italy. Scavolini is known for its innovative design and the quality of its products, including other home furniture.

**Mercatone Uno** has long been one of the leading furniture chains in Italy, offering a wide range of household products at competitive prices. Its tendency towards unbridled diversification led it to encounter many difficulties, as the proposed assortment had become excessively inconsistent.

On the other hand, focusing on less market-oriented companies in the furniture sector, Italy boasts numerous family-run companies, which pass on expertise through generations.

**Poltronesofà** One of the most famous and well-known companies in Italy, focuses on a very aggressive advertising strategy, in terms of intensity and promotions. Its focus is on customer proximity with its many points of sale.

**Poltrona Frau** Famous to produce luxury leather furniture, it is an icon in the Italian design industry.

**B&B Italia** It is a leading company in the field of furniture with a contemporary design.

**Molteni&C** Known for its innovative design and quality craftsmanship, it produces a wide range of home furniture, including sofas, tables, chairs, and cabinets.

**Flexform** Specializing in high-quality upholstered furniture, it offers a wide range of solutions for the home and office.

**Cassina Srl** Famous for its modernist and contemporary furniture, it has a long history in high-quality Italian design.

**Calligaris** It has been operating for over 100 years, and has a large collection of products that include coffee tables, chairs, sofas, beds, and much more. Calligaris is known for its innovative designs that are both traditional and contemporary at the same time. Their products are made of wood to ensure quality construction that lasts.

Halfway between the two positions is **Natuzzi**. Known for its high-quality sofas, it is a well-established Italian brand with an international presence.

### *3.2.1. Artisanality vs Industrialization*

Furniture combines two seemingly contrasting aspects: the importance of craftsmanship and the need for manufacturers to industrialize a production process that maintains a high degree of manual input.

Craftsmanship drives customization and high-quality, whereas industrialization is essential to reduce costs. The main challenges facing the sector derive from the need to combine authenticity with the application of industrial logic and processes.

Within the turnover of the wood-furniture sector armchairs and sofas amount to 2.5b€.

The upholstered furniture sector, compared to the general one features:

- Low industrialization and low barriers to entry for competitors
- More labor intensive and based on the containment of processing costs.
- characterized by a high incidence of transport costs as the products generally cannot be shipped disassembled and are heavy and bulky.
- qualified by both large leading groups and SMEs generally contractors and subcontractors.

New production techniques boosted design oriented towards modularity and ease of assembly. The automation of some phases such as nesting, packaging, internal transport, and storage helped increasing product customization while driving package standardization. With customization, it is necessary to have suppliers with different skills, given the different types of sofa components needed. They range from suppliers of mechanics and electronics, for electrified sofas, to carpentry shops, to polyurethane or foam rubber manufacturers, to leather sellers. The high diversification of the finished product, in terms of shapes, colors, coatings and accessories, does not allow for high automation, nor the creation of standard assembly lines, thus simplification and standardization of products, components and assembly processes are needed to reduce the amount of manual work.

### *3.2.2. Classic production cycle of a sofa*

The manufacture of a sofa starts from the realization of the frame which is the supporting structure. It includes a carpentry phase of the individual pieces that can be made inside the factory or arrive from outside. In the first case, after the first phase of wood shearing, the thickness of the planks that arrive semi-raw from the shearing are squared, smoothed, and reduced. Some operations can be done with CNC machines, others require completely manual machines. After cleaning with a splinter removal hose, the mold is composed, nailed, or stapled, glued and strength checked. The frame usually has solid wood parts and plywood parts.

When the frame is assembled, the elastic straps are applied to the seat to support the padding. The straps are braided perpendicularly and attached to the frame. Determining their tension is very important to give the desired comfort.

The polyurethane is cut to obtain the desired shapes to cover the frame.

Once the shapes have been created, the rubber layers are laid on the straps and on all the surfaces of the frame. Then the lining is carried out "in white" with the addition of an additional layer. To make the materials adhere, the surfaces are treated with a special substance.

The insertion of mechanical parts concerns structural or aesthetic parts, such as feet and bases or reinforcing elements, or mechanisms for supporting moving elements in reclining models. If the linkage is electrical, motors and related controls are added to these elements. In sofa beds, on the other hand, the metal mesh supporting the mattresses is the heaviest component of the sofa.

Parallel to these operations, those of conformation of the coverings can be carried out, i.e. cutting and sewing. The leather covers or rolls of fabric are placed on the cutting surfaces and, following a detailed technical scheme, cut manually to obtain the pieces of the size necessary to cover the sofa. After cutting, the fabric is re-linked to prevent fraying, then sewn to create the custom-made upholstery.

When the upholstery is ready, it is put on the padded frame and cushions.

The operations of coupling the structure–stuffing, insertion of mechanical and electrical parts and coating, assembly of the finished product, quality control and packaging are generally carried out entirely by one or two operators in a fixed station.

Below is a summary diagram:

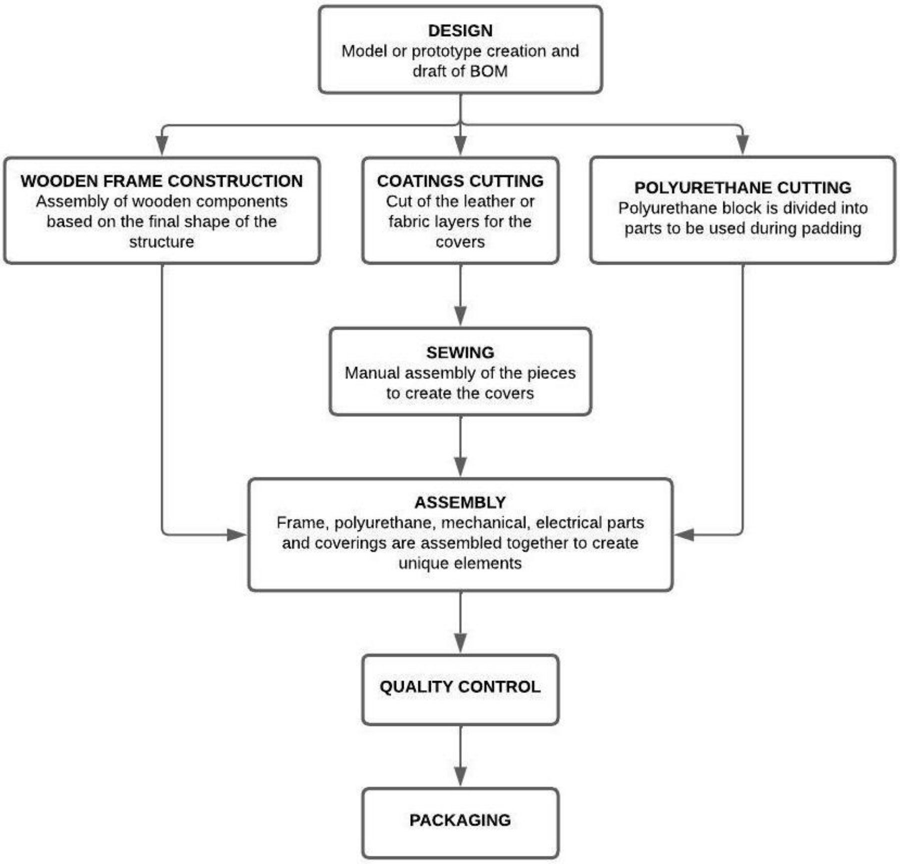


*Figure 11. Sofa's production cycle*

## 3.3. The Local environment

The Apulian upholstered furniture sector is geographically located in the Murgia area and confined to the triangle between the municipalities of Altamura and Santeramo in Colle, in Puglia, and Matera, in Basilicata, to constitute what is commonly defined as the so-called Murgian upholstered furniture district and its growth has been and still is driven by large companies.

The widespread presence of skills in the sectors of carpentry, knitwear and leather processing has formed the basis on which an integrated production system of a district nature has been developed.

Pasquale Natuzzi's entrepreneurial intuition to apply an industrial logic to the creation of upholstered furniture, when it was a typically artisanal product, fueled the growth of the local district. The creation of leather sofas with a contemporary design, has then become the fulcrum of the development of the upholstered furniture industry in Puglia and has contributed to the success of the entire Apulian wood-furniture system.

The industry faced significant growth in the ‘90s and has seen the companies grow in size and occupy important market positions. This growth was determined above all by the strong vocation for exports, as about 80% of production was exported, amounting to 40% of total Italian exports in the sector. In the early 2000s, it reached a stage of maturation followed by slowdown and recession.

Starting from the years 2000-2002, economic factors and structural dynamics have quickly put this sector in crisis, among which have contributed:

- the loss of competitiveness of the European manufacturers against emerging countries that have exploited low barriers to entry typical of labor-intensive industries with considerable availability of raw materials and semi-finished products at low cost.
- A system of predominantly product-oriented companies unable to withstand price competition and lacking an effective ability to enter foreign markets, needed in the international context.

The evolution of the global competitive scenario has meant that the Murgia upholstered furniture district has begun to experience enormous difficulties in exports.

The district had to rethink and reposition itself in a growing cost competitive scenario. Leader firms took two different approaches to improve cost efficiency in this sector: some decided to exploit globalization by outsourcing most of the production cycle in developing countries, other decided to increase the number of activities in their production facilities to better leverage on their investments and exploit economies of scope.

Because of both those approaches, there was a "rupture" in the relationship system among the district's suppliers and sub-suppliers. Many SMEs that previously belonged in the networks of leading companies ceased to exist, as their activities were either outsourced in developing countries or internalized.

Higher value-added, high-end products did not face outsourcing as much as mass production, leading to new structural relationships with local suppliers able to provide quality and time efficiency.

### *3.3.1. SWOT Analysis*

Below is the SWOT analysis for the Apulian upholstery furniture district:

| **STRENGTH** | **WEAKNESSES** |
|---|---|
| • Know-how and long experience gained by the companies of the district system in the sector<br>• System of local relationships that drive flexibility and product customization<br>• “Made in Italy” strength in the medium-high end market | • Low barriers to entry for competitors<br>• Technical replicability of the product<br>• Polarization of demand either price sensitive or focused on brand recognition and customization |
| **OPPORTUNITIES** | **THREATS** |
| • Demand for high-quality and sustainable products by the younger generations.<br>• Competitive advantage and strong positioning.<br>• Digitalization of the purchasing process, product customization on e-commerce. | • China can offer very good quality products, similar to Made in Italy, offsetting the lack of local *know-how* and creativity with the acquisition of Italian human capital.<br>• People prefer companies that differentiate the product offer as a one-stop shop.<br>• The loss of know-how due to migration of human capital and obsolescence of technological and practical knowledge with innovation. |

*Table 1. SWOT analysis*

## 3.4. The Natuzzi S.p.A. Company

The group, founded in 1959 by Pasquale Natuzzi, is one of the largest Italian furniture companies and one of the main global players in the furniture market. Listed on the New York Stock Exchange since 1993 and employing more than 4.000 people, it designs, manufactures, and sells sofas, armchairs and furniture for residential use.

Pasquale Natuzzi stood out for his vision, that made him one of the most respected Italian entrepreneurs in the world. The "Natuzzi Italia" and "Natuzzi Editions" brands are present in 105 countries around the world and the extensive sales and direct customer service network is managed by 11 sales offices.

It all stems from a small workshop in Puglia where sofas were handmade. In the 70s, without losing its artisan vocation, Natuzzi evolved into an industrial reality of excellence, focusing fully on the potential of "Made in Italy". In contrast to traditional Italian production focused on product durability, Natuzzi developed a more oriented approach to the American market, creating sofas that were more accessible and suitable for a more dynamic lifestyle. This has included offering a wide range of products to suit customers' needs and tastes, while also encouraging furniture renovation over time. One of the key innovations was the simplification of the sofa structure, using less expensive materials without compromising on quality. But perhaps the most significant innovation was the introduction of leather as the main material even for products intended for a low-to-mid-range market, thus expanding the market traditionally reserved for high-end consumers. In contrast to most Italian entrepreneurs, already at the end of the 90s, Pasquale Natuzzi had understood the importance of the challenges that globalization imposed and gave rise to a profound reorganization of the Group. During those years the Natuzzi Group was listed on the Wall Street stock exchange and founded the first Italian franchise chain dedicated to upholstered furniture: Divani&Divani® by Natuzzi.

In 2013, an impressive new industrial plan was launched that allocated over 550 million euros to the efficiency of the Italian plants and the rethinking of the product, with the aim of further improving the competitiveness of the group at a global level, through making "made in Italy" economically sustainable instead of price-matching competitors from developing countries.

Natuzzi has changed the production logic of the sofa, adopting the industrial platform method, already in use in the automotive industry. In the past, Sofas were made by a single operator in a fixed position, now sofas are designed for a single component to be assembled with the Moving Line production process. Several employees work in teams, assembling the various parts of the sofa in sequence. Currently, 80% of Natuzzi's turnover is achieved through models engineered according to the new design logics on the platform and produced with the new process: they moved from a process organized by departments with separate workstations to an in-line, integrated process, in which collaborators, equipment and materials are positioned contiguously, in sequential order,  and in which the product in its different phases is processed according to a continuous flow. The advantages are greater synergies, improved ergonomics of workstations, reduced product handling and reduced risk of damage.

In addition to the cutting automation already in place, the investments have also allowed the digitalization of the inspection phase of the leather covering, and of the nesting phase, i.e., the positioning of cutting patterns along which to make the cut.

Moreover, a new packaging system allows to obtain a production with constant and predefined characteristics, thus the company optimizes the use of resources dedicated to packaging and grants savings on materials.

Natuzzi, however, does not aim for total automation, aware that in this sector the artisanal component still makes the difference.

As far as respect for the environment is concerned, the strictest standards are adopted at Natuzzi. The concept of sustainable development has been embraced by the production and sales processes. Strong use of photovoltaic energy and technologies with low environmental impact. The materials used are natural such as wood and leather and stringent company policies have been adopted regarding deforestation.

Production is integrated through factories located in Italy, China, Brazil, and Romania. The distribution of Natuzzi products is primarily through wholesale channels and a global retail network, marketed under the "Natuzzi Italia" and "Natuzzi Editions" brand names.

“Natuzzi Italia” primarily sells its products through various retail channels, such as mono-brand stores, concessions, and galleries within multi-brand specialized stores and high-end department stores. Their product range includes sofas and armchairs crafted in Italy at the company's factories, targeting the upscale market. These items feature unique materials, craftsmanship, and finishes, reflecting Natuzzi's legacy of excellence in leather sofas.

“Natuzzi Editions” collection offers a diverse range of leather upholstery products aimed at the medium to medium-high market segments. Leveraging Natuzzi's expertise in leather upholstery, these products are manufactured in various locations including overseas plants in Romania, China, and Brazil, as well as in Italy. Natuzzi Editions products are primarily sold through mono-brand stores and galleries, with an expanded offering of furnishings.

Furthermore, the Group operates the Softaly division, which focuses on unbranded/private label products, targeting entry-level market segments primarily through large distributors. The private label/unbranded line aimed at the mass-market dealer market, such as Ikea, takes shape in the plants in Romania and China.

Since 1990, the Group has sold its upholstered products in Italy principally through the Divani&Divani® by Natuzzi franchise network of furniture stores. As of December 31, 2022, there were 76 Divani&Divani® by Natuzzi stores (of which 12 directly operated by the Company), and four Natuzzi Italia stores, all directly operated by the Company.

The subject of the study will be the dynamics that particularly affect Divani&Divani® products, made in Italy.

### *3.4.1. The Supply Chain of Divani&Divani®*

The main approach of the company's production logic is Make-To-Order. The new organization has organized all flows in Pull mode, i.e. reducing to a minimum the initial and intermediate inventory for the storage of components and semi-finished products. It is not produced in stock for the warehouse or trying to incentivize purchases in stores through discounts and promotions. The main competitor poltronesofà SpA instead uses a Make-To-Stock and aggressive marketing strategy.

Procurement is divided in two categories: some materials are procured when needed with a Just In Time on-demand logic; others, requiring longer lead times, are stocked in the warehouse and follow an inventory logic with reorder levels. Since both the safety stock and the reorder levels are defined at the article/plant level and depend on the historical consumption, there are no general reordering parameters suitable for all Stock Keeping Units (SKUs).

The safety stock formula is highly dependent on the coefficient linked to the expected level of service and the high rotating SKUs, have a higher expected level of service as a registry setting (85-90%) than the others.

An example of product treated with an always-in stock type includes all the subcomponents and small parts necessary for the assembly of a mechanism for headrests, backrests, etc., mainly sold by manufacturers located in China and upholstery for sofas, that have long supplier response time. For these products, less frequent orders are placed, with the objective to cover the expected demand for the lead time as well. Long journeys have higher variance in lead time, with external factors such as pandemics, wars or custom duties posing threats, that might lead to Out-of-Stocks scenarios and represent a problem for the system.

Managing components with short lead times with JIS logic, on the other hand, ensures that in theory, the parts are available exactly when required by production. This system facilitates handling a greater variety of product combinations while maintaining service levels and minimizing inventory size, mitigating the risk of material obsolescence.

The components are managed in two different warehouses, ubicated in Laterza: Raw materials Warehouse for materials managed with stock reorder levels and M8 Warehouse for on-demand materials, that are delivered on a weekly basis by local suppliers.

About 80/90% of the leathers come from a tannery controlled by Natuzzi SpA, the remaining part are leathers of Belgian, Brazilian, Chinese or Indian origin, characterized by a higher supply time, while the fabrics come from suppliers located worldwide. A shared portal with suppliers communicates real time progress of each order: in transit, delivered, produced, blocked.

To minimize the intermediate buffers on the production line, since there is not enough room to accommodate excessive inventory, the delivery to the departments must be made every two days. Suppliers of semi-finished wood products also deliver every two days to take up less space. The idea of having the assembled frame sent directly was proposed, but, in that case, it would be necessary to deliver every day, so it has never been experimented.

Natuzzi uses both Ex-works and FOB destination shipments depending on the case. Ex-works distribution requires customers handle the transport directly. In this case, Natuzzi owns the product until it is packaged in a box, then it is invoiced at the moment when the goods leave the doors of the factory.  On the other hand, when Natuzzi manages deliveries, it invoices on arrival. The Group mainly relies on several shipping and trucking companies operating under "time-volume" service contracts to deliver its products to customers, but also to transport raw materials to the Group's plants and processed materials from one plant to another. For Natuzzi's owned delivery, the company has identified 7/8 delivery routes.

### 3.4.2. Production cycle and planning of production

Natuzzi S.p.A. has 5 plants: Laterza, Graviscella, PS, Jesce 1 and Jesce 2.

The order of the production phases to build a sofa is: preparation of the coating, inspection of the materials, cutting. Once the coating is cut, goes through the enrichment, sewing and assembly phases.

We visited the PS plant, located in Santeramo in Colle, which stands out for its limited size and capacity compared to other plants. The Loading/Unloading area is located at the entrance of the plant, close to the department dedicated to the assembly of the wooden frame. Preliminary preparation phase and application of the straps also take place there.

The production process is *moving line or cellular manufacturing* in the modern plants, as they are designed to naturally implement *lean principles.* There are three production cells dedicated to different types of sofa:

- Fixed and modular sofas
- Mechanized
- Sofa beds

In the mechanized sofas cell, the operators are arranged sequentially, the set-up allows timing to be correct and rhythm constant: from the upholstery to the assignment of the foot bag and the insertion of the mechanisms.

