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Supplier risk management:

model definition and implementation in Pietro Fiorentini S.p.A.

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1.1 Abstract

During *Covid-19* pandemic, need of supply stability grew dramatically. In order to monitor the risk connected to *Pietro Fiorentini S.p.A*.'s suppliers in such a complex period, a thesis with the objective to enlarge vendors' qualification and evaluation was launched. Preliminary activity performed was a theoretical review, in order to understand purchasing dynamics and supply chain risk management techniques. The firm and its purchasing department were deeply analyzed to get confident with their needs. Then, a both qualitative and quantitative model was created, following the FMEA guidelines, that comprehend risk causes identification and assessment of probability, magnitude and detectability of eventual vendor disruptions. According to risk values, a possible supplier classification was drafted with different strategies per each typology. Nine active vendors were chosen for the launch of the project. Once computed their key risk indicator, actions for improvement were proposed into a precise action plan able to decrease of about 42% *Pietro Fiorentini's* supplier risk and increase its supply chain resilience. A critical analysis was conducted to identify benefits, limitations and possible next steps. Generally, the project shows how the traditional qualification and evaluation process is not enough anymore. It needs to shift towards a proper and formalized risk analysis. Together with it, role of the buyer is evolving too: negotiator, problem solver, creative thinker and, now, risk manager.

1.2 Prefazione

Durante la pandemia di *Covid-19*, il bisogno di assicurarsi una fornitura stabile è cresciuto esponenzialmente. Al fine di monitorare il rischio connesso ai fornitori di *Pietro Fiorentini S.p.A*. in un periodo così complesso, è stata lanciata una tesi con l'obiettivo di ampliare la qualificazione e la valutazione degli stessi. Preliminarmente, è stata svolta una attività di revisione teorica, per comprendere le dinamiche della funzione acquisti e le tecniche di *supply chain risk management*. L'azienda e il suo ufficio acquisti sono stati analizzati a fondo per poter capire in modo chiaro quali potessero essere le loro esigenze. Quindi, è stato creato un modello sia qualitativo che quantitativo seguendo le linee guida della FMEA, che comprendono l'identificazione delle cause di rischio e il calcolo di probabilità, impatto e rilevabilità di eventuali interruzioni di fornitura. In base ai diversi valori di rischio è stata redatta una possibile classificazione dei fornitori che contiene anche delle strategie da attuare per ciascuna tipologia di essi. Nove fornitori attivi sono stati scelti per il lancio del progetto. Una volta calcolato il loro indicatore di rischio, sono state delineate alcune azioni di miglioramento e inserite in un preciso piano d'azione in grado di ridurre il rischio di fornitura di *Pietro Fiorentini* circa del 42% e di aumentare la resilienza della sua catena di fornitura. È stata, inoltre, condotta un'analisi critica per identificare i vantaggi, i limiti e i possibili passi successivi alla chiusura del progetto. In generale, la tesi mostra come il tradizionale processo di qualificazione e valutazione non sia più sufficiente, ma debba orientarsi verso una profonda e formalizzata analisi dei rischi. Insieme ad essa, si evolve anche il ruolo del *buyer*: negoziatore, *problem solver*, *creative thinker* e, ora, anche *risk manager*.

2. Introduction

2.1 Objective of the internship

The internship was conducted in *Pietro Fiorentini S.p.A.* (*PF*) plant of *Rosate (Milan, Italy)* from July to December 2020. The role covered was the *junior buyer* one, that has to support the senior buyer, (*Enrico Merli*, also the company tutor assigned for the intern), in his activities. The reference purchasing macro-category regarded the mechanical components of the various gas metering solutions produced in the plant. It's important to notice that the role covered only the purchasing and not the procurement side, that is a task entrusted to some planners.

The objective of the stage was to continue the learning process started with the Master of Science in *Supply Chain Management* at *Politecnico di Milano* and to have some real-world experience of the concepts seen during the *Supplier Relationship Management* course held by *Prof. Antonella Maria Moretto*. In order to do that, the first step was to acquire proper knowledge about the products provided by the company and about the production flow. In fact, as *W.E. Deming* said, "*If you can't measure it, you can't manage it*", so, it's impossible to improve what you don't know. Then, another goal was to get confident with the purchasing procedures and with the ERP *Oracle JDE*, that can provide every information about every order and about every supplier. Once the bases were set, it was possible to go deeper into purchasing strategies of medium and long term, cost analysis, reporting and purchase marketing. Final goal was to tackle the negotiation phase and to learn how to act in such a critical step for a company belonging to a low margin industry.

Among the activities performed during this experience, the main ones were the following:

1. Analysis and simulation of supply mix quantities in order to understand how to reduce the average purchasing price or identify possible saving opportunities;
2. Analysis of the effects of new commercial conditions;
3. Economic enhancement of bill of materials in order to understand cost of the components of a single final product and related savings earned in the previous year;
4. Monitoring the current saving earned respect to the previous year for each sub-category and monitoring the actions aimed at the reduction of the average price;
5. Raw materials cost analysis in order to increase the bargaining power and have high control on the purchasing price;
6. Developing cost breakdowns for components to have high control on purchasing prices;
7. Meetings with existent suppliers in order to tackle issues arisen or to renegotiate commercial conditions;

8. Meetings with possible new suppliers in order to set the basis for a commercial relationship and for sending requests for quotation (RFQ);
9. RFQ sending and negotiation of new commercial conditions;
10. Qualification of suppliers;
11. Scouting and analysis of possible new suppliers;
12. Computation of KPIs in order to make possible to evaluate the buyer work;
13. Evaluation and formalization of actions for improvement for the next year;
14. Supplier risk mapping project.

2.2 Objective of the thesis

The objective of the thesis was to qualify vendors in a more comprehensive and strategic way. They were already evaluated by *PF*, but with a limitative approach and without considering the risk perspective in a deep manner: considering that the primary objective of the purchasing department is to assure a continuous supply and that the lean manufacturing approach emphasizes the need of stability, it could be a big issue. In fact, in absence of a proper stock coverage, a supply disruption can take to a production stoppage able to damage every actor involved in the chain: customers will not have products when they need them; the focal company cannot sell its products and cannot produce too, thus, a huge waste of resources, time and money arises; vendors cannot sell because the demand from the focal company is lower or null, due to production stoppages. Interruptions of flows are always more frequent, especially in the *Covid-19* period, when most of the activities were strained by months without working or with strong limitations.

So, in order to build a resilient supply chain and assure the continuity of the business, purchasing risk has to be managed in a proactive way and actions for improvement have to be developed and shared. Therefore, a project aimed at mapping the risk connected to each supplier was launched. It represents the first step towards a massive implementation by *PF* with both possible new and already existent vendors. The project consists in the creation of a model and a tool able to evaluate supplier risk and, then, in its trial launch, that comprehends the analysis of the results and the creation of some strategies aimed at reducing risk.

The possibility to do this evaluation through an algorithm is an innovation very useful for the company, because it allows to reduce time and costs of the analysis. Moreover, in this way it can also be repeated as needed, limiting the efforts. It is justified also by the fact that some of the actions found can be put into the department action plan for 2021. In addition, it allows the graduating

student to enter in the company world, interfacing with several entities as vendors, data, colleagues, tools, and to pursue some of the internship objectives.

2.3 Methodologies

The methodology selected for developing the supplier risk mapping project followed four main steps: preparation, execution, trial launch, closing. For a more detailed review of the actions done and of their timings, GANTT of the project can be found in *Annex 1*. In the first step, above all, a theoretical review was conducted. Firstly, it touched the purchasing department processes and its relevance for a company, in order to create awareness about the organization of the department and how it acts within firm boundaries. A specific focus was done on the supplier qualification process, in order to understand why it is important and how to conduct it, and on the supply chain risk management, in order to understand what risk is, how it can arise in the supply chain and, finally, possible approaches that can be followed in the analysis. Then, a deep analysis on *PF* and its purchasing department was pursued to discover their organization, strategies, procedures and priorities in the buying process. This analysis was fundamental to get confident with firm's needs.

After the preparation phase, the real execution of the project started. The whole project was carried on by the graduating student, while its company tutor *Enrico Merli* and an external consultant working with the company, *Massimiliano Poletti* were those who launched it. They also acted as source of information and support. Periodical meetings were arranged with them to solve possible issues and have a continuous comparison between managers expectations and results. Once defined the kind of approach to be followed, the model was developed. A proper tool able to gather data coming from several sources (i.e. ERP system, suppliers' interviews, contracts database, third-entities documents, senior buyer knowledge) and give a synthetic answer about the risk connected to each supplier was structured. Its aim was to collect and evaluate information about actual supply base risks both in terms of endogenous (e.g. supply disruption cost) and exogenous factors (e.g. financial default probability).

Once defined the model, some suppliers were selected to be evaluated in the trial launch. Here, data were collected and the model was filled. The main result was a KPI regarding their risk. In addition, actions aimed at decreasing risk were identified and suggested to the managers. Finally, in the closing phase, the model was validated by the managers and a critical analysis on the process was carried on, considering benefits, limitations and possible next steps.

3. Literature review

3.1 Strategic relevance of purchasing

The world context is dramatically changing and dealing with it is becoming always more complex. The market is increasingly unpredictable and demand volatility makes difficult to plan and to pursue economies of scale in the long run. Product life cycle is shorter and shorter and, thus, once reached the break-even point (BEP), investment payback is shorter. Products range is continuously enlarging due to the mass customization trend. Despite high requirements, price competition is always stronger and it's very important to control the cost structure. In order to manage such a complex environment, the need of multiple competences, different skills and a high flexibility degree arises. One of the main solutions can be to outsource specialized activities, so the ones that are necessary for running the business, but they are available on the market: differently from in-house production case, in this way they can reach critical mass and economies of scale. Looking at an elaboration of *Mediobanca* data on Italian companies of 2018 (*Annex 2*), it's possible to verify how much companies are trying to focus on a narrow circle of activities and relying for majority of activities on their supply network. Impact of purchased items is on average about 82%.

Therefore, the purchasing function assumes a critical role in managing the outsourcing trend, because it is the function deputy to deal with suppliers. In addition, it is necessary to highlight that this trend tends to move where the value is created. In fact, the participation of vendors in the value creation of a company is something that cannot be neglected, because skills needed are core competences for them and because they are able to bring innovation and higher quality to a company, produce with lower costs thanks to economies of scale and reduce time to market. Thus, supply activities are not only cost cutting activities, but they are strategic and value creating ones. Therefore, purchasing department has the potential to bring to the company a competitive advantage, both in term of cost, innovation, quality and time.

In this new kind of context, role of the buyer is changed too. If in the past he was only a negotiator focused on transactional aspects, now he should be a creative thinker able to manage the total cost of ownership of a good and to focus on innovation and systemic complexity, interacting effectively both internally and externally. He could be an agent of change that can predict what's happening on the market and drive transformation in a firm, considering several factors (e.g. geopolitics, sustainability, technology, finance) and impacts (e.g. profits, cash flows). His goals are improving purchase performances, quality, innovation, service level or decreasing the costs, guaranteeing contractual safety. However, main scope of procurement is certainly to assure a continuous and

stable supply, although production stoppages can arise. In fact, outsourcing has some drawbacks, among which there are the loss of control on business activities, a high complexity in managing relationships and some possible negative impacts on customers and sustainability: that's why it is fundamental for purchasing to investigate supply risk.

3.2 Purchasing process

The process of buying goods and services needed for running a firm is quite complex and articulated. Activities performed are very different among them and can be cross-functional too. Some of them have a strategic impact, so they can regard long-term decisions with a relevant movement of capital and a low frequency. Other activities, instead, are more operational, so more frequent and repetitive. As suggested by *Spina* (2016), in order to cluster these activities and to define properly the purchasing process, it's possible to refer to three sub-processes: strategic purchasing, sourcing and supply (*Figure 1*).

Figure 1. *The graphical representation of the purchasing process.*

3.2.1 Strategic purchasing

Strategic purchasing identifies the group of activities performed in the purchasing process with a high strategic relevance and with a low frequency. The three drivers that characterize a strategical decision are the following:

- Capital intensity, so the generation of high costs for the firm;
- Long-term orientation, that can regard both length of a contract, organization of the company and time needed to change it;
- Technology and competences, because some of them cannot be found in the company and others have to be kept internally in order to exploit competitive advantages.

These kinds of activities are the pure and real linkage between the purchasing and the overall company strategy in a two-fold perspective. In fact, they can be both supportive for the company strategy or they can define part of it, depending on the role and on the relevance that the department has in the firm. They can be divided in some sub-categories (*Figure 2*).

Figure 2. *List of activities performed in the strategic purchasing phase*

The first activity regards certainly the make or buy decision. A firm should decide if it wants to produce internally what it needs or if it prefers to outsource it to someone else. It can regard both goods, components and services and the choice can be done for every item or for only some of them. This kind of decision must involve some strategic levers as cost, competences and capital. Usually, core competences (i.e. the ones that can give a competitive advantage to a company) are kept internally, while the other are outsourced. At the increasing of production costs and capital needed to finance operations, usually the trend is toward outsourcing. This decision is so important that it is not taken by the purchasing department, but it involves the head of the company.

Once the make or buy choice is made, procurement has to define the supply network. For each buying category, the company should decide how many suppliers to have and, consequently, the kind of relationship with them. There can be four different approaches:

- Single sourcing, when the client has one unique supplier for a certain good or service; it can be a forced choice due to scarce resources, monopolies, exclusive technologies, patents or commercial agreements;
- Multiple sourcing, when the client continuously exploits spot transaction on the competitive market, in order to decrease risk of opportunistic behavior or to have lower prices for commodities, leveraging on the high level of competition;
- Dual sourcing, when the client has one main supplier and a back-up one in order to decrease the risk of opportunistic behaviors and of supply disruptions;
- Parallel sourcing, when the client builds a series of single sourcing relationship for each component for each different product family.

Next step is the purchase marketing (also called marketing intelligence). It regards the scouting of the market in order to remain updated on the state of the art of available technologies, know alternatives to actual implemented solutions, new suppliers and their possible offers. It's important to look also at competitors, in order to understand their products and supply network. One of the key aspects is certainly to gather as much as possible information: increasing the knowledge about

a certain category, allows to increase the bargaining power in the negotiation phase. There are several ways to conduct purchase marketing: web researches, meeting with professionals of other companies, exhibitions, magazines. Once the potential suppliers are identified, they should be evaluated on the basis of different criteria (e.g. reliability, punctuality, financial stability, competences) and then qualified, through questionnaires, visits, audits and samples.

If these analyses are positive, the vendor is eligible to start the supply and it's possible to pass to the supplier management. First of all, the kind of relationship to be shared with him has to be chosen. A partnership relationship can lead to high level of customization of offers and components, high level of flexibility, economies of scale due to higher volumes exchanged, possibility to exploit supplier competences in an exclusive way, cost advantages and many other positive factors. However, build a partnership is quite complex and requires trust, time, resources, managerial capabilities and efforts. Other possible decision can be the supply base rationalization in order to manage less relationship as possible, the option to manage also the 2-tier of suppliers or the possibility to support suppliers transferring them knowledge, resources and competences.

Finally, buyers should periodically do a strategic evaluation of vendors, analyzing their behavior and the results of the relationship started. It can be a simple updating of the one done in purchase marketing phase or it can regard deeper criteria and reasoning. This passage is also called *vendor rating* and can take to some response action, both in case of negative (e.g. costs for the supplier, suspension of the relationship) and positive outcomes (partnership creation, higher volumes, investments).

3.2.2 Sourcing

The second phase of the purchasing process is sourcing (*Figure 3*). It regards tactical decisions that connect the strategic ones with the daily operations. It starts when someone in the firm shows the need of something through a purchase request (*RdA, Richesta d'Acquisto*).

***Figure 3**. List of activities performed in the sourcing phase of the purchasing process*

The first step is to translate internal customer's needs (e.g. production, technical office, R&D) into as much detailed as possible specifications. The level of detail is very important from a two-fold perspective. Firstly, more information regarding, for example, technical characteristics, quantities, delivery and timing can help the purchasing department to find the best option that maximizes the satisfaction of internal customers. Then, with a high level of detail, the buyer can maximize results for the internal customer and minimize costs for the firm, thanks to his wide knowledge of the market. Obviously, this kind of activity needs an interaction between different functions. This is a reason why who works in the purchasing must have a spread knowledge about all the internal and external processes, in order to deal with different requests and their field.

Once defined the specifications, one of the established and qualified suppliers is chosen in order to satisfy the need. If none of them is able to do this, purchase marketing has to be done in order to find on the market a vendor able to provide what the internal customer wants. Supplying from already known suppliers reduces the transaction costs, because there is no need to perform scouting, strategic evaluation, qualification and each activity of the marketing intelligence phase.

Identified the possible suppliers, the buyer sends RFQs (Request For Quotations) to them, in order to know their best offer regarding costs, quantities, delivery mode and expected lead times. This is the starting point of the negotiation phase, where vendors are put in competition to obtain the lowest price and the best conditions as possible. The one that assures the best final offer is selected and he can sign the contract with the company.

3.2.3 Supply

***Figure 4**. List of activities performed in the supply phase of the purchasing process*

After having selected the supplier and having signed the contract, the operational part of the purchase can begin. The starting point of the supply phase (*Figure 4*) is the order emission. Activities performed have a high frequency and a low impact. Orders can be part both of close and open contracts. The first ones are valid for a unique purchase, while the others are valid for repetitive purchases and they establish technical specification, order batches, aggregate expected volume of the year, price and payment terms, but they leave freedom about quantities and date.

Once emitted the order, procurement proceed with the expediting, that means to monitor supply progresses and its punctuality. Then, bought elements arrive at the company warehouse and they have to be unloaded, registered and controlled. This step is usually done by the logistic and warehouse function with purchasing department supervision. After the order is sent, the company receives the invoice and proceeds with the payment in the agreed date. This activity is usually performed by the administration and finance function. Procurement can help them especially when there are some issues as the discrepancy between the agreed price and the invoice one.

Finally, a key activity is certainly the operative evaluation, when some operational data are gathered in order to evaluate the supplier regarding, for example, punctuality and quality. These data are fundamental to develop a proper and deep vendor rating.

3.3 Qualification of suppliers & vendor rating

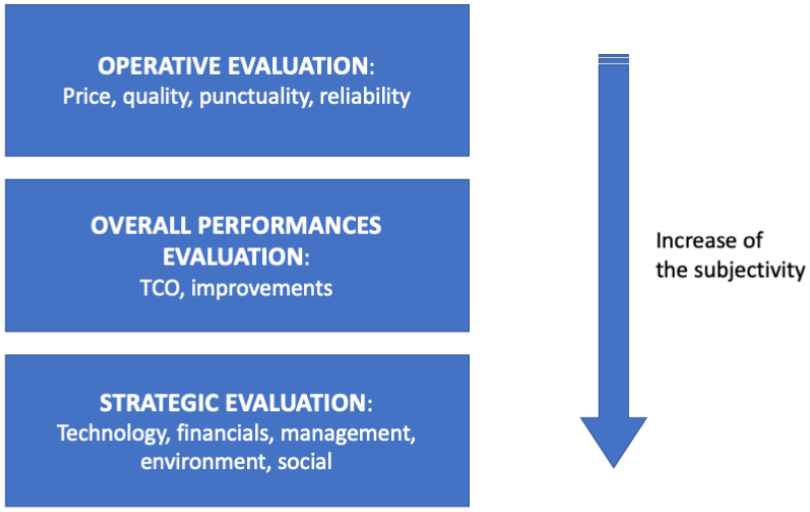

***Figure 5**. Vendor rating levels.*

As seen in the purchasing process, according to *Spina* (2016), the evaluation of the supplier has different levels of analysis (*Figure 5*). The lower level is the operative evaluation, that considers operative, objective, predictable and repetitive data coming from vendor's current performances in terms both of characteristics of products (e.g. price, conformance to specifications) and order fulfillment (e.g. punctuality, delivery lead time, order completeness). These operational KPIs monitor routine activities directly linked to operational processes and they are useful to take daily decisions about inbound flows and about routine activities. This kind of data are quite easy to retrieve, because all this information can be usually found in the ITC system of a company. It is executed in the supply phase of the purchasing process, where vendor rating activities consist basically in the systematic gathering of data and in the preparation of periodic reports that can analyze suppliers' behavior on a current base.

However, the operative evaluation is not enough to analyze suppliers' performances because it includes only the supply object. The overall performance evaluation, instead, is able to enlarge the analysis perspective and address also the effects that it has on the client. In order to do this, it does not consider price, but the Total Cost of Ownership (TCO). It is an estimation of all the direct and indirect costs of acquiring, commissioning, operating, maintaining and disposing of a product in a certain period of time (*Figure 6*). So, it assumes a medium-long term perspective in which is also important to look at the capacity of the vendor to maintain and improve its performances. These tactical KPIs are useful to support planning of resources, give the necessary support to operational activities and keep under control the achievement of purchasing goals (e.g. spending optimization, performance improvement). This activity is a hybrid between the other two levels of the vendor rating, because it uses data coming from the supply phase, but methodologies typical of the strategic purchasing one.

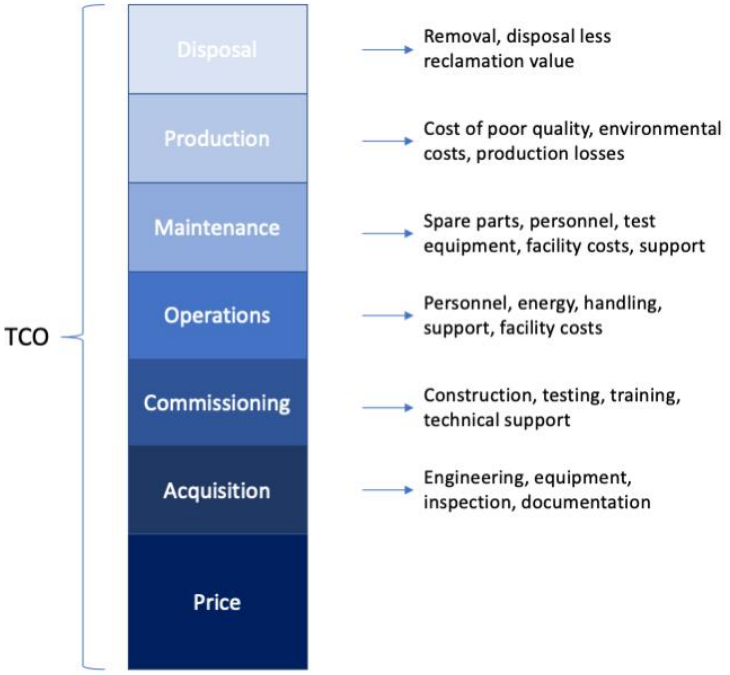

Figure 6. *The composition of the total cost of ownership.*

While first two vendor rating levels are done once the supplier is selected and the supply is started, strategic evaluation has to be done also before contract signing, in order to do a wise choice of the supplier. This analysis has a long-term and external orientation. It aims at understanding how much the relationship can be solid in the future and how much it can take to competitive advantage creation, trough the investigation of financial, technological, innovative and managerial strengths and weaknesses of the supplier. As procurement becomes more strategic, traditional metrics are not enough. Therefore, it's not possible to neglect to assess the status of the relationship and the value contribution given by a certain supplier, despite they are more qualitative than quantitative elements and quite difficult to retrieve. *Jonathan Hughes* (2005) developed a valid scorecard framework able to capture different kind of KPIs, that is shown in *Figure 7*.

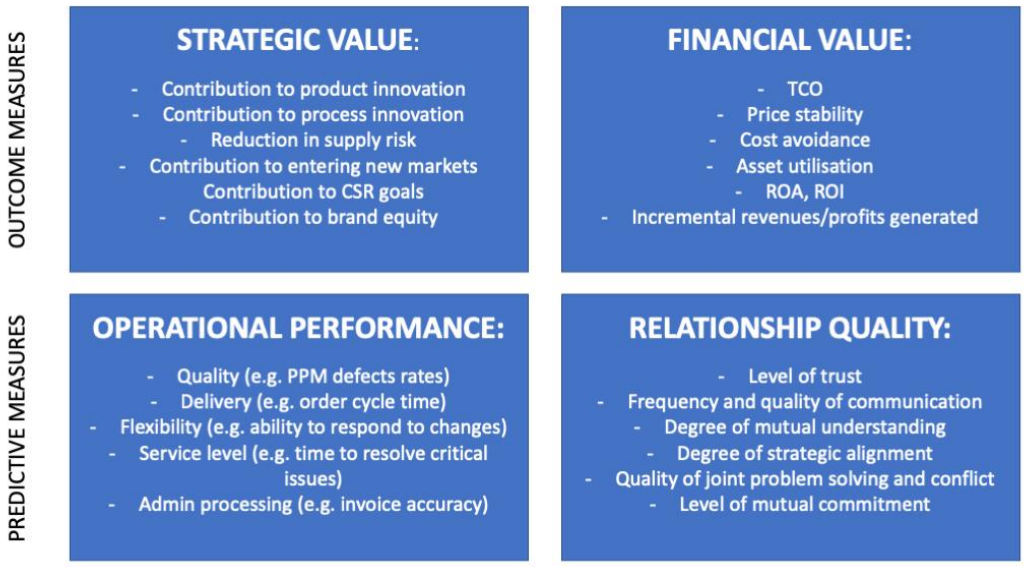

Figure 7. *Hughes' supplier scorecard.*

Strategic evaluation deals with the qualification of vendors, where strategic KPIs are measured in order to ground the strategic role of purchasing within the broader company strategy. The qualification process is articulated in the following steps:

1. Registration. For well-structured firms it is usually done through portals where suppliers insert general information (e.g. turnover, certifications, number of employees) and its aim is to check vendor's eligibility;
2. Pre-qualification and self-evaluation, usually done through questionnaires sent to suppliers asking different things, according to the purchasing strategy of the company. Information required have to be both qualitative and quantitative and they can regard credit class, financial solidity, legal compliance, sustainability, corporate social responsibility (CSR) procedures, technical competences, organizational chart, operations procedures, production capacity, innovation capability, quality standards, service and delivery capacity, previous and current customers and many others. Certainly, there is a trade-off between time saved letting fill the questionnaire to suppliers and possible biases;
3. Supplier qualification, usually done through auditing, in order to visit vendor plant and assess the truth of the answers. Moreover, supplier management is a kind of human management, so numbers are not enough to evaluate someone, while it is important to interpretate data and see in person what is really happening. Its aim is to qualify suppliers, but it is not implemented for every vendor. In fact, it is very time and resource consuming, so it is done only for strategic or little/unreliable ones.