*Figure 12. Upholstery assembly line*

The Graviscella and PS (HQ) plants were born to be Industry 4.0 optimized, whereas Jesce 1, Jesce 2 and Laterza were born organized by departments, and are currently being redeveloped from current to 4.0 logics. Such a system requires the flow to be ordered, sequenced, traceable. Some examples of lean approach are the existence of a controlled buffer of cassettes between sewing and assembly, signage to limit the inventory on the line, SOPs for disposing of the excess of semi-finished products in front of a bottleneck. The size of upstream buffers allows better prioritization.

The cutting phase, instead, takes place in advance and with its own logic that responds to the need to minimize waste. This implies sometimes cutting the fabric days in advance for efficiency purposes.

Laterza houses the central warehouse of raw materials, as well as the largest cutting department, where the goal of saving leather as much as possible is pursued. The leather, or the fabric, is preliminarily subjected to a control activity that identifies any defects, that might as well be acceptable if present on hidden areas. The nesting technique then makes it possible to optimize the cut to reduce material waste. It is an automated optimization phase that allows the best disposition for cutting to maximize the useful surface. In the old manual nesting process, the operator used a mouse to position the virtual templates assisted by a projector that fixed the image on the mantle. In Automatic Nesting, on the other hand, the positioning of the cutting patterns is performed by a server that tests millions of combinations to choose the best one. When producing leather-upholstered sofas or other furniture, it is crucial to use the material efficiently to avoid costly waste.

Graviscella is equipped with a machine that does dynamic nesting, i.e., a single-layer macro-neck nesting, which is more efficient than a multiple cutting of several overlapping layers.

The software automatically positions parts so that adjacent edges are processed at the same time, thus saving material, machine time, gas, and electrical energy, as well as tool wear. The software calculates and displays common cuts automatically, whenever a sheet is manually moved or placed.

Natuzzi owns Natco company based in Udine, which is the biggest supplier for leather coatings of the company. In addition to covering 80-90% of Italian needs, Natco also exports its products abroad.

The cutting activity is now automated in all the biggest plants: Santeramo PS, Altamura and Laterza, where the operation is carried out centrally to serve the plants of Laterza itself, Jesce 1 and Jesce 2.

This is followed by the coupling, where an operator is responsible for finishing the cut to ensure swift overlapping and pairing. Then the enrichment phase follows, with ornamental add-ons included in the production. Automated light signals facilitate the picking activity, after.

Once enriched, the coating goes through the sewing and assembly phases. The WIP at this stage is called "frame". The WIP is usually heavy and bulky, so it is fundamental to minimize useless stock. Once this stage is reached, the parts can be assembled into the final product.

After assembly, there is cleaning and quality check. Intermediate and final quality controls are an activity that has remained highly dependent on the tester, who takes the place of the end customer and must verify multiple conditions of possible defects. This step cannot be automated, e.g. with artificial vision systems.

A camera then takes a picture of the approved finished product from different perspectives. The packaging can be either "airball" or in a box depending on the customer's preference.

The taping process is undergoing evaluation: currently the application of adhesive tape is done manually, but an automatic application with a packing machine could be implemented. Automated taking has been found to highly increase customer satisfaction, that appreciate tidy packaging.

As far as timing is concerned, a sofa that begins to be assembled on a given day will be completed on the same day, reiterating that all the upstream phases will have to start in the previous weeks.

The finished packaged products are placed on trolleys designed to transport from 2 to 5 pieces at a time. Up to 6 trolleys are then moved by a shuttle to the distribution center, ubicated in La Martella.

The total production across plants is about 500-600 boxes each day, however throughput capacity is over 1000 per day in peak times. That means 10 shuttles/shift (20/day) among all plants.

The sales process starts when the customer chooses the model that fits their needs among the offering catalogue with over 100 items. This vast range of models covers all styles from casual to traditional, suitable for all markets even in different geographies.

Once the model is chosen, the customer needs to select their favorite upholstery and version, as there could be 20 variants depending on size and corner, modular or mechanized features.

The 2023 collection offers 11 leather types available in 107 colors and 17 fabrics available in 108 colors for hundreds of combinations. Finally, the client picks some final features such as rigid or normal comfort, the material of the sofa's feet and the color of the details.

An estimated lead time is calculated and if the customer accepts the offer, a purchase order is entered into the system. One of the issues that needs to be resolved is the one that links the company's policy of offering the customer any sofa configuration, with any leather or fabric, to the difficulty of guaranteeing a similar lead time for all versions.

The CRM communicates the data to SAP, which reads the bill of materials (BOM) of the ordered product and queries the warehouse. If any of the components needed to assemble the sofa is out of stock, the system automatically issues extraordinary orders to close suppliers. Once verified the proposed lead time can be fulfilled, the MRP (Material Requirements Planning) is filled in. The estimate of the overall lead time is given by 3 weeks of production lead time, plus backlog, plus transit time (which implicitly also includes temporary storage times).

Considering n as the week in which the product is assembled, the first level programming is done on the Thursday of week n-3: the collected orders are assigned to the plants, so the "assembly minutes" are assigned to the plants for week n. The order to the JIS suppliers for the production plant is triggered, with the relative quantity needed. Suppliers have about ten working days, by Friday of week n-1, to prepare what is needed for week n. This is followed by a second-level programming with "Last Planner" software: every day, the planning for the next three days is updated at production line level.

Sometimes production is suspended, and other orders are prioritized if some products are not delivered on time, this often happens with wooden feet arriving from Romania.

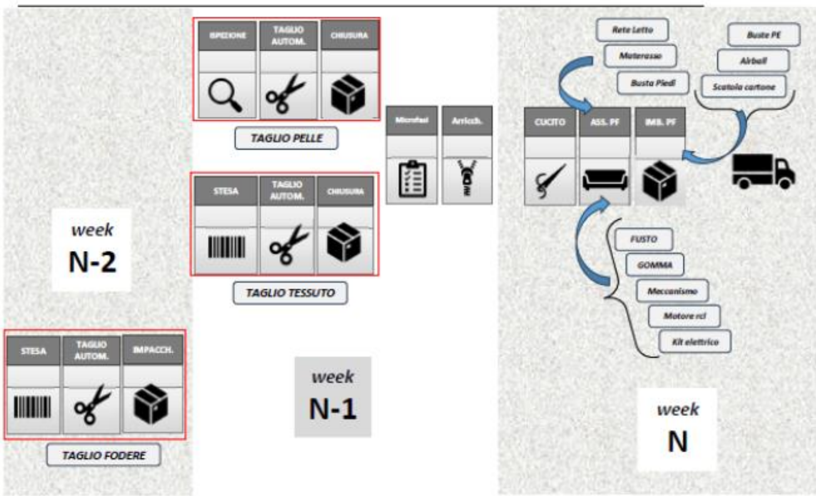


*Figure 13. Natuzzi's planning of production*

The unit production cost in the Italian plants is split 60% raw materials cost, 40% labor cost. Less than 20% of the items (leather, barrel, rubber, and mechanism) account for 80% of the cost, with highest contributor being leather.

| |
|---|
| Coating |
| Wooden frame kit |
| Stuffing kit |
| Mechanism kit (electrical) |
| Motor/transformer/actuator |
| Elastic straps |
| Packaging kit |
| Feet |

*Table 2. High-level bill of materials of a generic mechanized sofa*

The time needed for assembly can vary between an hour for fixed sofas, and 2 and a half hours for complex products such as the Chester armchair, with the predominant part of the assembly being the upholstery. As the total sum of value-added activity times, the average time is estimated at 300 minutes.


*Figure 14. Natuzzi's average production time by phase*

Some tasks such as ornamental sewing are not carried out in all establishments, thus that is a factor to establish what is the most suitable plant to produce each item.

Below is a summary of the production process:

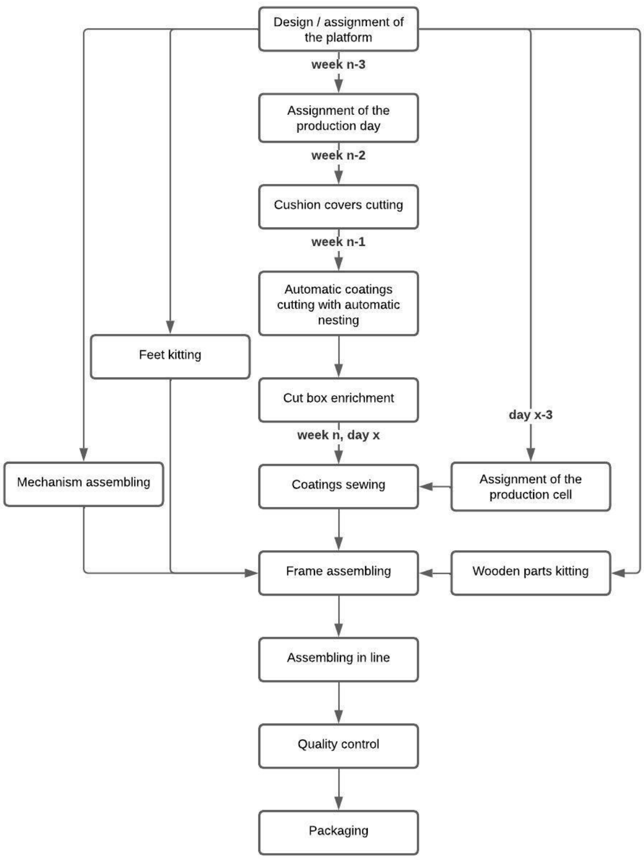


*Figure 15. Natuzzi's production cycle*

At Natuzzi, production sequencing is based on activities. Frame assembly only starts when all final assembly materials are ready, minimizing waste. Cutting happens independently in week n-1 as it's organized by color, unlike subsequent phases in week n on contiguous workstations. In-line operators perform subtasks progressively in one of three assembly cells. Daily sequences organize sofas by model within each cell, so operators repeat identical operations multiple times.

### *3.4.3. Supply chain's critical issues*

In the early months of 2022, a surge in global demand following the pandemic led to significant increases in the cost of certain raw materials and container transportation rates worldwide. This upward price trend was further intensified by Russia's invasion of Ukraine, which disrupted global supply chains. Particularly affected were Natuzzi's European plants, which faced challenges in receiving raw materials via the Black Sea trade route, especially from Asia. Moreover, waiting times for ships at major ports rose from under 20 days at the beginning of 2021 to nearly 50 days in 2022 due to heightened port activity and lockdowns causing worker shortages, particularly in Asian ports. Consequently, orders received by the Group couldn't be fulfilled as promptly as anticipated due to missing components, resulting in delays in delivery and invoicing to end customers. These supply chain complexities also contributed to shipping bottlenecks causing delivery delays. Consequently, its inventory levels increased notably, especially in the first half of 2022.

The critical success factor identified by the company is the lack of visibility into inbound, outbound, and internal logistics dynamics that helps determine when it will be possible to fulfill the customer's order considering the impact of international disruptions or stockouts.

Procurement choices remain the focus to address with a view on improving the supply chain, in a context in which the choice is whether to shift towards local or remote sourcing. The inconveniences, even with the on-demand supply mode, are not uncommon and it often happens, for example, that suppliers are unable to meet their deadlines.

The choice of a redefinition of Natuzzi's supplier landscape must consider the transformations that Natuzzi has gone through in the last ten years, launching numerous projects that have each set a turning point for its business.

One effort that has had a huge industrial impact is the project to implement industrial product platforms based on a modular approach. The modular approach to the "product" is based on the concept that multiple models, previously designed in succession and separately from the others, must be designed simultaneously. The goal of this project was to produce more models with less different components. An attempt was therefore made to build a first industrial platform composed of similar models for the logistics of product construction and for the manufacturing structure.

A plan has been applied to the platforms to reduce the variety of models identified, with a consequent reduction in the number of codes and an increase in common component indexes. An example of the component reduction technique is shown in the following figure, with a case where the wooden frame of sofas is standardized.

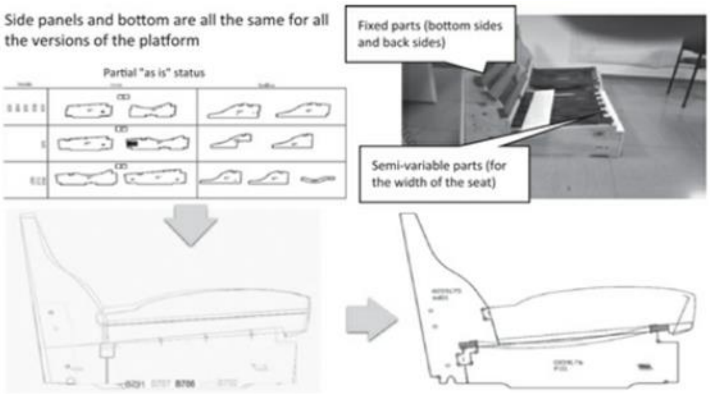


*Figure 16. Example of a technique for reducing components in the pilot industrial platform*

After the first encouraging results, the "lightening" of all commercial ranges was adopted by converging on industrial platforms. If there is a high level of standardization of the parts, then the choices related to procurement can only be oriented towards a "thinning" of the supply network that is currently very populated. If the cost of the raw material makes it more convenient to source from abroad, then the premises point to remote sourcing.

Another criticality arises from the rising customization trends. Fabric being treated the same way as on-demand components leads to procurement issues. Whenever a sofa with uncommon colors or patterns is ordered, the company must procure the leather mantle in question even if the demand is very limited. This leads to higher procurement costs, as it is impossible to batch or to reach minimum order lots, increasing the production costs tremendously. One answer to this problem that the company is facing is to provide incentives in terms of discounts as well as less waiting time to the customer, to divert their preference to more common tones.  On the other hand, Natuzzi does not want to reduce the vast offering of customization, as it is a competitive advantage against mass competitors.

One of the key issues is the trade-off between keeping a varied and customizable catalogue and standardize lead times for all the different variants.

Finally, it is important to uniform the lead times of the different models, to make the delivery promise more sustainable.

# 4. The simulation model

## 4.1. Simulation model construction

AnyLogistix software is used for this thesis project.

The scope of this project is limited to the dynamics related to the Italian territory: from the procurement of Italian plants to produce for the Italian market, to their distribution.

The analysis of a supply chain can be divided into 3 levels: high, medium, low. Below is an explanatory figure.

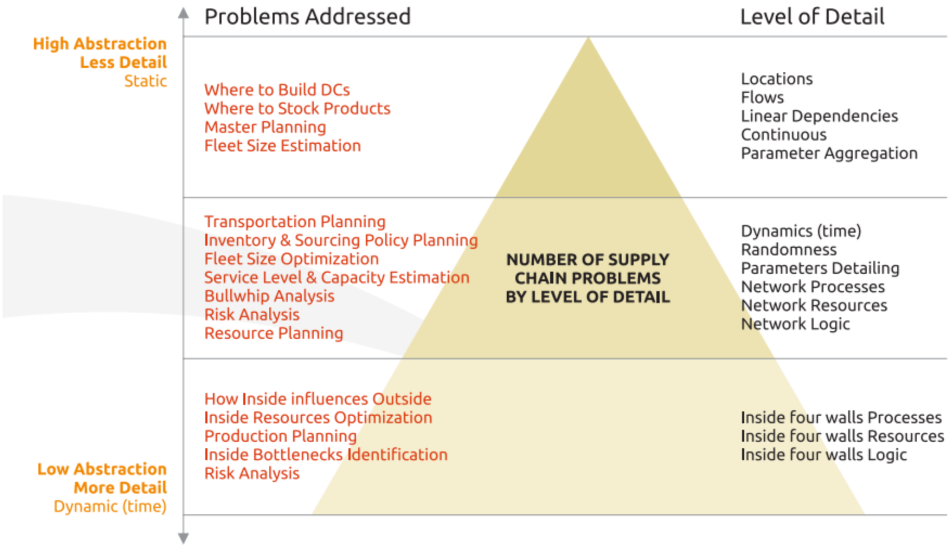


*Figure 17. Challenges addressed by supply chain models and the level of detail*

The level of detail at which the study and construction of the model is conducted is medium.

The company has several critical factors that the analysis focuses on. The goal is to develop a model that studies the trade-off between costs, which include order, transport and warehouse costs, and delivery lead time to customers to make it as efficient as possible.

The construction of the model in anyLogistix is based on tables that must be populated to best simulate the supply chain. Below is a summary of the ones we will use:

| NAME | DESCRIPTION |
|---|---|
| BOM | Define Bills of Materials (list of components and their quantities needed to produce the end product) |
| Customers | Define the customers consuming the products of your supply chain |
| DCs and Factories | Define distribution centers and factories that comprise your supply chain |
| Demand | Define the mechanism of how the customer's demand for the product is formed |
| Events | Define events that will affect the data of the scenario during runtime |
| Facility Expenses | Define expenses for each site |
| Fleets | Allows to assign a certain vehicle type (with quantity) to a site (DC or Factory) that will be using them to deliver products |
| Groups | Aggregates multiple sites of the supply chain |
| Inventory | Define inventory policies for your supply chain facilities |
| Locations | Contains information on locations of all sites involved in your supply chain |
| Milk runs | Allows to form a succession of destination points (customers) that will be served in a certain order |
| Ordering Rules | Defines limits of sale batch's size |
| Paths | Connects location points within your supply chain, allowing a product to be transported from one location to another |
| Periods | Define the start and the end of the scenario |
| Processing Time | Define policies for calculating processing time for orders and shipments |
| Product Groups | Aggregates multiple products into one entry |
| Production | Define production policies |
| Products | Contains information about products that are delivered within the supply chain |
| Sale Batch | Defines price per unit when ordering from a certain supplier |
| Shipping | Defines policies describing how products are sent |
| Sourcing | Define sourcing policies |
| Suppliers | Define product suppliers |
| Unit Conversions | Define conversions for the user-defined measurement units |
| Vehicle Types | Define all types of vehicles that are used to ship products in the supply chain |

*Table 3. Tables used for model construction*

The most relevant performance measures we will analyze are:

- Service Level (% of orders shipped to the customer within the expected lead time)
- Lead time of delivery to customer (time elapsed between the purchase order and the delivery date)
- Total cost

The KPIs are all directly provided as output by the anyLogistix model.

Total cost function:

$$\begin{aligned} Annual\ total\ cost &= \sum_i (\, average\ inventory_i * inventory\ cost_i) \\ &+ \sum_i \sum_j (unit\ price_{ij} * delivered\ units_{ij}) \\ &+ \sum_i \sum_j (transportation\ cost_{ij} * deliveries_{ij}) \end{aligned}$$

*Where: $i = product, j = supplier$*

The cost of keeping materials in stock ideally includes both explicit costs such as rent, labor, risk of attrition, etc., and the implicit costs of capital immobilization. Considering the difficulty in providing a precise estimate of the above-mentioned costs, we assume a value equal to 15% of the volume of the stored good, a value attributed as an annual unit cost.

The unit price of the component is defined by the data provided by Natuzzi.

The cost of transport, on the other hand, is defined according to the shipping distance on a lump sum logic.

In fact, we will have a dual purpose:

- Aim for total cost minimization
- Keep LT and its variability as low as possible, thus increasing the Service Level

The supply chain involves 3 main players: suppliers, Natuzzi SpA and end customers.

Here is a summary:

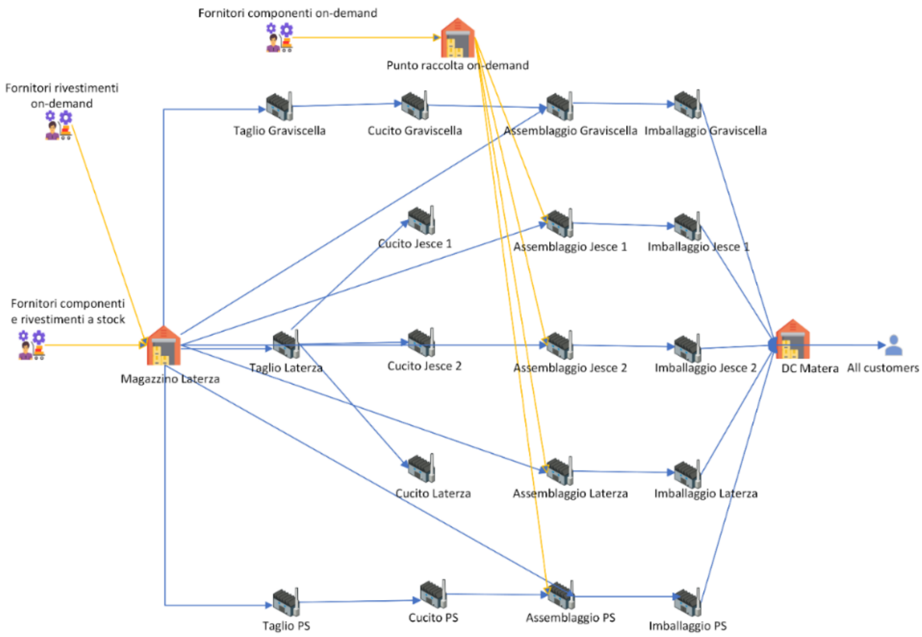


*Figure 18. Conceptual model*

### 4.1.1. BOM and products

The application includes 9 sofa models, defined based on the little data received from the company. Each of them is defined in a single-color variant and pattern. For all of them, however, a generic BOM is defined that includes:

- Coating (leather or fabric)
- Frame kit
- Stuffing
- Straps
- Feet (metal or wood)
- Mechanism kit (if required)
- Motor (if required)

The sofa models in the system depicted are made with the items with the most personal information: 5 leathers and 4 fabrics.

Each sofa is made with one of these items in quantities equal to 15 $m^2$ or 20 $m^2$ depending on whether it is a two-seat or three-seat sofa.

Below are the models with their respective components:

| | Beige and pink leather Sofa | Orange leather Sofa | Beige and yellow leather Sofa | Red leather Sofa | Gray leather Sofa | Medium pink fabric Sofa | Orange fabric Sofa | White fabric Sofa | Antique pink fabric Sofa |
|---|---|---|---|---|---|---|---|---|---|
| Straps | 60 | 75 | 50 | 75 | 50 | 75 | 75 | 50 | 50 |
| Stuffing | 7 | 8 | 6 | 8 | 6 | 8 | 8 | 6 | 6 |
| Cherry wooden feet D40 | | | | 4 | 4 | | | | |
| Cherry wooden feet D90 | | | | | | | | | 4 |
| Black metal feet | 4 | 4 | | | | 4 | | | |
| Wooden feet | | | 4 | | | | | 4 | |
| Metal feet | | | | | | | 4 | | |
| Frame kit | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Mechanism kit | | | 4 | 3 | | | 6 | | 2 |
| Beige and pink Leather | 1 | | | | | | | | |
| Orange Leather | | 1 | | | | | | | |
| Beige and yellow Leather | | | 1 | | | | | | |
| Red Leather | | | | 1 | | | | | |
| Gray Leather | | | | | 1 | | | | |
| Medium pink Fabric | | | | | | 1 | | | |
| Orange Fabric | | | | | | | 1 | | |
| White Fabric | | | | | | | | 1 | |
| Antique pink Fabric | | | | | | | | | 1 |
| Motor | | | 1 | | | | 1 | | 1 |

*Table 4. BOM and products*

The 3-seater sofas are:

- Orange leather Sofa
- Red leather Sofa
- Medium pink fabric Sofa
- Orange fabric Sofa

The models not listed above are all 2-seater sofas.

### *4.1.2. Customers and demand*

The total demand for each individual sofa has been estimated based on the information received by the company regarding the procurement of upholstery during 2023, see Annex 1. Each sofa model is associated with a type of upholstery. A reordering policy is used for each of them, of which we have the following data: lead time (LT), safety stock (SS) and reorder point (R).

The company's expected average annual demand for each product can be calculated as follows:

$$AVG\ D = \frac{R - SS}{LT}$$

*Equation 1. Mean of demand*

Having a safety stock also means protecting yourself from the variability of demand.

Assuming the random variable of distributed demand according to a normal of mean AVG and standard deviation STD, it is demonstrable that ideal R corresponds to:

$$R = LT * AVG\ D + z * STD\ D * \sqrt{LT}$$

*Equation 2. Reorder level*

Fluctuations in demand will be mitigated by the presence of an additional stock with a probability equal to the desired Service Level, whose standardized equivalent value is the z of the formula. From here it is also possible to derive the standard deviation of the demand, knowing the Service Level provided by the company, according to the formula:

$$STD\ D = \frac{R - LT * AVG\ D}{z * \sqrt{LT}}$$

*Equation 3. Standard deviation of demand*

| PRODUCT | LT(d) | z | SS($m^2$) | R($m^2$) | STD D($m^2/d$) | AVG D($m^2/d$) |
|---|---|---|---|---|---|---|
| Beige and pink Leather | 35 | 0.675 | 10,357 | 24,157 | 2,594 | 0,394 |
| Orange Leather | 42 | 0.675 | 3,675 | 10,371 | 0,840 | 0,159 |
| Beige and yellow Leather | 42 | 0.675 | 25,349 | 144,431 | 5,795 | 2,835 |
| Red Leather | 35 | 0.675 | 34,129 | 160,484 | 8,546 | 3,610 |
| Gray Leather | 118 | 0.84 | 90,936 | 658,073 | 9,966 | 4,806 |
| Medium pink Fabric | 35 | 0.525 | 14,449 | 56,694 | 4,652 | 1,207 |
| Orange Fabric | 63 | 0.675 | 46,766 | 281,189 | 8,729 | 3,721 |
| White Fabric | 42 | 0.675 | 10,631 | 27,881 | 2,430 | 0,411 |
| Antique pink Fabric | 42 | 0.675 | 29,263 | 94,765 | 6,689 | 1,560 |

*Table 5. Demand and its variability calculated with standard reorder point formula*

With such high levels of safety stock (about 50% of the reorder point), based on the items under exam, there is a very impactful demand std. *Equation 3. Standard deviation of demand*, to estimate the demand function, values look overestimated.

Since, whatever the distribution of demand, it is unthinkable to attribute to it a higher-than-average level, we will look for other reasons to maintain such high levels of emergency stocks.

By having the actual week-by-week consumption available, we can estimate the mean and standard deviation of the weekly demand with this sample.

| PRODUCT | AVG D($m^2$/week) | STD D($m^2$/week) |
|---|---|---|
| Beige and pink Leather | 37,200 | 62,765 |
| Orange Leather | 17,007 | 23,321 |
| Beige and yellow Leather | 8,590 | 17,251 |
| Red Leather | 22,814 | 29,124 |
| Gray Leather | 26,089 | 35,794 |
| Medium pink Fabric | 6,670 | 20,867 |
| Orange Fabric | 12,595 | 27,334 |
| White Fabric | 14,745 | 29,016 |
| Antique pink Fabric | 11,112 | 16,295 |

*Table 6. Demand average and variability calculated based on consumption data*

Fluctuations around the average value of weekly demand in terms of $m^2$ appear once again too large. The explanation that can be given is that the data sample is too inconsistent: it would take a higher number of weeks to observe a plausible sample standard deviation. It is not possible to establish a statistical inference with this sample.

A correct sizing of the safety stock should also consider the variability of the lead time of raw materials, as follows:

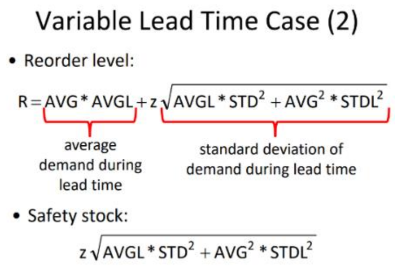


*Figure 19. Reorder level with variable Lead Time*

Taking into consideration, as an example, the article Orange Fabric, the AVG LT, different from the LT considered above, equals to 52.5 days.

The estimated average demand is:

$$AVG\ D = \frac{R - SS}{AVG\ LT} = \frac{281{,}189 - 46{,}766}{52{,}5} = 4{,}47\ m^2/gg$$

*Equation 4. Average demand with variable lead time*

Based on the recorded deliveries in 2023, the sample variability of the LT is 16.96 days.

$$STD\ D = \sqrt{\frac{\frac{SS^2}{z^2} - AVG\ D^2 * STD\ LT^2}{AVG\ LT}} = \sqrt{\frac{\frac{46{,}766^2}{0{,}675^2} - 4{,}47^2 * 16{,}96^2}{52{,}5}} = \sqrt{-17{,}75} = ERR$$

*Equation 5. Standard deviation of demand with variable lead time*

It means that the safety stock would be even too low.

Separating the two sources of variability is therefore too complex.

In the model, demand is simply treated as a Poisson distribution because the order, by sofa model and by customer, is unitary and arrives at each time interval, which is an exponential c.v. In fact, to formalize a number of random events that occur in a unit of time, a Poisson process is usually used, which corresponds to independent and stationary interarrival times.

The variance of a Poisson's distribution is equal to its mean.

In our case, the quantity demanded is small. Only 9 of the hundreds of models produced by Natuzzi are handled, thus 3 customers representing buyers from northern, central and southern Italy are sufficient. The difference in actual lead time that could occur by placing customers in a dislocated manner throughout the territory is negligible, as the criticality does not lie in the end of the supply chain. We will see how the need to increase the level of abstraction has become apparent for many other aspects of modeling.

The three representative customers are considered identical: they generate demand equally. An order for a single sofa is generated by the individual customer at constant time intervals on average. A customer orders a model on a day of the interval that may be different from that of another model, as well as another customer. This is possible by defining the first occurrence in the Demand table in "random time within interval".

The time interval set as the interval between one order and the next is such as to have a resulting annual demand equal to that expected:

$$Time\ interval_i = {}^{365}\!/_{(annual\ demand_i/3)}, \qquad i = sofa$$

*Equation 6. Time interval*

| PRODUCT | AVG D ($m^2$/year) | AVG D (PCS/year) | Time interval (days) |
|---|---|---|---|
| Beige and pink Leather | 143,91 | 9,59 | 114,13 |
| Orange Leather | 58,19 | 2,91 | 376,34 |
| Beige and yellow Leather | 1034,88 | 68,99 | 15,87 |
| Red Leather | 1317,70 | 65,89 | 16,62 |
| Gray Leather | 1754,28 | 116,95 | 9,36 |
| Medium pink Fabric | 440,56 | 22,03 | 49,71 |
| Orange Fabric | 1358,17 | 67,91 | 16,12 |
| White Fabric | 149,91 | 9,99 | 109,57 |
| Antique pink Fabric | 569,24 | 37,95 | 28,85 |

*Table 7. Demand and time interval of products*

The customer has an expected lead time of 35 days. By assumption, the customer is willing to wait forever to receive the order, because the company promises to deliver the purchased product. This assumption is useful for calculating the ELT (or service level).

### 4.1.3. Suppliers and inventory

For a complete, albeit superficial, overview of suppliers, we have been provided with a report on the monthly deliveries received in 2023 by the various own or external companies with which Natuzzi has supply relationships, see Annex 2. This was useful for us to understand Natuzzi's complexity and variability.

For the items in the template, the company has provided us with more information about their suppliers. In addition, we were provided with useful data to understand the specific reordering policies of the materials examined, which are mostly coatings.

Listed below are the suppliers with the type of material required. For simplicity's sake, each supplier has both the type of material and the country of origin in the name.

| MATERIAL | SUPPLIER |
|---|---|
| Leather | NATCO |
| Leather | Leather_Italy |
| Leather | Leather_Italy 2 |
| Leather | Leather_India |
| Mechanism kit | Mechanism kit_China |
| Several different products | Italsofa_Romania |
| Frame kit | Frame kit_Italy |
| Fabric | Fabric_Italy |
| Fabric | Fabric_Turkey |
| Stuffing | Stuffing_Italy |
| Straps | Straps_China |
| Straps | Straps_Italy |
| Straps | Straps_Germany |
| Motor | Motor_Italy |
| Black metal feet | Black metal feet_China |
| Metal feet | Metal feet_Italy |
| Cherry wooden feet D40/D90 | Cherry wooden Feet_Italy |

*Table 8. Suppliers*

The two suppliers that are owned by Natuzzi are:

- NATCO: tannery owned by Natuzzi where they source some types of leather
- Italsofa: Natuzzi production company, located in Romania, from which the Italian supply chain is supplied during stock outs

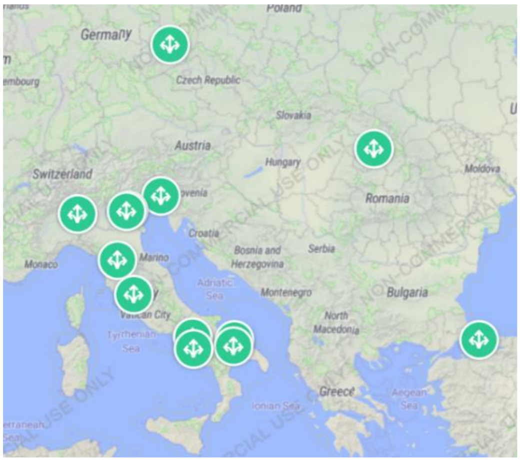


Figure 20. European suppliers

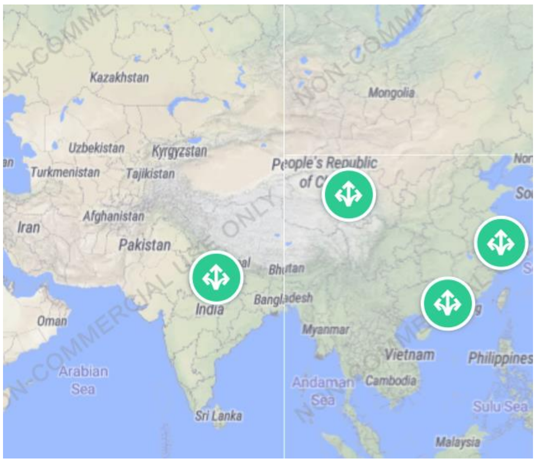


Figure 21. Asian suppliers

For suppliers for whom we do not have specific information, we rely on the data we receive in bulk. Those with a procurement percentage of less than 1% were considered negligible. After an initial skimming in which those who weighed, at least in 2023, for an insignificant percentage in terms of supply volumes were ignored, all those who, being in the same country, do not have a reason to be distinguished within the modeling, were merged into a single actor.

Starting from the report, see Annex 3, of the deliveries made by the company in 2022 and 2023 of the aforementioned items, the sample variances of the lead times for each item-supplier pair have been calculated.

Regarding demand data, estimating parameters from such a poor sample in terms of numerosity is too approximate and possibly misleading.

2022 data is strongly influenced by the effects of Covid-19 and Russian invasion of Ukraine, and the duration of any delivery in 2022 is significantly longer than a delivery in 2023. Regarding demand 2022 and 2023 data can be treated the same way, as on the one hand people did not have the opportunity to go out to shop but at the same time had greater incentive to renovate domestic spaces. The same assumption does not apply to lead time.

Looking at Orange fabric, below a table showing the impact of 2022 on lead time.

| 2023 | | 2022-2023 | |
|---|---|---|---|
| STD LT | 16,96 | STD LT | 23,84 |

Table 9. Standard deviation of lead time of Orange fabric

Due to external effects, 2022 data is not suitable for inclusion in the assessments, so it was excluded by assumption.

We assume in the modeling that processing times are normal distribution.

For the products we have details of, the mean and variance are equal to that observed.

For suppliers for whom no information is available, the standard deviation has been assumed to be 1/10μ.

For general suppliers in Italy and Italsofa, the company has estimated a lead time of 2 weeks, but we don't have firm data.

| SUPPLIER | PRODUCT | MEAN LT (days) | STD LT (days) |
|---|---|---|---|
| NATCO | Beige and pink Leather | 38,75 | 15,44 |
| NATCO | Beige and yellow Leather | 43,33 | 25,79 |
| NATCO | Red Leather | 34 | 8,19 |
| Frame kit_Italy | Frame kit | 14 | 1,4 |
| Mechanism kit_China | Mechanism kit | 87 | 9,2 |
| Italsofa_Romania | Coatings | 9,09 | 3,39 |
| Italsofa_Romania | Wooden feet/Mechanism kit | 14 | 1,4 |
| Metal feet_Italy | Metal feet | 14 | 1,4 |
| Fabric_Italy | White Fabric | 32 | 18,92 |
| Fabric_Italy | Antique pink Fabric | 35 | 28,47 |
| Leather_Italy | Orange Leather | 62,67 | 29,30 |
| Leather_Italy | Beige and yellow Leather | 43,33 | 25,79 |
| Leather_Italy 2 | Red Leather | 34 | 8,19 |
| Leather_India | Gray Leather | 97,5 | 19,09 |
| Stuffing_Italy | Stuffing | 14 | 1,4 |
| Straps_China | Straps | 115 | 11,5 |
| Straps_Italy | Straps | 14 | 1,4 |
| Straps_Germany | Straps | 21 | 2,1 |
| Motor_Italy | Motor | 14 | 1,4 |
| Black metal feet_China | Black metal feet | 111 | 11,1 |
| Fabric_Turkey | Medium pink Fabric | 82,33 | 45,93 |
| Fabric_Turkey | Orange Fabric | 52,5 | 16,96 |
| Cherry wooden Feet_Italy | Cherry wooden feet D40/D90 | 11,35 | 4,16 |

*Table 10. Lead time average and variability for suppliers*

European suppliers ship by road with vans, while foreign suppliers deliver goods by sea in containers in ships.