4. Product qualification. Once the supplier is qualified, its product can be too, through trial orders and samples.

This process has to be done certainly at the beginning of the relationship, but it is important to refresh periodically data gathered, in order to continuously monitor its status. In fact, for example, certifications have an expiration date and processes, machines and people can change, thus it's necessary at least to refresh analysis annually and repeat audits every three years.

Suppliers' strategic evaluation is one of the keys in the purchasing process: as shown in *Figure 8*, it is one of the most value adding activities. In fact, it can create a common vendor list in which supplier are linked with their buying category and supports purchasing in the selection or confirmation of the right vendor as a firm's business partner. Moreover, through platforms and questionnaires, there can be a unique registration form for every supplier, where they can apply autonomously, dramatically reducing the time consumed.

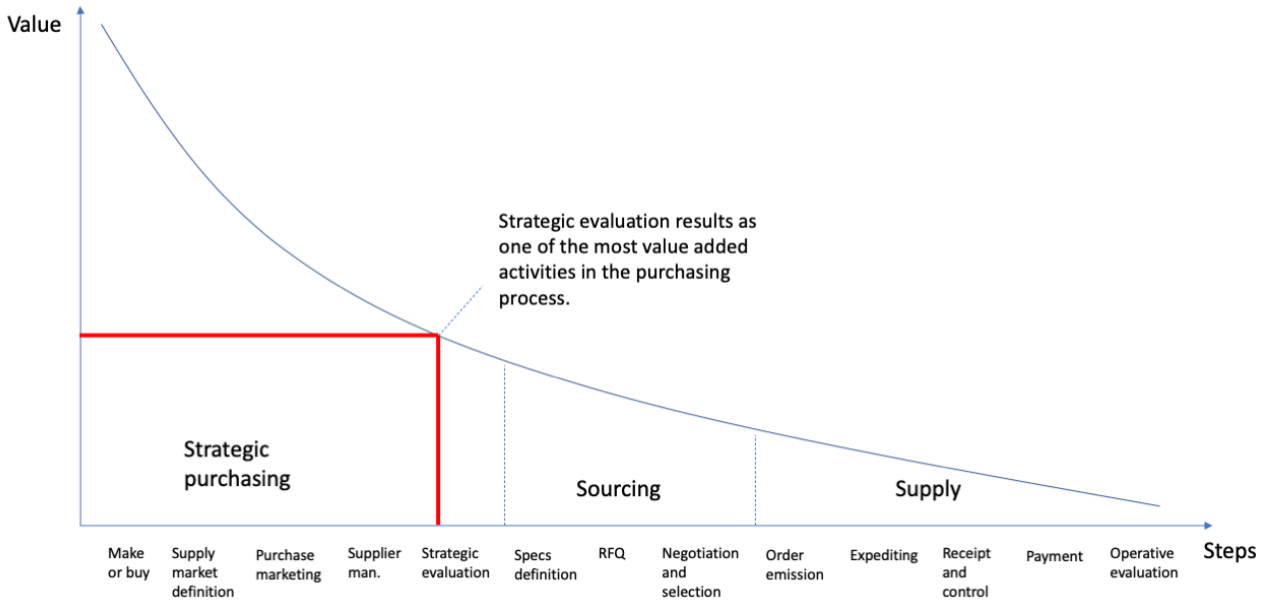

***Figure 8**. The relative value added provided by each step of the purchasing process.*

Summing up, companies seek an assurance when they do significant purchases to decrease the risk of their investment. In fact, suppliers are a strategic source of competitive advantages, but of risks too (e.g. price, service level, quality, safety, security). This is a reason why, nowadays, strategic evaluation of suppliers considers so many parameters and it is shifting towards a real risk analysis.

3.4 Supply risk management

3.4.1 Introduction to risk management

Risk and uncertainty are two critical factors in nowadays world; however, there are different point of view regarding their definitions. According to *Knight* (1921), risk is an event subject to a known or knowable probability, while uncertainty is an event for which it is not possible to specify numerical probabilities. Unknown outcomes can be classified on the basis of their probability: a priori, where it is possible to deduct the likelihood of occurrence (e.g. as in the case of the rolling dice); statistical, that are generated by empirical evaluation of relative frequencies (e.g. life insurance); estimated, when there are no basis for classifying instances.

More recently, *Hubbard* (2009) defines uncertainty as the lack of complete certainty, that is, the existence of more than one possibility. Thus, the ''true'' outcome is not known, like in the weather prevision case, when there are chances that it will rain and chances it will not. Risk, instead, is a state of uncertainty where some of the possibilities can involve a loss, an injury, a catastrophe, or other undesirable outcomes. So, it is possible to identify a set of possibilities, each with quantified probabilities and quantified losses. Finally, *ISO 73:2009* guide defines uncertainty as the state, even partial, of deficiency of information related to the understanding or knowledge of an event, its consequence or likelihood. In this case, risk is an effect of uncertainty on objectives, so there can be a possible deviation from expected outcomes, that can be both positive or negative on several aspects (e.g. financial, health and safety, environmental).

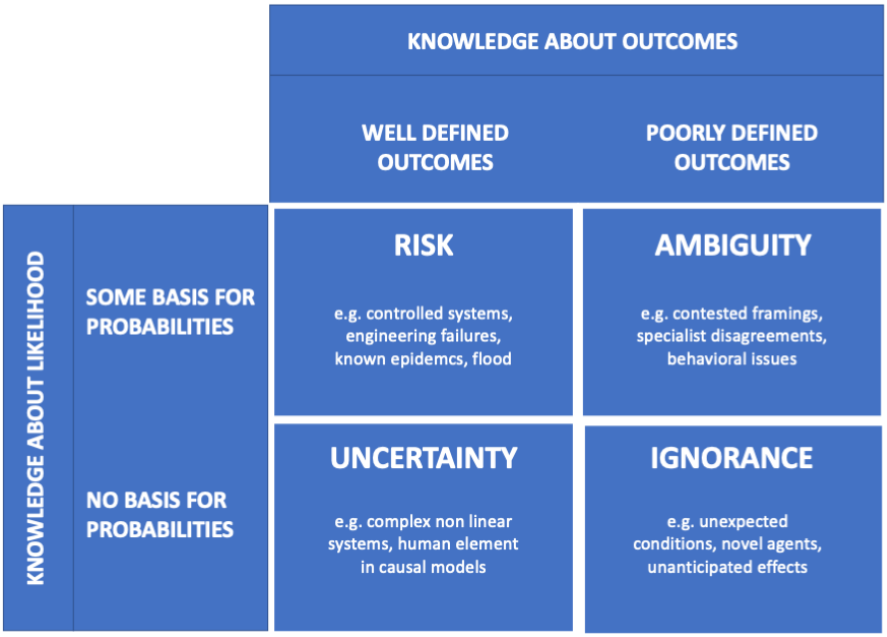

Figure 9. *The incertitude matrix developed by Stirling and Gee (2002).*

Stirling and *Gee* (2002) developed a matrix trying to classify various kind of incertitude (*Figure 9*). For them, there's not a cause-effect relationship between uncertainty and risk, but they are different concepts. The first one is the condition in which there is not the possibility to map the likelihood of occurrence of an event when, instead, it is possible to define the possible outcomes. On the other hand, the second one is the condition in which both the probability and the severity of an event can be measured. Among various kinds of incertitude, risk is the less problematic one, because, differently from the others, it can be managed.

Even if there are different definitions, it's possible to identify uncertainty as the condition in which it is not possible to know and understand everything. It can derive from aleatory situations (i.e. those coming from variability in known or observable populations and, therefore, represent randomness in samples) or from epistemic ones (i.e. those coming from lack of knowledge about fundamental phenomena). In this context, risk is the possibility that an undesirable event occurs, reflecting variation in the distribution of the possible outcomes, in their likelihood of occurrence and in their subjective effects.

It is wrong to consider risk as only a negative thing. In fact, it is neutral and the value variation may be both positive or negative. For example, financial risk is linked with the instability of the financial market caused by movements in stock prices, currencies, interest rates and more. It can take to losses, but betting on the right investment, it can create also huge returns.

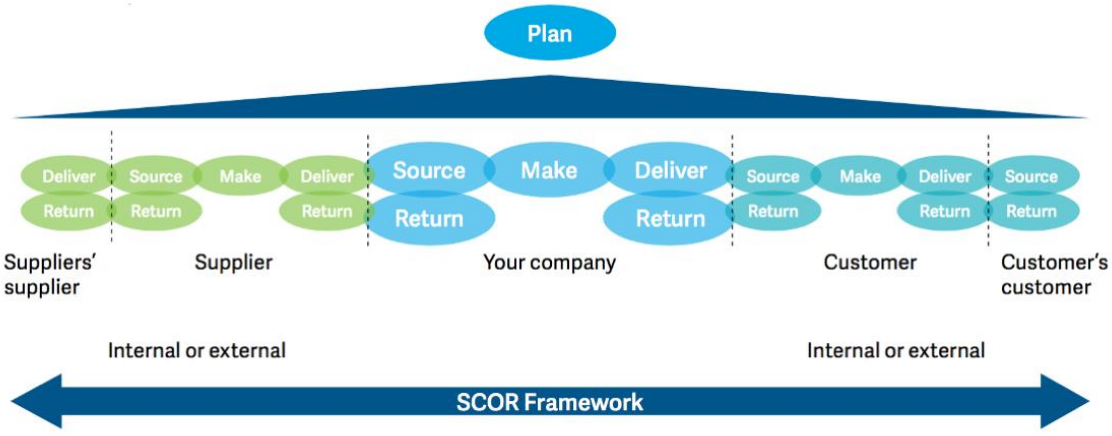

***Figure 10**. The SCOR (Supply Chain Operations Reference) model.*

There are different typologies of risks. Apart from the financial one, surely the one that regards firms the most is the operational one. It results from any possible event that influences internal processes, people, systems or external resources causing a variation of a core operating, manufacturing or processing capability of the company that is quantifiable in a value variation for the stakeholders. The operational nature of the risk is defined on the basis of the specific nature of

the target affected and can regard each phase of the SCOR model (*Figure 10*): plan (e.g. demand risk), source (e.g. supply risk), make (e.g. production risk), deliver and return (e.g. environmental risk, information risk).

There are also different kind of risk drivers and they can be classified in several ways. First of all, they can be divided on the basis of their occurrence: recurrent risks are the ones that refer to continuous fluctuations in a reasonable range of demand, supply, quality and many others fields; disruptive ones refer, instead, to events with a low and hard to estimate probability (e.g. earthquakes). They can also be classified as internal and external. The first ones are those one that lie in the boundaries of a firm (e.g. production capacity, internal operations, information systems, corporate social responsibility), while the others regard the external environment (e.g. nature, politics, competitors, market). Another possible taxonomy can regard the area of impact in the company: here possible categories are technology, information, supply chain, occupational, environmental, organizational and production.

In past years, the most common way to cope with risk was to use other functions in the organization to buffer the core operations. However, it took to major disadvantages, such as communication delays between operations and other functions, operations inability to develop the understanding of the environment helpful to exploit new opportunities, lack of responsibility for long range impact operations action, large stock of input or output resource. Moreover, risk is becoming more complex, because they belong to interconnected systems that can create cascades: danger is no more a unique one, but a runaway collapse. Therefore, a new approach to risk management was needed. Operations function is now expected to contribute to company's strategic objectives acting under uncertain context conditions and it has some long-term objective mainly referred to value generation for stakeholders. It has to identify which are the best way to achieve performance objectives, given a spectrum of possible different operational contexts, remembering that risk can be both a positive and negative impact, as shown by the Business Risk Continuum (*Figure 11*). If in the past managers only looked to the downside part of the graph, trying to develop solution to prevent from hazardous situation, now it is fundamental to look at the upper part in search of strategic initiatives that can both avoid disruption and provide a competitive advantage to a company.

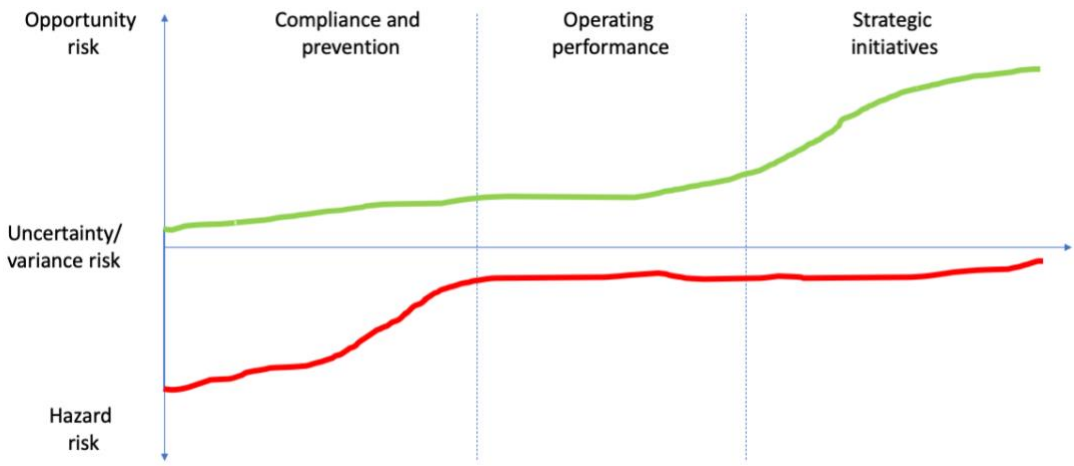

Figure 11. *The BRC (Business Risk Continuity) issue.*

The approach that should be followed is the one descripted by the bow-tie model (*Figure 12*). Risk event is in the middle and actions have to be done both before and after it. Before, it is important to understand the root causes of that event and their conditions in order to develop prevention measures that aims at eliminating (if possible) or decreasing them. Then, it is necessary to assess the consequences and create some protection solution that are able to decrease risk event impact.

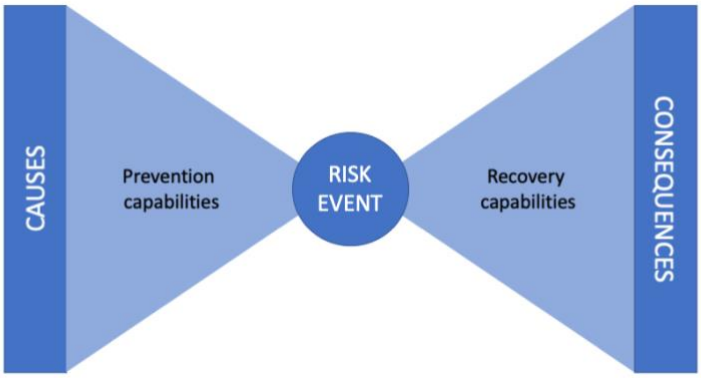

Figure 12. *The bow-tie model graphical representation.*

Addressing all potential risk causes is fundamental, although a disruption can happen despite protection measures implementation. Today's uncertainty drivers to deal with are linked with a lot of fields that may include climate change, globalization of markets, disrupting technologies, increase of regulations, increase awareness on customers, sustainability issues, natural disasters and lack of capabilities at each level of the firm organization. So, there is the need to overcome the fragmented approach made of several specialized risk management systems, considering the Enterprise Risk Management (ERM) methodology. It is a systematic and structured approach addressing all company's risks at a strategic level that allows the risk management of a firm to be tailor made, because it is aligned with the organization's external and internal context and risk profile.

Finally, a proper risk management, comprehensive of deep analyses and mitigation actions, can represent a competitive advantage for a firm, leading it to be resilient. Resilience is the ability of an organization to absorb and adapt in changing environments. It allows to minimize damages coming from an eventual disruption and correspondent response time. In fact, reactions to a disruption have to be as quick as possible to decrease long-term impacts. As shown by *Figure 13*, recover from a negative event requires a lot of time, actions and it will always have an impact. It's fundamental to be as much as possible prepared, so, when the disruption happens, consequences are lighter: detection is a key for a good risk management approach. After the risk event happening, a first response is set by the company in order to react to the initial impact, that is lower to the full one due to some preventive actions (e.g. safety stocks presence). Then, time passes and the full impact overwhelms the firm, bringing to a big reduction in the performances. Actions are then set in order to return at the previous level of performances, but it is difficult and requires a lot of time. Lower the preparation and the resilience, higher the long-term impact is, increasing the risk of failure.

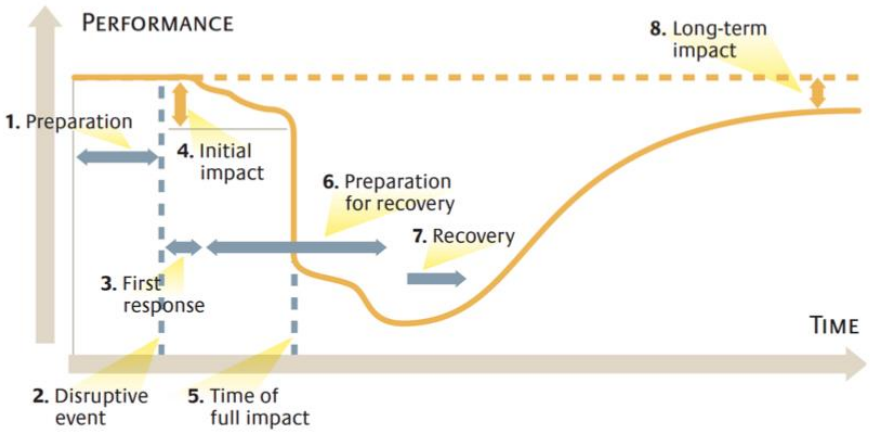

Figure 13. *A graph showing the anatomy of a disruption considering time and performances.*

Resilience is not only a defense mechanism, but a precious quality that allows to success and prosper on the market that touches three different areas:

- Business continuity, so the capability of an organization to continue the delivery of products and services at an acceptable predefined level;
- Crisis management, so the capability to manage crises, defined as abnormal and unstable situations that threaten the organization's strategic objectives, reputation or viability;
- Enterprise risk management, so the capability to manage the effect of uncertainty on objectives.

3.4.2 Supply chain risk management

Supply chain is defined as the network of entities (i.e. organizations, people, activities, information and resources) that produce raw material, transform them into intermediate goods and then into final products and deliver them to end customers through a distribution system. Its primary goal is to deliver product in the right quantity, in the right place, at the right moment and at the right cost. In this context, the main risk is certainly a disruption of the flow, that can regard information, materials or money. Moreover, the concept of supply chain itself does not lie in a single firm' boundaries, so, also supply chain risk has a cross-company orientation. In fact, an eventual disruption can happen in each stage of the supply chain or even in the connection between different stages and can regard any actor involved (e.g. raw material suppliers, component producers, OEM, assemblers, distributors, wholesalers, retailers, customers).

Supply chains are vulnerable to local and global risk factors and, within those with high structural and dynamic complexities, disruptions are highly uncertain in type, location and consequences. Thus, there can be a lot of possible typologies of events that can create a mismatching between demand and supply. They can be classified in several ways: two examples can be the one of *Cristopher* (2003) or *Rangel* (2015). The first one, divides operational and disruption risks. Operational risks regard the uncertainty of customer demand, supplier performance and costs. Despite the name can be confusing, they do not consider only the operations side of a company, but the whole supply chain perspective.

***Figure 14**. A graph showing the impact and the probability of the risk typologies identified by Christopher (2003).*

Disruption risks, instead, regard natural disasters (e.g. earthquake, flood), man-made disasters (e.g. cyberattacks, terrorism) and economic crisis. Usually, the last ones have a low likelihood of occurrence, but high impact. Vice versa, operational risks have a higher probability and a lower severity (*Figure 14*). Every supply chain, regardless the strategy chosen, has to deal with disruption risks, because, despite the low likelihood of occurrence, they are linked with the external environment.

Rangel's taxonomy (*Figure 15*), instead, starts from the SCOR model and identifies different possible kind of risks that can arise in each phase.

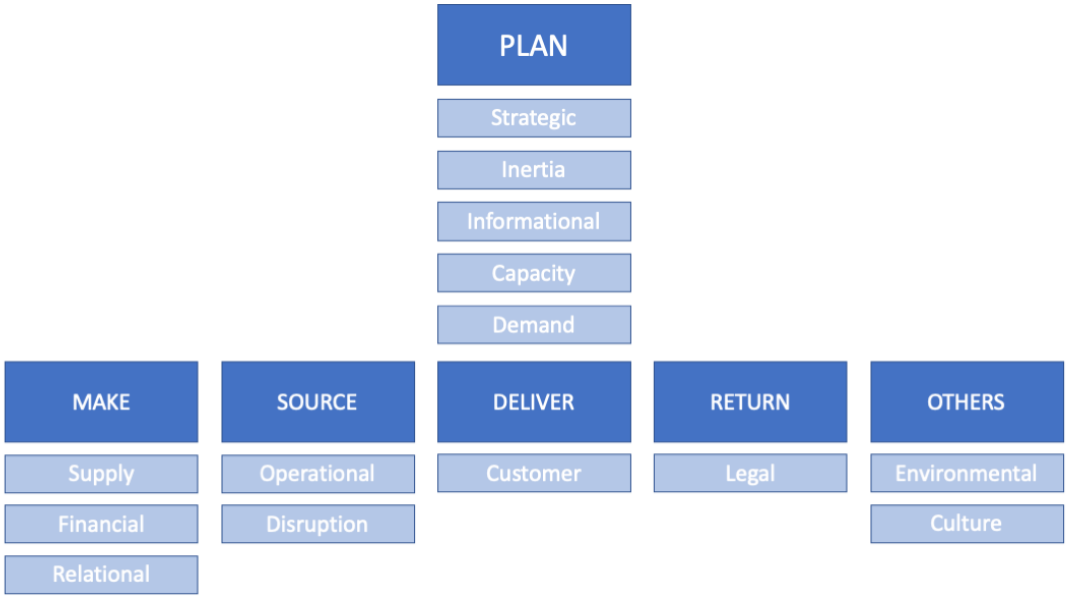

***Figure 15**. Representation of Rangel's taxonomy of supply chain risks (2015).*

In the planning stage, main risk areas are the following:

- Strategy, characterized by any event affecting business strategy, like lack of a systemic planning perspective or absence of supply chain planning;
- Inertia, so the inability to remain in a competitive market, usually caused by failures in the organization or in the chain due to market changes (e.g. technological, regulations, functions);
- Information, so the result of information system failures due to the inability to receive, transfer and manage information (e.g. deficient data feed system, failures, cyber-attacks);
- Capacity, caused by effective over- or underproduction as a consequence of lack of flexibility to respond to market fluctuations or inability to plan, schedule and control production and inventories in the supply chain;
- Demand, so all the elements regarding when there is a poor demand forecasting both in terms of quantity and mix (e.g. too short product lifecycle, small customer base, long lead time, information distortion due to promotions, too much inventories). It can bring to a bullwhip effect all along the supply chain.

Source-related risks, instead, can regard:

- Supply, when they stem from inefficiencies in supply chain process (e.g. increase in raw materials price, supplier lack of responsibility, unavailability of input, problems in the internal product flow, poor quality, possible recalls);

- Financials, when there are cash flow issues (e.g. product or input pricing volatility, delinquencies of debtors, non-payments) or change in the financial market (e.g. taxes, exchange rates, licenses);
- Relationships among supply chain members (e.g. lack of visibility, opportunistic behaviors, lack of trust in information sharing, violation of confidential documents or of intellectual property rights).

In the make step of the SCOR model, *Rangel* classification is quite the same of *Cristopher* (2003). In fact, risks are divided into operational and disruptive. The firsts result from any situation preventing the focal company from performing its production activities (e.g. production system issues, internal policies, procedures, people, processes). The second ones, instead, result from the discontinuity in the material flow, due, for example, to single sourcing, labor strikes or unintended events, and cause the suspension of value-added activities for the customers.

Delivery-related risk regards the customer perspective: it is focused on any possible situation that can modify their choice (e.g. obsolescence, punctuality of the delivery, appropriate customer service, counterfeiting). On the other hand, return risks are main legal: they begin with the inability of a company or of the whole chain to comply with legal restrictions or further exposure to litigation.

Finally, there are some risk areas that cannot be properly identified in a specific stage of the SCOR model because they can regard every part of it: the environmental and the cultural one. The first stems from events outside the chain (e.g. natural disasters, economic crisis, technological and social policies, uncertain legislation, geopolitical instability). The second one, instead, regards the differences between the business culture of the different actors of the chain (e.g. language, culture). Both of them can result in sustainability-related risks: not respecting the environment (e.g. pollution of air, water, wastes) or people (e.g. child labor, low wages, poor working conditions, lack of safety) can take to huge reputational loss, as well as pecuniary sanctions.

However, supply chain is increasingly becoming a strong source of risk. It can depend by several factors. First of all, dependency between the various actors (i.e. suppliers, partners, customers) is increased, so, rise of opportunistic behaviors and the lack of support in a collaborative environment can bring to big difficulties. Strong inter-dependence of businesses makes also minor issues to become potentially detrimental. Then, products are more complex to be managed: mass customization trend takes to a lower standardization and the market continuously asks for new introductions, bringing to a short lifecycle and product cannibalization. The network is changed too, because number of entities is increased and extended supply chain configuration is always more

frequent. In addition, current business environment changes rapidly and disruptions could emerge anywhere at any time, no firm is immune. As a stone that falls in the water and creates waves in every direction, also the effects of a risky event can propagate in any direction.