Taking into account the difference in transportation cost for shipping between various suppliers, different vehicles with different costs have been identified. These have been estimated based on publicly available information, as they were not provided by the company.

| SUPPLIER | VEHICLE TYPE | TRANSPORTATION COST |
|---|---|---|
| NATCO | Truck_Italy | 150,00 € |
| Frame kit_Italy | Truck_Italy | 150,00 € |
| Mechanism kit_China | Container_China | 700,00 € |
| Italsofa_Romania | Truck_Romania | 250,00 € |
| Metal feet_Italy | Truck_Italy | 150,00 € |
| Fabric_Italy | Truck_Italy | 150,00 € |
| Leather_Italy | Truck_Italy | 150,00 € |
| Leather_Italy 2 | Truck_Italy | 150,00 € |
| Stuffing_Italy | Truck_Italy | 150,00 € |
| Straps_China | Container_China | 700,00 € |
| Straps_Italy | Truck_Italy | 150,00 € |
| Straps_Germany | Truck_Germany | 250,00 € |
| Motor_Italy | Truck_Italy | 150,00 € |
| Black metal feet_China | Container_China | 700,00 € |
| Leather_India | Container_India | 700,00 € |
| Fabric_Turkey | Truck_Turkey | 500,00 € |
| Cherry wooden Feet_Italy | Truck_Italy | 150,00 € |

*Table 11. Transportation costs*

The product costs will also be different by type of supplier and material, for which the real prices have been defined, based on the data provided by Natuzzi. For the remainder, average selling prices for the product type were used.

| SUPPLIER | PRODUCT | UNIT COST (€/pcs) |
|---|---|---|
| NATCO | Beige and pink Leather | 15,28 |
| NATCO | Beige and yellow Leather | 15,28 |
| NATCO | Red Leather | 15,28 |
| Leather_Italy | Orange Leather | 16 |
| Leather_Italy | Beige and yellow Leather | 16 |
| Leather_Italy 2 | Red Leather | 20,58 |
| Leather_India | Gray Leather | 8,5 |
| Fabric_Turkey | Medium pink Fabric | 7,9 |
| Fabric_Turkey | Orange Fabric | 7,6 |
| Fabric_Italy | White Fabric | 26,90 |
| Fabric_Italy | Antique pink Fabric | 27,80 |
| Italsofa_Romania | Orange Leather | 17,5 |
| Italsofa_Romania | Beige and yellow Leather | 16,5 |
| Italsofa_Romania | Red Leather | 22 |
| Italsofa_Romania | Gray Leather | 10,35 |
| Italsofa_Romania | Medium pink Fabric | 8,12 |
| Italsofa_Romania | Orange Fabric | 8,3 |
| Straps_China | Straps | 0,3 |
| Straps_Italy | Straps | 0,6 |
| Straps_Germany | Straps | 0,35 |
| Frame kit_Italy | Frame kit | 120 |
| Mechanism kit_China | Mechanism kit | 12,38 |
| Italsofa_Romania | Mechanism kit | 15 |
| Metal feet_Italy | Metal feet | 13 |
| Black metal feet_China | Black metal feet | 11,7 |
| Italsofa_Romania | Wooden feet | 0,5 |
| Cherry wooden Feet_Italy | Cherry wooden feet D40/D90 | 0,125 |
| Motor_Italy | Motor | 10 |
| Stuffing_Italy | Stuffing | 10 |

*Table 12. Unit cost of products*

### 4.1.4. Natuzzi's supply chain

The Natuzzi structure with five geolocated plants has been replicated in the model. Distribution Center is the finished products warehouse. Raw materials Warehouse is the raw materials warehouse, where coatings and components are stored for longer times. In M8 Warehouse the 'On-demand' suppliers deliver their products.

All the production lines are divided into 4 activity steps: cut, sewing, assembly and packaging.

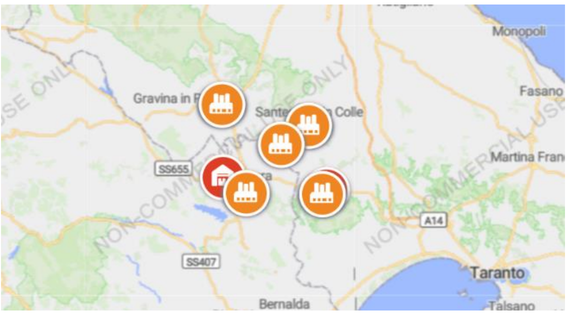


*Figure 22. Natuzzi's plants*

Through the anyLogistix "Events" table, weekend and evening closures have been configured with total operating time of 16 hours x 5 days a week. Shipments are also scheduled, from any supplier or site, from Monday to Friday.

The model is based on cycle time, as setting both production time and throughput in anyLogistix generates parallel production issues. In the simulation environment, the 'production' table allows you to enter the production time but does not consider multiple production departments that process several products at the same time. Therefore, considering a single production station, it produces one product at a time and in the space of a day, for example, the finished products are only 24/time(h).

The 'production time' assigned to all our phases from cutting to packaging has been calculated by imposing the condition that the plant is able to produce, in the manner conceived by anyLogistix, the number of units that corresponds to its maximum production capacity, defined as cycle time. This information is reported in the annual report published by Natuzzi.

Daily throughput of the plants in units:

- PS → 100 seats
- Jesce1 → 800 seats
- Jesce 2 → 340 seats
- Altamura → 250 seats
- Laterza → 500 seats

| Country | Location | Size (approximate square meters) | Function | Production Capacity for day | Unit of Measure |
|---|---|---|---|---|---|
| Italy | Santeramo in Colle (BA) | 28,000 | Headquarters, prototyping, showroom (owned) | NANA | |
| Italy | Santeramo in Colle (BA) | 2,000 | Experimental laboratory: leather cutting, sewing, assembling wooden parts for frames, product assembly (owned) | 100 | Seats |
| Italy | Santeramo in Colle, Jesce (BA) | 28,000 | Sewing and product assembly (owned) | 800 Seats | |
| Italy | Matera La Martella | 38,000 | General warehouse of sofas and accessory furnishings (owned) | NANA | |
| Italy Matera, Jesce Italy | | 12,500 | Leather cutting, sewing, assembling wooden parts for frame, product assembly (owned) | 350 Seats | |
| Graviscella Italy Laterza | | 8,000 | Leather cutting, sewing, assembling wooden parts for frame, product assembly (owned) | 250 Seats | |
| (TA) | | 12,000 | Leather and fabrics warehouse, leather and fabrics cutting, (owned) | NANA | |
| Italy Laterza (TA) | | 10,500 | Sewing, assembling wooden parts for frames, product assembly (owned) 19,000 | 500 Seats | |
| Italy Laterza (TA) | | | Semi-finished products and accessories warehouse (owned) | NANA | |
| Italy Pozzuolo del Friuli (UD) | | 21,000 | Leather dyeing and finishing (owned) 10,000 | 11,000 Square Meters | |
| USA High Point, North Carolina | | | Office and showroom for Natuzzi Americas (owned) | NANA | |
| Romania Sea Bay | | 75,600 | Leather cutting, product assembly, manufacturing of wooden frames, polyurethane foam shaping, fiberfill production and wood and wooden product manufacturing (owned) | 1,300 | Seats |
| China | Shanghai | 38,000 | Leather cutting, sewing and product assembly, manufacturing of wooden frames, polyurethane foam shaping, fiberfill production (leased) | 1,200 | Seats |
| China | Quanjiao County – Anhui province | 3,900 | Sewing and product assembly, manufacturing of wooden frames, polyurethane foam shaping, fiberfill production (leased) | 170 | Seats |
| Brazil | Salvador de Bahia – Bahia | 28,700 | Leather cutting, sewing and product assembly, manufacturing of wooden frames, polyurethane foam shaping, fiberfill production (owned) | 195 | Seats |

*Figure 23. Plants' capacity*

On the basis of this takt time, an example of which is given

Hp: seats=2, plant=Santeramo (PS) $\quad Takt\ time = \dfrac{960\ ^{min}/_{day}}{100\ seats/day\,/_{2\ seats/sofa}} = 19{,}2\ ^{min}/_{sofa}$

A dummy time was later added so that the average transit time within the system, barring any waits for slowdowns, was about 300 minutes for a three-seater sofa and 250 for a two-seater sofa.

In fact, it has been imposed that from the packaging departments to the DC each shipment requires a certain processing time. Due to the wait, a time is generated that is ideally added to the actual processing time to total a total time of 250/300 minutes on average. This allows you to guarantee a daily throughput equal to demand if the system is demand constrained, or equal to maximum capacity if we assume demand that exceeds maximum capacity, while specifying that the output product entered the system approximately 300 (or 250) minutes earlier.

All production times, including the outbound processing process, are normal random variables with a standard deviation of μ/10.

| Plant | Max capacity (seats/day) | 2 seats sofas | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Flowtime (min) | Cutting (min) | Sewing (min) | Assembly (min) | Packaging (min) | Processing time (min) | Takt time (min) |
| Santeramo | 100 | 250 | 19.2 | 19.2 | 19.2 | 19.2 | 173.2 | 19.2 |
| Jesce 1 | 800 | 250 | 2.4 | 2.4 | 2.4 | 2.4 | 240.4 | 2.4 |
| Jesce 2 | 350 | 250 | 5.49 | 5.49 | 5.49 | 5.49 | 228.06 | 5.49 |
| Altamura | 250 | 250 | 7.68 | 7.68 | 7.68 | 7.68 | 219.28 | 7.68 |
| Laterza | 500 | 250 | 3.84 | 3.84 | 3.84 | 165.6 | 72.88 | 3.84 |

*Table 13. 2 seats sofas' production time*

| Plant | | 3 seats sofas | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Flowtime (min) | Cutting (min) | Sewing (min) | Assembly (min) | Packaging (min) | Processing time (min) | Takt time (min) |
| Santeramo | 100 | 300 | 28.8 | 28.8 | 28.8 | 28.8 | 184.8 | 28.8 |
| Jesce 1 | 800 | 300 | 3.6 | 3.6 | 3.6 | 3.6 | 285.6 | 3.6 |
| Jesce 2 | 350 | 300 | 8.23 | 8.23 | 8.23 | 8.23 | 267.09 | 8.23 |
| Altamura | 250 | 300 | 11.52 | 11.52 | 11.52 | 11.52 | 253.92 | 11.52 |
| Laterza | 500 | 300 | 3.84 | 3.84 | 3.84 | 3.84 | 284.64 | 5.76 |

*Table 14. 3 seats sofas' production time*

Focusing on a small part of the total annual production, it is sufficient in the virtual model to operate with a single plant, so by assumption only the Santeramo plant is operational.

To reflect the real functioning of Natuzzi's supply chain, overcoming the limitations of the model, simplifications have been made. For instance, in reality goods received weekly from local suppliers are disaggregated and delivered every day (or every two) of the week in which they are produced, depending on the weekly schedule. Instead, the orders received by the suppliers are communicated once a week in the model and as soon as they are received, the goods are transferred to the line. The impact of this assumption on the output is very limited.

Natuzzi's modus operandi was modeled on the software using the *Inventory*, *Sourcing* and *Processing Time* tables. In fact, the pull logic of the system is declared in the inventory table: the finished goods warehouse is filled (and emptied) on demand, the production plants produce on demand and replenish raw materials. The Distribution Center, having received the customers' request, will forward the production order to the plant and in particular to the packaging department which will cascade it to the department assigned to the previous phase and so on up to the first step which is the cutting of the leather or fabric. The cutting department will call back from the Raw materials warehouse, where the upholstery, leather or fabric converges, when an order triggers the start of production. The other components are required during the assembly phase only. If the Distribution Center in Matera asks for any "Sofa", the packaging department asks for an "Assembled sofa" that needs a mechanism kit, frame kit, straps, stuffing, feet and a "Sewing". The respective Italian suppliers or the plant located in Romania get involved and are responsible for delivering what is required directly to M8 Warehouse, or the Raw materials Warehouse, located in Laterza. Raw materials Warehouse operates on a stock reorder logic, so raw materials coming from distant suppliers are always expected to be present. At the same time, a production request is sent to the sewing department, which in turn starts from a "Cut", which is what results from the cutting operation.

One way to possibly deal with the cutting phase that was evaluated, but not inserted in the final model is setting up the cutting operation as if it were a batch. A coat of a certain type of fabric/leather will only be processed together with two others of the same type. In the same way, since from sewing onwards the order follows the logic of repetitiveness of the model, at least three sofas of the same type are grouped together and then produced one after the other, with the production batch. Without filling in the BOM table, production would not take place because each "factory" needs to know which semi-finished product it will make and which sub-components it is composed of. The proposal to group by color and then by model using the batch expedient was not necessary for only 9 different models in this case study, but it could be exploited in more complex and realistic scenarios, to replicate their programming-optimization method. In addition, with "pending orders" the reorganization can be limited to the orders of the week, just as in practice.

As in reality, there are two methods of procurement: some materials are managed in stock, others are managed on demand, in some one of the two policies prevails over the other. For example, for rubber, drums and electrical kits, we are supplied exclusively as needed from Italian suppliers, Campania for polyurethane, for the generic wooden feet of the sofas from the production plant in Romania which, in addition to the production of sofas, deals with the production of wooden products, and from a supplier in Santeramo in Colle.

The suppliers we order on demand from are:

- Frame kit_Italy
- Italsofa_Romania
- Metal feet_Italy
- Stuffing_Italy
- Straps_Italy
- Motor_Italy
- Cherry wooden Feet_Italy

These suppliers, like all suppliers of this type, are placed with an order every Thursday and are given 14 days to fulfill it. The processing time that can be read in the table of the same name includes both the predisposition and the transit time, which is limited. In fact, subcontractors may have difficulties in meeting this deadline: this is why the data is treated as a variable distributed according to a normal with an average of 14, but they may take longer, or less, as we have already seen in chapter 4.1.3.

The choice of the warehouse is made a priority through the cheapest-dynamic source sourcing policy. The choice is first directed towards the Raw materials Warehouse, closer and therefore cheaper than the Italian supplier, however in case of stockouts, the order is placed to the M8 warehouse, replenished on demand.

In chart the physical flows from suppliers to the two warehouses.

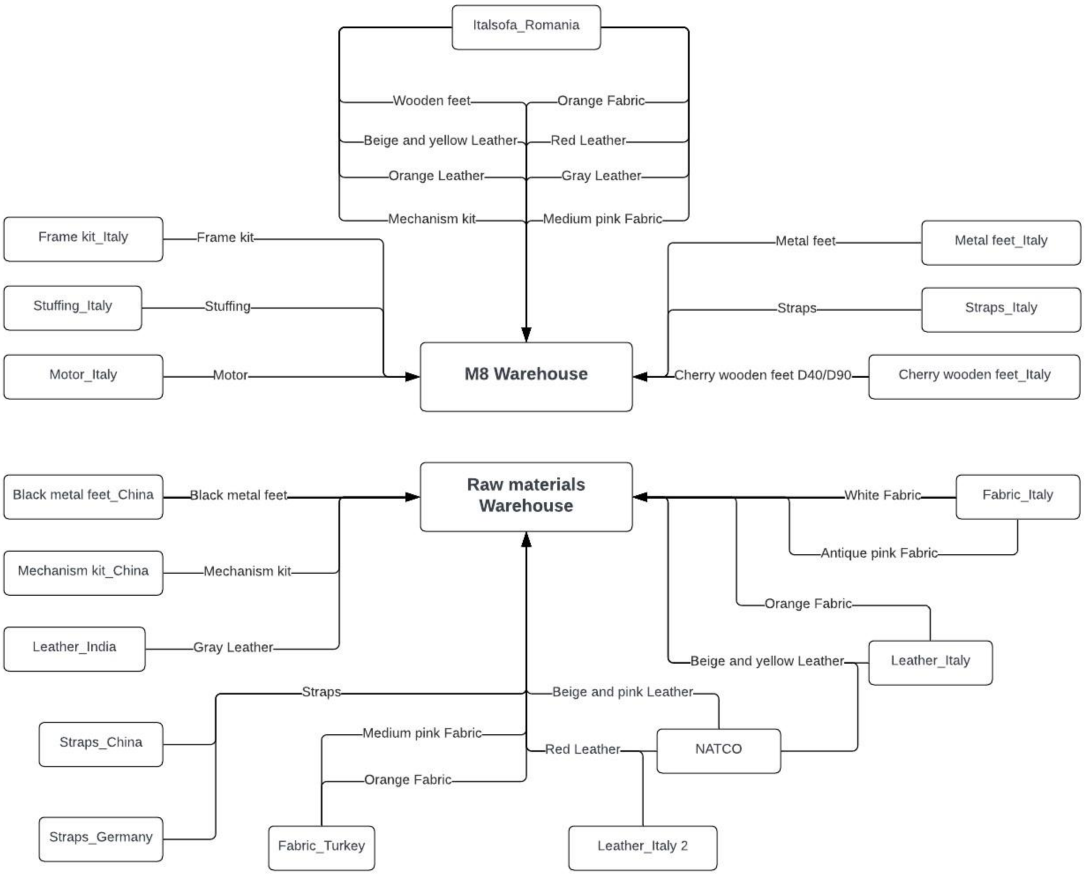


*Figure 24. Material flows into Warehouses*

All routes must be listed in the *Paths* table, also showing transport cost, otherwise the connection is not viable to the software.

In addition to specifying where the shipment comes from, it is also necessary to specify in the *Shipping* table how the shipment will take place. We initially consider a 1-week LTL policy with periodic check departing every Monday, a policy currently adopted by the company.

Once the model programming has been verified a robustness analysis is carried out followed by the design of the experiment.

## 4.2. Sensitivity analysis

The goal of this phase is to test the model, seeing how it behaves under different "boundary" conditions. It is useful to understand which inputs affect our outputs the most and how.

Suitable for a sensitivity analysis is the variation experiment that allows to vary a p-parameter within a chosen range, with a sensitivity defined in the "step". Within the software, it is possible to alter more than one parameter together, it will simulate altering one at a time, for a total number of iterations equal to $\# replications * \Pi(p) \frac{\max(p)-\min(p)}{step}$

### 4.2.1. *Vehicles*

We started with a variation experiment on the capacity and the number of vehicles available for the Raw materials Warehouse to Plants route. We confirmed if the system would work equally if, for example, the vans had a lower load capacity, or if we had less.

It was decided to test capacities of 6, 18 and 30 $m^3$ based on the standard dimensions of a truck with trailer.

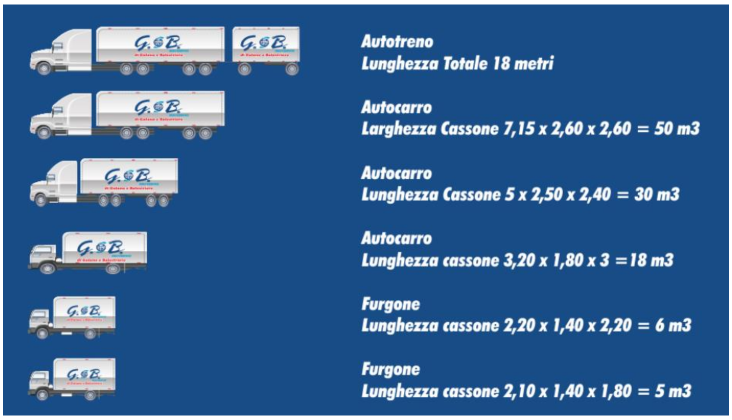


*Figure 25. Transport capacity by type of vehicle*

The data we will take into consideration are:

- Number of sofas produced
- Mean lead time
- Transportation cost

Refer to Appendix 1 for the tables with all results.

The model is not robust in the configurations marked in red because it cannot produce as much as it should. In acceptable configurations, on the other hand, the transportation cost tends to increase as fleets and vehicle capacity decrease.

We ran the same test for the downstream sections of production. The fulfillment received by site statistic is taken as an indicator (Distribution Center). The results are shown on the Appendix 2.

From the factory to the Distribution Center, there are no constraints and even a single vehicle of the smallest size is sufficient.

In the table in Appendix 3, reference is made to the fulfillment received by customers statistic, as well as to the transportation cost. The variables that have changed are the capacity and size of the Natuzzi van and the sizing of the fleet used for final delivery, from Distribution Center to Customers.

To find the minimum size of the vehicle beyond which the model is robust, the step of the change in capacity is reduced to 1 $m^3$, as shown in Appendix 4.

We then set up a variation experiment to evaluate how much the choice of shipping policy to end customers affects delivery frequency. Currently, the criterion is to ship the ready sofas once a week. In addition to the mean lead time, the ELT service level is also reported, which is closely linked to it. Full results in Appendix 5.

Considering these results, we will assume that we own or rely on an external logistics provider that has a limited fleet of:

- 2 vehicles for Raw materials Warehouse-Plant route
- 2 vehicles for M8 Warehouse-Plant route
- 1 vehicle for Plant-Distribution Center route

With all trucks measuring 18 $m^3$.

On the other hand, we assume that there are no fleet constraints from suppliers to Natuzzi's hubs.

Surely a limitation of the model that we will also carry with us in the analysis of scenarios, calculation of costs, etc., is that of having to define separate fleets of vehicles for each route. Not being able to use the same vehicles for more than one connection does not exactly reflect reality.

### 4.2.2. Milk run

Determining the Milk Run, on the other hand, is something that strongly influences the main output of our model?

We verified this by simulating the system with different ways of grouping customers.

| Case | Milk run | South LT | Centre LT | North LT |
|---|---|---|---|---|
| Case 1 | Sud-->Centro-->Nord | 33.0223 | 33.7033 | 34.0832 |
| Case 2 | Nord-->Centro-->Sud | 36.2687 | 35.1272 | 34.3286 |

*Table 15. Milk run variation experiment*

The best routing to follow is the first, because it minimizes the sum of lead times, as the Distribution Center is in the South.

### 4.2.3. Lead time

Doing a robustness analysis on the parameters of delivery times by suppliers was difficult because the software does not consider the times as a parameter that can be altered as part of the variation experiment. Separate scenarios were then simulated using the comparison experiment tool.

How long would the delivery lead time to customers be extended if the processing time of an "on-demand" supplier stabilized at averages higher than the assumed one (14 days)? Among these, we consider the frame's Italian supplier, a component that is common to all models and delays would invalidate production process of all of them, to justify the choice. Results are shown in Appendix 6.

The Appendix 7 shows how the lead time varies with the standard deviation of the processing time within a range ranging from 0 to 100% of its mean value.

### 4.2.4. Length of experiments

Repeating the simulation with different durations allows to determine which is the most correct length to set as a "time period".

| | Period | Demand | Fulfillment Received | Mean Lead Time | | ELT SL | | Inventory Carrying Cost | Order Cost | Transportation Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Description | Mean | Mean | Mean | Standard deviation | Mean | Standard deviation | Mean | Mean | Mean | Mean |
| 1 | baseline 1 year | 400.94 | 360.22 | 32.44593433 | 2.454301331 | 0.697126925 | 0.07486741 | 60.17576156 | 112608.4364 | 145614.5973 | 258283.2095 |
| 2 | 2 years | 398.03 | 378.26 | 34.91910855 | 3.236194225 | 0.632375462 | 0.06744869 | 61.08915665 | 111295.6737 | 148794.8812 | 260151.6441 |
| 3 | 3 years | 395.6066667 | 382.86 | 35.36846375 | 2.319694386 | 0.612727295 | 0.043452455 | 62.49582212 | 111554.6994 | 149794.8208 | 261412.0160 |
| 4 | 4 years | 394.79 | 385.185 | 35.11744021 | 1.69167576 | 0.609203979 | 0.037484106 | 61.599749 | 111601.9269 | 150532.3353 | 262195.8620 |
| 5 | 5 years | 392.544 | 383.004 | 35.45663641 | 1.868328416 | 0.59752023 | 0.04175352 | 61.81161073 | 110799.6480 | 150538.1256 | 261399.5853 |

*Table 16. Time period variation experiment*

It is therefore decided to conduct the experiments for 4 years, because in the fourth year the Mean Lead Time stabilizes with a reasonably low standard deviation.

## 4.3. Design of Experiments

From a strategic point of view, the Design of Experiments consists of identifying the scenarios in which the simulation model will test the system. From a tactical point of view, it means determining the number of simulations as well as the transitional period (output analysis).

The goal of the simulation is to study the system during a long operating period. The assumption is that the system reaches a stable condition, and it is possible to measure performance from when the system is in a stable condition.

It is necessary to identify the time it takes for the system to reach this state, from the initial moment, and to discard the performance measures collected before the stable state is reached. A qualitative method to identify this moment is used in this thesis.

Since we want to determine a value d such that for j>d results E(Yj) ≈ μ, graphically, this translates into determining when the curve E(Yj), j = 1, 2, . . . "stabilizes" around the value μ. The problem is that, very often, there is a trend influenced by a high variance and therefore very fluctuating. To overcome this drawback, a procedure known as the Welch procedure has been introduced, which, before carrying out the graphical analysis, involves "processing" the data to reduce variance. An outline of Welch's procedure is as follows:

1. Trace the mobile average within window $w$ (with $w \le m/4$):

$$\bar{Y}_j(w) = \begin{cases} \dfrac{1}{2w+1} \sum_{k=-w}^{w} \bar{Y}_{j+k} & w+1 \le j \le m-w \\ \dfrac{1}{2j-1} \sum_{k=-j+1}^{j-1} \bar{Y}_{j+k} & 1 \le j \le w \end{cases}$$

2. Select $d$ to be that value of $j$ beyond which the mobile average appears to have converged.

*Equation 7. Welch method*

Once the total number of finished products shipped to customers per week has been chosen as a generic indicator, the Welch method procedure is applied.

m = Number of observations in the replication = 52

$n_0$ = Number of Initial Replications = 5

w = Moving Average Window (w<=m/4) = 13

It is found that convergence is achieved at week 17.

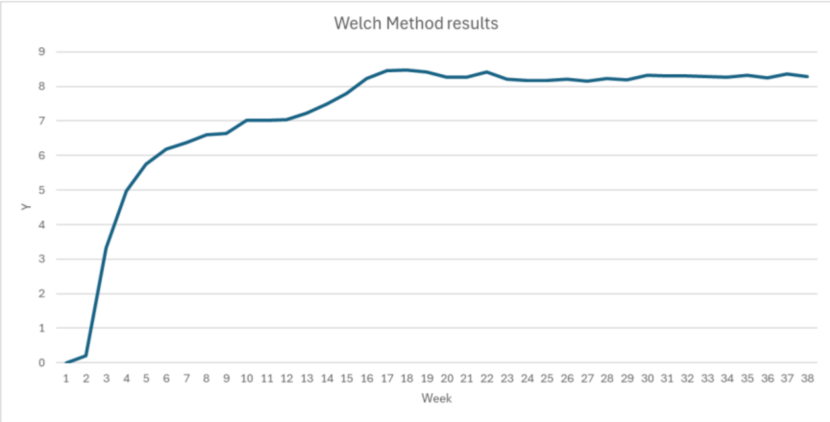


*Figure 26. Welch method results*

The final results of our analysis will exclude the first 16 weeks to ensure stability and reduce noise accordingly.

As a next step, it is advisable to establish a number of replications suitable for the case. The minimum number of replications that need to be performed to obtain results that with a certain level of confidence are within the desired range.

In other words, the more replications are performed, the more reliable the results returned as an average of the results of the individual replicates are and are not affected by oscillations due to stochasticity.

For example, we affirm with a risk level of 5%, that the performance measure used to calculate the warm-up period, i.e. the total number of finished products shipped to customers per week, is within a range with a semi-amplitude of c*=0.14 (products). We assume this level of uncertainty is acceptable.

Then, having calculated $S^2$ with the pilot replication, we calculate the minimum number of replications n.

$$\hat{\sigma}^2 = S^2 = \frac{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}{n-1} \qquad \frac{\bar{Y}-\mu}{S/\sqrt{n}} \approx t_{n-1}$$

$$P\left(\bar{Y} - t_{n-1,1-\alpha/2}\sqrt{\frac{S^2}{n}} \le \mu \le \bar{Y} + t_{n-1,1-\alpha/2}\sqrt{\frac{S^2}{n}}\right) = 1-\alpha$$

$$c = t_{n-1,1-\alpha/2}\sqrt{\frac{S^2}{n}}$$

$t_{f,1-\alpha/2}$ is the $100(\alpha/2)\%$ percentile of the $t$-distribution with $f$ degrees of freedom.

*Equation 8. Interval estimation*

- Calculate $S^2$ with some pilot replications.
- Fix the desired half-width $c^*$ we want to obtain from simulation.
- Choose a confidence level $1-\alpha$.
- Calculate $n$:

$$c = t_{n-1,1-\alpha/2}\sqrt{\frac{S^2}{n}} \quad \Rightarrow \quad n = \left(\frac{t_{n-1,1-\alpha/2}}{c^*}\right)^2 S^2$$

*Equation 9. Number of replications*

Reference to Appendix 8 for all the computations. We will do a number of replications equal to 50.

Now let's design the scenarios we want to test.

### *4.3.1. Scenario 0 - Baseline*

Data used in this scenario is as described above. Reorder policies are consistent with the information provided by the company. Products that use Reorder policies are those that are ordered on stock, i.e. that are stored in the Raw materials Warehouse. When the stock runs out, the on-demand component is requested from the M8 Warehouse, as shown in the Figure 24.

For straps, on the other hand, a policy of reordering every 30 days has been hypothesized, with quantities equal to 1053 pcs. The total quantity demanded for straps every 30 days is 1987 pcs out of which 53% is ordered from China and Germany, the remaining amount is requested on demand by the Italian supplier.

| PRODUCT | R | Q |
|---|---|---|
| Mechanism kit | 345 | 250 |
| Black metal feet | 60 | 100 |
| Beige and pink Leather | 24.16 | 300 |
| Orange Leather | 10.37 | 300 |
| Beige and yellow Leather | 144.43 | 300 |
| Red Leather | 160.48 | 300 |
| Gray Leather | 658.07 | 1000 |
| Medium pink Fabric | 56.69 | 100 |
| Orange Fabric | 281.19 | 100 |
| White Fabric | 27.88 | 70 |
| Antique pink Fabric | 94.77 | 47,5 |

*Table 17. RQ policy in Baseline scenario*

### 4.3.2. Scenario 1

Starting from Scenario 0 - Baseline, we tried to analyze what would happen if, for materials ordered in stock, there was no option to acquire them on demand when needed.

We disabled the dual replenishment between the two warehouses from the Shipping table and left only the Raw materials warehouse active. We maintained the same parameters as Scenario 0 - Baseline for RQ policy.

Having disabled on-demand orders, everything will be required from China and Germany for straps. So, we change the order quantity to 1987 pcs, every 30 days.

### 4.3.3. Scenario 1.1

Starting from Scenario 1, the policy of reordering straps from China and Germany is improved. Previously, it was established with a frequency of 30 days, now a reordering every 115 days is assumed.

A better version of Scenario 1, in which the reordering policy for straps from China, which is the most critical, with quantity and fixed period type, ensures coverage for a reorder interval of 115 days (LT of this supplier) with the quantity needed for the average requirement for that time frame.

### 4.3.4. Scenario 2

Starting from Scenario 1.1, we tried to improve the reordering policies. We realized that the policies currently used by the company are not sufficient to ensure production, at 100% Service Level.

The reordering policies are not sufficient to meet the demands, as it can be seen from the fact that materials are also requested from the M8 Warehouse. In fact, if the policies were optimal, we would never find ourselves in stock-out and therefore with the need for on-demand replenishment by short-time suppliers.

Another way to visualize problems of availability is to make anyLogistix show the "Available inventory including backlog" graphs, for Raw materials Warehouse. In the next page, single graphs for all items are depicted. To make the display clearer, 1 of 50 replications is visible. Where the line, which represents the inventory position, falls below the 0 axis, a stock-out occurs.

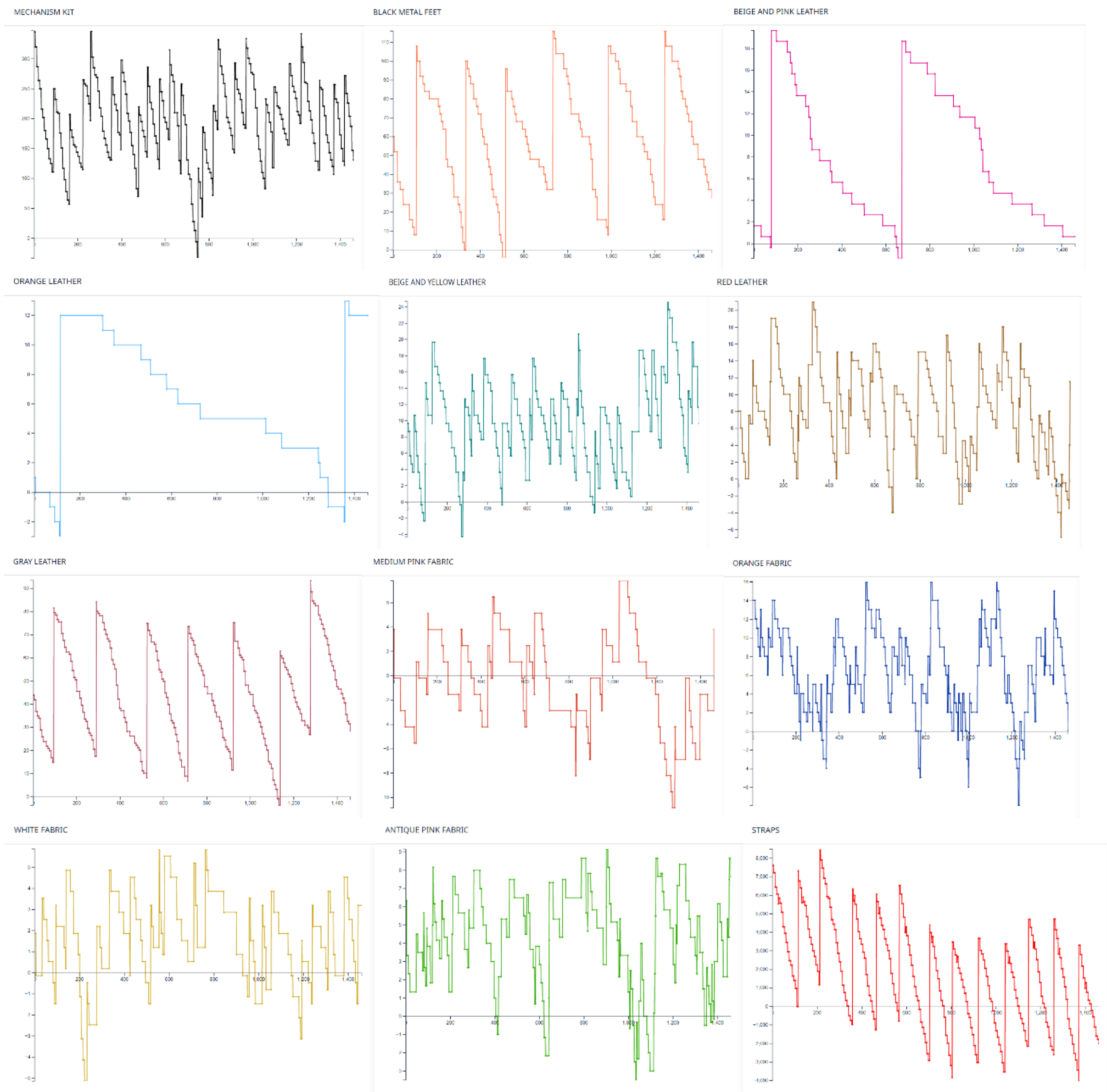


*Figure 27. Available inventory including backlog for materials*

Based on the Safety stock estimation provided by anyLogistix, we can improve the R's for better management.

For the calculation of the Safety stock estimation, we input a Service Level of 100% to have the maximum improvement. Averaging the values of the different replications, the resulting data, are:

| PRODUCT | SAFETY STOCK ESTIMATION |
|---|---|
| Mechanism kit | 2 |
| Black metal feet | 7 |
| Beige and pink Leather | 34 |
| Orange Leather | 22 |
| Beige and yellow Leather | 97 |
| Red Leather | 99 |
| Gray Leather | 29 |
| Medium pink Fabric | 199 |
| Orange Fabric | 149 |
| White Fabric | 71 |
| Antique pink Fabric | 67 |
| Straps | 1466 |

*Table 18. Safety stock estimation*

Based on this, the new Rs were considered, as the old R + Safety stock estimation.

Considering that in this scenario there is no integration of on-demand materials, we have the data of materials on stock without bias generated in the system that excludes demand whenever the product is out-of-stock. In the Scenario 0 - Baseline, whenever a product is out-of-stock demand is redirected to M8 Warehouse, not present in this scenario, generating lower demand in Raw materials Warehouse, thus providing sub-optimal outputs.

For this reason, in future scenarios where an improvement in the R's is expected, the R's defined in this scenario will be used.

Modified parameters are highlighted in light blue compared to Scenario 1.1.

| PRODUCT | R | Q |
|---|---|---|
| Mechanism kit | 347 | 250 |
| Black metal feet | 67 | 100 |
| Beige and pink Leather | 58 | 300 |
| Orange Leather | 33 | 300 |
| Beige and yellow Leather | 242 | 300 |
| Red Leather | 259 | 300 |
| Gray Leather | 687 | 1000 |
| Medium pink Fabric | 256 | 100 |
| Orange Fabric | 431 | 100 |
| White Fabric | 99 | 70 |
| Antique pink Fabric | 162 | 47,5 |
| Straps | 9083 | 10000 |

*Table 19. RQ policy in Scenario 2*

### 4.3.5. Scenario 3

Starting from Scenario 0 - Baseline, we tried to improve the reordering policies by setting reorder points R, as done in Scenario 2, that allow for better stock management.

Modified parameters are highlighted in light blue compared to Scenario 0 - Baseline.

| PRODUCT | R | Q |
|---|---|---|
| Mechanism kit | 347 | 250 |
| Black metal feet | 67 | 100 |
| Beige and pink Leather | 58 | 300 |
| Orange Leather | 33 | 300 |
| Beige and yellow Leather | 242 | 300 |
| Red Leather | 259 | 300 |
| Gray Leather | 687 | 1000 |
| Medium pink Fabric | 256 | 100 |
| Orange Fabric | 431 | 100 |
| White Fabric | 99 | 70 |
| Antique pink Fabric | 162 | 47,5 |
| Straps | 9083 | 10000 |

*Table 20. RQ policy in Scenario 3*

### 4.3.6. Scenario 4

Starting from Scenario 0 - Baseline, we tried not to rely on suppliers that sell with on stock modality for materials that may be requested JIT.

We disabled the dual replenishment between the two warehouses from the Shipping table and left only the M8 warehouse active. In addition, reordering policies for these products should also be disabled so as not to have unnecessary costs.

The only products that can only be ordered on stock are:

| PRODUCT | R | Q |
|---|---|---|
| Black metal feet | 60 | 100 |
| Beige and pink Leather | 24.16 | 300 |
| White Fabric | 27.88 | 70 |
| Antique pink Fabric | 94.77 | 47.5 |

*Table 21. RQ policy in Scenario 4*

### 4.3.7. Scenario 5

Starting from Scenario 4, we tried to improve the reordering policies for materials that remain in stock. Although on-demand products are preferred, some can only be ordered from stock. So, we can identify more suitable R's for these components, based on R used for Scenario 2.