So, planning, communicating, managing the supply chain and assuring the achievement of its primary goals in this context is surely more challenging. A survey conducted in 2011 by BCI (Business Continuity Institute) found that over 85% of 559 companies have suffered at least one supply chain disruption during the year. Surely, after *Covid-19* the percentage is increased, probably touching the 100%. This is a reason why nowadays there is a huge need of performing supply chain risk management. It is the process of taking strategic steps to identify, measure and mitigate the risk in the end-to-end supply chain. It should adopt a comprehensive approach able to consider all tiers of the chain, actors involved and events, both every day and exceptional ones, independently from the adopted strategy. It can result in a critical enabler that is embedded and integrated into core processes of an enterprise. It has a very relevant role in companies for several reasons. Firstly, supply chain risks can have a long-term impact that is difficult to be recovered (as shown by *Figure 13*). Moreover, a supply chain disruption is more likely to happen, because the environment involves so many different actors and perspectives. Finally, firms with mature processes in supply chain risk management usually outperform their rivals also in business and financial performances.

Original supply chain risk management scope was “the identification of potential sources of risk and the implementation of appropriate strategies through a coordinated approach among supply chain members, to reduce supply chain vulnerability” (*Cristopher*, 2003). However, the aim of this practice is now broader because it involves “the management of supply chain risks through coordination or collaboration among the partners […] to ensure profitability and continuity” (*Tang*, 2006). The final aim is to build a resilient supply chain able to adapt and recover from any kind of possible scenario.

As previously defined, supply chain risk management is a process. Its steps are the following:

1. Risk identification, the discovering of all current relevant events and the recognizing of future uncertainties to manage them proactively. It can be done in both qualitative (e.g. interviews, Delphi, brainstorming, checklists) or quantitative ways (e.g. real time geo-mapping, assessment surveys, audits, business impact analysis).
2. Risk assessment, the understanding of the importance of risks in order to prioritize them and to allocate the limited treatment resources. It can be done using quantitative information (i.e. real experience data) or qualitative expert judgments.
3. Risk treatment, that consists in planning and execute actions in order to face risks.

4. Risk monitoring, due to the fact that risks are not static phenomena. So, continuous monitoring is required to evaluate if the intervention done is enough or it is necessary to develop new plans.

3.4.3 Supplier risks

The complexity and globally outsourced nature of today's supply chains combined with the practice of optimization techniques (e.g. lean and just-in-time manufacturing) has increased supply chain vulnerabilities to even minor supply disruptions. While these models have allowed companies to reduce overall costs and expand quickly into new markets, they also expose companies to the risk of a supplier suddenly going bankrupt, closing operations, data breach or being acquired. Suppliers are one of the key actors in the supply chain, both from a value and a risk perspective. If, on one hand, they are able to be a competitive advantage, supporting innovation and quality and assuring the high service level targets imposed by a firm, on the other hand, they can completely stop the delivery of good of a company. Supplier's disruptions are very common. As stated by BCI Supply Chain Resilience Report 2017, the 65% of firms interviewed experienced at least one supplier disruption in that year. Moreover, it's not enough to look only at the tier-1, because only 44% of problems arose here. So, it's important to look in the previous level of the chain and evaluate risks related in these stages. However, this can be an issue, because the 69% of firms had not an adequate level of visibility, thus, probably, sometimes it happens that a company does not even know that there can be further tiers.

However, regardless where the event can arise, the importance of managing risks at suppliers' level is undeniable, especially considering that the main objective of the purchasing department is to secure a stable supply. An overall reliable and consistent framework that enables firms to manage them throughout the sourcing lifecycle is needed. Supplier risk management is an evolving discipline in operations management for manufacturers, retailers, financial services companies and government agencies where the organization is highly dependent on vendors to achieve business objectives. It entails the identification, assessment, treating and monitoring of risk linked to the suppliers. Its aim is to encourage cost effective sourcing, ensuring that risks, their accountability and service delivery are clearly defined, managed, monitored and understood by both an organization and its supplier. It not only offers increased levels of control; but it can also help organizations in maximizing value, bringing to several advantages.

Reducing this kind of risk can take to lower supplier costs related to inefficiencies, urgencies or emergencies: with everything under control, for example, it's not necessary to search from new suppliers that have to deliver to the firm components in a short period of time, investing time and moneys into activities like scouting, qualification, negotiation and evaluation. Thus, there is a reduced need of replace failed suppliers. Moreover, in these cases, there is no time to evaluate properly the level of trust with the vendor and sometimes it can happen that opportunistic behaviors can arise. Managing vendor's risk means also to prevent loss of reputations towards customers, because a stop in the production/selling of an item can take to unsatisfaction of the customer toward the firm, regardless the real responsibility of delays or stock out lies not in its boundaries. Summing up, performing supplier risk management takes to evaluate vendors in a better way, enhancing the ability to outsource non-core activities and create partnership with strategic actors on key processes.

It's obvious that each of these situations can impact on profitability. Therefore, managing suppliers' risk means also to try to assure the own business continuity. In fact, as said before, nowadays everything has to be seen from a supply chain perspective, where an individual firm has a limited role in delivering good to the final consumer; so, survival of each actor in the chain and collaboration and coordination with them is fundamental to be profitable and to improve the competitive position in the market.

The extent and complexity of recent sourcing and outsourcing arrangements has increased the likelihood of supplier risks. They can belong to different areas: source, financials, products, contracts and intangible assets. The first one regards where the supplier comes from and considers two different parameters: country and market. Each country has different financial and credit risk, due to various reasons (e.g. political instability, taxes, insolvency rate). Every market is characterized by some purchasing constraints. They represent a lack of freedom in the procurement process of a certain company and they can be both external and internal. The external ones are related to what the market offers, thus, for example, if there is a monopoly or not, if the offer is higher than the demand, if the resource searched is scarce or if there are some specific know-how or patents needed. The internal ones, instead, regard the demand side and all the things that a firm imposes to its purchasing department (e.g. certifications, confidentiality of projects, short lead time, homologation).

Another important aspect to be monitored is certainly the financial risk related to suppliers. It can be oriented towards the financial stability of a company or towards the economic dependance

between a vendor-buyer couple. In the latter case, if supplier revenues are for the vast majority coming from a single firm, its condition is not solid, because if its primary customer fails, he will fail too. On the other hand, if the buying firm purchases components from a single supplier, its risk is higher because if its partner fails, its production is completely blocked. Moreover, the supplier has a higher bargaining power in this case and there is the possibility to be in a lock-in situation. So, it is important to evaluate the financial risk from a double perspective. Looking at economic performances, some parameters that should be looked at can be revenues, insolvencies or risk of bankruptcy. Analyzing financials of a company is not enough. In fact, suppliers have to guarantee a business continuity from an organizational point of view, so, for example, assuring that once the head of the firm will leave it, there will be a future for the enterprise. Even the capability of a company to pursue innovation and to stay in the market is a key element.

Vendors are entities that deliveries items to customers per definition, thus, also the risk related to the products they provide must be analyzed. However, considering only products without an overlook on the processes is limitative. Quality is certainly the first element to be considered, because poor quality increases supply costs and can create manufacturing stoppages. It's necessary to look both at the quality of the items purchased and at the organization of the quality department (if present): without a specific function, risk of incurring in defective parts increases. Then, also delivery has an important role, because it involves punctuality and quantities precision. If in a company there are well organized processes regarding planning of production, safety procedures, maintenance, renovation of machineries and empowerment of employees, risk of incurring in a supply disruption is lower.

The relationship between two entities is usually regulated by contracts, therefore they are another important element to look at in the risk assessment. If vendors do not respect what is signed in terms of quantity, quality or compliance, they are prosecutable by law: this is an assurance that they respect it or, at least, there will be a guarantor (i.e. a judge) of the fact that the buying company will be compensated in some way. Even their relationship is important: a partnership has a lower risk than a spot transaction on the market and historical partners are more trusted than new ones.

Suppliers can also take to intangible assets-related risks, like the ones related with image and reputation. If, for example, there are violation in sustainability field at source level (e.g. child labor in a sub-contractor), there is a sort of green bullwhip effect that transport the attention from the upstream to the downstream part of the chain. Therefore, even if the firm is not responsible of the violation, it is exposed to the consequences. Differently by the traditional concept of risk, the

attention has not to be only on the event, but also on stakeholders' reactions. That's why involving stakeholders in the company decision making processes can help decreasing this kind of risk.

Finally, there will always be some totally random phenomena that are difficult to be classified and that can dramatically create a supply disruption. Clear examples are climatic threats, natural disasters or unintended events.

Summing up, suppliers' risks are the most tailor-made one, because they strongly depend by the entities involved and they have to analyze both internal and external variables respect to the supply chain. They have a different internal visibility: each function perceives as primary only what matters mostly for it. Even employees in the same role can have different perceptions due to different company's priorities.

3.4.4 Risk treatment

Risk treatment is surely the most important part of the risk management process: identification of possible events and assessment of their likelihood of occurrence and impact are useless if then actions are not implemented. There are different kind of responses on the basis of the characteristics of the risk to be treated (*Figure 16*). If both probability and severity are low, the right strategy to undertake is the risk acceptance one, that means to deal with the risk without taking any kind of countermeasure. It depends by the risk tolerance concept: how much risk an organization or its stakeholders is ready to bear in order to achieve its objectives. This kind of acceptance is called passive, but there is also the possibility to have an active one when a contingency plan is developed. It is not a risk response, but an emergency plan that can be implemented in case the event really happens.

Figure 16. *Right risk management strategies to undertake with different kind of risks.*

When probability is low, but severity is high, the most suitable strategy is risk sharing or transfer. It means that the responsibility of managing risky event and its negative consequences is shared with or passed to someone else that is more capable to handle with it. It results in outsourcing, off-shoring and contracting, that often take to develop global supply chains. Among the several types of supplier disruptions, most severe are those that have a relatively low likelihood of occurrence.

Here, the right approach consists in detecting and monitoring risky events in order to identify them before they will happen and, maybe, to understand some possible trends. While such risks cannot be eliminated, however, their severity can be reduced.

On the opposite side of the matrix, when likelihood of occurrence is high and consequences are light, the right approach is risk mitigation. It generally means to decrease probability or severity of a risky event. Acting on the first aspect, means doing prevention. Acting on the second, instead, means doing protection. Here it is very important to continuously monitor these events in order to understand if their likelihood remains low or not. According to *Tang* (2006), there are four possible approaches to mitigate risks, that can be pursued both at strategical and tactical level:

- Product management, that means to modify the product/process design to make easier the supply-demand match (e.g. product variety as a strategic initiative; postponement and process sequencing as tactical);
- Demand management, so the collaboration or coordination with downstream partners to influence demand in a beneficial manner (e.g. product pricing and rollovers as strategical changes; demand shifting across time, markets and products as tactical actions);
- Supply management, so the coordination or collaboration with upstream partners to ensure an efficient and effective supply of materials along the chain (e.g. modification of the supply network, control of critical actors of the chain though integration as strategical initiative; supplier selection, contract management and order allocation as tactical initiatives). Hedging is one of the best practices in this field and it consists in having a globally dispersed portfolio of suppliers (but also of customers and facilities) to decrease the impact of a single event;
- Information management, when supply chain partners can improve their collaborative effort having visibility on different kind of information (e.g. supply chain visibility at strategical level; information sharing, vendor managed inventory, replenishment, forecasting, collaborative planning at a tactical level). Current technological research in the fields of sensors increase the ability to sort out what's happening almost in real-time.

Finally, if both axis' value is high, risk avoidance is the correct choice to undertake. It means to modify objectives of a project, process or product in order to eliminate any risky element. It is certainly the most effective approach, but it is also the most time and resource consuming, so it is chosen only for the most dangerous and probable kind of events. It is used when risks are considered unacceptable, but sometimes can cause a loss of some opportunities: for example: some firms avoid doing business in Afghanistan for terrorism issues, but they loss one piece of the market.

In order to catch a real and complete snapshot of the supplier network, it is very important to focus on both the axes for several reasons. Firstly, likelihood of a supply disruption depends mainly by the vendor. So, two different companies with the same supplier can potentially have the same risk factor. However, it is not true, because each customer gives a different relevance to that vendor and because each company has a different risk appetite that should be considered. In addition, evaluating only probability means to not consider potential economic consequences of an event, making impossible to quantify in a proper way the investments to be done in order to monitor risks. Regardless the kind of risk strategy pursued and the various possible actions to take, there are seven factors that can enable an effective risk response. They are:

- Risk governance, the presence of adequate structures, procedures and culture;
- Flexibility and redundancy in product, network and process architectures, in order to absorb and adapt to changes and disruptions;
- Alignment between partners in the supply chain on key value dimensions, in order to have a common strategy and to identify in advance risky patterns;
- Upstream and downstream integration though visibility, information sharing and collaboration;
- Alignment and integration between different internal functions on a strategical, tactical and operational level;
- Complexity management/rationalization, that is the ability to standardize and simplify network, processes and products;
- Data, models and analytics development and use to support supply chain risk management.

4. Company and purchasing department overview

4.1 Pietro Fiorentini S.p.A.

Pietro Fiorentini S.p.A. is an Italian company leader in providing solutions regarding both up- and downstream segment of oil & gas sector on international level. It was founded in 1940 by *Pietro Fiorentini* in *Bologna*, Italy and now it is led by his grandchildren. Firm initiative was connected to the energy development phase in Italy, firstly creating small equipment for domestic consumption of gas and, later, by supplying gas distribution systems and other installation for factories mainly belonging to the Milan hinterland. Now it designs, manufactures and sells components, systems and services for the treatment, regulation and metering of natural gas all over the world, with the goal of enabling and increasing its safe usage by both distributors and consumers.

Over the years, the range of products and services has been greatly diversified, ranging from the production of low, medium and high-pressure systems, to applications in the oil sector, to process reading and metering systems. Smart solution both for domestic and industrial context were developed too, demonstrating how much the firm tries to drive innovation in the industry. The company was able to address many segments thanks to strong R&D contributes and strategic acquisitions of external companies, like *Terranova s.r.l.*, *Samgas s.r.l.* and *Tecnosystem s.r.l.* in 2011, that allowed to reach also the downstream segment of the market, or *TIV Valves s.r.l.* in 2019, bought in order to expand the product range and conquer more market share. *PF* boasts operation across the whole globe, where it is present with subsidiaries and associated firms both for production and sales. In fact, now it has 11 owned plants and several others controlled distributed between Italy, Ukraine, China, Uzbekistan, USA, Mexico, Hungary, Algeria, France, Tunisia and it has commercial offices spread in quite every country of the world, thanks to distributors and sales agents. The company also has active partnerships with foreign production companies in order to participate jointly in tenders both in Italy and abroad and to establish local production in individual countries serving directly that market.

PF was born as a family company, but, over the years, its organization has undergone several changes. After a deep crisis in 1998-2000, it started adopting the lean enterprise principles, inspired by the Japanese culture, trying to become as much efficient as possible.

A proof of the potential and growth of the firm can certainly be its 282,854 mln€ of 2018 revenues and its CAGR of 13,47% registered between 2012 and 2018. The 60% of the revenues comes from exports, showing the strong international presence of the company. Considering only the directly owned plants, it has more than 2000 employees.

4.2 Rosate plant

Headquarters are located in *Arcugnano (Vicenza, Italy)*, but there are other important locations, as *Rosate (Milan, Italy)*. It was born as the joint of two previous *PF* plant in *San Genesio ed Uniti (Pavia, Italy)* and in *Vernate (Milan, Italy)*. Here, more than 500 employees work on every stage of the *Porter*'s value chain (*Annex 3*) of the gas metering, excepts the marketing & sales phase, that is a prerogative of the HQ: R&D, procurement, operations, supply chain & logistics, administration, human resource management can be found in the *Rosate* pole. However, the number of employees is variable because it follows the fluctuation in the demand.

All the gas meter division was concentrated here in order to exploit economies of scale both in production, R&D and other functions: more than 6.000 gas meters and 10.000 measurement groups (the heart of the meters, it is sent to Uzbekistan plant for the final assembly) are produced every day on average and volumes are growing, thanks to new commercial agreements.

The products coming from *Rosate* now are mainly the following.

- *G4 RS/2001*: high accuracy and reliability diaphragm gas meter. It contains two boxes of plastic with one side made by a diaphragm in synthetic fabric. Gas passes in and deforms the membrane, allowing the computation of the volume of gas, thanks to some valves and counters. A body in pressed zinc-coated steel plate allows to avoid dangerous losses.
- *G4 RSE/2001*: new generation smart gas meter that comes from the integration of the traditional *RS/2001* with new electronic modules. Exploiting the *Internet of Things* paradigm, it is able to communicate the gas consumption trough radio frequency or through GSM/GPRS technology.
- *G6 RS/2,4*: same technology of the *G4 RS/2001*, but with bigger dimension in order to manage a bigger gas capacity.
- *G6 RSE/2,4*: same technology of the *G4 RSE/2001*, but with bigger dimension in order to manage a bigger gas capacity.
- *G10 MM*: high accuracy and reliability diaphragm gas meter studied for a capacity 4 times higher than the *G4 RS/2001*.
- *SSM*: new kind of gas meter that, thanks to its advanced technology, is able to interrupt gas supply in case of leaks, losses, earthquakes and other unpleasant events, in order to guarantee the safety of buildings and people. It exploits the concept of ultrasonic measurement and, thus, it is part of the static meters. The *SSM* exists both as a *PF* product (*SSM-U4*) and both as a collaboration with *Hera* multiutility group and *Panasonic* (*SSM-H*).

Every product can be customized with different kind of attacks, depending on the costumer market addressed, and with different kind of serigraphy, depending on the customer that will distribute it.

***Figure 17**. Pietro Fiorentini products created in Rosate.*

4.3 Lean manufacturing

4.3.1 Why lean?

After the deep crisis of 1998-2000, the company understood that its supply chain strategy was not properly aligned with its kind of business. The matrix developed by *Hau Lee* (*Figure 18*) allows to identify the right supply chain strategy of a company respective to the degree of process stability (i.e. the internal variability) and of demand volatility (i.e. the outbound variability). Analyzing it, it's possible to see how coherent the choice of undertaking the lean principles was. At that time, the process stability in *PF* was quite high, because there was a clear supply system, stable productivity and mature processes. The demand variability was low too, because gas meters are functional products characterized by long lifecycle, low variety, low marginality, low forecasting error no, mark-down at the end of the season absence and, thus, by a predictable demand. The positioning in the matrix suggested the objective for the firm: maximizing the efficiency, minimizing costs, through the elimination of wastes, the exploitation of scale economies, the maximization of production capacity and optimization of the processes.

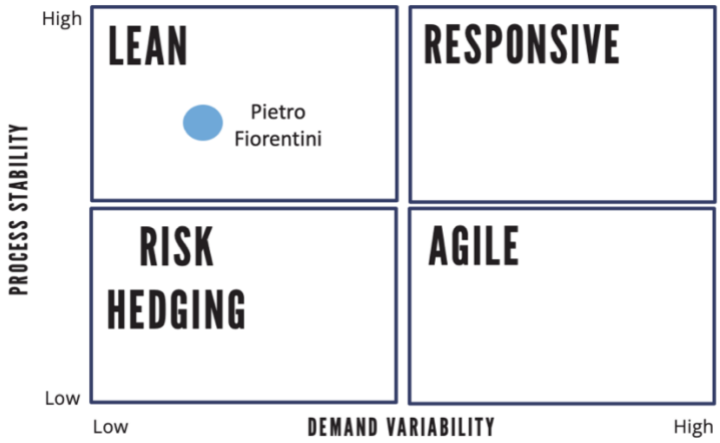

***Figure 18**. The Hau Lee matrix for Pietro Fiorentini in the early 2000s.*

4.3.2 What lean manufacturing is?

In the XX century a process addressed to the quality improvement began, in order to sustain the world's massive industrialization. The first step was certainly the statistic quality control of the processes, that in the 1920s introduced statistical tools to govern processes, in particular the control charts invented by *W.A. Shewhart*. Two World Wars pushed these concepts and advanced techniques were developed, especially in some large firms that produced weapons and items related to the war field. However, the application of these tools was low, due to the low level of schooling of the manpower. The turning point was when *W.E. Deming* and *J.M. Juran*, two US' quality gurus, went in Japan to help the Japanese industry to get up after the defeat in the war. Here, Total Quality Management (TQM) was born. It is a paradigm that identifies growth and continuous improvement as the unique possible ways of a company to survive. This was the key of the development of the TPS (Toyota Production system), a model that integrates and systematize TQM all over the firm. It was the result of a revolution in the Toyota company led by his president *Eiji Toyoda* in 1950 and it is the basis of the *lean thinking*. TPS goal is to minimize every resource needed to make the enterprise work (e.g. human resources, capital, space, time).

The Toyota way is not only a set of tools and rules to govern the operations of a company, but it is a proper managerial philosophy. It is led by some principles:

1. Decisions have to be done considering a long-term perspective and not only short-term financial objectives. The starting point is to create value for the customers and for the society, even to the detriment of the economic profit;
2. Production processes have to be designed as a one-piece flow that increase the visibility of the line, allowing to understand easily where the bottlenecks are;
3. Only what the customers ask for is produced, that means adopting a pull logic in order to avoid over-production;
4. Eliminate the three kind of wastes: *muda* (non-value-added activities, time and resources wastes), *muri* (people and machines overload that takes to higher risks about breakdowns, quality issues and operator's safety) and *mura* (variability in processes and in the production);
5. Create the habit to stop the production when problems arise in order to get to the result at the first attempt and to pursue the quality target in every single part of the process;
6. Use visual check to understand if the process is in control;

7. Use only reliable technology able to support people and processes, not substitute them with a technology that is not reliable and difficult to be standardized;
8. Make leaders grow and make them able to learn and teach the entire lean philosophy. Managers usually comes from an internal path and they have to incarnate the ideas of the company;
9. Increase the standardization of the jobs in order to empower performance thanks to the learning curve effect (*Figure 19*);

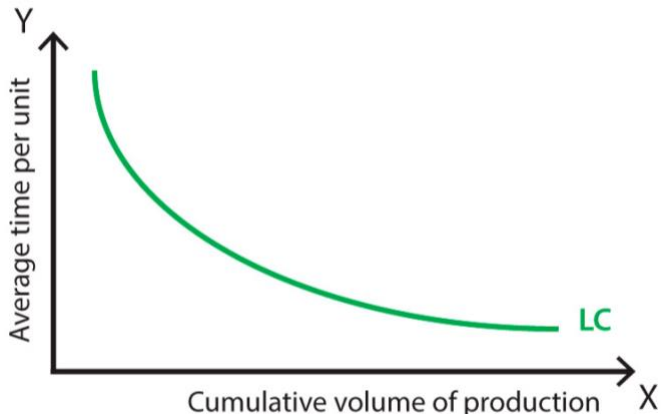

Figure 19. *The learning curve (LC): as the cumulative volume of production, and thus the number of times an operation is repeated, increases, the average time needed for complete that job decreases (learning effect).*

10. Develop people and teams that follow firm strategy and philosophy thorough a strong company culture, powered by investments in growth and training of employees;
11. Respect suppliers and partner, challenging and supporting them in a continuous improvement path;
12. Observe personally things in order to understand properly what's happening and where inefficiencies and wastes can arise (*genchi genbutsu* concept);
13. Take decisions with patient and through consensus, analyzing all possible alternatives and finding the best solution;
14. Once reached a stable process, continuous improvement (*kaizen*) has not to be abandoned and, at the end of each project, it's fundamental to reflect about problems and corrective actions (*hansei*).

4.3.3 Implementation in Pietro Fiorentini S.p.A.

The path undertaken by *PF* towards lean manufacturing was not simple and it is not totally completed yet: there are still new steps to do in order to spread this philosophy all over the company. However, it allowed to avoid a lot of wastes of time, resources and capital and, thus, to

became competitive in a low margin industry market, where keep under control the cost of production is fundamental.

TPS can be adopted in different areas: product, process, management, organization, supply. In the first one, *PF* tries to simplify the projects standardizing as much as possible its products: even if the kind of gas meters are quite different, small metal parts, attacks, the body and other components can be used both for the RS and for the RSE models. Modularization is used too: a clear example is the measurement group, that is common for different kind of products.

Regarding the processes, the company has developed a one-piece flow path for each of the three production lines (*Figure 20*). Level of automation is low and each operation is performed by humans, often supported by some machines. Repetitiveness of these actions takes people to increase their performance and reduce time needed per unit, increasing productivity. Each line is divided in U-shaped sub-lines where some sub-assemblies are made and then pushed ahead. A takt time is set, that is the time window in which the operator has to complete his job and pass to the next step the piece: it allows to maintain a high production rhythm. Some advantages of the U-shape can be less space needed, easier communication between workers and minimization of handling: entering and leaving point are the same. The production is a batch-one, so the line makes only one kind of product during a certain batch: it allows to reduce set-up times (the size of the batches is quite high) and to increase the repetitiveness of the job. One of the keys of the lean implementation is certainly quality: in *Rosate* it is monitored along all the line through some employees that look at each step of the flow, understanding when problems can arise. One-piece flow configuration helps in increasing visibility of the process. Then, there are two massive quality check: the first one is massive and regards the leak test in water and the correctness of the measurement of pressure; the second one, instead, is a sample quality check done on the final product. Some visual signals can indicate when there are issues on the flow, grabbing the attention of the technician in charge of doing tooling, maintenance and each kind of

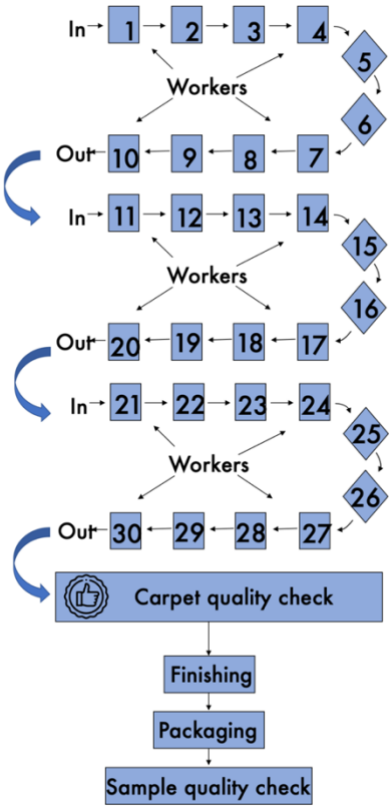

***Figure 20**. A figurative representation of the Rosate production line.*

action that can solve the problem. The presence of different lines, with the consequent duplication of the machines, increases the resilience of the line.