Modified parameters are highlighted in light blue compared to Scenario 4.

| PRODUCT | R | Q |
|---|---|---|
| Black metal feet | 67 | 100 |
| Beige and pink Leather | 58 | 300 |
| White Fabric | 98,78 | 70 |
| Antique pink Fabric | 162,015 | 47,5 |

*Table 22. RQ policy in Scenario 5*

### 4.3.8. Scenario 6

Starting from Scenario 0 - Baseline, we used the EOQ method to derive the optimal Q, leaving R unchanged.

The EOQ model is a theoretical approach that minimizes the cost of order issuance (our transportation cost) with the cost of holding inventory and is based on some assumptions, including that the cost of issuing order K is unique for any quantity ordered. Our cost is per vehicle shipped, and the number of vehicles depends on their capacity. Calling K the cost of the single order, the optimal quantity to be shipped in each cycle is calculated. If this exceeds the capacity of the vehicle, then K is updated and K* will be the new cost of issuing the order, i.e. single cost*number of vehicles needed. The procedure is repeated n times until the EOQ calculated at iteration n converges with the EOQ calculated at iteration n-1.

To calculate Q we used the following formula:

$$Q = \sqrt{\frac{2K * D}{h}}$$

*Equation 10. EOQ method*

*where K = fixed cost of order (in our case the transportation cost)*

*D = annual demand*

*h = annual inventory cost*

The results are shown in 8.9.

Convergence would be achieved much sooner if the costs of keeping in stock were higher.

By dividing the resulting EOQs by the average annual demand, it is checked whether the established simulation length is suitable. It turns out that for the black metal feet item, an order of 10767 is enough for 78 years. It would be wrong to make comparisons between this quantity and the basic quantity over a time horizon that does not cover the period for the disposal of these stocks. For this article, therefore, an adjustment is made for the output, transportation, cost and inventory spend. The share of both costs for that item is multiplied by 4/78.

Modified parameters are highlighted in light blue compared to Scenario 0 - Baseline.

| PRODUCT | R | Q |
|---|---|---|
| Mechanism kit | 345 | 1988 |
| Black metal feet | 60 | 10767 |
| Beige and pink Leather | 24,16 | 318 |
| Orange Leather | 10,37 | 130 |
| Beige and yellow Leather | 144,43 | 2217 |
| Red Leather | 160,48 | 2812 |
| Gray Leather | 658,07 | 3571 |
| Medium pink Fabric | 56,69 | 1079 |
| Orange Fabric | 281,19 | 3269 |
| White Fabric | 27,88 | 331 |
| Antique pink Fabric | 94,77 | 1092 |
| Straps | 7617 | 48962 |

*Table 23. RQ policy in Scenario 6*

### *4.3.9. Scenario 7*

Starting from Scenario 6, we tried to improve R, based on data from Scenario 2.

Modified parameters are highlighted in light blue compared to Scenario 6.

| PRODUCT | R | Q |
|---|---|---|
| Mechanism kit | 347 | 1988 |
| Black metal feet | 67 | 10767 |
| Beige and pink Leather | 58 | 318 |
| Orange Leather | 33 | 130 |
| Beige and yellow Leather | 242 | 2217 |
| Red Leather | 259 | 2812 |
| Gray Leather | 687 | 3571 |
| Medium pink Fabric | 256 | 1079 |
| Orange Fabric | 431 | 3269 |
| White Fabric | 99 | 331 |
| Antique pink Fabric | 162 | 1092 |
| Straps | 9083 | 48962 |

*Table 24. RQ policy in Scenario 7*

# 5. Analysis and discussion of the results

For analysis, anyLogistix allows us to use the comparison experiment in such a way that it provides us with the data we need for all the identified scenarios.

For the actual simulation phase, we built an ad-hoc dashboard with all the statistics that we want anyLogistix to return to us at the end of the run.

It is important to establish in advance which indicators are useful for analysis to have a clear and usable reading of graphs and tables in output:

- Mean Lead time: time between sending the order to the manufacturer and delivering the product to the customer. Lead time is one of the most relevant statistics for this study and one that the company would like to work on. It is an average between the mean lead times of the products.
- ELT service Level by Products: shows ratio of products delivered on time to the overall number of products shipped. The data on products is taken from the processed orders. The valued is defined as:

$$ELT = \frac{value\ of\ products\ in\ the\ on\ time\ orders}{value\ of\ products\ in\ the\ outgoing\ orders}$$

*Equation 11. ELT Service Level*

- Demand placed (products) by customers, products produced and fulfillment received (products) by customers are useful statistics.
- Inventory carrying cost = average inventory ($m^3$)*0,15(€/$m^3$*anno). This cost item is in fact almost irrelevant as it is a matter of low-volume raw materials (those that stay for prolonged periods of time)
- Inventory expense: order cost of products.
- Transportation cost: includes the fixed order issuing price to company's suppliers and the cost of subsequent transfers of raw materials, semi-finished and finished products, calculated as €/kilometer*distance (km). The latter was assumed to be 0.6 €/km as the cost of using and refueling the vehicle.
- Total cost: total cost desired for final evaluations. It's the sum of the three above statistics.

| Scenario | Demand Placed (Orders) by Customer | | Fulfillment Received (Products) by Customer | | Mean Lead Time (days) | | ELT Service Level by Products | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std | Mean | Std | Mean | Std | Mean | Std |
| Baseline | 1516 | 34 | 1516 | 40 | 38,01 | 2,59 | 0,54 | 0,05 |
| Scenario_1 | 1519 | 32 | 1464 | 33 | 117,48 | 18,24 | 0,03 | 0,01 |
| Scenario_1.1 | 1514 | 44 | 1512 | 33 | 52,09 | 10,40 | 0,35 | 0,10 |
| Scenario_2 | 1507 | 36 | 1566 | 42 | 50,15 | 7,62 | 0,40 | 0,06 |
| Scenario_3 | 1516 | 31 | 1507 | 38 | 37,25 | 2,70 | 0,42 | 0,06 |
| Scenario_4 | 1526 | 42 | 1528 | 44 | 32,85 | 0,62 | 0,64 | 0,03 |
| Scenario_5 | 1517 | 37 | 1520 | 38 | 32,22 | 0,52 | 0,66 | 0,03 |
| Scenario_6 | 1519 | 41 | 1516 | 50 | 50,32 | 7,81 | 0,39 | 0,06 |
| Scenario_7 | 1516 | 44 | 1496 | 46 | 49,57 | 7,90 | 0,41 | 0,07 |

*Table 25. Comparison of scenarios*

| Scenario | Inventory Carrying Cost (€/year) | | Order Cost (€/year) | | Transportation Cost (€/year) | | Total Cost (€/year) | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std | Mean | Std | Mean | Std | Mean | Std |
| Baseline | 63 | 3,7 | 120778 | 5407,4 | 154925 | 3890,4 | 275766 | 8320,1 |
| Scenario_1 | 65 | 4,7 | 118750 | 5209,0 | 119710 | 3945,2 | 238525 | 6189,8 |
| Scenario_1.1 | 65 | 5,2 | 119165 | 7658,7 | 124311 | 7566,9 | 243542 | 6181,0 |
| Scenario_2 | 105 | 4,7 | 119698 | 6391,3 | 130595 | 4705,8 | 250398 | 7329,3 |
| Scenario_3 | 105 | 4,7 | 120186 | 5451,2 | 130729 | 5982,1 | 251019 | 8400,5 |
| Scenario_4 | 9 | 1,0 | 122021 | 7275,6 | 143682 | 2753,5 | 265713 | 9419,9 |
| Scenario_5 | 14 | 1,0 | 121190 | 5902,7 | 143327 | 2378,7 | 264532 | 7439,0 |
| Scenario_6 | 358 | 12,5 | 91216 | 30925,6 | 113943 | 5755,5 | 205517 | 30841,6 |
| Scenario_7 | 375 | 12,5 | 98882 | 29641,0 | 116124 | 9144,3 | 215382 | 31699,8 |

*Table 26. Comparison of scenarios*

Scenario 1 is not comparable to the others. The specific problem with this configuration is that having the straps shipped from China with a frequency of 30 days gives rise to a lot of stock outs due to delays in delivery given the high variability (11.5 days) of the delivery lead time. In Scenario 0 - Baseline, the problem is limited, since the company relies on the secondary supplier, the Italian one, when it needs additional straps. Being a common component of all sofas, the average final delivery lead time reaches 90 days on average. Therefore, when comparing the results of the scenarios, Scenario 1 was completely ignored as it was not sustainable.

| | Total Cost | Inventory Carrying Cost | Order Cost | Transportation Cost | Mean Lead Time | ELT Service Level by Products |
|---|---|---|---|---|---|---|
| 1st | Scenario_6 | Scenario_4 | Scenario_6 | Scenario_6 | Scenario_5 | Scenario_5 |
| 2nd | Scenario_7 | Scenario_5 | Scenario_7 | Scenario_7 | Scenario_4 | Scenario_4 |
| 3rd | Scenario_1.1 | Baseline | Scenario_1.1 | Scenario_1.1 | Scenario_3 | Baseline |
| 4th | Scenario_2 | Scenario_1.1 | Scenario_2 | Scenario_2 | Baseline | Scenario_3 |
| 5th | Scenario_3 | Scenario_3 | Scenario_3 | Scenario_3 | Scenario_7 | Scenario_7 |
| 6th | Scenario_5 | Scenario_2 | Baseline | Scenario_5 | Scenario_2 | Scenario_2 |
| 7th | Scenario_4 | Scenario_6 | Scenario_5 | Scenario_4 | Scenario_6 | Scenario_6 |
| 8th | Baseline | Scenario_7 | Scenario_4 | Baseline | Scenario_1.1 | Scenario_1.1 |

*Table 27. Breakdown of the rankings*

As the quantity increases and the frequency of orders for straps from China decreases, the probability of a delay decreases and therefore the lead time returns to being plausible (Scenario 1.1).

Without the possibility of making up for a stock-out in the Raw materials Warehouse by transferring the order to nearby suppliers, there are more limitations and forces longer waits (LT Scenario 1.1>LT Scenario 0 - Baseline). If at the same time the management of the remaining suppliers is perfected, increasing the R's that are too low, then the situation improves (LT Scenario 0 - Baseline<LT Scenario 2<LT Scenario 1.1). Once the baseline situation has been restored, there is an improvement in lead time (Scenario 3) with the new R.

The refinement of the parameters of the reordering policies has effect, as expected, in the lead time of Scenario 5 compared to that of Scenario 4 and in Scenario 7 compared to Scenario 6.

If the company relies exclusively and totally on Italian suppliers for straps, Italsofa Romania for different components, except in cases where it is not possible (Scenario 4 and Scenario 5), the customer would have a great benefit because production would not be subject to high variability.

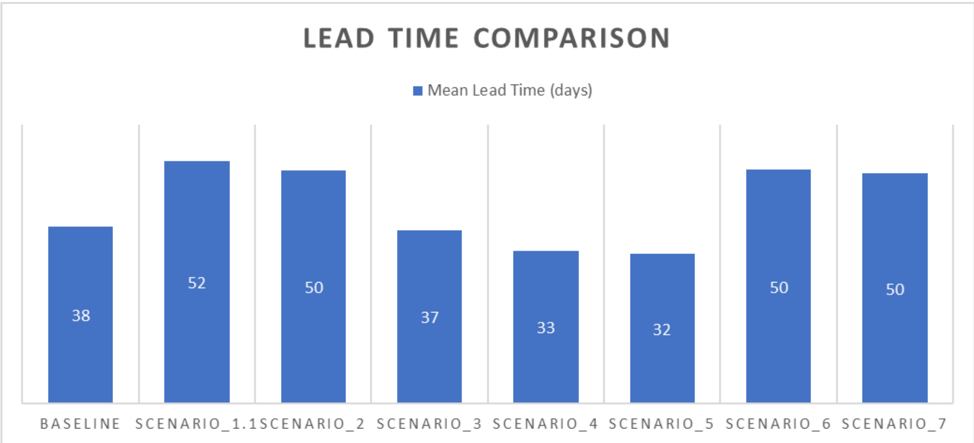


*Figure 28. Lead time comparison*

Instead, it is correct to note a more marked difference in inventory cost between Scenario 6-Scenario 7, Scenario 0 - Baseline-Scenario 1.1-Scenario 2-Scenario 3, and Scenario 4-Scenario 5. The first is the scenario set with EOQ method. The ordered quantities are high due to the high order costs, that means higher inventory than in the scenarios with the quantities decided by the company, which in turn are higher than in the no-stock case. In any case, the unit cost of keeping in stock is so low in the context of the company that fluctuations will not affect the determination of the most cost-effective scenario. Please note that the most voluminous products, which are finished products, stay in the Distribution Center for a maximum of one week.

The scenarios that offer significant savings in terms of transport costs are 6 and 7: order fulfillment guarantees a supply for more than 2 years, except for the black metal feet which are enough for 78 years, which are also the ones with the lowest total cost. On the other hand, those with the worst performance in this sense are 4 and 5 (some foreign suppliers excluded) and therefore deliveries, although costing less individually, are more numerous because they are weekly. The baseline is even more expensive because it combines a substantial number of weekly deliveries from close suppliers with monthly deliveries from China.

When deliveries from emergency suppliers are excluded, order costs also improve, because the quantity received is the same, but the unit price is lower.

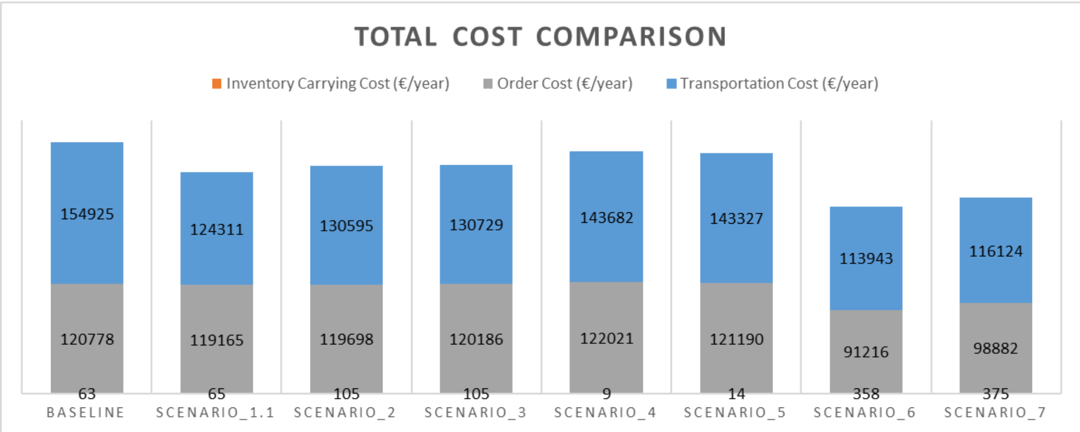


*Figure 29. Total cost comparison*

Provided the previous outputs on lead time and costs separately, it is important to compare them and understand their trade-offs.

Scenario 4 and Scenario 5 guarantee lead times between 4.5 and 5 weeks, which is a nice advantage to the expense of a very high total cost. Scenario 3, together with the Scenario 0 - Baseline, guarantees 5.5 weeks. Once again, the Scenario 0 - Baseline is to be excluded due to its total cost. Scenario 7, Scenario 6, Scenario 2, and Scenario 1.1 show lead times ranging from 50 to 52 days. In Scenario 7 and Scenario 6 such long lead times are to be attributed to the fact that, even if the probability of a delay occurring is low, with 2 deliveries in 4 years, the impact is significant due to the large quantities. Considering these dynamics, the best path to take, according to these assumptions and reasoning, is the one indicated by Scenario 3, in which the company continues to act as before, but with a redefinition of the reordering levels. However, if the company's strategy is to minimize total costs at the expense of customer waiting times, then it could opt to place large orders (EOQ scenarios). On the other hand, this not only translates into a disadvantage for the customer, but also for Natuzzi itself, given the organizational difficulty that arises.

These conclusions are valid for the assumptions made: if the costs or capabilities of the truck were different from those assumed, there could be a subversion of the results that could lead to other decisions.

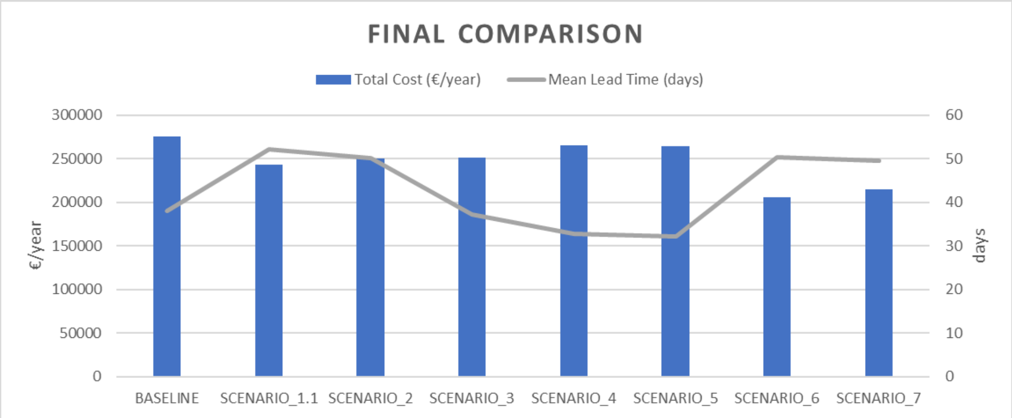


*Figure 30. Final comparison*

# 6. Conclusions and Future Directions

The software proves to be a good tool for this type of analysis. With simulation tools, it is possible to predict what will be the outcome of any innovation in the management or creation of a supply chain from scratch and its long-term effects, thanks to the computing power of the machine. The software has to be instructed in a precise, rigid manner. In reality, there are more unpredictable events and the software cannot encompass all of them. The evolution technologies have faced in this field certainly creates high expectations about future improvement.

Theoretically, it is always possible to make trade-offs between several decision-making variables to achieve an improvement in the AS-IS situation, proposing a TO-BE. On the other hand, the theoretical formulations are based on assumptions that clash with practice, characterized by a multitude of constraints that would make the study with a theoretical approach too complicated.

It is also pointed out that companies often lack efficient management and sharing of information, which is often lost, unusable or inconsistent. In the absence of reliable data, a corrective analysis is not even imaginable. We should therefore start from a correct way of collecting and cataloguing historical and present data.

For accurate demand forecasting, better data collection is needed from the company. It should not only look at the last few weeks (6-8 weeks as of now) but it should consider seasonality or events that may affect demand, for example. It is a starting point for better stock sizing.

Some reasoning emerged from the study of the software in the attempts to duplicate in the model a business context that is as real as possible and compatible with that of the case study.

To achieve a more complete model, i.e., one that includes the real network of flows in terms of variety and quantity of material handled in the supply chain, a more accurate analysis should be carried with more information on what distinguishes the different suppliers from the same territory explaining their coexistence, for example peculiarities in the products supplied. There are still other reasons that can explain the structure of Natuzzi's suppliers. For some items, for example, it is obliged to source from other countries because these are pieces that in Italy are protected by a patent, think of a particular mechanism mounted on some models of sofa beds, which Natuzzi buys from a German supplier. Due to these constraints, it is impossible to generalize. Certainly, if Natuzzi continues with the strategy of standardization of components (excluding coatings), there will be fewer variables to consider in procurement management.