Talking about the management, there is a high synchronization between production and market: only what customers want and order is produced and no inventory of final product is created. Thus, a pull supply chain is set. Another important managerial approach is the *Kanban* methodology. *Kanban* is a Japanese word that means ticket, tag and it indicates the cards through which production control is made. Every component is moved in standard size containers with a tag containing different information (e.g. ID code, number of pieces per container). Each of its movements establishes the operative flow, showing which are the operations needed on the basis of the requirement at that precise moment. It can be distinguished between the production and the transfer one. The first one is used in the production line and it specifies the quantity to be produced. The second one, instead, is useful for the operator to understand how many pieces he has to pick from the warehouse. In *PF* both these kinds of Kanban are used. The production one is internal and it is useful for pickers that take the containers from the internal warehouse (managed with a supermarket approach) or directly from the line (when a sub-assembly is completed, it has to be moved ahead) and bring them in the point of the line where the need of them arise. Transfer one, instead, is used for managing the orders with suppliers: every time there is a need in the production site, an order of a certain standard quantity is made. In this way, suppliers are considered as the company warehouse and, thus, some of the most active suppliers deliver every day.

From the organizational point of view, there are different kind of implementation of the TPS in *Rosate*. First of all, there is a strong company culture creation thanks to some initiatives. An example can certainly be the high amount of training courses, not only in a job perspective, but also regarding the general concept of the lean thinking and about lifestyle and many other topics. A high utilization of cross-functional teams helps improving quality and productivity, because people can share their knowledge, also from different departments. However, the clearest implementation of the lean approach in *PF* is represented by KPOs (Kaizen Promotion Officers). They are in charge of spread continuous improvement all over the company in each department. They monitor that every process in the plant is done in the proper way and, then, they try to develop solutions for doing it in a better way or to overcome eventual issues. They are responsible of the organization of the *Kaizen week*, that is a monthly week dedicated to the improvement of processes, where a Japanese *sensei* comes in the plant to support the lean implementations and to share his experience. KPOs

continuously hunt for wastes. As stated by *Taichi Ohno* (1988), there are "seven capital sins" that they try to fight every day, that are:

- Wastes for overproduction;
- Wastes for machine waiting times;
- Wastes for semi-finished products transportation;
- Wastes for production and management of scraps;
- Wastes for inventories;
- Wastes for avoidable movements;
- Wastes for defects.

The approach followed by KPOs in this initiative is the *5S* one, called in this way due to the initial letters of the Japanese words. It means that, firstly, they have to separate (*seiri*) what is functional from what does not add value, thus the *muda*, and throw it away. Then they have to reorder (*seiton*) what is useful and to assure that everything is cleaned (*seiso*), because it allows to understand better the defect and to avoid the malfunction of the machines. Finally, they have to systematize (*seiketsu*) the virtuous behaviors identified in the critical analysis phase and to standardize (*shitsuke*) them.

Finally, it is important to see what the consequences of the lean manufacturing into the supply area are. The *Kanban* methodology has certainly a great impact, because majority of suppliers are managed with the transfer *Kanban*. It is declined in two different ways: electronically, that means that orders are automatically generated by the IT system of the company, or manually, where orders are done by the planners through e-mails. So, orders follow *Kanban*'s rules: small size and standard containers. For this reason, some suppliers deliver every day and, to decrease the logistic cost, a milk-run approach is followed: a vehicle of a third party logistic provider partner of *PF* starts in the early morning from *Rosate* loaded with empty containers and goes in suppliers' plants leaving them and retiring the full ones. Reliability and synchronization of deliveries are key elements to assure production continuity, because, pursuing the lean approach, the inventories are quite equal to zero. Due to demanding requests that the firm asks to vendors, usually there is the willingness to develop partnership with them.

4.4 Purchasing function

4.4.1 Purchasing function description

PF operates in a very low margin industry, especially because its products are usually sold to multiutility companies through tenders or auctions, where price is a key element to win the order.

This is one of the reasons because the firm decided to convert itself to lean manufacturing, trying to eliminate every kind of waste of time and money that can in some way increase costs of its products. Kanban adoption and theoretical zero stocks approach are only two of the critical factors to be managed by the purchasing department. In such a complex environment, it has to guarantee a safe and continuous supply and, in the same time, reduce as much as possible cost of the components, in order to be competitive on the market. Late deliveries and quality problems are the first enemies of a lean producer, because they can stop the continuous production flow and create troubles in the final delivery of the products. So, purchasing department has certainly a critical role, because it has to guarantee continuity of production in the upstream part of the chain and because it has to assure a continuous cost reduction to be successful in the downstream part of the chain.

4.4.2 Purchasing function organization

Purchasing is managed in a decentralized way: every plant has its own department, due to different products, different requirements and to the necessity to use as much local as possible suppliers according to the lean principles. However, there is a strategic purchasing function based in *Arcugnano* that supports in an informal way local functions, coordinating joint activities, providing high level guidelines for procedures to be followed and helping them in market researches, especially for raw materials and common components. Its role is limited, because each plant has big autonomy, due to big differences between each factory. It can also happen that the plant that consumes the highest volume of one component becomes the towing of the other ones, allowing them to have access to its same economic conditions, partially substituting strategic function's role. So, *PF* purchasing is structured as a supporting organization, where a central unit provides support, informal coordination and consulting and local units are in charge of doing decisions and execution. In *Rosate*, there are three purchasing categories: mechanical components, electronic components and indirect services. The first comprehends each metallic or plastic item that is contained in the gas meter, like body, attacks, valves, small metal parts, screws, membranes and its boxes. Moreover, packaging and items like glue and lubricating grease are considered as part of this category too. The second one, instead, comprehends components like batteries, circuits, antennas, SIM cards, screens and every item linked with the connectivity and the intelligence of the products. The last one, finally, comprehends all the services that are not linked with the products (e.g. maintenance, cleaning, company cars) and the facility costs (e.g. energy). *Rosate*'s overall 2019 spending was about 56 mln€ and the three categories are accountable respectively for about 38%, 50% and 12% (*Figure 21*). In

2020, spending and percentages will certainly change due to a growth in production volumes. It will increase the percentages of the categories inherent to the products and decrease the one relative to the services.

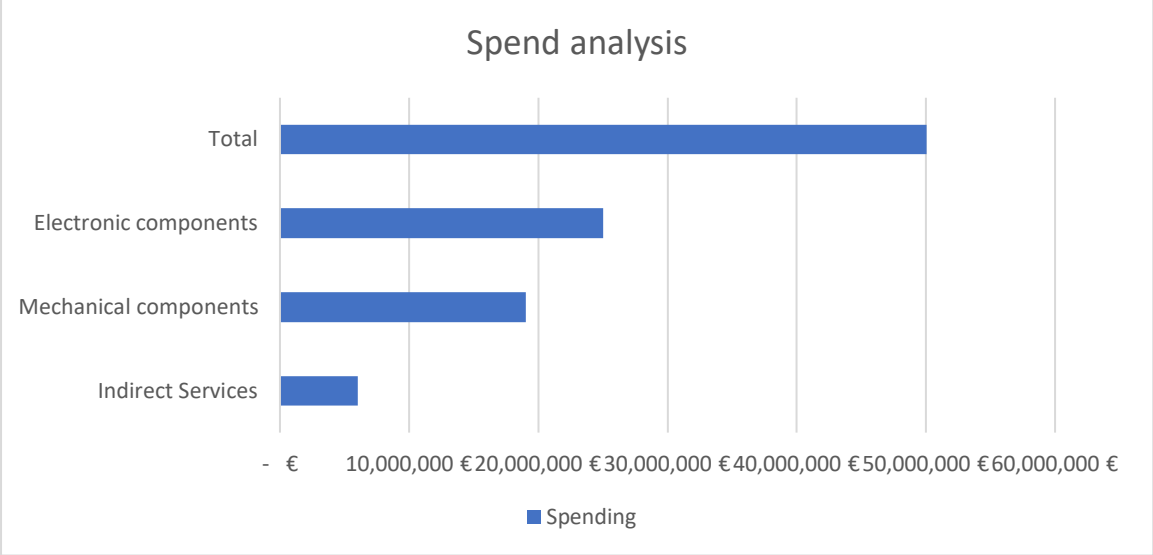

***Figure 21**. Rosate 2019 spend anaysis.*

Looking at the volumes (*Figure 22*), instead, mechanical category moves the 81% of the purchased items. Components from this category are the majority, but they are very cheaper respectively to the electronic ones. In 2019 more than 93 mln of items were bought by *Rosate*'s buyers.

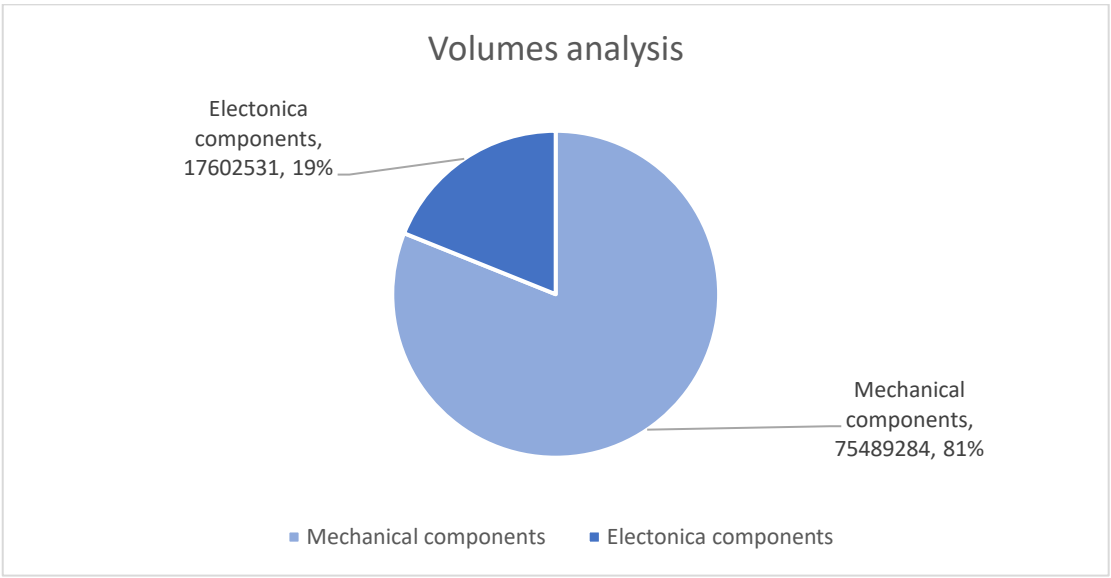

***Figure 22.** Rosate volumes analysis on the purchased items in 2019.*

Here, the organization of the department is quite simple and vertical (*Figure 23*). Each category is managed by a different senior buyer that answers directly to the responsible of the division, that is basically the head of the plant. Indirect services buyer works without a back-up. The electronic components responsible has a junior buyer and they both are in charge of each phase of the

purchasing process from strategic sourcing to supply. The situation in the mechanical components' category, instead, is more complicated. In fact, theoretically both senior and junior buyer should be responsible only of strategic purchasing and sourcing, while supply phase is in charge of two planners. However, the latter have not completed yet their learning process and the planning responsible has not the capacities to teach them about procurement, so, the senior buyer keeps control also on them. Activities performed in strategic purchasing and sourcing are definition of supply network, supplier scouting, negotiation, performance measurement, price and cost analysis, supplier relationship management and supply mix definition. The ones carried on by the planners, instead, regards basically the orders: starting from the MRP, they verify the need of components and send orders to suppliers to assure continuity of production. Moreover, they are in charge of doing basic vendor rating actions (e.g. gathering of supplier certifications) and expediting.

Figure 23. *The organizational chart of Rosate purchasing department.*

4.4.3 Procedures

The usual procedure starts from the recognition of the need, thanks to the collaboration with planning and technical office. Then, supply specifications are defined and the buyer starts doing scouting on the market, identifying potential suppliers and demanding for request for quotations. Audits to suppliers' plant and visits to *PF* production facility can be organized too. Once received, the buyer evaluates the offers and select the proper vendor, considering price from a total cost of ownership perspective and quality. Contracts are usually open and they can last six months, one year or a certain number of pieces. Relying on them, planners emit orders.

Before the supply can start, it's necessary to qualify a supplier. Qualification is composed by different factors. First of all, products must be qualified through the obtaining of the *BIF* (*Benestare*

Interno di Fornitura), that is a *PF's* approval of the components purchased thanks to some trial orders. A first sampling is sent to *PF* plant to verify measures, tolerances and correct shapes. Then, a small pre-series is manufactured with the line that will do it in the final stage of the supply, in order to try if these items can create some issues in the final assembly. Once these tests are passed, planners can emit orders.

Moreover, planners must gather vendors' certifications and some conditions suppliers have to sign in order to qualify them. Those are the *CGA* (*Condizioni Generali d'Acquisto*, general condition of purchase) and the *DSGR* (*Dichiarazione di Sussistenza dei Requisiti di ordine Generale*, declaration of the existence of the general requirements). The first one is related to stringent rules that suppliers have to respect in order to sell products to *PF*. Sometimes they are not signed because of their rigidity. The second one, instead, guarantees that the supplier is not a criminal.

Once the supply is started, the company starts to evaluate them. In particular, the *Oracle JDE* ERP system computes automatically the quality index (related to the number of defective pieces found) and the punctuality index, calculated as the difference between deliveries and orders.

Generally, there is a high level of collaboration between the different departments of the company. Cross functional teams are frequently used to solve issues (e.g. quality problems, invoice blocking), monitor critical components supply and inventories or develop new projects. This is highlighted by the fact that there is a unique office for every department (planning, purchasing, administration, production, supply chain), increasing the possibility to communicate and coordinate their work.

4.4.4 Evaluation criteria

The work of buyers is basically evaluated by one single criteria: the amount of savings reached in one year. Despite focusing only on one cost related driver could seem a bit limiting, it reflects the great relevance that it has for *PF*. The approach selected is the past vs present one: once computed the weighted average price for a certain component in the actual and in the precedent year, they are compared and the percentage of saving or loss is calculated. This approach is quite simple and considers real savings respect to the previous year, but it has also some pain points: in fact, it cannot be used for new products, where a past year price does not exist, and it does not consider the incidence of external factors (e.g. raw material price variance, volume increases, different market trends).

In order to decrease the cost of supplies, buyers are focused on each level of the saving pyramid (*Figure 24*). First of all, they can work on the project design in collaboration with the technical office,

in order to develop better specification following the design to cost methodology. Making some investments in the industrial machinery used or changing shape or material of a component can bring to cost avoidance and to a reduction in costs up to the 70%. Other levels of the pyramid are more connected with buyer's capability to close a deal. Firstly, there is a technical negotiation, where the *PF* employee can reduce costs exploiting increase of volumes, distribution of some interests or the possibility to develop cost breakdowns that make him understand the real cost structure of the supplier. Even if it is rarely used in the company, another important part of the negotiation is the commercial one, that regards logistics, terms of payment and the possibility to implement collaborative cost management thanks, for example, to partnerships. Finally, there is the bonus sector, that can bring generally up to a 5% discount linked to some objectives. An example can be the achievement of some volume targets in an open contract: at the end of the year the supplier recognizes to *PF* a credit note of a percentage of the spending according to the threshold reached.

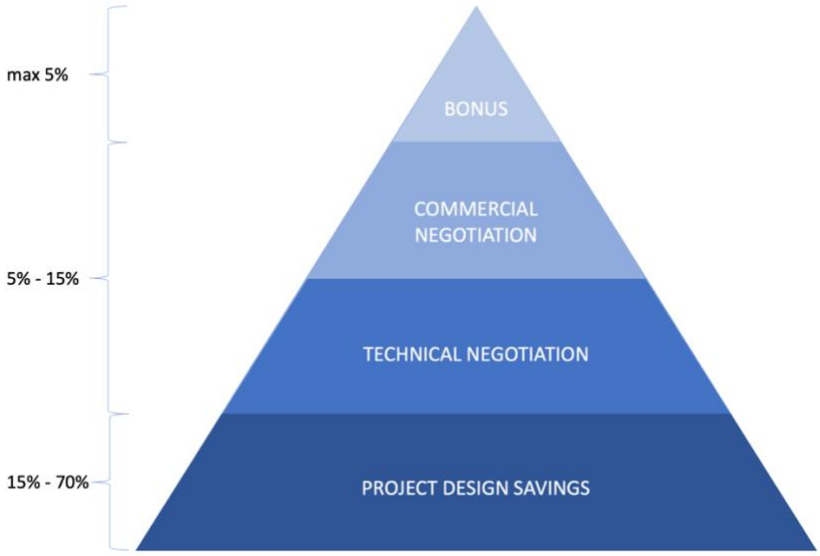

Figure 24. *Pietro Fiorentini's saving pyramid.*

In order to evaluate buyer's work, it's important to monitor savings during the year. It is made both by the strategic purchasing function and by the local department. The first entity does it not in real time and provides results with at least one month of difference, due to delays in the administration function linked to their e-invoicing procedures. In order to fight against this time lag, *Rosate* team has developed a monthly A3 sheet where they upload each variation, allowing to have real time values that can be both useful to judge and to support buyers' work.

4.4.5 Purchasing strategy

PF's purchasing strategy consists in supporting the overall company strategy, so the TPS adoption. In this context, it is possible to define what the *lean purchasing* is. Every action suggested by TPS is done in order to reach operations excellence, but it cannot be reached without the collaboration of the purchasing department. JIT approach (Just In Time, the name of the lean manufacturing applied to the management of the production and to the supply) imposes a pull supply chain: only what the customer orders is produced and, thus, only what is needed for these items is ordered. One of its pillars is to buy less: consumption is carefully controlled and optimized according to the real needs of both the company and the internal customer. So, order batches are small, with high assortment and frequency. Theoretically, there are no stocks, but, in reality, there are some safety stocks that can cover a couple of working days for extreme cases. Moreover, this inventory target is not shared among all the components: for each sub-category is possible to identify different strategies according to their position in the *Kraljic matrix* (*Figure 25*).

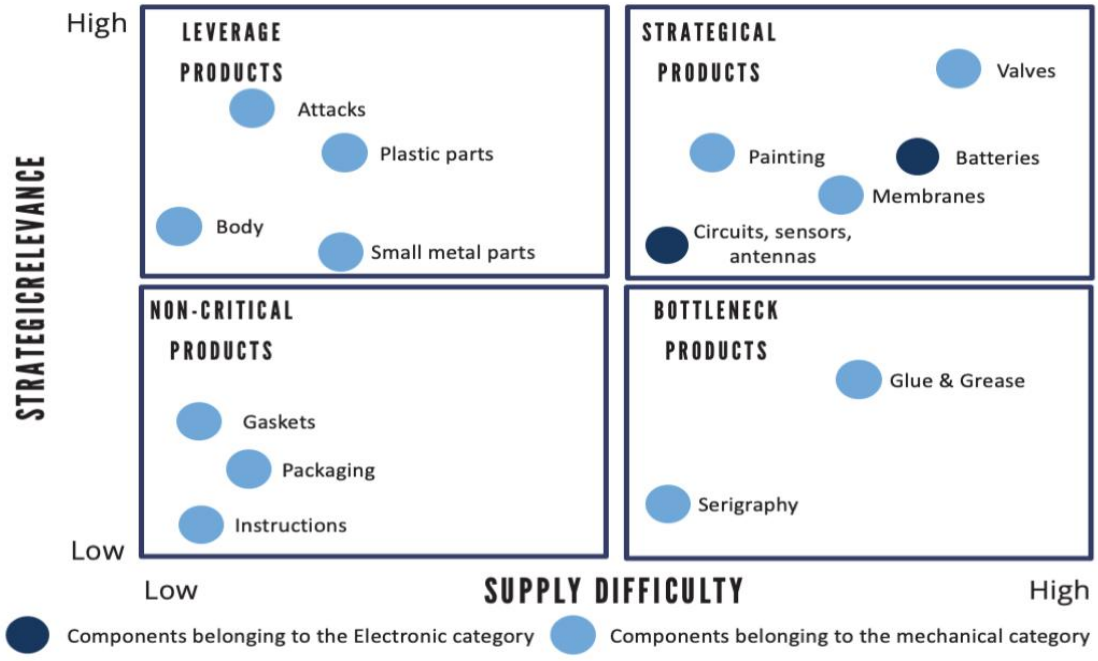

Figure 25. *A possible Kraljic matrix for the component bought in the Rosate plant.*

It is a tool useful to classify the purchases category and to recognize weaknesses and strength of each of them. Considering the supply market difficulty and the strategic relevance that a component has on the final product in terms of contribution to volumes, competitive advantage and quality, it's possible to formulate strategies that guide procurement decisions.

Packaging and instruction booklets are quite easy to find on the market: they are commodities and not strategic contributor to the value of the final assembly, so they are non-critical products. They

are managed with the *Kanban* methodology and with approximately no inventories. Gaskets are non-critical products too, but they are managed with a higher inventory target due to their negligible size, allowing to save transportation costs. Same reasoning can be done for some really small metal parts like screws and washers. Other small metal parts have bigger dimensions and they are managed with the *Kanban*. Small metal parts, together with the body, attacks and plastic parts are leverage products. In fact, they are components that comes from quite simple processes (e.g. industrial printing, deep drawing, galvanizing), but their strategic relevance is quite high: small metal parts are fundamental for the correct operation of the internal engine, while the other three sub-categories are among the keys to avoid dangerous gas leaks. Leverage products are present in each gas meter, so the company uses its contractual power coming from high volumes to reduce costs. Serigraphy, glues and greases are, instead, bottleneck products. The first one is done with special tools and only few near suppliers are available. This work is managed with the *Kanban* methodology: *PF* sends to suppliers a container of blank parts and they print them. Glues and greases are specific products sold by a single player that cannot be substituted unless a huge investment is done, because the certification of the security authority is needed. They are managed with reorder point methodology and with EOQ.

Strategic products can have high incidence on the final assembly cost (e.g. valves account for 20% in the G4/RS2001 cost; batteries, circuits and antennas can have prices higher than 300% respect to mechanical items), high contribution to the quality of the product (e.g. membranes and painting are critical item for assuring the safety of the product) or both. Moreover, they are difficult to find on the market: batteries are produced only in China and Sud Korea, membranes require particular tools and materials and painting requires special powders. Lot of them are not manageable with the *Kanban* methodology because they are too far from *Rosate* and it is impossible to do daily deliveries. In order to assure the highest collaboration and service level, partnerships are developed with these kinds of suppliers. However, JIT and *Kanban* are not manageable with everyone, but a high level of trust, transparency and collaboration is required: this is the reason because with quite every supplier regardless its positioning in the *Kraljic* matrix a partnership is developed. High rotation suppliers have to deliver every day. The relationship with them it's very important, because they have to guarantee the availability of the materials the firm needs, although a production discontinuity can arise. In order to support them, a high level of visibility has to be shared, allowing them to organize their production and inventories. Sometimes, it can also happen that a certain amount of their production capacity can be bought to assure the availability of the materials.

PF strategy is to have few partners instead of a lot of suppliers. Spot transaction are usually avoided and the objective is sustainable relationship: the company needs price decreasing, but supplier margin must exist to guarantee its continuous improvement. Sharing their cost structure, for example, allows to understand which is the correct price with a correct marginality, but it is also possible for the firm to help the supplier reducing some cost voices. *Dantotsu* concept implies that *PF* can share its best practices to assure both an increasing in quality and a decreasing in costs. Often, investments are launched by the firm in order to sustain its partners. The development of a partnership allows an easiest access to supplier innovations too.

Main enemies of JIT are late deliveries and quality issues, because they can cause a stop in production flow. In order to fight against the first one, logistics has a key role: this is a reason why *PF* generally does not make manage it to the suppliers. Moreover, going as much local as possible is a smart strategy, because it allows to dramatically reduce lead times and, thus, time reliability of deliveries. Usually, company's suppliers can be found in Lombardy, so lead times are very low. Sometimes, instead, there are components that are sourced globally, because they are not produced in Italy (e.g. batteries needed are only produced in China or in south Korea) or because this choice can generate very huge savings without compromising the quality of the products (e.g. some plastic parts are sourced in China). In these cases, *Kanban* approach cannot be followed and larger orders that can cover a much higher period of time have to be submitted.

Regarding the quality issues, there are different levels of application. First of all, *genchi genbutsu* principle is followed. Before a contract is signed, the buyer and, at least, the quality manager go to supplier plant to inspect its processes with their eyes. It is also frequent that the vendor comes to *Rosate* in order to understand how its piece will be used, allowing him to develop in the best way as possible the component and also to give some precious improvement suggestions. Then, *ISO 9001* certification and a quality check at the source is imposed to suppliers in order to guarantee compliance of pieces. Another sample check is done in the acceptance area of the warehouse to definitively prove the goodness of the piece.

In order to recap, lean purchasing identifies the focusing of the purchasing department on value added activities and this is a reason why there is the willingness to separate procurement and purchasing: buyers are freed from operational and repetitive action (e.g. sending the orders) and they can focus on actions oriented to gain a competitive advantage. According to the general view of the Pareto rule, in fact, traditionally the 80% of the value that a buyer can take to the company can be found only in the 20% of the activities he performs. Thus, lean purchasing tries to buy better:

processes are simplified, standardized and optimized. It is part of the continuous improvement and it aims to streamline processes within the supply chain to eliminate wastes, that can be defined as time, costs or inventory. Thinking lean often involves utilizing suppliers as often as possible in order to free up internal resources to execute in core areas of the business. Striking the right balance between value-added services and the cost of goods and services can generate huge savings, in terms of both costs and time. It can be viewed as a way to improve the procurement process and workflows, reducing time and eliminating waste, reduce costs while improving the quality of products and services, improve the performance and responsiveness of suppliers, increase the focus on those activities that add value to the firm and enhance procurement's strategic rather than transactional focus.

4.4.6 Maturity assessment of the purchasing department

In order to understand the actual maturity level of *PF*'s purchasing department in *Rosate*, the *Purchasing & Supply Management Maturity Model* by *Johnsen, Howard and Miemczyk* was applied. For each driver, a score from 1 to 4 has been attributed to evaluate its maturity level. The correspondence between each value and its meaning can be seen in *Annex 4*. Generally, an increasing number means an increasing level of maturity. Then, each driver was weighted according with its strategic importance for the company. Interviews with the main actors involved and the on-the-field experience contributed to the definition of the various weights. Finally, the overall weighted average score is computed (*Table 1*) in order to understand if actual procurement organization is mature enough to support all key processes.

Drivers	Score	Weight
PSM strategy	3	16%
Global sourcing	1	5%
Organizational visibility and influence	3	6%
Data, communication & organization	1	6%
KPIs	1	17%
Skills training and development	3	4%
Basis of supplier selection & evaluation	2	11%
Supplier involvement in NPD	2	7%
Supplier development	2	11%
Supplier relationships	3	11%
Sustainability strategy	1	2%
Sustainability implementation	1	2%
Sustainability reporting	1	2%
Overall weighted average score	**2,03**	

Table 1. *The evaluation and the weights for each driver of the Purchasing & Supply Management Maturity Level*

As shown by the model, it's possible to identify some strengths and some weaknesses of the department. Surely, the adoption of the lean purchasing concepts is a clear purchasing strategy that is supportive to the company one and it highlights a good maturity level from this point of view. Moreover, supplier relationships are for the majority partnerships and these suppliers are starting to be evaluated with a total cost of ownership (TCO) perspective, but, ultimately, now it is cost driven. Looking at the internal organization, procurement department has a good visibility, because it answers directly to the head of the plant, but still have limited influence on company decisions. Looking again at internal organization, level of training and personnel development is quite high and cross functional courses are provided to employees. However, there are some pitfalls. Sourcing is pretty local due to the adoption of the *Kanban* methodology, except for some items that can be found only abroad. This fact can limit the possibility of the firm to buy better, cheaper or innovative products from other countries. In addition, there is a decentralized organization and the department shows a low level of spend analysis and information and basic ICT tools. Suppliers are usually approached only during prototyping, even if in rare cases there are attempt of doing it in an earlier phase, and programs for their development are mainly investment done by *PF* in order to increase their production capacity. The poorest factors are certainly the ones connected to sustainability, that is quite irrelevant at purchasing level, despite it is an emergent trend that is no more negligible. Even if they have the lowest evaluation, they the lowest weight, It's impressive to see that the most important driver is very immature: the unique KPI that is really considered and measured during the year is the one related to the price saving.

Finally, looking at the weighted average, it's possible to identify *Rosate* purchasing department as a developing one. The objective is certainly to become a supportive unit, but, even if some processes are ready and mature, there are other factors that have to be improved.

5. Supplier risk: model definition

5.1 Description of the AS-IS situation

Mapping supply risks of a company enables it to have an overview about dangers connected with the actual supply base both in terms of endogenous (e.g. supply disruption cost) and exogenous factors (e.g. financial default probability) and develop some possible mitigation actions. Moreover, it allows to support the strategic objective of assuring the supply continuity. However, this kind of evaluation in *PF* was done in a not formalized way, through the experience of buyers or without the adoption of specific tools. Critical suppliers were considered those one with highest purchases expenses or with few inventories, without looking at risk with a broader perspective. Suppliers were chosen mainly looking at their cost and quality, without a proper risk analysis. Risk should be one of the main priorities in an environment which strongly requires a stable supply. As highlighted by *Hendricks* and *Singhal* (2005), bad risk management may take to less revenues, lower stock price (and, thus, less shareholder value) and lower financial indexes, as ROA and ROE, due to several kind of possible problems (e.g. poor quality, long LT, bad financials, logistics, geopolitics).

In 2018 an attempt of formalization of this analysis was conducted by *Enrico Merli*, mechanical components senior buyer in *Rosate*, and *Massimiliano Poletti*, external consultant and collaborator of the *PF*'s purchasing departments. They started working on this project because one of the objectives highlighted by the management in the previous final year meeting was to decrease the overall firm risk. However, it was never really launched: only a blank file exists, without any supplier involvement or evaluation.

Now, with one more human resource available (i.e. the mechanical components junior buyer) there is the possibility to recover this activity and create an ex-novo instrument that can help mapping the supply risk in a more complete and easy way. This is very important also because volumes are increasing and the risk of a disruption can have higher consequences: with higher quantities to deliver on the market, suppliers have higher volumes too and if one of them fails, the economic consequence is larger. It's very important to consider also the fact that most of the components bought by *PF* are not commercial ones, but they are made from drawings developed by the R&D or by the technical department of the firm. So, switching costs necessary to change a supplier are not negligible: scouting, agreements, *BIF* obtaining, trial orders are only few of the possible elements that can increase costs and lead times necessary to access the supply. This is something that *PF* cannot afford, even more in a period (i.e. after the *Covid-19* crisis in 2020) where the production is under constant pressure due to the production and supply stoppages occurred during the lockdown.

Covid-19 pandemic is the clearest example that testifies how much being resilient should be a key priority for nowadays companies.

5.2 FMEA

FMEA (Failure Mode and Effect Analysis) is a well formalized and documented technique for an accurate analysis of the causes of potential failures that may incur in products or systems. It was first developed by the US military industry in 1949 and then implemented also by *NASA*, *Ford*, *Toyota* and many other firms to prevent accidents into products and processes. It is a risk management tool able to conduct a cause-effect analysis with the goal of preventing failures, building a more robust system without potential causes of issues. It has a both preventive and proactive approach that is very structured. The steps to be followed are the following:

1. Identify the failure mode, that is the manner in which an item could potentially fail in meeting requirements;
2. Identify the effects, that are the possible negative consequences that customers can bear if a failure happens;
3. Estimate risk associated with a specific cause that can generate a failure mode;
4. Evaluate current process plans or design validation plans;
5. Prioritize actions to take to a reduction of risk on the basis of the Risk Priority Number (RPN).

The approach is vertical and considers both qualitative, quantitative and corrective phases. In the preliminary stage possible risky areas and relative causes are described in a qualitative way, thanks to some useful tools (e.g. Ishikawa diagram). Then, to every possible risk is associated a number. For each element level of occurrence (O), severity of the impact (S) and detectability (D), (i.e. the ability to identify failure modes and to control the system), have to be computed. Once this calculation is done, the product of these three elements is the Risk Priority Number (RPN). It is able to provide a critical ranking to the various modes and, as a consequence, to prioritize possible interventions.

$$RPN = O \; x \; S \; x \; D$$

The last phase is the corrective one and regards the developing of recommended action to mitigate or eliminate risks. The process is iterative: once the actions are executed, it starts again and RPN's components are computed one more time. The result is a set of new RPNs, able to provide new priorities for different risks.

As previously stated, FMEA model is a risk management tool and can be adapted also for purposes different from the correct running of machines. In this case, it inspired the development of an instrument that can measure and analyze *PF* supplier risks. Despite detectability was never kept in considerations by the company, each factor was quantitatively computed and put into the priority number. Some names have been changed: occurrence is now called probability (P) and severity is called magnitude (M). The result of the multiplication of the three factors is the KRI (Key Risk Indicator), that identifies riskiness degree and prioritization of de-risking actions to complete.

$$KRI = P\ x\ M\ x\ D$$

5.3 Risk causes identification

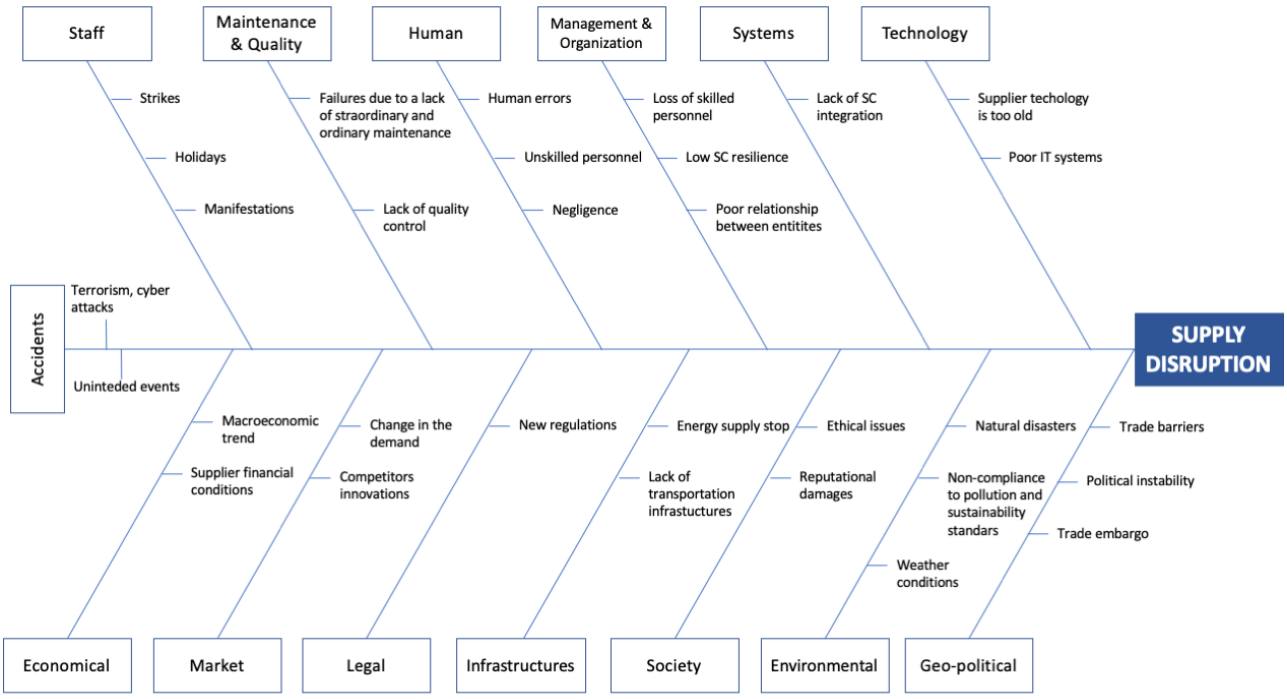

***Figure 26**. The Ishikawa fishbone diagram that shows all the main possible causes of supply disruption risks.*

The first step to do in the qualitative phase of the FMEA approach is certainly to understand which are the possible causes that can generate a supply discontinuity. A very useful tool can be the cause-effect diagram of *Ishikawa* (*Figure 26*), called also fishbone due to its shape. *Kaoru Ishikawa* (1915-1989) was a Japanese guru that gave a large contribution in the quality revolution in place in his country after the second World War. In 1982 he developed the fishbone in order to analyze root causes of machine breakdowns and defects in production processes, but it can be adopted for quite every kind of potential risk. It is a graphical representation of a list of possible causes of an issue clustered in different nodes, that can assist people during the investigation of this problem.

After an analysis conducted on the company and on context in which it acts, it was possible to identify the main clusters of risks that can lead to supply disruptions. They can lie into *PF* supply chain boundaries (i.e. human factors, staff issues, management & organization, technology, maintenance & quality) or they can be external (i.e. economical, legal, market, geo-political, environmental, societal, infrastructures related issues). If a risk lies into supply chain boundaries, it means that it regards directly issues born into the company or in one of its suppliers. An external one, instead, does not depend directly on them. There are also some possible events, (e.g. terrorism, cyber-attacks, unintended events), that are difficult to classify into one of these categories, because they can belong to both of them.

5.4 Magnitude assessment

Magnitude represents the size of the impact that a risky event can create. It usually corresponds to the operative cost coming from the interruption of the supply and considers:

- Operative cost increase, due to purchasing cost, poor quality or working capital;
- Una tantum investments needed, for example, to search and activate a new supplier or for transferring machineries and tools;
- Consequences on sales as stock-out, discounts, delays and reputational damages that can take to loss of customers.

However, considering the monetary impact is quite complex, because it requires not available data. In fact, the increase in the purchasing cost or the percentage of poor quality of the new vendor are possible to be identified only once the agreement is reached and once the supply is started. Not knowing who the new supplier will be, it is not possible to assess if there is the necessity to do una tantum investments too. Finally, to understand consequences on revenues, the price of a finished product must be known, but prices are not fixed because they can change in order to win auctions and tenders. Moreover, it is necessary to assess the probability of losing a customer.

Therefore, the monetary impact is not considered in the analysis performed in *PF*. Parameters that are considered are the following:

- Time needed to substitute the existent with a new supplier. It starts with the understanding of the need and comprehends every activity until the receiving of the order (i.e. specification definition, market identification, scouting, vendor qualification, product qualification, order emission, lead time). It's fundamental to consider also the inventories kept along the supply chain (e.g. in the firm warehouse, in the third-party logistics provider warehouse, in transit

stocks, sub-supplier stocks, supplier warehouse stocks). So, it is the sum of the time needed to perform the first set of activities less the stock coverage. It is the most important factor, because it shows how many days the production would be stopped. Time to recover can vary also depending on the capacity of the new vendor to assure quality and quantity standards. It strongly depends by the purchasing category provided by the supplier.

- Incidence of components provided by a supplier at finished product level, so, a percentage representing in how many products a single component is used. As this value increases, magnitude is higher, because number of products that cannot be produced increases. One possible solution is certainly to manufacture something else in the meanwhile, creating some inventories, but, in a lean and pull environment as *PF* one, it is not coherent with firm philosophy. It analyzes the impact looking at the product level. It is computed looking at in how many final product's bill of materials a component provided by a supplier is. In case of more than one component provided by the same supplier, the value to be considered is the maximum one, because it represents the heaviest bottleneck.
- Procurement mix. It analyzes the starting procurement approach (i.e. single, multiple, dual, parallel sourcing) and represents the percentage of how many items of the same code are purchased from a single vendor. In case of single sourcing, this percentage is equal to 100% and it is the high impact situation, because it means that the supply interruption is total.
- Maximum average procurement mix of the alternative supplier. Starting from the procurement approach, it analyzes the maximum procurement mix that the alternative supplier can bear in case of a supplier disruption. Higher the value, lower the risk. Obviously, if an alternative vendor does not exist (i.e. single sourcing), this percentage is 0% and magnitude is higher. In case of different components provided, percentage to be chosen is the minimum, because it represents the heaviest bottleneck. In case of more than one alternative vendors, instead, the value to be chosen is the sum of them. The maximum procurement mix reachable can vary according to the free production capacity of the vendor, so it is necessary to consider the average value.

In order to perform this analysis, a questionnaire to be filled by the buyer in the qualification process was developed on a *Microsoft Excel* spreadsheet (*Annex 5*). The approach followed is the weighted point plan: each term has a given weight in accordance to corporate and purchasing strategy and the sum of these terms gives a global evaluation on the magnitude of a supply disruption of the analyzed supplier. Each element is evaluated according to a specific transcoding table that

associates a value from 1 to 5 for each possible answer (*Table 2*). The final score is included between 1 and 5, where 1 means very low and 5 means very serious impact. It is useful to give priorities to actions aimed at reducing risk of vendors that can bring to the company the highest damages in case of a supply interruption.

MAGNITUDE	WEIGHT	1	2	3	4	5
How many days to substitute the old with a new supplier?	40%	0 days	1-15 days	16-30 days	31-60 days	61+ days
Incidence on finished products	10%	0-20%	21-40%	41-60%	61-80%	81-100%
Percentage of the procurement mix of the evaluated supplier	25%	0-20%	21-40%	41-60%	61-80%	81-100%
Max average percentage of the procurement mix of the alternative suplier	25%	81-100%	61-80%	41-60%	21-40%	0-20%

***Table 2**. Magnitude assessment's transcoding table.*

5.5 Probability assessment

Risk always implies probability, that is the extent to which something is likely to happen. In the model, it is considered as the likelihood of occurrence of a supply interruption of a certain vendor. The evaluation regards four different drivers (*Table 3*): source, supplier organization, product-process and contract risk. As in the magnitude assessment, the weighted point plan approach is followed and a score from 1 to 5 is assigned to each factor considered, where 1 means very low probability and 5 means high likelihood of occurrence. The mode chosen to investigate it is an *Excel* spreadsheet questionnaire (*Annex 6*).

RISK SOURCE	AREA	PARAMETERS	PARTIAL WEIGHT	AREA WEIGHT
Source	Country	Political risk SACE	2,5%	20%
		Credit risk SACE	2,5%	
	Market/purchasing category	Purchasing constraints	15%	
Supplier organization	Firm risk	Firm risk questionnaire	15%	40%
	Economical dependance	Revenues	10%	
	Financial risk	Cerved Group Score	15%	
Product/Process	Quality	Questionnaire Product/Process Risk	30%	30%
	Service level			
	Delivery capacity			
Contract	Orders-CGA-DSRG	Contract analysis	10%	10%

***Table 3**. A table showing probability drivers considered in PF risk assessment and their weights.*

5.5.1 Source risk

The first probability driver is related to the source of origin of the vendor. It considers both its geographical provenience and its belonging market. In the first case, the country analyzed is the one in which production is done and not the one with the legal headquarters. Foreign customers' and

suppliers' reliability depends heavily from economic, financial and political situation of their countries. This evaluation is done through two parameters: political and credit risk. The first one is related to every kind of non-economic event linked with political factors (e.g. conflicts, government policies, political instability). The second one, instead, is the risk that the foreign counterparty is unable or unwilling to honor its obligations under a commercial or financial contract.

The recent past is a clear testimony of how companies, especially those operating beyond national borders, are continually urged to react to events that are beyond their control: Brexit vote in 2016, US exit from the Trans-Pacific Partnership Agreement in 2017, tariffs war between China and US in 2019; *Covid-19* reactions in 2020. These are just a few examples that have forced firms to review and update their strategies on the market in recent years. It is important to monitor these risks and rely on a trusted entity capable of facilitating companies to consciously orient themselves on international markets. The entity chosen is *SACE SIMEST*, an Italian group owned by the ministry of the economy specialized in supporting the global growth of firms. Through synergies between different competences in assurance and financial services, they are able to guide Italian companies in market choice and management of linked risks. For both risks, *SACE* assigns a score between 0 and 100, where higher the score, higher the risk. Then, this value is transformed into another one more coherent with the model through a transcoding table (*Table 4*). Credit risk is computed as the average between the probability that a bank, government or corporate counterparty does not pay its obligations. The political one, instead, is the average between conflicts and civil disorders risk, expropriation and contractual violation risk and restrictions on currency transfer and convertibility risk.

COUNTRY RISK	1	2	3	4	5
SACE credit risk	0-20	21-40	41-60	61-80	81-100
SACE political risk	0-21	21-41	41-61	61-81	81-101

Table 5. *SACE country risk transcoding table.*

COUNTRY RISK	SPAIN	LIBIA
Bank counterparty does not pay its obligations	41	100
Government counterparty does not pay its obligations	28	100
Corporate counterparty does not pay its obligations	41	100
SACE credit risk	**37**	**100**
Conflicts and civil disorders risk	30	96
Expropriation and contractual violation risk	38	94
Restrictions on currency transfer and convertibility risk	1	92
SACE political risk	**23**	**94**

Table 4. *Examples of the computation of SACE political and credit risk.*

If country risk of a certain supplier is high, the likelihood of incurrence in an interruption of its flow is higher, because there is a high probability that it has no access to credit from banks or government or that some political troubles can delay or stop production or transportation. Looking at the market of belonging of vendors, instead, is important in order to understand risks connected to purchasing categories. In order to analyze them, purchasing constraints are evaluated. A list of internal and

external constraints is set and the buyer has to give a score (i.e. a value among 1, 3 and 5) to each of them, on the basis of the correspondence between each value and the desired answer (*Table 6*).

MARKET RISK			
EXTERNAL CONSTRAINT FROM THE EXTERNAL MARKET	1	3	5
Presence of agreements on the market	No	Cartel	Monopoly
Is demand higher than the offer?	No	Sometimes	Yes
Does the supplier have speicific know-how or patent?	No	Know-how	Patent
Does the customer impose the supplier?	No	Suggested	Yes
Should the supplier be near to the company?	No	Suggested	Yes
Is technology in rapid evolution?	No	Slow	Yes
Does a technological monopoly exist?	No	Oligopoly	Yes
Does the supplier ask for minimum batches of production?	No	Not binding	Yes, binding
Is product life-cycle binding?	No	Could become	Yes
Does the supplier need a specific technology?	No	Not specific	Yes
Are laws binding?	No	Yes, not binding	Yes, binding
Is political or social protection needed?	No	Social	Social and political
Does cultural differences exist among company and supplier?	No	Yes, negligible	Yes, binding
Should the supplier be flexible?	No	In production mix	In mix and volume
Are investments required to access the supply?	No	Restrained	Yes
INTERNAL CONSTRAINTS FROM PIETRO FIORENTINI	1	3	5
Is the Supplier and the Purchase Policy imposed by Pietro Fiorentini?	No	Suggested	Yes
Does the Supplier believe that PF specifications and tolerances are overestimated?	No	Medium	High
Are the required lead times short?	> 3 months	1-3 months	< 1 month
Is the examined Supplier imposed by the PF internal organization?	No	Technical dep.	Yes
Is there a lack of product knowledge and lack of know-how on the part of PF?	No	Purchasing dep.	Purchasing & technical dep.
Are the Purchase Specifications clear and comprehensive?	Yes	Not clear	No
Are Specific Certifications Required?	No	Not binding	Yes
What is the estimated time required for supplier activation?	< 1 month	1-3 months	> 3 months
Does the purchased product(s) have a corporate secret?	No	Disclosable	Undisclosable
Is the required quality level higher than what the market offers on average?	No	Within the average	Higher than the offer
Do control tools exist (quality, price drift, performances)?	Yes	Not formalized	No
Do heavy amministrative procedures exist?	No	Some	Yes
Who has the bargaining power?	PF	Par	Supplier
Internal communication level	Adequate	Not adequate	Not existent
Is there a preliminary technical commitment (support) from the supplier?	No	Low	High

Table 6. *Internal and external purchasing constraints selected and the respective transcoding correspondences.*

Higher the value, higher the probability of a risky event happens. In fact, purchasing constraints limit the freedom in the purchasing choice and, thus, with less options available, there are less (if any) alternative possibilities that can help a company in reducing the probability of a supply disruption. A clear example is the monopoly one: if only one supplier has what a firm needs, risk associated is high, because only one vendor failure is enough to completely interrupt the supply. So, probability is higher than when there is more than one supplier available on the market. Another perspective regards some actions to follow to respect these constraints. In case of, for example, compliance with binding laws, cultural differences, needed support or confidentiality of projects, some actions (e.g. do not divulgate projects, help the part that need support, try to talk the same language, try to understand and solve the possible cultural differences) have to be done both from the vendor and from the company, in order to align requirements and results. If these actions are not done, the likelihood of occurrence of a supplier disruption is higher.

Only the four internal and the four external constraints with the highest score are then considered to assess the final market risk. It is calculated as the sum of the risk associated with the selected internal and external constraints. Only the best four per category are chosen because only few

heavy impediments are needed to have a high probability of a supply discontinuity. Thus, considering also the lower risks when there are some heavy impediments could decrease the risk value. The minimum value of the market risk is 20, because per each category of risk the four highest scores are multiplied from the highest to the lowest respectively per 4, 3, 2 and 1. So, in case of no binding constraints (i.e. every parameter has a score of 1), the result is equal to 10 per each category and their sum is equal to 20. Consequently, the transcoding table starts from this value (*Table 7*).

MARKET RISK	1	2	3	4	5
Market risk	20-38	39-59	60-75	76-90	91-100

Table 7. *Market risk transcoding table.*

5.5.2 Supplier organization risk

Another important probability driver is related with supplier organization. The objective of the questionnaire is to assess if conditions to guarantee the business continuity exist: if a vendor has a well-structured organizational chart and well-defined procedures, its likelihood of incurring in failures or discontinuities is lower. Obviously, if a supplier can assure its business continuity, risk connected to a its commercial relationship is lower. In order to do this analysis, a questionnaire investigates four areas: organizational chart, quality, safety and environment systems (*Table 8*).

SUPPLIER ORGANIZATION RISK	WEIGHT
ORGANIZATIONAL CHART	**50**
Managerial, familiar or single owner organization?	10
Presence of commercial, technical, quality, production directors	10
Indirect/direct employees ratio	8
Age and fidelity of employees analysis	8
Historical firm	7
Innovation capabilities	7
QUALITY	**30**
Certification ISO 9001	10
Well defined control structure	12
Procedure from Pietro Fiorentini are really implemented?	8
SAFETY	**12**
Certification BS OHSAS 18001	10
Procedure are really implemented?	2
ENVIRONMENT	**8**
Certification ISO 14001/EMAS	7
Procedure are really implemented?	1
	100

Table 8. *The list of drivers analyzed In the supplier organization risk and their relative weights.*

The organizational chart is the most important factor because it determines the vendor structure and how it is directed. If the firm has a managerial organization, its risk is lower because it does not depend by one single person. At the same time, presence of indirect employees and directors in commercial, quality, technical and production field assures that the vendor has a proper structure.