Still with a view to a realistic model, if a capillary distribution with delivery from the distribution center in Matera to the customer's home (city) is to be included in the modeling, it is possible to create customer entities scattered throughout the country. The management of too many entities could be difficult, however the model allows to limit the number of customers to 574, as center of demand collection. In fact, there are 574 Italian locations that the software database records, and it turns out to be an aggregation of 1:14 compared to the total Italian municipalities. In any case, it is allowed to manually add any location by specifying the city, the software will automatically provide the coordinates, or vice versa.


*Figure 31. Example with 574 customers*

Cities can generate demand in direct proportion to population. In addition, the modelling should consider the significant increase in demand for a product if there is a store in the city. In addition, the extent of the increase depends on several factors, including the presence of competitors: if there is already strong competition, the impact is less pronounced.

The tool does not allow to optimize delivery routes, so transport is not organized to minimize costs. An order to visit different locations of a milk run could be imposed, but in addition to taking a lot of time, it would still not be useful as fixed and not evolving during the simulation. Transport optimization function, previously present, should be re-implemented in anyLogistix.

The software might consider as inputs production programming and control, so it could be exploited to implement the programming and optimization logics actually used in Natuzzi's operations in the proposed way and therefore have more accurate results.

Due to the limited number of treated SKUs, the typical problem of low-rotating items for which suppliers impose a minimum production batch has not been massively addressed. In that case, different scenarios can arise and be evaluated: from still requesting the item in low quantities by paying considerable penalties, to increasing the quantity requested up to the minimum batch, thus increasing the fixed stocks, to waiting for the demand to reach that threshold, thus extending the customer's waiting time. The best solution depends on what are the real costs of keeping in stock and the strategy of the company.

In general, having all the necessary inputs available to conduct a simulation is certainly essential to ensure that what we call a "Digital Twin" is truly such.

# 7. Bibliography

## 7.1. Academic papers


- Agrawal, S. et al. (2023). *Can industry 5.0 technologies overcome supply chain disruptions?—a perspective study on pandemics, war, and climate change issues.* Oper Manag Res.
- Attolico, L. (2019). *Lean Development and Innovation: Hitting the Market with the Right Products at the Right Time.*
- Badakhshan, E. et al (2022). *Using digital twins for inventory and cash management in supply chains*, IFAC-PapersOnLine, 55(10): 1980-1985.
- Belgiojoso, G. et al. (2008). *The Natuzzi Group and the Bari-Matera (Italy) Upholstered Furniture District. A Case Study of Internationalisation in a Traditional Industry*. Centre for Industrial Studies, Working Paper N. 03/2009.
- Brito Oliveira J. et al. (2016). *Perspectives and relationships in Supply Chain Simulation: A systematic literature review*, Simulation Modelling Practice and Theory, Volume 62, Pages 166-191.
- Cachon, G. et al. (2000). *Supply Chain Inventory Management and the Value of Shared Information*. Management Science 46(8): 1032-1048.
- Capaldo, A. et al. (2012). *Un modello di simulazione per la quantificazione dei benefici della fiducia nelle supply chain distrettuali*. Esperienze d'impresa, 47-70.
- Ciupan, E. et al. (2018). *Opportunities of Sustainable Development of the Industry of Upholstered Furniture in Romania. A Case Study.* Sustainability, 10(9): 3356.
- Dangelico R. et al. (2013). *Developing Sustainable New Products in the Textile and Upholstered Furniture Industries: Role of External Integrative Capabilities.* Journal of Product Innovation Management, 30(4): 642–658.
- dos Santos Hermogenes, L. et al. (2022). *E-Commerce Supply Chain Analysis Using the ANYLOGISTIX Computational Tool*. Procedia computer science. 214.C: 487–494.
- Eksioglu, B. et al. (2010). *A Simulation Model to Analyze the Impact of Outsourcing on Furniture Supply Chain Performance*. Forest Products Journal, 60: 258-265.
- Fayez, M. et al. (2005). *Ontologies for Supply Chain Simulation Modeling*. Proceedings of the ... Winter Simulation Conference. Vol. 2005. New York, NY: Institute of Electrical and Electronics Engineers, 2364–2370.

- Hosseini, S. et al. (2019). *Review of quantitative methods for supply chain resilience analysis*. Transportation Research Part E: Logistics and Transportation Review, Volume 125, Pages 285-307.
- Ivanov D. (2019), *Disruption tails and revival policies: A simulation analysis of supply chain design and production-ordering systems in the recovery and post-disruption periods,* Computers & Industrial Engineering, Volume 127: 558-570.
- Ivanov, D. (2021). *Supply chain simulation and optimization with anyLogistix*.
- Jardim-Goncalves, R. et al. (2011). *Standards Framework for Intelligent Manufacturing Systems Supply Chain.*
- Kamble, S. et al. (2022). *Digital twin for sustainable manufacturing supply chains: Current trends, future perspectives, and an implementation framework*, Technological Forecasting and Social Change, 176: 121448.
- Lins, P.S. et al. (2021). *(Re)layout as a Strategy for Implementing Cleaner Production: Proposal for a Furniture Industry Company.* Sustainability 2021, 13.
- Min, H. et al. (2002). *Supply Chain Modeling: Past, Present and Future.* Computers & industrial engineering 43.1–2: 231–249.
- Østbø Haugen H. et al. (2024). *Supply-chain Disruptions under COVID: A Window of Opportunity for Local Producers?,* Forum for Development Studies, 51:1, 165-187.
- Piancastelli, C. et al (2020). *The Role of Digital Twins in the Fulfilment Logistics Chain*, IFAC-PapersOnLine, 53(2): 10574-10578.
- Robb, D. et al. (2008). *Supply chain and operations practice and performance in Chinese furniture manufacturing.* Int. J. Production Economics , 112: 683–699
- Sahebjamnia, N. (2020). *Resilient supplier selection and order allocation under uncertainty.* Scientia Iranica, 27(1), 411-426.
- Sellitto, M. (2018). *Lead-time, inventory, and safety stock calculation in job-shop manufacturing.* Acta Polytechnica, 58(6): 395–401.
- van der Valk, H. et al. (2022). *Supply Chains in the Era of Digital Twins – A Review*, Procedia Computer Science, 204: 156-163.
- Vitorino, L. et al. (2022). *Analysis of Food Distribution Network Using Anylogistix Computational Tool*. IFAC-PapersOnLine 55.10: 2018–2023.

## 7.2. Sitography


- https://www.industriaitaliana.it/divani-come-toyota-nuove-tecnologie-e-lean-manufacturing-nella-natuzzi/
- https://www.sistema.puglia.it/portal/pls/portal/sispuglia.ges_blob.p_retrieve?p_rowid=AAAh67AABAACsqwAAE&p_tname=sispuglia.documenti&p_cname=testo&p_cname_mime=mime_type_testo&p_esito=0
- https://www.anylogistix.com/resources/white-papers/
- https://www.natuzzi.com
- https://www.mics.tech/
- https://www.statista.com/
- https://www.startus-insights.com/innovators-guide/furniture-industry-trends/
- https://myhfa.org/navigating-the-furniture-industry-supply-chain-challenges/
- https://www.federlegnoarredo.it/it/servizi/centro-studi-dati-e-ricerche

# 8. Appendix

## 8.1. Appendix 1

| Iteration | Description | Produced | Mean LT | Transportation Cost | Iteration | Description | Produced | Mean LT | Transportation Cost |
|---|---|---|---|---|---|---|---|---|---|
| 1 | capacity: 6, amount: 1, amount: 1 | 24 | 597,06 | 99569 | 55 | capacity: 6, amount: 1, amount: 4 | 25 | 580,81 | 99505 |
| 2 | capacity: 18, amount: 1, amount: 1 | 83 | 195,69 | 117018 | 56 | capacity: 18, amount: 1, amount: 4 | 86 | 200,38 | 117840 |
| 3 | capacity: 30, amount: 1, amount: 1 | 157 | 123,98 | 126215 | 57 | capacity: 30, amount: 1, amount: 4 | 116 | 36,73 | 122640 |
| 4 | capacity: 6, amount: 2, amount: 1 | 53 | 398,96 | 108238 | 58 | capacity: 6, amount: 2, amount: 4 | 55 | 383,63 | 111845 |
| 5 | capacity: 18, amount: 2, amount: 1 | 342 | 35,13 | 146645 | 59 | capacity: 18, amount: 2, amount: 4 | 335 | 34,30 | 146828 |
| 6 | capacity: 30, amount: 2, amount: 1 | 341 | 30,04 | 148758 | 60 | capacity: 30, amount: 2, amount: 4 | 340 | 29,86 | 147717 |
| 7 | capacity: 6, amount: 3, amount: 1 | 85 | 214,60 | 121253 | 61 | capacity: 6, amount: 3, amount: 4 | 84 | 226,70 | 120589 |
| 8 | capacity: 18, amount: 3, amount: 1 | 343 | 30,01 | 147907 | 62 | capacity: 18, amount: 3, amount: 4 | 336 | 30,03 | 149700 |
| 9 | capacity: 30, amount: 3, amount: 1 | 346 | 30,31 | 150375 | 63 | capacity: 30, amount: 3, amount: 4 | 343 | 29,91 | 148186 |
| 10 | capacity: 6, amount: 4, amount: 1 | 223 | 163,21 | 136353 | 64 | capacity: 6, amount: 4, amount: 4 | 228 | 108,39 | 133162 |
| 11 | capacity: 18, amount: 4, amount: 1 | 342 | 30,34 | 150550 | 65 | capacity: 18, amount: 4, amount: 4 | 332 | 30,10 | 148490 |
| 12 | capacity: 30, amount: 4, amount: 1 | 337 | 30,22 | 149508 | 66 | capacity: 30, amount: 4, amount: 4 | 340 | 29,78 | 147651 |
| 13 | capacity: 6, amount: 5, amount: 1 | 340 | 33,60 | 185476 | 67 | capacity: 6, amount: 5, amount: 4 | 339 | 34,13 | 187390 |
| 14 | capacity: 18, amount: 5, amount: 1 | 345 | 29,97 | 150115 | 68 | capacity: 18, amount: 5, amount: 4 | 336 | 29,78 | 146365 |
| 15 | capacity: 30, amount: 5, amount: 1 | 341 | 29,92 | 148662 | 69 | capacity: 30, amount: 5, amount: 4 | 346 | 30,35 | 149296 |
| 16 | capacity: 6, amount: 6, amount: 1 | 342 | 30,66 | 189068 | 70 | capacity: 6, amount: 6, amount: 4 | 341 | 30,31 | 189690 |
| 17 | capacity: 18, amount: 6, amount: 1 | 350 | 30,28 | 151469 | 71 | capacity: 18, amount: 6, amount: 4 | 346 | 29,88 | 150476 |
| 18 | capacity: 30, amount: 6, amount: 1 | 336 | 30,11 | 145290 | 72 | capacity: 30, amount: 6, amount: 4 | 345 | 29,86 | 149015 |
| 19 | capacity: 6, amount: 1, amount: 2 | 25 | 571,36 | 99588 | 73 | capacity: 6, amount: 1, amount: 5 | 25 | 588,21 | 99442 |
| 20 | capacity: 18, amount: 1, amount: 2 | 85 | 229,51 | 119331 | 74 | capacity: 18, amount: 1, amount: 5 | 90 | 200,76 | 120156 |
| 21 | capacity: 30, amount: 1, amount: 2 | 116 | 37,81 | 125687 | 75 | capacity: 30, amount: 1, amount: 5 | 111 | 35,67 | 126792 |
| 22 | capacity: 6, amount: 2, amount: 2 | 55 | 410,71 | 111726 | 76 | capacity: 6, amount: 2, amount: 5 | 57 | 394,99 | 109811 |
| 23 | capacity: 18, amount: 2, amount: 2 | 340 | 33,73 | 147712 | 77 | capacity: 18, amount: 2, amount: 5 | 337 | 35,84 | 146234 |
| 24 | capacity: 30, amount: 2, amount: 2 | 343 | 30,26 | 150560 | 78 | capacity: 30, amount: 2, amount: 5 | 339 | 30,02 | 149675 |
| 25 | capacity: 6, amount: 3, amount: 2 | 83 | 223,25 | 121171 | 79 | capacity: 6, amount: 3, amount: 5 | 84 | 201,05 | 120541 |
| 26 | capacity: 18, amount: 3, amount: 2 | 334 | 29,96 | 148740 | 80 | capacity: 18, amount: 3, amount: 5 | 336 | 30,60 | 150141 |
| 27 | capacity: 30, amount: 3, amount: 2 | 345 | 30,54 | 149002 | 81 | capacity: 30, amount: 3, amount: 5 | 342 | 29,85 | 148372 |
| 28 | capacity: 6, amount: 4, amount: 2 | 170 | 105,86 | 132073 | 82 | capacity: 6, amount: 4, amount: 5 | 210 | 131,72 | 133512 |
| 29 | capacity: 18, amount: 4, amount: 2 | 343 | 30,28 | 149406 | 83 | capacity: 18, amount: 4, amount: 5 | 342 | 30,69 | 150894 |
| 30 | capacity: 30, amount: 4, amount: 2 | 347 | 29,91 | 149180 | 84 | capacity: 30, amount: 4, amount: 5 | 339 | 29,84 | 148089 |
| 31 | capacity: 6, amount: 5, amount: 2 | 347 | 34,19 | 188383 | 85 | capacity: 6, amount: 5, amount: 5 | 345 | 33,71 | 188618 |
| 32 | capacity: 18, amount: 5, amount: 2 | 345 | 30,65 | 150786 | 86 | capacity: 18, amount: 5, amount: 5 | 344 | 30,33 | 149683 |
| 33 | capacity: 30, amount: 5, amount: 2 | 341 | 29,95 | 148086 | 87 | capacity: 30, amount: 5, amount: 5 | 338 | 29,95 | 149080 |
| 34 | capacity: 6, amount: 6, amount: 2 | 341 | 30,62 | 187432 | 88 | capacity: 6, amount: 6, amount: 5 | 345 | 30,76 | 189499 |
| 35 | capacity: 18, amount: 6, amount: 2 | 339 | 29,57 | 148832 | 89 | capacity: 18, amount: 6, amount: 5 | 336 | 30,06 | 150022 |
| 36 | capacity: 30, amount: 6, amount: 2 | 343 | 30,17 | 146959 | 90 | capacity: 30, amount: 6, amount: 5 | 338 | 29,88 | 148296 |
| 37 | capacity: 6, amount: 1, amount: 3 | 24 | 598,42 | 99356 | 91 | capacity: 6, amount: 1, amount: 6 | 27 | 568,81 | 99625 |
| 38 | capacity: 18, amount: 1, amount: 3 | 84 | 220,02 | 117555 | 92 | capacity: 18, amount: 1, amount: 6 | 85 | 208,84 | 119846 |
| 39 | capacity: 30, amount: 1, amount: 3 | 115 | 36,55 | 127960 | 93 | capacity: 30, amount: 1, amount: 6 | 115 | 35,95 | 127081 |
| 40 | capacity: 6, amount: 2, amount: 3 | 55 | 406,35 | 110708 | 94 | capacity: 6, amount: 2, amount: 6 | 53 | 389,62 | 111797 |
| 41 | capacity: 18, amount: 2, amount: 3 | 342 | 35,28 | 146630 | 95 | capacity: 18, amount: 2, amount: 6 | 341 | 34,90 | 150763 |
| 42 | capacity: 30, amount: 2, amount: 3 | 343 | 29,91 | 150106 | 96 | capacity: 30, amount: 2, amount: 6 | 348 | 30,01 | 151217 |
| 43 | capacity: 6, amount: 3, amount: 3 | 82 | 210,03 | 120419 | 97 | capacity: 6, amount: 3, amount: 6 | 84 | 211,17 | 118697 |
| 44 | capacity: 18, amount: 3, amount: 3 | 337 | 30,40 | 150122 | 98 | capacity: 18, amount: 3, amount: 6 | 345 | 30,38 | 151920 |
| 45 | capacity: 30, amount: 3, amount: 3 | 344 | 30,40 | 150961 | 99 | capacity: 30, amount: 3, amount: 6 | 345 | 30,12 | 150062 |
| 46 | capacity: 6, amount: 4, amount: 3 | 165 | 68,69 | 135220 | 100 | capacity: 6, amount: 4, amount: 6 | 208 | 150,71 | 131864 |
| 47 | capacity: 18, amount: 4, amount: 3 | 341 | 30,13 | 150263 | 101 | capacity: 18, amount: 4, amount: 6 | 344 | 30,35 | 149838 |
| 48 | capacity: 30, amount: 4, amount: 3 | 336 | 30,18 | 146755 | 102 | capacity: 30, amount: 4, amount: 6 | 345 | 30,30 | 149125 |
| 49 | capacity: 6, amount: 5, amount: 3 | 339 | 34,18 | 188772 | 103 | capacity: 6, amount: 5, amount: 6 | 339 | 33,78 | 189000 |
| 50 | capacity: 18, amount: 5, amount: 3 | 338 | 29,90 | 148936 | 104 | capacity: 18, amount: 5, amount: 6 | 337 | 29,88 | 147790 |
| 51 | capacity: 30, amount: 5, amount: 3 | 339 | 30,19 | 147533 | 105 | capacity: 30, amount: 5, amount: 6 | 346 | 30,52 | 149021 |
| 52 | capacity: 6, amount: 6, amount: 3 | 344 | 31,13 | 189492 | 106 | capacity: 6, amount: 6, amount: 6 | 338 | 30,78 | 189753 |
| 53 | capacity: 18, amount: 6, amount: 3 | 346 | 30,52 | 149675 | 107 | capacity: 18, amount: 6, amount: 6 | 342 | 29,89 | 148401 |
| 54 | capacity: 30, amount: 6, amount: 3 | 347 | 30,41 | 148104 | 108 | capacity: 30, amount: 6, amount: 6 | 342 | 30,17 | 149159 |

## 8.2. Appendix 2

| Iteration | Description | Received by DC | Mean LT | Transportation Cost |
|---|---|---|---|---|
| 1 | capacity: 6, amount: 1 | 360 | 32,61 | 147115 |
| 2 | capacity: 18, amount: 1 | 369 | 34,77 | 145983 |
| 3 | capacity: 30, amount: 1 | 383 | 34,41 | 146834 |
| 4 | capacity: 6, amount: 2 | 385 | 36,18 | 145261 |
| 5 | capacity: 18, amount: 2 | 374 | 36,99 | 148422 |
| 6 | capacity: 30, amount: 2 | 368 | 32,63 | 147911 |
| 7 | capacity: 6, amount: 3 | 370 | 34,44 | 149062 |
| 8 | capacity: 18, amount: 3 | 374 | 36,87 | 145202 |
| 9 | capacity: 30, amount: 3 | 352 | 31,55 | 143420 |