While the age of the company can demonstrate its past trend continuity, age and fidelity of employees show the future one. Moreover, its innovation capabilities should be assessed in order to being sure that it will not go out of the market when technology will change.

The second most important driver is the quality-related one, because *PF* is a lean manufacturer that pursues a TQM approach. Quality problems can cause production stoppages that can be detrimental for *PF*. Thus, the importance of having the *ISO 9001* certification and a well-defined control structure is high. In addition, very often *PF* provides to vendors some special quality procedures that should be followed to guarantee qualitative components and to reduce the control checks in the assembly phase.

Finally, safety and environmental system are analyzed. If safety policies are not adopted by the vendor, some issues related, for example, to the health of workers can arise and create production stoppages and delays for *PF*. Despite its increasing relevance, the environment field has a lower consideration in *PF* and it is looked at only for big disruption cases.

The buyer can give a score from 1 to 5 to each driver. In order to be as much objective as possible, to each value corresponds a precise answer (*Annex 7*). Then, considering the relative weights, the final value of supplier organization risk is computed and transformed again into a value between 1 and 5, as showed by the transcoding table (*Table 9*).

SUPPLIER ORGANIZATION	1	2	3	4	5
Supplier organization risk	20-30	31-45	46-60	61-80	81-100

Table 9. *Supplier organization risk transcoding table.*

However, this kind of analysis is not enough, because it does not consider the financial perspective. It has to be done in two ways. The first looks in an absolute way to financials of the vendor, the second one, instead, put in relationship its revenues with the money that *PF* gives him, defining the dependance degree. Assessing the supplier financial risk is complex, time consuming and requires specific skills, so, this activity is outsourced to a third-party entity, that is the *CERVED* group. It is a primary Italian operator in analyzing the credit risk of companies and one of the main credit rating agencies in Europe. Among its offered services, *CERVED group score* is the one considered in this model. It is a value representing a quantitative, statistical and automated evaluation of historical information as balance sheets, industry, payment habits regarding a

FINANCIAL RISK	CERVED group score	Reliability degree
1	83-100	Maximum
1	73-82	High
2	63-72	Good
2	53-62	Medium
3	42-54	Moderate
3	35-41	Limited
4	25-34	Low
5	0-24	Non reliable

Table 10. *Correspondences between reliability degree and CERVED group score and related transcoding table.*

single firm. It considers and integrate the evaluations of each informative area (i.e. financial situation, negative events, legal pending, payment terms, risk perceived by the market, structure, real estate consistency). It is useful to understand the reliability of a company, its capacity of paying its obligations and the evolution of its risk of default. Its value is between 0 and 100 and correspond to several judgements on the reliability of the financial stability of the vendor (*Table 10*). Then, this value is translated as always into a score between 1 and 5 according to the transcoding table (*Table 10*).

As said before, the second parameter to evaluate in the financial analysis is the dependance rate between a vendor and the company. The dependance rate (DR) can be computed as:

$$DR = \frac{sales\ of\ vendor\ i\ to\ buying\ company\ j}{total\ sales\ of\ vendor\ i}$$

It measures the risk of a supplier being dependent from a single buying company. Its value lies between 0% and 100% and shows how much the revenues of a vendor depend on a single customer. If this value is high, the risk of the vendor is high too, because in case that the customer fails or does not want any more to buy from him, the vendor loses high part of its revenues. Thus, the probability of incurring in a supply disruption increases. Once computed the DR, a score from 1 to 5 is assigned to this voice of the model through a transcoding table (*Table 11*).

FINANCIAL RISK	1	2	3	4	5
Dependance Rate	0-10%	11-20%	21-35%	36-50%	51-100%

***Table 11**. Dependance rate transcoding table.*

5.5.3 Product/Process risk

Suppliers per se are not the only one possible source of risk, but products they deliver and processes they follow are that too. The probability of an interruption of the flow increases as those factors are not properly controlled. So, a proper analysis that considers several elements (i.e. machines, control checks, materials, homologations, tools, training, maintenance, production management) has to be done (*Table 12*).

	TYPES OF PURCHASES			
PRODUCT/PROCESS RISK	A = direct from drawing	B = direct commercial	C = indirect	D = services
FLEET OF MACHINES	19	0	0	24
Machines age	3	0	0	0
Level of adequacy of machines and instrumentation	5	0	0	12
Machines census	3	0	0	0
Management/maintenance plan for equipment and machines	4	0	0	12
O.E.E. (Overall Equipment Effectiveness)	4	0	0	0
Availability = gross operating time/net operating time	X	-	-	-
First three causes of machine stop	X	-	-	-
Efficiency= (theoric cycle time * volume) / gross operating time	X	-	-	-
Quality = (total production volume - defective production volume) / total prouction volume	X	-	-	-

CHECK IN ACCEPTANCE	**16**	**31**	**32**	**0**
Does the Supplier use 2-tier suppliers?	3	6	7	0
Does the supplier adopt a vendor rating system?	4	8	7	0
Does the Supplier have an incoming quality control system?	5	9	11	0
Are incoming non-compliant materials segregated?	4	8	7	0
MATERIAL IN WORK ACCOUNT (CONTO-LAVORO)	**4**	**0**	**0**	**0**
Is the material provided by Pietro Fiorentini managed correctly and easily traceable?	4	0	0	0
CONTROL OF THE PRODUCTION PROCESS	**20**	**18**	**7**	**12**
Is there a control plan indicating all the activities and phases of the process?	5	9	7	12
When are the checks carried out?	5	9	0	0
How are the checks carried out recorded?	5	0	0	0
Are non-conformities collected and analyzed?	5	0	0	0
PRODUCT CERTIFICATIONS	**3**	**8**	**8**	**8**
Is there a specific product certification?	3	8	8	8
TOOLS, TRAINING AND MAINTENANCE	**13**	**0**	**0**	**24**
Is there an instrument control and calibration plan?	5	0	0	12
Do the personnel performing product quality activities have a specific training plan?	4	0	0	12
Is there a scheduled maintenance plan?	4	0	0	0
MANAGEMENT OF PLANNING AND PRODUCTION PROGRAMMING	**25**	**43**	**53**	**32**
How are Lead Times (LT) determined?	5	9	11	10
How is the confirmation of production / delivery dates managed?	5	9	11	8
How is production planning done?	5	8	10	8
How is the progress check done?	5	8	10	6
How are warehouse stocks managed?	5	9	11	0
	100	**100**	**100**	**100**

Table 12. *Product/process risk probability drivers and their weight relative to the type of purchasing.*

Looking at the fleet of machines, parameters to be evaluated are their age and their level of adequacy and maintenance. More they are old and not kept in the best way possible, higher the probability to incur in a production stop and, thus, in an interruption of the supply. If the vendor shares the machines census, there could be the possibility to better plan the orders, helping both parties. Another important KPI is surely the O.E.E. (i.e. Overall Equipment Effectiveness) that identifies the percentage of manufacturing time that is truly productive. Higher this value, higher the quality of the production and lower the likelihood of occurrence of a disruption. However, some not well-structured supplier could not know what O.E.E. is, so, in the questionnaire given to them, there is also the possibility to compute it starting from its component. The O.E.E. is given by

$$O.E.E. = Availability\ x\ Quality\ x\ Efficiency$$

where

$$Availability = \frac{Gross\ Operating\ Time}{Net\ Operating\ Time};$$

$$Quality = \frac{Total\ Production\ Volume - Defective\ Production\ Volume}{Total\ Production\ Volume};$$

$$Efficiency = \frac{Theoric\ Cycle\ Time\ x\ Total\ Volume}{Gross\ Operating\ Time}.$$

Usually, world class manufacturers have an O.E.E. equal or higher to 85%. According to this, the transcoding table has been developed (*Table 13*).

PRODUCT/PROCESS RISK	1	2	3	4	5
O.E.E.	100-85%	84-70%	69-50%	49-25%	24-0%

Table 13*. The transcoding table for the O.E.E. computation.*

Even if they are not considered in the final score computation, also the first three causes of machine stoppages are investigated, in order to understand where issues can arise and, eventually, to support the supplier in some improvement actions.

Then, it's important to do control checks, both in acceptance and during the production process. In the first case, an entry quality control system must exist to decrease the risk of passing in next stages of the chain defective pieces. For the same reason, non-compliant materials have to be segregated, identified and, possibly, this fact has to be communicated to their vendor. In fact, suppliers can have suppliers too, providing, for example, raw material or components: this is the so called 2-tier of the chain. As *PF* does for the tier-1, suppliers should perform a proper vendor rating to have assurance about quality, reliability and security of tier-2. Sometimes, materials are received from *PF* in work account (i.e. *conto-lavoro*) and they always should be easy to trace and be identified.

Regarding checks done during the production, first of all it is important to understand if a proper plan exists. Then, the company should know where and how they are conducted. The ideal situation consists in checks done both during and at the end of the process, in order to assure quality all along the flow and better understand where problems arise. In addition, automation enhances security of data gathering. After data collection, firm should analyze them and develop action plans.

Production is carried out thanks to tools and people, so, they should be "updated" in order to maintain it stable and qualitative. People should be trained and instruments should be maintained and calibrated. In this way, probability of issues rising is lower.

Sometimes products can be certified for several reasons (e.g. regulations, customer willingness). If certifications and homologations exist, risk connected to products is lower because a third entity has already performed checks on it.

Finally, planning the production is a key element to secure supplies. Probability of disruptions decreases as involvement of technology increases, because it makes processes easier. It can be used in production planning, definition of lead times, stock management and progress checks. Lead times should theoretically be defined considering the real production capacity and considering all possible stages (i.e. time needed to have materials, time spent in queue, cycle time). Communication of delivery dates has an important role too, allowing to better coordinate the two entities. Better planning, less possibilities to incur in lack of deliveries and in production stoppages.

As shown in *Table 12*, there are different purchasing typologies with different characteristics (i.e. direct purchases from drawing, commercial direct purchases, indirect purchases, services). In order to evaluate suppliers, a different questionnaire for each of them is developed. Direct purchases from

drawing are the most complex category and every parameter is analyzed. Suppliers that provide this kind of items are generally partners and a broader evaluation has to be done. Commercial ones, instead, are standard products usually kept in stock by the producer (e.g. screws), so, what really matters regards the quality of the products and the ability to plan production and delivery to never miss orders. Therefore, the customer firm does not care about machines, tools, efficiency, training of people and production checks. The same reasoning can be done for indirect purchases: the firm cares only that the vendor is able to fulfil the orders in every moment and that quality is aligned with agreements. Finally, a different approach has to be followed to evaluate services (e.g. maintenance of equipment, cleaning). In fact, here people and tools assume a relevant role, thus, each parameter regarding them has to be considered. Planning remains important, especially regarding punctuality and lead time estimation. Apart from having a control plan across all the steps of the process, the firm does not care about the other control checks done by the service provider. Weights for each parameter are different too, because a different number of questions alters them and because for different kind of purchases, relative importance of each element changes.

It is possible to evaluate each question with a value from 1 to 5 that corresponds to a precise answer (*Annex 8*). The final score is given by the weighted sum of each voice. Then, through an adequate transcoding table (*Table 14*), it is transformed into a value between 1 and 5, where 1 means that there is a low likelihood of occurrence of a supply disruption linked with vendor's products and processes and 5 means that it is high.

PRODUCT/PROCESS RISK	1	2	3	4	5
Product/process risk	20-30	31-45	46-60	61-80	81-100

***Table 14**. Product/process risk's transcoding table.*

Theoretically, the best way possible to investigate product and process risk is to perform an audit, following the lean concept of *genchi genbutsu*, that consists in going in the supplier plant and looking in person what is happening. However, especially in the *Covid-19* period, it is not so easy. Therefore, this part became a self-evaluation questionnaire sent to each vendor. In this way, time and resources are saved, but there is possibility of vendor biases.

5.5.4 Contract risk

Theoretically contracts are legal constraints intended to be enforceable by law. As contract completeness increases, risk decreases, because binding agreements are signed and, if they are not respected, the damaged party can be compensated. However, very often buyers are not expert in

this field and related legal expenses are quite high. Thus, it is not rare to have incomplete contracts. In *PF* there are mainly three kind of documents to be signed from both the parties: *CGA*, *DSGR* and order confirmations. The firsts have to be signed only once. However, very often they are not signed because of their rigidity: many vendors try to modify some elements and many others simply do not sign them. Theoretically, *CGA* are mandatory to start the supply, but it does not always happen. They represent one of the main contracts risk, because, if not signed, the supplier has not agreed supply conditions and *PF* is not protected by any kind of opportunistic behavior of the vendor.

The most important document to be signed is the *DSGR* one. Basically, it is a declaration of the supplier to not be a criminal. In Italy, it is out of law to have deals with criminal people and companies, so, it is very important to be protected against possible legal issues. They have to be signed annually. Finally, the sign of order confirmations is the less critical document, because its absence is usually due to a lack of coordination. In fact, *PF* sends the order to the supplier that has to sign it and send it back. However, very often suppliers do not send back the original orders signed, but new different documents emitted by them.

Obviously, the most dangerous situation is when none of these documents are signed, because there is no legal protection and, thus, the probability of incurring in a supply disruption are higher. On the other hand, having every document signed is the more secure situation. A set of different combinations and the relative scores from 1 to 5 to assess the contractual risk are defined (*Table 15*).

CONTRACTUAL RISK			
	CGA	DSGR	ODA
1	1	1	1
1	1	1	0
2	0	1	1
2	0	1	0
3	1	0	1
4	1	0	0
5	0	0	1
5	0	0	0

Table 15. *Contractual risk matrix and its relative transcoding criteria (1= yes, 0=no).*

5.6 Detectability assessment

Detectability is the ability to control the situation, detect possible causes or preventing failures. In the model described, it focuses on the capability to understand magnitude and probability of a certain supplier disruption. It depends by two drivers. The first one is the level of market knowledge. It considers various aspects as number of suppliers knew, raw materials and technology used, processes, regulations, possible alternatives and all those things that allow a buyer to be reactive in solving possible problems that can arise. It is very important in assessing, for example, the number of days needed to substitute the old disrupted vendor with a new one or in the evaluation of the purchasing constraints relative to a certain purchasing category.

The second one, instead, is the level of collaboration between the company and the supplier. More a vendor shares information regarding its processes, organization and products, more the customer can detect possible issues. In addition, in this way the customer can support the supplier in developing risk mitigation strategies that can secure a stable supply. If the level of collaboration is low, for example, it is hard even to fill the product/process risk questionnaire in the probability assessment and, thus, a not complete risk evaluation can be done. Moreover, collaboration level shows the strength of the relationship: partnership solidity decreases the likelihood of occurrence of flows interruptions. As always, for each driver a score from 1 to 5 has to be submitted in the detectability questionnaire, following the appropriate transcoding table (*Table 16*).

DETECTABILITY	WEIGHT	1	2	3	4	5
Market knowledge	15%	High	Medium-high	Medium	Medium-low	Low
Level of collaboration	85%	High	Medium-high	Medium	Medium-low	Low

Table 16. *Transcoding table for the detectability assessment and weights of each detectability driver.*

Even here, a weighted point plan is followed and a weight is given to each driver. Market knowledge has a lower weight because, usually, a buyer should have this kind of knowledge in order to perform well his job. Moreover, there is the possibility of a buyer bias: he can lie because he does not want to reveal some lacks of knowledge. Level of collaboration, instead, has a bigger impact, because it depends by something that is more measurable and less affected by possible biases.
Finally, the result is a score from 1 to 5, where 1 means that is easy to detect possible issues and to collect information and 5 means that it is very difficult.

5.7 Weight definition

The approach chosen for the risk value computation is the weighted point plan. It needs a proper definition of weights. Several models were analyzed, in particular the Analytic Hierarchy Process (AHP), a multicriteria decision support technique developed in the 1970s by *Thomas L. Saaty*. It allows to prioritize the highest value in a certain scenario pursuing team results aligned with company goals; thus, it can be a good method for the weight definition. However, it is a complex and time-consuming methodology, useful to understand weights of different criteria starting from an existent answer of some actors. Having only two possible actors to be involved in the project was probably too less to develop this kind of computation. Moreover, time available was quite stringent. So, the decision was to select some weights (*Table 2*, *3, 8* and *12*) on the basis of the experience of the people involved in the project. Not being the result of an analytical computation, this choice

leaves also some degree of freedom in personalizing the weights on the basis of the needs of the company in a precise moment or on the basis of the different purchasing categories.

5.8 Final risk evaluation

After having defined how to compute magnitude, probability and detectability, it is necessary to compute the KRI and to analyze the results. First of all, the KRI is a number between 1 and 125. In fact, the result of the analysis of its components is always a score between 1 and 5, where 1 means low risk and 5 means high risk. This range is constant in quite every section of the model, in order to increase the uniformity and the easiness in filling it. Consequently, values assessing the riskiness of a supplier follow the same scale. A proper transcoding table is created in order to prioritize the actions to do in order to decrease vendors' risk (*Table 17*). Obviously, higher value, higher priority.

KRI	Risk degree	Strategy
0-5	Not risky	Do not act
6-15	Acceptable risk	Develop contingency plans
16-24	Medium risk	Develop actions in the long run
25-50	High risk	Try to mitigate the risk
51-125	Very high risk	Intervene istantaneusly with risk avoidance actions

***Table 17**. Correspondence between KRI and strategies to be implemented.*

In order to classify suppliers in a better way, a 3-axis matrix was developed (*Figure 27*). It allows to define a proper strategy for each category identified. Axes represent magnitude, probability and detectability scores.

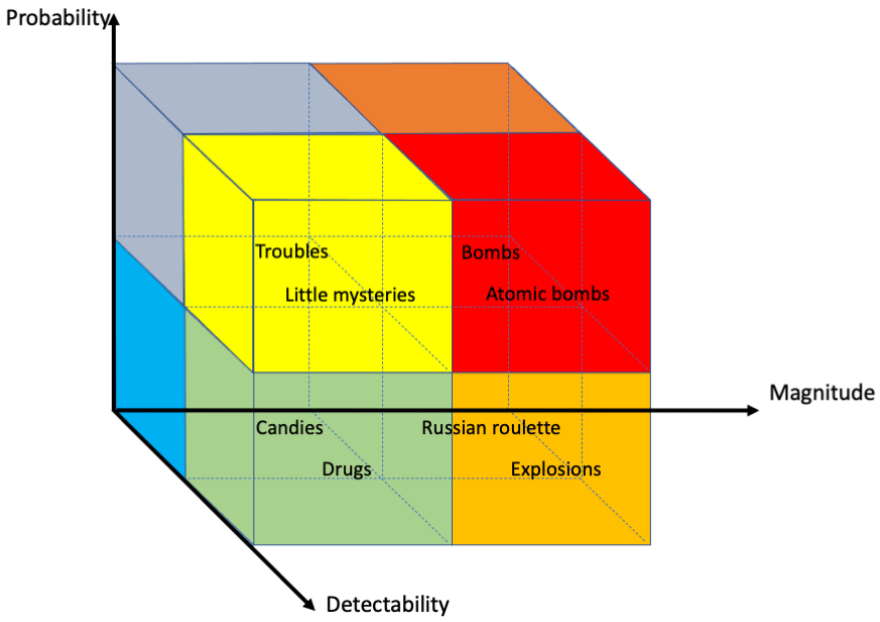

***Figure 27**. 3D KRI matrix showing the classification of suppliers on the basis of their KRI components.*

Therefore, vendors can be divided in the 8 following categories:

- *Candies*. Ideally, every supplier must be positioned in this category. Their eventual disruption has a low magnitude and a low likelihood of occurrence. Moreover, it's easy to retrieve data and detect possible issues. None actions have to be developed for this kind of vendors.
- *Drugs*. An interruption of their flow has a low probability and a low magnitude, but it is difficult to detect eventual issues. They are not very dangerous, but some simple actions aimed at increasing the relationship with the vendor or the market knowledge can be done. It is possible to act on contracts in order to force the vendor to collaborate. However, the difficulty to retrieve data can bring to a wrong evaluation of the other two parameters, so, it is always better to develop some contingency plans to apply in case of emergency.
- *Troubles*. Suppliers with high probability of incurring in an interruption of the flow, but with low magnitude and easy detectability. Probably, if severity of an eventual disruption is low, time needed to substitute the vendor is low. Thus, if the actual one guarantees exceptional conditions (e.g. price, quality, service level), it's possible to keep it without intervene or developing some actions aimed at increasing the control of their processes, thanks to quality inspections, technical support, certifications. Having insurances policies can mitigate the risk too. Alternatively, if the vendor doesn't provide any kind of competitive advantage, it may be quite easy and quick to substitute it with another one with a lower likelihood of failure.
- *Little mysteries*. Vendors which eventual interruption of flow has a low magnitude, but high probability. Moreover, it is also difficult to detect. Here, the reasoning is similar to the troubles' category. If the supplier guarantees a competitive advantage to the company, the best option is to try to develop a partnership relation able to increase the easiness of retrieve data and identify possible issues or supporting the vendor in increasing the quality and the control of its processes. Alternatively, it may be quite easy and quick to substitute it.
- *Russian roulettes*. Suppliers that have low likelihood of incurring in an interruption of flows, but a high magnitude value. Detectability is easy. They do not represent an actual issue, because of their good level of collaboration and because they seem very stable and solid companies. However, it's always better to keep them under control in order to prevent possible variation in the probability value. Some actions can be implemented in order to decrease the magnitude value (e.g. increasing the inventories), but without urgency.
- *Explosions*. They are very similar to Russian roulettes' vendors, but with more incertitude. In fact, in the Russian roulette game, risk is represented by a gun. Instead, in an explosion, it

can come from several sources (e.g. fire, shock wave, smoke, flying debris). In the same way, suppliers from this category has a high magnitude value and it's difficult to retrieve data and identify possible causes of a disruption. De-risking strategies can follow two possible approaches: increasing the collaboration, through partnership creation, or decreasing the magnitude, identifying possible alternative suppliers or increasing the stock volume.

- *Bombs*. This category comprehends suppliers which eventual interruption of flows is likely to happen and has a high magnitude. Detectability is easy. Despite they are very dangerous, the good level of collaboration shows a good relationship. Thus, there still is the possibility to save them. However, there is huge urgency in developing actions to decrease risk. This kind of vendors may need financial or operational support, in order to increase the reliability and safety of their supply. In addition, the company can protect itself increasing the stock value and searching alternatives on the market. Ultimately, if there is no chance to improve their risk value and if an alternative on the market exists, it is possible to substitute the vendor, knowing that this switch might require a lot of time.
- *Atomic bombs*. The most dangerous suppliers. Their disruption is high probable and has high severity. Moreover, detectability is difficult, making complex to identify causes of an interruption of the flow and to retrieve data from the vendor. The main solution is to substitute this kind of suppliers. If an alternative does not exist on the market, it is also possible to perform product management and change specifications in order to avoid any kind of possible issue. Priority of intervene is maximum.

In case of supplier smaller than the client company, a possible alternative to the substitution is to acquire it or to internalize the production, but it requires cash resources, time and skills. Thus, it is not always convenient and a deep cost/benefits analysis should be done before.

In the matrix, it is possible to introduce a zone of acceptable risk. Theoretically, all suppliers should be within it. Dimensions of this zone depend by risk appetite and tolerance of the company.

However, data and analysis without intervention do not help anybody. Therefore, it is fundamental to develop action plans aimed at decreasing suppliers' risk. This is the reason why in the tool developed for *PF* there is a proper section in which actions for improvement for each supplier are identified. Moreover, it is possible to verify the impact of these actions comparing the actual KRI with the one obtained if the de-risking strategy is implemented.

6. Launch

Once the model was developed, it was necessary to validate it through a trial launch. This first attempt allowed to gain feedbacks and insights on strengths and weaknesses of the model. It is better to identify errors or concerns prior to massively launch something, rather than finding out about them too late. Once selected the suppliers involved in the launch through the assessment of several criteria, data gathering from the required sources started. Information obtained allowed to compute the KRI and its components. Then, actions for decreasing risk of each supplier were set.

6.1 Choice of suppliers

First of all, only mechanical components vendors were considered in the project, due to the area in which the internship was conducted. The company proposed to choose suppliers to be involved through an ABC analysis aimed at identifying the ones with the highest percentage of *PF* expenses. However, this approach could be limitative, because riskier suppliers may not be included in the analysis and they are the ones who need it the most. Moreover, experiment the model on something more challenging can help discovering issues and criticalities. So, thanks to the collaboration of the Senior Buyer, the number of possible alternatives (*Table 18*) for each supplier is computed, both considering the active and the ones that are knew, but actually they are not in any kind of relationship with the firm.

Obviously, suppliers with less alternatives are the most critical, because an interruption of their flow can cause production stoppages or delays, if there are not possible instantaneous substitutes. Thus, the 15 suppliers that were in single or dual sourcing were preliminary selected. In fact, also dual sourcing can be very risky if one of the two vendors involved is not able to cover the whole demand of the company with its production capacity.

However, time was quite stringent and there were some barriers (e.g. language, culture, opportunism) with some of these vendors that may need more time. So, detectability was assessed for each of them and, then, those with an insufficient level of it were discarded, because of lack of collaboration and difficulty to retrieve data. Despite they could represent bottlenecks too, *Supplier ND* and *Supplier IN* were discarded because of their quite insignificant impact on *PF* expenses.

Once completed this first screening phase, 9 selected suppliers were contacted. Finally, after frequent reminders, every selected vendor answered to the call. The short list of the chosen supplier is shown in *Table 19*.