## 8.3. Appendix 3

| Iteration | Description | Received by Customer | Mean LT | Transportation Cost |
|---|---|---|---|---|
| 1 | capacity: 6, amount: 1 | 66 | 114,70 | 114498 |
| 2 | capacity: 18, amount: 1 | 352 | 34,61 | 143576 |
| 3 | capacity: 30, amount: 1 | 367 | 30,27 | 144892 |
| 4 | capacity: 6, amount: 2 | 71 | 119,49 | 111372 |
| 5 | capacity: 18, amount: 2 | 356 | 36,84 | 144842 |
| 6 | capacity: 30, amount: 2 | 361 | 29,44 | 144456 |
| 7 | capacity: 6, amount: 3 | 65 | 121,88 | 110945 |
| 8 | capacity: 18, amount: 3 | 359 | 34,57 | 144717 |
| 9 | capacity: 30, amount: 3 | 377 | 30,21 | 147120 |
| 10 | capacity: 6, amount: 4 | 62 | 115,38 | 109968 |
| 11 | capacity: 18, amount: 4 | 347 | 32,81 | 142771 |
| 12 | capacity: 30, amount: 4 | 365 | 30,11 | 146604 |
| 13 | capacity: 6, amount: 5 | 63 | 116,13 | 111249 |
| 14 | capacity: 18, amount: 5 | 373 | 35,33 | 146708 |
| 15 | capacity: 30, amount: 5 | 358 | 29,80 | 146221 |
| 16 | capacity: 6, amount: 6 | 64 | 114,56 | 109446 |
| 17 | capacity: 18, amount: 6 | 371 | 33,05 | 146034 |
| 18 | capacity: 30, amount: 6 | 371 | 29,72 | 145175 |

## 8.4. Appendix 4

| Iteration | Description | Fulfillment Received (Products) by Customer | Mean Lead Time | Transportation Cost |
|---|---|---|---|---|
| 1 | capacity: 1 | 8 | 214,77 | 93423 |
| 2 | capacity: 2 | 21 | 178,52 | 99180 |
| 3 | capacity: 3 | 30 | 164,87 | 99691 |
| 4 | capacity: 4 | 43 | 142,20 | 103117 |
| 5 | capacity: 5 | 51 | 139,75 | 106581 |
| 6 | capacity: 6 | 64 | 111,90 | 110865 |
| 7 | capacity: 7 | 72 | 99,18 | 111500 |
| 8 | capacity: 8 | 94 | 90,78 | 118132 |
| 9 | capacity: 9 | 99 | 74,68 | 119791 |
| 10 | capacity: 10 | 120 | 61,78 | 123834 |
| 11 | capacity: 11 | 164 | 52,88 | 126041 |
| 12 | capacity: 12 | 199 | 55,72 | 127252 |
| 13 | capacity: 13 | 284 | 76,14 | 139874 |
| 14 | capacity: 14 | 307 | 50,51 | 144357 |
| 15 | capacity: 15 | 353 | 47,42 | 144015 |
| 16 | capacity: 16 | 357 | 45,17 | 145534 |
| 17 | capacity: 17 | 364 | 37,84 | 147058 |
| 18 | capacity: 18 | 366 | 34,73 | 145678 |
| 19 | capacity: 19 | 362 | 32,85 | 145539 |
| 20 | capacity: 20 | 355 | 29,97 | 146783 |

## 8.5. Appendix 5

| | Period | ELT Service Level by Products | | Mean Lead Time | | Transportation Cost | |
|---|---|---|---|---|---|---|---|
| Iteration | Description | Mean | St.dev | Mean | St.dev | Mean | St.dev |
| 1 | period: 1 | 0,72 | 0,061268 | 32,28346 | 2,339562 | 179448,9 | 3485,346 |
| 2 | period: 2 | 0,71 | 0,045844 | 33,31824 | 1,803510 | 176507,2 | 5655,803 |
| 3 | period: 3 | 0,62 | 0,075382 | 35,29023 | 2,676315 | 160717,4 | 2780,465 |
| 4 | period: 4 | 0,63 | 0,030244 | 34,18927 | 1,641209 | 160647,4 | 3690,662 |
| 5 | period: 5 | 0,58 | 0,076802 | 35,71335 | 3,153469 | 145022,8 | 1152,65 |
| 6 | period: 6 | 0,62 | 0,064976 | 34,96466 | 1,606163 | 144995,3 | 3357,028 |
| 7 | period: 7 | 0,65 | 0,111387 | 34,17432 | 3,654116 | 142839,1 | 1975,338 |
| 8 | period: 8 | 0,60 | 0,092875 | 35,83316 | 3,758998 | 142545,1 | 3053,475 |
| 9 | period: 9 | 0,56 | 0,031636 | 35,50711 | 1,272615 | 135836,7 | 2921,148 |
| 10 | period: 10 | 0,54 | 0,03543 | 36,70548 | 2,210613 | 134222,9 | 2107,647 |
| 11 | period: 11 | 0,54 | 0,052567 | 37,25791 | 2,237476 | 134449,1 | 2625,544 |
| 12 | period: 12 | 0,51 | 0,027549 | 36,24508 | 0,340126 | 126279,7 | 1478,902 |
| 13 | period: 13 | 0,47 | 0,023878 | 38,23183 | 1,510133 | 127285 | 2292,469 |
| 14 | period: 14 | 0,49 | 0,044272 | 37,48514 | 1,299394 | 131234,6 | 2141,767 |
| 15 | period: 15 | 0,50 | 0,032574 | 36,7974 | 0,849665 | 126635,7 | 1565,678 |
| 16 | period: 16 | 0,44 | 0,049428 | 40,72594 | 3,766498 | 126348,4 | 3244,562 |
| 17 | period: 17 | 0,41 | 0,055427 | 38,0257 | 1,901925 | 124018,3 | 2202,375 |
| 18 | period: 18 | 0,40 | 0,013423 | 38,52464 | 0,393237 | 125861,9 | 1938,061 |
| 19 | period: 19 | 0,39 | 0,0355 | 39,12186 | 1,395515 | 121744,9 | 2880,472 |
| 20 | period: 20 | 0,38 | 0,055672 | 40,04188 | 2,402158 | 124901,2 | 5180,989 |
| 21 | period: 21 | 0,37 | 0,031944 | 39,93705 | 2,117451 | 123925,9 | 1321,345 |

## 8.6. Appendix 6

| | Period | Mean Lead Time | | ELT Service Level by Products | |
|---|---|---|---|---|---|
| Iteration | Description | Mean | Standard deviation | Mean | Standard deviation |
| 1 | baseline 14 days | 34,10 | 3,10 | 0,65 | 0,074 |
| 2 | 16 days | 35,22 | 3,57 | 0,63 | 0,08 |
| 3 | 18 days | 34,67 | 2,81 | 0,64 | 0,06 |
| 4 | 20 days | 35,73 | 2,65 | 0,60 | 0,06 |
| 5 | 22 days | 34,90 | 2,78 | 0,62 | 0,071 |
| 6 | 24 days | 34,38 | 1,52 | 0,61 | 0,047 |
| 7 | 26 days | 35,88 | 3,42 | 0,57 | 0,062 |
| 8 | 28 days | 34,63 | 2,52 | 0,61 | 0,073 |
| 9 | 30 days | 36,51 | 3,79 | 0,57 | 0,070 |
| 10 | 32 days | 36,97 | 2,51 | 0,52 | 0,051 |

## 8.7. Appendix 7

| Iteration | Description | Statistics name | Mean | Standard deviation | Statistics name | Mean | Standard deviation |
|---|---|---|---|---|---|---|---|
| 1 | Sigma=0 mean | Fulfillment Received (Orders) by Customer | 363,4 | 13.3031 | Mean Lead Time | 31.13503072 | 1.89066 |
| 2 | Sigma=0,1mean | Fulfillment Received (Orders) by Customer | 368,8 | 8.8982 | Mean Lead Time | 31.20527716 | 1.20608 |
| 3 | Sigma=0,2mean | Fulfillment Received (Orders) by Customer | 361,6 | 7.2498 | Mean Lead Time | 32.30197591 | 0.57052 |
| 4 | Sigma=0,3mean | Fulfillment Received (Orders) by Customer | 371,8 | 17.1718 | Mean Lead Time | 32.30162509 | 0.87582 |
| 5 | Sigma=0,4mean | Fulfillment Received (Orders) by Customer | 363 | 12.5325 | Mean Lead Time | 31.48772904 | 0.49805 |
| 6 | Sigma=0,5mean | Fulfillment Received (Orders) by Customer | 369,4 | 7.3111 | Mean Lead Time | 33.59806323 | 1.23536 |
| 7 | Sigma=0,6mean | Fulfillment Received (Orders) by Customer | 362,4 | 9.4628 | Mean Lead Time | 33.48821082 | 0.81221 |
| 8 | Sigma=0,7 mean | Fulfillment Received (Orders) by Customer | 360,2 | 13.8203 | Mean Lead Time | 33.65457035 | 0.62431 |
| 9 | Sigma=0,8mean | Fulfillment Received (Orders) by Customer | 369,8 | 15.0008 | Mean Lead Time | 34.14584176 | 1.33399 |
| 10 | Sigma=0,9mean | Fulfillment Received (Orders) by Customer | 363,4 | 19.2721 | Mean Lead Time | 35.18953934 | 0.98361 |
| 11 | Sigma= mean | Fulfillment Received (Orders) by Customer | 354,4 | 16.6556 | Mean Lead Time | 35.64062514 | 1.24574 |

## 8.8. Appendix 8

| Time | Replication 1 | Replication 2 | Replication 3 | Replication 4 | Replication 5 | Average |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | 0 | 0 | 0 | 1 | 0,6 |
| 3 | 5 | 6 | 14 | 11 | 8 | 8,8 |
| 4 | 4 | 16 | 1 | 12 | 3 | 7,2 |
| 5 | 15 | 6 | 18 | 7 | 12 | 11,6 |
| 6 | 7 | 1 | 10 | 13 | 2 | 6,6 |
| 7 | 7 | 8 | 3 | 0 | 12 | 6 |
| 8 | 2 | 13 | 8 | 21 | 11 | 11 |
| 9 | 10 | 6 | 9 | 9 | 3 | 7,4 |
| 10 | 10 | 11 | 4 | 7 | 12 | 8,8 |
| 11 | 5 | 20 | 3 | 7 | 4 | 7,8 |
| 12 | 5 | 3 | 7 | 5 | 15 | 7 |
| 13 | 14 | 3 | 6 | 11 | 7 | 8,2 |
| 14 | 4 | 11 | 10 | 5 | 10 | 8 |
| 15 | 6 | 4 | 3 | 4 | 6 | 4,6 |
| 16 | 8 | 10 | 16 | 5 | 8 | 9,4 |
| 17 | 11 | 10 | 4 | 11 | 10 | 9,2 |
| 18 | 9 | 17 | 3 | 19 | 7 | 11 |
| 19 | 9 | 6 | 5 | 7 | 8 | 7 |
| 20 | 13 | 4 | 15 | 0 | 4 | 7,2 |
| 21 | 6 | 13 | 5 | 9 | 11 | 8,8 |
| 22 | 9 | 3 | 7 | 3 | 7 | 5,8 |
| 23 | 5 | 15 | 5 | 7 | 10 | 8,4 |
| 24 | 12 | 9 | 12 | 4 | 14 | 10,2 |
| 25 | 6 | 4 | 4 | 16 | 10 | 8 |
| 26 | 7 | 14 | 6 | 9 | 5 | 8,2 |
| 27 | 7 | 8 | 7 | 5 | 0 | 5,4 |
| 28 | 0 | 3 | 8 | 16 | 13 | 8 |
| 29 | 4 | 13 | 16 | 12 | 16 | 12,2 |
| 30 | 8 | 3 | 6 | 7 | 8 | 6,4 |
| 31 | 10 | 6 | 16 | 9 | 5 | 9,2 |
| 32 | 2 | 6 | 10 | 6 | 6 | 6 |
| 33 | 8 | 6 | 4 | 12 | 8 | 7,6 |
| 34 | 8 | 11 | 4 | 6 | 4 | 6,6 |
| 35 | 16 | 10 | 12 | 8 | 4 | 10 |
| 36 | 1 | 5 | 6 | 3 | 11 | 5,2 |
| 37 | 2 | 4 | 13 | 11 | 3 | 6,6 |
| 38 | 9 | 12 | 4 | 3 | 16 | 8,8 |
| 39 | 11 | 6 | 11 | 10 | 5 | 8,6 |
| 40 | 3 | 11 | 3 | 3 | 8 | 5,6 |
| 41 | 10 | 10 | 13 | 4 | 15 | 10,4 |
| 42 | 9 | 11 | 4 | 7 | 2 | 6,6 |
| 43 | 13 | 10 | 7 | 6 | 5 | 8,2 |
| 44 | 4 | 21 | 7 | 7 | 6 | 9 |
| 45 | 10 | 5 | 12 | 4 | 14 | 9 |
| 46 | 15 | 11 | 6 | 12 | 10 | 10,8 |
| 47 | 7 | 6 | 13 | 3 | 3 | 6,4 |
| 48 | 10 | 1 | 3 | 17 | 13 | 8,8 |
| 49 | 5 | 7 | 14 | 5 | 2 | 6,6 |
| 50 | 14 | 7 | 8 | 9 | 8 | 9,2 |
| 51 | 6 | 13 | 5 | 4 | 3 | 6,2 |
| Average | 7,97 | 8,64 | 8,17 | 7,75 | 7,83 | 8,07 |
| Variance | 0,01 | 0,32 | 0,01 | 0,10 | 0,06 | |

| | | | |
|---|---|---|---|
| S^2 | 0,125231481 | t Student (4,5%) | 2,776 |
| c* | 0,14 | n | 49,24 |

## 8.9. Appendix 9

| EOQ method and Iterations | | Straps | Beige and pink Leather | Orange Leather | Beige and yellow Leather | Red Leather | Gray Leather | Medium pink Fabric | Orange Fabric | White Fabric | Antique pink Fabric | Mechanism kit | Black metal feet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inputs | Annual Demand (D) | 24.175,00 | 143,91 | 58,19 | 1.034,88 | 1.317,70 | 1.754,28 | 440,56 | 1.358,17 | 149,91 | 569,24 | 957,00 | 138,00 |
| | Fixed cost of order (K) | 700 | 150 | 150 | 150 | 150 | 700 | 500 | 500 | 150 | 150 | 700 | 700 |
| | Volume (m^3) | 0,02 | 0,20 | 0,20 | 0,20 | 0,20 | 0,20 | 0,20 | 0,20 | 0,20 | 0,20 | 0,10 | 0,00 |
| | Vehicle Capacity (m^3) | 100 | 20 | 20 | 20 | 20 | 100 | 60 | 60 | 20 | 20 | 100 | |
| Iteration n. 1 | EOQ (Units) | 15.932,28 | 179,94 | 114,42 | 482,54 | 544,50 | 1.357,20 | 574,82 | 1.009,27 | 183,66 | 357,88 | 1.417,64 | **10.766,62** |
| | EOQ Volume (m^3) | 318,65 | 35,99 | 22,88 | 96,51 | 108,90 | 271,44 | 114,96 | 201,85 | 36,73 | 71,58 | 141,76 | 2,69 |
| | Vehicles needed (Units) | 3,19 | 1,80 | 1,14 | 4,83 | 5,45 | 2,71 | 1,92 | 3,36 | 1,84 | 3,58 | 1,42 | |
| | K* | 2.230,52 | 269,92 | 171,64 | 723,81 | 816,75 | 1.900,08 | 958,04 | 1.682,12 | 275,48 | 536,82 | 992,35 | |
| Iteration n. 2 | EOQ (Units) | 28.440,15 | 241,38 | 122,40 | 1.060,00 | 1.270,57 | 2.236,05 | 795,68 | 1.851,19 | 248,89 | 677,03 | 1.687,91 | |
| | EOQ Volume (m^3) | 568,80 | 48,28 | 24,48 | 212,00 | 254,11 | 447,21 | 159,14 | 370,24 | 49,78 | 135,41 | 168,79 | |
| | Vehicles needed (Units) | 5,69 | 2,41 | 1,22 | 10,60 | 12,71 | 4,47 | 2,65 | 6,17 | 2,49 | 6,77 | 1,69 | |
| | K* | 3.981,62 | 362,07 | 183,60 | 1.589,99 | 1.905,86 | 3.130,47 | 1.326,14 | 3.085,32 | 373,34 | 1.015,55 | 1.181,53 | |
| Iteration n. 3 | EOQ (Units) | 37.997,83 | 279,57 | 126,59 | 1.571,04 | 1.940,88 | 2.870,12 | 936,14 | 2.507,11 | 289,74 | 931,20 | 1.841,79 | |
| | EOQ Volume (m^3) | 759,96 | 55,91 | 25,32 | 314,21 | 388,18 | 574,02 | 187,23 | 501,42 | 57,95 | 186,24 | 184,18 | |
| | Vehicles needed (Units) | 7,60 | 2,80 | 1,27 | 15,71 | 19,41 | 5,74 | 3,12 | 8,36 | 2,90 | 9,31 | 1,84 | |
| | K* | 5.319,70 | 419,35 | 189,89 | 2.356,57 | 2.911,32 | 4.018,16 | 1.560,24 | 4.178,51 | 434,61 | 1.396,80 | 1.289,25 | |
| Iteration n. 4 | EOQ (Units) | 43.921,01 | 300,87 | 128,74 | 1.912,63 | 2.398,83 | 3.251,69 | 1.015,42 | 2.917,65 | 312,62 | **1.092,10** | 1.923,91 | |
| | EOQ Volume (m^3) | 878,42 | 60,17 | 25,75 | 382,53 | 479,77 | 650,34 | 203,08 | 583,53 | 62,52 | 218,42 | 192,39 | |
| | Vehicles needed (Units) | 8,78 | 3,01 | 1,29 | 19,13 | 23,99 | 6,50 | 3,38 | 9,73 | 3,13 | 10,92 | 1,92 | |
| | K* | 6.148,94 | 451,31 | 193,11 | 2.868,94 | 3.598,24 | 4.552,36 | 1.692,36 | 4.862,75 | 468,93 | | 1.346,74 | |
| Iteration n. 5 | EOQ (Units) | 47.220,33 | 312,12 | 129,83 | 2.110,34 | 2.666,85 | 3.461,10 | 1.057,53 | 3.147,49 | 324,72 | | 1.966,34 | |
| | EOQ Volume (m^3) | 944,41 | 62,42 | 25,97 | 422,07 | 533,37 | 692,22 | 211,51 | 629,50 | 64,94 | | 196,63 | |
| | Vehicles needed (Units) | 9,44 | 3,12 | 1,30 | 21,10 | 26,67 | 6,92 | 3,53 | 10,49 | 3,25 | | 1,97 | |
| | K* | 6.610,85 | 468,19 | 194,74 | 3.165,50 | 4.000,28 | 4.845,53 | 1.762,56 | 5.245,81 | 487,08 | | 1.376,44 | |
| Iteration n. 6 | EOQ (Units) | **48.961,80** | **317,91** | **130,38** | **2.216,73** | **2.811,89** | **3.570,80** | **1.079,24** | **3.269,11** | **330,95** | | **1.987,90** | |
| | EOQ Volume (m^3) | 979,24 | 63,58 | 26,08 | 443,35 | 562,38 | 714,16 | 215,85 | 653,82 | 66,19 | | 198,79 | |
| | Vehicles needed (Units) | 9,79 | 3,18 | 1,30 | 22,17 | 28,12 | 7,14 | 3,60 | 10,90 | 3,31 | | 1,99 | |
| **Demand Covered (Years)** | | **2,03** | **2,21** | **2,24** | **2,14** | **2,13** | **2,04** | **2,45** | **2,41** | **2,21** | **1,92** | **2,08** | **78,02** |