SUPPLIER	Purchases at 08/2020	%	% cumulative	Class	Purchasing category	Detecatability	Number of alternatives
Supplier J	3.579.810 €	25,47%	25%	A	Solenoid valves	4,15	1
Supplier N	1.385.883 €	9,86%	35%	A	Plastic molding	1,85	4
Supplier S	1.352.792 €	9,63%	45%	A	Sheet metal stamping	1,00	3
Supplier T	871.276 €	6,20%	51%	A	Thermosetting molding	2,70	3
Supplier SM	711.042 €	5,06%	56%	A	Thermosetting molding, membranes	4,40	3
Supplier C	676.351 €	4,81%	61%	A	Plastic molding	1,85	4
Supplier Co	624.248 €	4,44%	65%	A	Multi-spindle turning	1,00	3
Supplier L	437.093 €	3,11%	72%	A	Small turned metal parts	1,85	4
Supplier G	389.442 €	2,77%	75%	A	Thermosetting molding	1,00	3
Supplier E	327.632 €	2,33%	77%	A	Sheet metal stamping	2,70	3
Supplier V	289.050 €	2,06%	79%	A	Painting	1,00	2
Supplier F	265.209 €	1,89%	81%	B	Membranes	4,40	3
Supplier H	253.202 €	1,80%	83%	B	Membranes	3,55	3
Supplier B	223.024 €	1,59%	85%	B	Multi-spindle turning	1,00	3
Supplier SR	221.836 €	1,58%	86%	B	Sheet metal stamping	2,70	3
Supplier NE	204.534 €	1,46%	88%	B	Small turned metal parts	1,00	4
Supplier P	192.091 €	1,37%	89%	B	Multi-spindle turning	2,70	3
Supplier TO	153.314 €	1,09%	90%	B	Small turned metal parts	1,00	4
Supplier I	135.046 €	0,96%	91%	B	Painting	2,70	2
Supplier SA	134.648 €	0,96%	92%	B	Small turned metal parts	2,70	4
Supplier D	129.433 €	0,92%	93%	B	Packaging	2,70	1
Supplier M	106.938 €	0,76%	94%	B	Plastic molding	2,70	4
Supplier EJ	102.623 €	0,73%	94%	B	Special screws	3,00	1
Supplier GU	94.740 €	0,67%	95%	C	Special gaskets	1,00	2
Supplier GA	90.306 €	0,64%	96%	C	Special gaskets	1,00	2
Supplier NI	62.730 €	0,45%	96%	C	Plastic molding	4,40	4
Supplier TA	53.770 €	0,38%	97%	C	Metal blanking	2,70	4
Supplier HE	53.708 €	0,38%	97%	C	Gaskets on case	2,15	3
Supplier ST	42.887 €	0,31%	97%	C	Serigraphy	3,00	2
Supplier BO	41.674 €	0,30%	98%	C	Serigraphy	1,30	2
Supplier DA	36.428 €	0,26%	98%	C	Gaskets on case	3,00	3
Supplier IN	35.400 €	0,25%	98%	C	Girelli	4,40	2
Supplier EL	32.897 €	0,23%	98%	C	Small turned metal parts	1,00	4
Supplier MO	30.317 €	0,22%	99%	C	Springs	3,00	5
Supplier R	29.515 €	0,21%	99%	C	Small turned metal parts	2,70	4
Supplier A	29.050 €	0,21%	99%	C	Magnets	3,00	3
Supplier RA	27.172 €	0,19%	99%	C	Seals	4,40	3
Supplier FR	26.550 €	0,19%	99%	C	Small turned metal parts	2,70	4
Supplier CA	22.870 €	0,16%	99%	C	Springs	3,85	5
Supplier O	17.732 €	0,13%	100%	C	Protection caps	3,85	5
Supplier P	16.803 €	0,12%	100%	C	Turning from wire	2,70	1
Supplier IT	8.603 €	0,06%	100%	C	Labels	1,00	5
Supplier V	6.134 €	0,04%	100%	C	Standard Screws	2,70	5
Supplier TT	5.705 €	0,04%	100%	C	Gaskets (standard)	3,55	4
Supplier W	4.544 €	0,03%	100%	C	Gaskets for Deutch market	4,70	4
Supplier AF	3.818 €	0,03%	100%	C	Benzin rings	3,00	4
Supplier BK	3.425 €	0,02%	100%	C	Girelli	4,40	2
Supplier IN	2.205 €	0,02%	100%	C	Seals from wire	3,00	1
Supplier DO	2.011 €	0,01%	100%	C	Canotti e girelli	2,70	5
Supplier ND	1.900 €	0,01%	100%	C	Dial blanking	3,85	1
Supplier GN	668 €	0,00%	100%	C	Canotti e girelli	3,55	5
Supplier GR	392 €	0,00%	100%	C	Typography	1,30	5
Supplier U	275 €	0,00%	100%	C	Tooling	4,40	5

Table 18. *Table showing for each supplier number of possible alternatives. For confidentiality reasons, names are hidden.*

SUPPLIER	Purchases at 08/2020	%	% cumulative	Class	Purchasing category	Detecatability	Number of alternatives	Answer
Supplier V	289.050 €	2,1%	79%	A	Painting	1,00	2	YES
Supplier I	135.046 €	1,0%	91%	B	Painting	2,70	2	YES
Supplier D	129.433 €	0,9%	93%	B	Packaging	2,70	1	YES
Supplier EJ	102.623 €	0,7%	94%	B	Special screws	3,00	1	YES
Supplier GU	94.740 €	0,7%	95%	C	Special gaskets	1,00	2	YES
Supplier GA	90.306 €	0,6%	96%	C	Special gaskets	1,00	2	YES
Supplier ST	42.887 €	0,3%	97%	C	Serigraphy	3,00	2	YES
Supplier BO	41.674 €	0,3%	98%	C	Serigraphy	1,30	2	YES
Supplier P	16.803 €	0,1%	100%	C	Multi-spindle turning	2,70	1	YES

Table 19*. The short list of selected suppliers.*

6.2 Data gathering

For the launch of the project, it was necessary to gather data from several sources (*Table 20*). Data coming from ERP, contract database, MRP and *SACE SIMEST* were retrieved autonomously through some queries. A contract with *CERVED* organization was signed in order to have access to their credit reports. Information coming from the Senior Buyer are the result of a series of interviews conducted with him. Due to the *Covid-19* restriction imposed by *PF*, it was not possible to do audits to the suppliers in order to see directly what happens in the plants and obtain all information needed. So, a quick self-questionnaire was sent to vendors in order to retrieve data required, reducing time consumed. This questionnaire was composed by simple standard questions with pre-defined answers (*Annex 7*, *8*) in order to increase its simplicity. Only 10 minutes were required for its filling. Telephonic support was given as needed to solve eventual doubts or misunderstandings. Some suppliers showed a bit of resistance in answering to the it, so frequent reminders were needed.

AREA	PARAMETER	INFORMATION SOURCES	
MAGNITUDE	Time to substitute suppliers	Senior Buyer	
	Impact on final products	MRP	
	Procurement mix	JDE ERP System	Senior Buyer
PROBABILITY	Country risk	SACE SIMEST	
	Purchasing category risk	Senior Buyer	
	Supplier organization risk	Supplier interview	
	Economic dependance	JDE ERP System	
	Financial risk	CERVED	
	Product/Process risk	Supplier interview	
	Contract risk	Contracts database	
DETECTABILITY	Level of collaboration	Senior Buyer	
	Level of market knowledge	Senior Buyer	

Table 20. *Data sources table.*

6.3 Findings

The first analysis done was the detectability one. It was conducted on every mechanical components' supplier, because it represented one of the filters in the choice of the vendors to be evaluated. Results are shown in *Table 18*. The overall average level of detectability is 2,68, while the selected suppliers' one

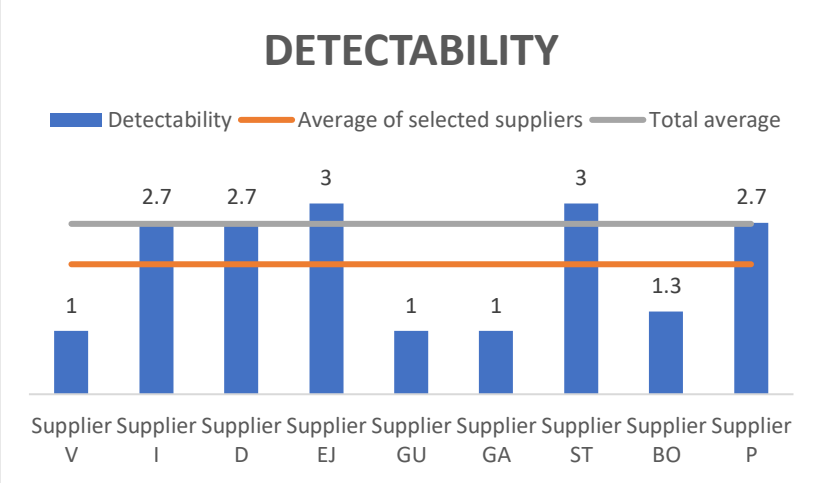

Figure 28. *Detectability assessement results.*

is 2,04 (*Figure 28*). After all, it is an acceptable level. The goodness of these results depends mainly by two factors. Firstly, the senior buyer has more than 30 years of experience in the industry, so the market knowledge is high or in the average for every category purchased. The only exception regards the solenoid valves, because it is a technology recently introduced in *PF* portfolio and it is out of buyer's core competences. Secondly, vast majority of commercial relationships with suppliers are partnerships, due to lean principles. Partnerships need collaboration per definition. It is curious to note that the worst level of detectability belongs to foreign suppliers (i.e. *Supplier J, F, H, NI, IN, W, BK*). In fact, their average level is 4,21, demonstrating how much is difficult to retrieve data from them. This is mainly due to cultural and language barriers.

Looking at the selected suppliers, most critical vendors are *Supplier EJ* and *ST*. The first one is the Italian subsidiary of a multinational company. They provide to *PF* a commercial component. The relationship with them regards basically the negotiation phase and sending/receiving orders. Their revenues coming from *PF* are a negligible part respect to the overall ones, thus there are not so many ways to improve the relationship. *Supplier ST*, instead, is an Italian little supplier that sometimes shows a bit of resistance in collaborating, especially in the negotiation phase. Moreover, serigraphy is not a so well-known category from the buyer, because it is quite far from the referring industry. Detectability level is over the average for *Supplier D*, *I* and *P* too. The first two are very big companies and impact on revenues and power of *PF* is quite low. *Supplier P*, instead, is used for a niche part of the products and, thus, its revenues coming from *PF* are very low: in this way the company cannot require too much and the level of collaboration is not high. Other selected vendors show easiness in retrieving data. However, the average selected vendors detectability level is acceptable and, thus, there is no urgency in pursuing some actions for improvement.

The second part of the analysis regarded the magnitude assessment and it was conducted only on selected suppliers. Here, results are not negligible and the average magnitude level is equal to 3,61 (*Figure 29*). In fact, *PF*, according to the lean principles, uses to have

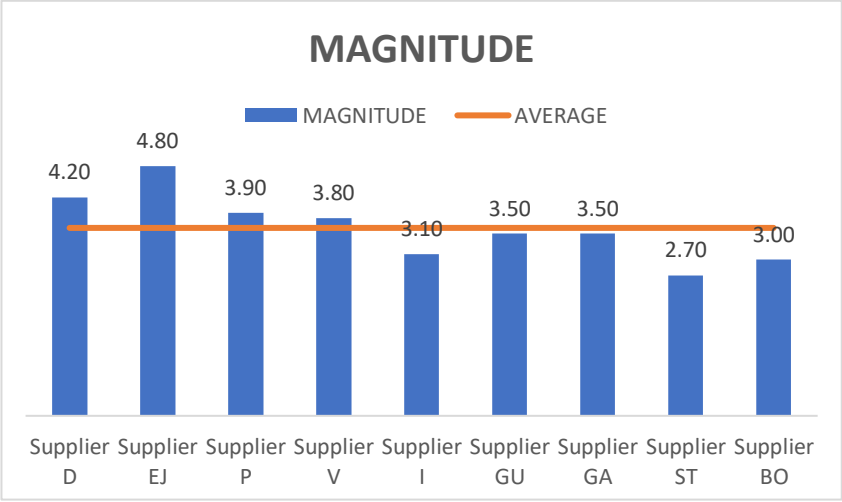

Figure 29. *Magnitude assessment results.*

partnership relationships with his vendors. This kind of agreements implies that to substitute a supplier is not an easy and quick task, but it requires time, resources and trust. Moreover, partnerships are different from spot market transaction where there can be a lot of suppliers used by the company: only few suppliers are selected. Thus, the usual supply approach is the single or dual sourcing. However, in this kind of situations, the severity is higher in case of a disruption.

It is possible to decompose the results in order to understand which are the critical factors that incur in high level of magnitude (*Table 21*). As previously said, severity is very high in case of single sourcing (suppliers with 100% of the procurement mix), because there are no alternative vendors able to substitute instantaneously the main source. In the purchasing categories where dual sourcing is implemented, results can vary. In fact, *Supplier GU* and *GA* have quite the same percentage of the procurement mix and they can both cover the whole production. In these category, dual sourcing is used in order to create a sort of competition able to decrease prices and risks. Instead, *Supplier V* and *ST* are not able to cover the whole *PF* demand, so, in case of an interruption of *Supplier I* or *BO* flows, whole demand cannot be satisfied and magnitude is higher.

	Supplier D	Supplier EJ	Supplier P	Supplier V	Supplier I	Supplier GU	Supplier GA	Supplier ST	Supplier BO
MAGNITUDE	4,20	4,80	3,90	3,80	3,10	3,50	3,50	2,70	3,00
ALTERNATIVE SOLUTION RESEARCH	3,00	5,00	3,00	5,00	5,00	5,00	5,00	4,00	4,00
How many days to substitute the old with a new supplier?	25	140	29	91	91	97	97	45	45
Need comprension	0	7	0	0	0	0	0	0	0
Specification definition	0	7	0	0	0	0	0	0	0
Market identification	0	0	0	0	0	0	0	7	7
Scouting	5	3	14	7	7	7	7	7	7
Qualifacation of the supplier	28	28	28	60	60	60	60	40	40
Econim offer analysis	0	0	0	0	0	0	0	0	0
Sample	0	45	0	0	0	7	7	0	0
BIF	0	7	7	0	0	7	7	5	5
Order emission	1	0	0	0	0	0	0	0	0
Supplier LT	14	80	40	60	60	60	60	7	7
Days of inventories in PF	2	30	0	2	2	14	14	21	21
Days of inventories in supplier warehouse	21	7	30	14	14	30	30	0	0
Days of inventories in sub-supplier warehouse	0	0	30	20	20	0	0	0	0
IMPACT ON FINISHED PRODUCTS	5,00	3,00	2,00	3,00	3,00	5,00	5,00	1,00	1,00
Incidence on finished products	81%	59%	22%	59%	59%	100%	100%	16%	16%
IMPACT ON PROCUREMENT MIX	5,00	5,00	5,00	3,00	1,50	2,00	2,00	2,00	2,50
Percentage of the procurement mix of the evaluated supplier	100%	100%	100%	68%	32%	54%	46%	51%	49%
Max average percentage of the procurement mix of the alternative suplier	0-20%	0-20%	0-20%	81-100%	61-80%	81-100%	81-100%	81-100%	61-80%

Table 21. *Decomposition of the magnitude results for selected suppliers.*

Impact on finished products depends by bill of materials. Packaging and gaskets are quite in each finished product: if *Supplier D*, *GU* or *GA* incurs in a disruption, severity is higher respect to the other vendors' failure.

Looking at the time needed to find an alternative, there are some peculiarities. First of all, for *Supplier EJ* there is some time needed to understand the need and to define specifications. This is quite strange, because it has been providing the same component for several years. However, the product purchased by *EJ* was covered by patent at the beginning of the relationship. So, time to understand if the patent is expired or not and, consequently, to develop the same or a new drawing

for the component is needed. Then, time to identify a proper market or, more in general, to perform scouting is needed: this is a sign that for quite all the purchasing categories there is not a clear idea about where to go if a supplier is disrupted.

The real bottlenecks in the process are represented by the time need to activate a supply and the lead time of the supplier. The first is composed by the supplier technical evaluation and all the steps needed to obtain the *BIF* (e.g. samples, audits, trial orders). Due to the big number of regulations of the gas industry, it is quite difficult to reduce these operations. Moreover, it considers also the time needed by the supplier to purchase and receive the raw materials and the one needed to equip its machines. Lead time of the supplier starts when *PF* shares with the vendor the order and, then, the supplier should retrieve the raw materials, receive them, transform them into the components purchased and, finally, send them to its customer. Both the examination of the economic offer and the order emission are considered negligible in an emergency context.

Generally, it is possible to observe that time needed to find an alternative depends by the purchasing category. In fact, different vendors providing the same kind of component require the same time to find an alternative. The vast majority of *PF* purchases are customized or special items. First ones are realized from drawings, but with standard operations. The second, instead, come from drawings of the client and require particular processing. An investigation carried out by *Laboratorio RISE* of Univerisity of *Brescia*, Italy and by the academic spin-off *IQ Consulting* in 2019, showed that time needed to restore a supply after a disruption is 9,5 weeks for custom items and 17,4 weeks for special ones. These results are quite aligned with what was found by the analysis done.

As shown by the results, *Supplier EJ* should be the most critical, especially because 140 days are needed to find a possible alternative. In addition, this single sourcing situation with a so high risk increases dramatically the bargaining power of the supplier in the negotiation phase. It sounds quite strange that packaging, that should be a non-critical item, has, instead, a high magnitude score. This is due to the fact the packaging come from *PF* drawings and some not standard papers are required, but especially because, in the assessment of the time needed, the price perspective is evaluated too: the senior buyer estimated the time to find an alternative on the same price level.

Last part of the analysis was conducted on the likelihood of occurrence of an interruption of suppliers' flow. The average probability value is 2,16 (*Figure 30*). It is an acceptable value that testifies that vendors' choice was done conscientiously. In fact, quite big and structured suppliers were chosen. Moreover, they were supported in every step of the process to be aligned with *PF*

requirements: several audits and investments were launched by the company in order to make suppliers grow. Results can be decomposed in their sub-components (*Table 22*). Probability of a supplier being disrupted seems lower than the probability of having a difficult collaboration with one of them.

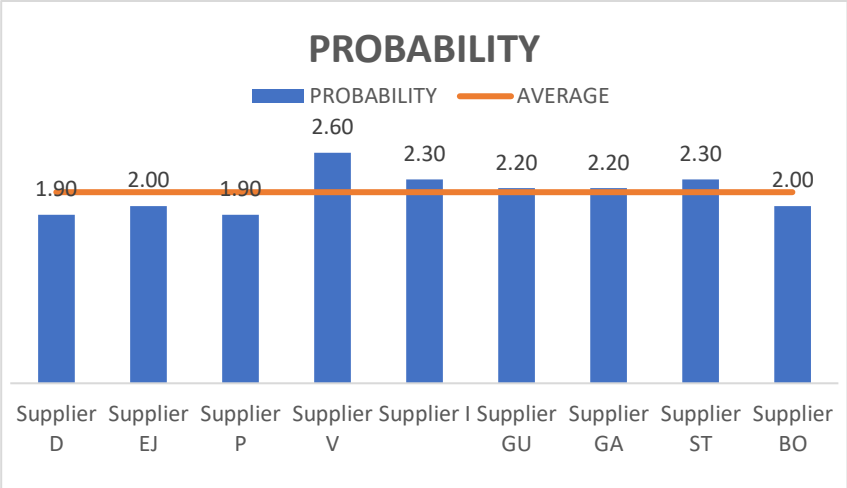

Figure 30. *Probability assessment results.*

	Supplier D	Supplier EJ	Supplier P	Supplier V	Supplier I	Supplier GU	Supplier GA	Supplier ST	Supplier BO
PROBABILITY	1,90	2,00	1,90	2,60	2,30	2,20	2,20	2,30	2,00
Country Risk	2	2	2	2	2	2	2	2	2
Purchasing category risk	4	4	3	5	5	5	5	3	3
Supplier organization risk	2	2	2	3	2	3	2	3	4
Financial risk	1	2	2	2	2	1	1	3	1
Dependance Rate	1	1	1	4	1	1	1	2	1
Contract risk	1	1	1	1	1	1	1	1	1
Product/Process risk	1	1	2	2	2	1	1	2	2

Table 22*. Decomposition of results of the probability assessment of the selected suppliers.*

First component of the analysis is the country risk. Each of the selected suppliers comes from Italy, so, they have the same score. It is an acceptable level, even more considering that it is the same of the acquiring company: vendors will have the same risk selling to *PF* that *PF* has in buying from them. Another common trend consists in the same level of contract risk for every selected vendor. Since selected suppliers have a good or medium level of collaboration with *PF*, they respect the indication regarding the signing of the various document requested.

Looking at financials, *CERVED* assessed a medium-high reliability degree for each vendor. Only *Supplier ST* has a lower score, because it is the less structured, with only 1 shareholder, 5 employees, few real estates and a lower bank credit. However, it does not represent a critical situation, especially considering that it is a healthy firm that operates with several customers. In fact, its dependance rate respect to *PF* is only about 15%. Dependance rate for other suppliers is even lower and it is between 0% and 3%, because these are quite big supplier and, despite big order coming from *PF*, their production capacity is much bigger. Lot of other customers are sign of reliability. The only exception is represented by *Supplier V*. In fact, in 2019 *PF* orders were unbalanced towards him instead of towards *Supplier I* mainly for cost and reactivity reasons. So, dependance rate for *Supplier V* is about 37%, a quite high percentage.

Supplier organization risk is quite steady for all vendors. Vast majority of firms contacted have distinct management figures able to regulate processes and capability to follow the innovations on the market. *Supplier D, EJ* and *I* are very big, so, their organization is more mature than the others' ones. Certifications are quite ignored among them. Despite *ISO 9001* certification about quality is quite spread, only 2 vendors have a safety certification and 2 have an environmental one. Firms without the certificate, generally, do not even follow procedures in line with them: only 3 firms do it. *Supplier BO* and *ST* do not even have the *ISO 9001*, but it is possible to consider it quite negligible for their kind of business. Lack of any kind of certification and willingness to pursue them are the main reason why *Supplier BO* has a high risk connected to its organization.

Product/process risk is low for all vendors too. In fact, during the years *PF* performed several audits in order to verify that processes suggested were effectively in place. Moreover, support in the implementation of correcting and improving actions was given in order to reach standard requirements of both company and market. Generally, machine fleets are not old and well maintained, people are coherently trained, sub-supplier are evaluated through a proper vendor rating system, lead times are objectively determined and transition towards software usage along all the process is advanced. Only 3 suppliers (*V, I, P*) maintain a paper check for the quality inspections and only *Supplier ST* does not implement vendor rating and entry quality checks: being a subcontractor, it relies on the output quality check of the previous actor in the supply chain.

The most relevant source of risk probability comes from the purchasing categories analysis. Here, risk is quite high for each category, because both internal and external stringent purchasing constraints exist. Due to lean manufacturing characteristics, each category's suppliers need to be flexible both in volume and in mix, procurement times need to be short and, generally, near suppliers are preferable. Some of these categories (i.e. painting, packaging) are supplied with daily *kanbans*, thus, supplier must be near. Investments have to be done in order to produce in the quantity and quality required and with the homologations for the gas market. Usually, *PF* economically participates in this kind of investments. Homologations for the gas market are one of the main reasons that make the company deal with heavy administrative procedures (e.g. *BIF* obtaining). Painting is the most critical category because there are few available vendors near the company, thus, demand is higher than the offer. In addition, particular technologies, specific know-how and minimum production batches are required. The kind of gaskets analyzed is critical too, because they are composed by special blends, differently from the others used by *PF*. So, also here demand is higher than the offer. Moreover, specific know-how, minimum production batches,

higher quality respect to the average offer and specific certifications for the gas market are required. With *Supplier D* and *EJ*, the company is in a weaker position in the negotiation phase, because due to the lower dimension it has lower bargaining power.

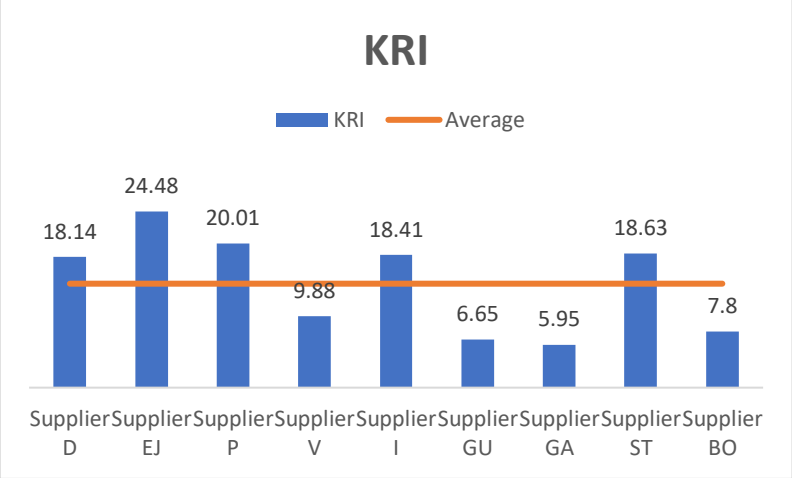

Figure 31. *KRI assessment results.*

Finally, multiplying its components, it is possible to compute the KRI value for each supplier (*Figure 31*). The average value is 14,44. This is a quite acceptable result that shows that vendors were chosen carefully before starting the commercial relationship. In fact, there are not critical suppliers (i.e. the ones with a KRI higher than 25). The higher urgency for intervene in reducing risk is connected to *Supplier EJ*. Then it's important to develop actions that can reduce risk of *Supplier D, P, I* and *ST*, but in the long run, without urgency. With *Suppliers V, GU and GA* it is necessary to develop contingency plans able to decrease the impact of a supplier disruption. In order to simplify the graphical representation of the positioning in the 3D matrix of each supplier, the orthogonal projection of the matrix was done (*Figure 32*). Here, three quadrants represent one of the three components' values respect to the other two. An acceptable risk area is created and identifies the amount of risk accepted by the firm.

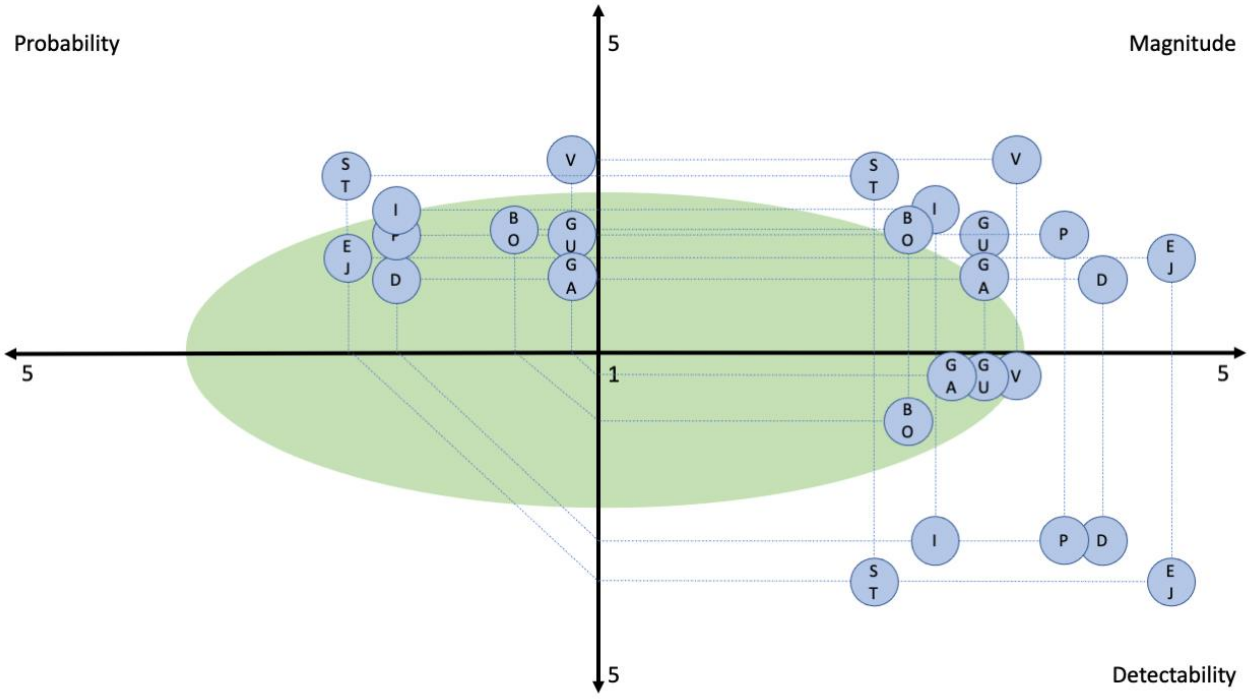

Figure 32. *The orthogonal projection of the positioning of each supplier in the KRI matrix.*

6.4 Actions for improvement

In order to mitigate the risk connected with suppliers, it is possible to act on each KRI component. Acting on magnitude, means doing protection. The three areas of the magnitude assessment are impact on final products, impact of procurement mix and time needed to find an alternative. The first area depends strongly by the bill of materials. It could be possible to decrease the severity having one supplier for one component of one finished product, but it is an impossible and unfeasible solution that, among other things, makes it impossible to access to economies of scale. Moreover, number of supplier available for the gas industry is not infinite as stated before. Acting on the purchasing mix means doing supply management: it is possible to configure in a different way supply network, number of vendors involved and percentage of mix they provide. Decreasing the maximum procurement mix of a supplier and increasing the alternative suppliers' maximum one can help being more resilient. Finally, it is possible to work on the time needed to find a substitute. Here, there are two ways: decreasing time cutting some phases of the project doing them in advance or increasing the coverage. Increase the level of stock beyond a certain level is difficult, costly and against the lean methodology. It is possible also to increase the inventories in the supplier plant or warehouse, but when you do not have the control, risk is higher. Moreover, from an absolute point of view, increasing the stocks in supplier's warehouse is not so protective: in case of a supply disruption (e.g. natural disaster, fire, geopolitics) what the vendor has is not available anymore. Therefore, main preventive actions identified to decrease the magnitude of selected suppliers regard finding an alternative supplier and reducing the time needed to find an alternative.

The first identified action is the creation of a potential vendor list. This is a sort of preventive scouting that aims at identifying suitable suppliers for the industry and for the company. Suppliers from this list should be eligible for being part of the *PF* network, thanks to coherent products, good financial reliability, right certifications and distance from the company coherent with the procurement approach chosen. A first pre-qualification at least of the company is done and RFQ are sent. However, they may not be active suppliers, because, for example, other vendors have best price conditions. The creation of this list allows to decrease the time needed to find a substitute of around 2 weeks, because there is not the need to identify markets and perform scouting. Certainly, it would be a very time-consuming action, but it can also help finding opportunities regarding reductions of price or innovations. It can be applied on each vendor.

Another possible action is to develop a contingency plan to follow in case of a disruption happens. Now, there is not a formalization of what to do in case of an interruption of the flow, also because

it would be difficult to understand what can happen: each situation is different. However, it can be possible to think to introduce and formalize an emergency plan that can cut some time from the usual procedures. An example can lie in the time needed to obtain the *BIF* and in the supplier LT. In fact, both are bottlenecks in the process and consider the time needed for the supplier to retrieve raw materials. Unfortunately, all activities done in the qualification of the component are necessary to not incur in big issues in the gas industry. It would be enough to make that the vendor retrieve at the beginning all the raw materials needed both for sample and trial orders of the *BIF* procedure and for the real final order to halve the time needed for this kind of operation. In this way, it would be done only once, instead of two times, taking to an important reduction of the time needed. This action can be applied for each vendor too.

The other suggested action regards the variation of the supply network. Here, it is necessary to look at each purchasing category. Packaging is in single sourcing and this is not acceptable from a risk point of view. Even from the commercial perspective there are issues: *Supplier D* has higher bargaining power than *PF*, both for its dimensions and for the fact that there are no alternatives. Therefore, finding another vendor to be placed side by side to him can take both to commercial and risk advantages, increasing the competition level and the number of alternatives.

As already seen, painting is a critical category. Its high volumes and its daily *Kanban* suggest that to introduce a third supplier would be beneficial for several reasons. In fact, actual vendors would be less stressed by the continuous demand of *PF*, impact on the procurement mix would decrease and *PF* could also have some savings from the higher competition. This may be a difficult research, because of the use of special powders and the difficulty in doing the homologation of the painting. The same reasoning can be done for special gaskets.

Special screws deserve a deeper analysis. In fact, *PF* does not know the actual state of the patent of *Supplier EJ*. In addition, specifications of the component are not clear to the buyer. These things are quite inacceptable. Therefore, first of all it is necessary to investigate the status of the patent and, if it is expired, it is possible to find a different supplier that can do the same screw. If it is still valid, it is important to understand clearly the specifications and doing product management in collaboration with the technical office: developing a new component with the same functionality that can substitute the one owned by *EJ*. In this way, it is possible to shift from a strong single sourcing to a single sourcing where the vendor can be substituted by every firm that produces screws from drawings or, better, to a dual sourcing, drastically reducing the risk connected to this category and, probably, also the cost of the item.

Probably, *Supplier P* too needs an alternative to abandon the single sourcing status. However, quantities and cash flow involved are not so high to introduce another vendor. Thanks to high stock quantities already in place, only introducing the potential vendor list and developing the contingency plan about the procedures, it is possible to reach 0 days needed to find an alternative. Risk connected to *Supplier BO* and *ST*, instead, is quite low. So, it is important to monitor their situation and it is not necessary to introduce a new vendor.

If all those actions are put in place, the magnitude score of suppliers can decrease as shown in *Table 23*.

Supplier	Old magnitude	New magnitude
Supplier D	4,2	2,8
Supplier EJ	4,8	3,3
Supplier P	3,9	3,1
Supplier V	3,8	2,7
Supplier I	3,1	2,7
Supplier GU	3,5	2,9
Supplier GA	3,5	2,9
Supplier ST	2,7	2,3
Supplier BO	3	2,6

Table 23. *Magnitude values post actions.*

After dealing with the actions that allow to reduce the impact of a possible supply disruption, it is necessary to identify ways to mitigate the likelihood of occurrence. Acting on the probability of a risky event, means doing prevention. In this case, it is more challenging than doing protection for two main reasons. The first one is that results of the probability assessment were already encouraging. Secondly, preventing a supplier to not disrupt means to act not directly on your own company and processes, but on the vendor's one. Thus, if the choice does not consider selecting a different partner or different products, it is very difficult or sometimes even impossible to act on country risk, purchasing category risk or supplier organization risk. However, it is fundamental to support suppliers in their growth and make them become more solid firms through, for example, better procedures, better processes or presence of certifications.

The assessment of the likelihood of occurrence depends strongly by the vendor involved. Thus, in order to understand which can be the possible prevention actions it is necessary to look at each supplier case by case. *Supplier D* is waiting for *ISO 14001* certification. Once arrived, its risk connected to environmental issues will decrease. For such a big company, the presence of the *BS OHSAS 18001* one would be beneficial too and, probably, its economic impact may not be so huge. Even if it does not have a great impact on the KRI calculation, solve an internal purchasing constraint like the low clearness of specifications may help the easiness in find alternative on the market.

Supplier EJ deserves a separate chapter. In fact, it is very difficult to decrease its probability score, because it is a big and solid company. However, if protection actions suggested before will be put in place, probably the vendor of special screws will change, so also the probability connected to the vendor of special screws will change. Thus, a new evaluation of the risk connected to the new supplier would be necessary.

Supplier P can switch from paper quality checks to at least tabular ones. It may increase traceability, increase easiness and safety of archiving, reduce time needed and allow the possibility to analyze data. In the era of digital supply chains, being still anchored to pen and paper is totally anachronistic. *Supplier I* and *V* can both doing the same change. *Supplier I* can also try to increase its O.E.E., especially acting on the quality index: number of defective components seems too high, despite the production process is quite complex. A target value for this improvement can be having a O.E.E. equal to 70%. *PF* already tried to motivate them including some quality clauses in the contract signed. *Supplier V* will obtain the product homologation and the *ISO 9001* certification, reducing related risk items. For both vendors, it seems too much expensive from an economical and efforts point of view to ask certifications related to environmental and safety system, even if their obtaining can decrease the likelihood of occurrence of supply disruptions. Dependance rate of *Supplier V* is equal to 36,9% and it is not negligible. It directly depends by *Supplier I* one, because they are alternative vendors. In 2019 procurement mix was 77% for *V* and 23% for *I*. In 2020, it is already changed: it is 59% for *V* and 31% for *I*. Trying to balance even more this percentage will take to decrease the dependance rate of *Supplier V*, decreasing its probability of incurring in a supply disruption. Increasing the percentage in charge of *I* will not increase its dependance rate, because quantities still remain little respect to *Supplier I* total revenues.

Supplier GU can decrease its probability of being part of a flow interruption simply formalizing some safety procedures aligned with the *BS OHSAS 18001*. *Supplier GA* may need both *BS OHSAS 18001* and *ISO 14001* to reduce its probability. However, it represents again a too big effort, especially considering the low risk connected to *GA*.

Supplier BO can achieve same benefits of *V*, *I* and *P* switching to tabular quality checks instead of paper ones. *Supplier ST* can decrease likelihood of a supply interruption introducing quality checks of inputs: even if it is a subcontractor, take for granted that the previous actor in the chain perfectly performs its job can take to some problems and can decrease the accountability of defects and mistakes along the chain. Both *ST* and *BO* do not own any kind of certification. However, in serigraphy industry relevance of certification is not a primary characteristic. Moreover, the effort required to obtain them is too big for the size of the two firms.

One possible option to reduce the risk connected to the serigraphy is doing in-sourcing. In fact, *PF* could buy the machine needed to complete this job with an investment of a few hundred thousand of euro. The process is quite simple and does not imply special knowledge, even if it is not a core competence of the company. Internalize the job can easily take the supplier risk to 0, because a

supplier may not exist anymore in this case. Only risk factors will be the ones connected to *PF* and its employees (e.g. ability to use the machine, eventual failures, production defects). However, the company does not want to in-source this activity both for a reason of strict spaces in the plant and because they prefer to keep variable instead of fixed costs.

Results on probability scores if all actions (except the in-sourcing of serigraphy) are put in place are shown in *Table 24*.

Supplier	Old probability	New probability
Supplier D	1,6	1,4
Supplier EJ	1,7	1,7
Supplier P	1,9	1,6
Supplier V	2,6	2,6
Supplier I	2,2	1,9
Supplier GU	1,9	1,7
Supplier GA	1,7	1,7
Supplier ST	2,3	2
Supplier BO	2	2

***Table 24**. Probability values post actions.*

Finally, it is also possible to act on detectability in order to decrease the KRI of vendors. There are two ways: train the buyer on key competences of the market or increase the collaboration level. This last option is part of the information management. There are several options available to increase collaboration. First of all, increase the level of communication, transparency, visibility and alignment among the supply chain actors. It's important to give feedbacks, support and to avoid price-wars. Obviously, it could mean to transform the commercial relationship into a partnership, but all supplier selected for this analysis are partners of *PF*. It is also possible to share investments or to force supplier to collaborate, giving ultimatums. However, this last option is not suggested, because it can create tension and because it is suitable only with suppliers with less bargaining power.

Generally, selected vendors have not so critical values of detectability. *Suppliers V, GU, GA* have the lowest possible score. *Supplier BO* detectability can improve if the buyer will increase his knowledge about the serigraphy industry. Knowledge of the market regarding the product provided by *Supplier EJ* can increase if prevention and protection actions are put in place. In fact, knowing the specifications, it is possible to commission these screws to other simpler screws producer. The senior buyer has a spread knowledge of the screws' producer. Moreover, if there will be the switch from *Supplier EJ* to another one, the level of collaboration could change and increase.

Acting on the level of collaboration of *Suppliers D* and *I* could be difficult. In fact, if alternative suppliers will be added to *PF* portfolio, their volumes can decrease and they could be not satisfied of it. Thus, it will be improbable that the relationship between them and the company will improve. During the revision of the scores, the Senior Buyer understood that the level of collaboration intended in the detectability evaluation does not regard the negotiation of commercial conditions:

it is more related to the operative field and to the way the relationship between the two entities is conducted. Thus, marks of *Supplier ST* and *I* shifted from 3 to 2 and *Supplier P* one from 3 to 1, because some actions intended to increase transparency and info sharing were already put in place. Results obtained on detectability scores by the actions thought and by the corrections done are shown in *Table 25*.

Supplier	Old detectability	New detectability
Supplier D	2,7	2,7
Supplier EJ	3	2,7
Supplier P	2,7	1
Supplier V	1	1
Supplier I	2,7	2,15
Supplier GU	1	1
Supplier GA	1	1
Supplier ST	3	2,15
Supplier BO	1,3	1,3

Table 25. *Detectability values post actions.*

Summing up, if these actions are put in place it is possible to achieve appreciable results in the risk mitigation strategy of the company. However, it is important to consider that they have a cost. It is quite difficult to assess the exact cost of them, because they depend by a lot of elements (e.g. reactivity of the vendor, capacity of the company to share the information, level of collaboration in mitigating the risk, time available). Therefore, cost of the improvements is evaluated by the estimated number of days that a *PF* employee require for each operation. Most of the times are taken by the senior buyer evaluation in the magnitude assessment. Vendor list creation, in fact, requires the sum of the number of days needed to identify the market and perform scouting. Same reasoning is done for the introduction of new vendors, that is equal to the time needed to substitute the old supplier with a new one for the relative purchasing category. Obviously, the coverage in *PF* is not considered in the computation. Time needed for certification is usually between 6 and 12 months, depending on various element of the requiring firm. An average of 9 months is set for who has to require a certification from 0. An average between 1 day and 12 months is set, instead, for who has already started the procedures, without communicating the state of progress of the process. Internal operations as the developing of a contingency plan and clarification of specification can requires from 1 to 3 weeks. Time needed is bigger when actions have to be put in place by the vendor and its manufacturing process.

A precise action plan that formalizes actions to do, number of days required, their accountability and deadlines is delivered to the company (*Annex 9*). It allows to have clear in mind which are the steps to do and their priorities, giving responsibility to the actors identified. New suppliers to be evaluated are identified too.

Finally, results show a decrease of the KRI for each selected supplier (*Figure 33*). The average risk decreases from 14,44 to 8,36.

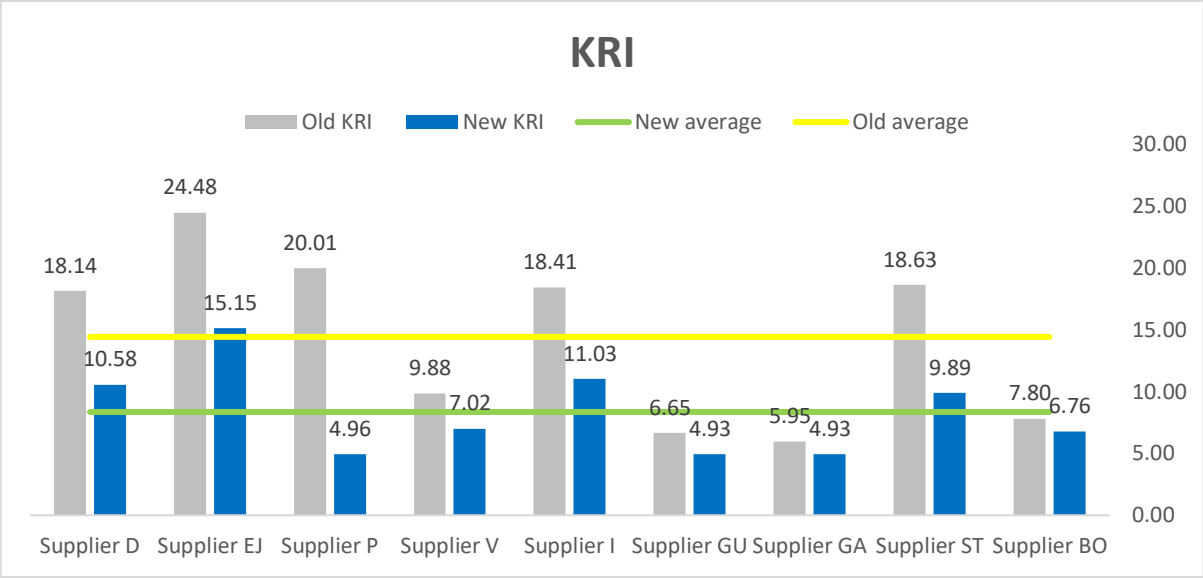

***Figure 33**. Comparison between KRIs before and after the implementation of actions for improvement.*

New KRI assessment shows an average reduction of 42,1% of risk, with a peak of 46,91% of *Supplier ST* (*Table 26*).

Supplier	Supplier D	Supplier EJ	Supplier P	Supplier V	Supplier I	Supplier GU	Supplier GA	Supplier ST	Supplier BO
Reduction	41,67%	38,13%	75,21%	28,95%	40,10%	25,86%	17,14%	46,91%	13,33%

***Table 26.** Reduction of KRI for each selected supplier after the Implementation of actions for reducing the risk.*

Despite the big improvement, *Supplier EJ* still remains the only one a medium risk degree (KRI higher than 15, as shown in *Table 17*). All the others have an acceptable level of risk or even less. Positioning in the KRI matrix is changed: most of suppliers lie in the acceptable risk area (*Figure 34*).

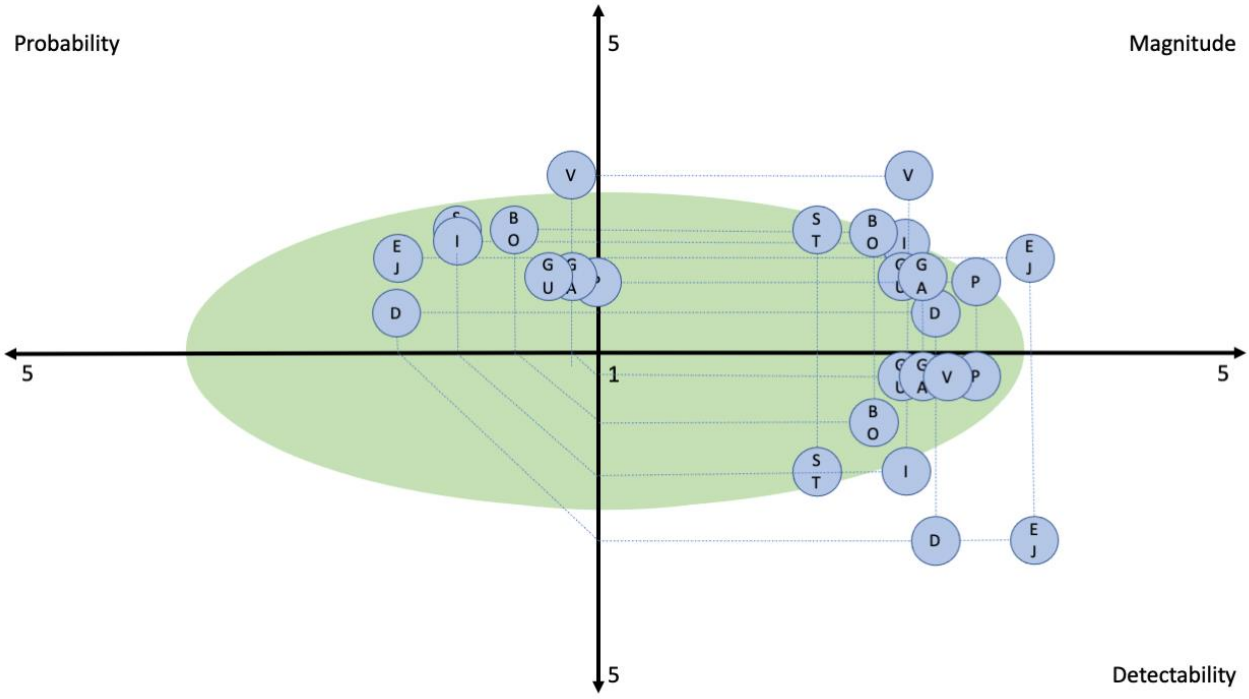

***Figure 34**. The KRI matrix post the implementation of the action aimed at reducing the risk.*

7. Critical analysis

7.1 Benefits

The project conducted in *PF* can take to several benefits for the company and, in particular, for the purchasing department. The structured approach built in the previous chapters allows to do a first evaluation of the supply network, providing a snapshot of the risks connected to its actual configuration, considering different perspective. In fact, if before only factors considered in the awarding phase were mainly financial stability, quality and price offered, now a more comprehensive view is set and a lot of new parameter are introduced (i.e. supplier organization risk, product/process risk, purchasing category risk, dependance rate, contract risk, time to substitute the supplier, incidence on finished products, level of collaboration, market knowledge).

As multiple times stated, primary objective of the buyer should be to assure a stable and secure supply at a competitive price. Thus, he has to look at price only once assessed the reliability degree of the vendor. In this way, unpleasant disruptions can be avoided: risk areas are identified even before the agreement is signed and possible actions for mitigate risk can be shared along the chain. New risky suppliers can be discarded. Active ones can be supported in their growth or substituted in time to avoid discontinuities. The approach has to be preventive and proactive, because reacting once risk is already happened is too late. This tool has precisely these characteristics.

Risk is becoming always more present in nowadays environment, especially in 2020 with *Covid-19* crisis. Therefore, it is extremely important for a company to be resilient. A company as *PF*, that only assembles components and operates with lean principles, should develop a resilient supply base to achieve this goal. It may become a competitive advantage and help overperforming competitors. The formalized and structured approach develop in the document, has this objective.

The actions suggested, if implemented, are the key to reduce the time needed to substitute the existent with a new supplier and to decrease the overall risk in its three components: magnitude, probability and detectability. Considering all three factors of the FMEA method is an innovation for the company and allows to have a more complete view about risks.

Differently from the past, now the approach to follow in analyzing risk is formalized: there are easy and clear procedures to follow through the adoption of the specific tool created. The possibility to do this kind of evaluation with a specific algorithm is a very useful innovation for the firm, because it allows to reduce time and costs of the analysis. Moreover, it is easy to repeat and refresh the model whenever this need arises, allowing to focus only on necessary efforts and to update only what is changed.

In addition, results of the risk assessment can justify actions to be proposed by buyers to the head of the plant or to the strategic sourcing function. It was never done before in *Rosate*, where actions were proposed only to decrease costs and the only concept about risk was to suggest shifting from single to dual or parallel sourcing. Now, it is possible to link actions for improvement to a quantitative and qualitative analysis based on suppliers. It is also possible to develop a concrete and precise action plan, where activities to be done are linked to who has to do them and their deadlines. In this way, accountability can be created. The possibility to evaluate risk can take to the development of new KPIs that can help evaluating buyers' work, enlarging the actual limitative perspective based only on savings. On the other hand, some actions proposed (e.g. potential vendor list creation, introduction of new suppliers) can also help to decrease the price, finding valuable solutions on the market or creating competition among the various vendors.

Through the trial launch of the project, that involved 9 *PF* suppliers, it was possible to confirm the effectiveness of the new model and understand possible limitations and lacks that could be improved in the near future.

7.2 Limitations

The way in which the project was conducted has certainly some limitations. Looking at the model, weights of the parameters evaluated are the result of the experience of the three people involved. Thus, they are not precisely and clearly objective, but they are under some subjectivity degrees. Probably, objectivity may increase using an algorithm or increasing the number of people involved. The choice of leaving them based on the experience was the result of time constraints and of the possibility to leave freedom in determine weights for different situations.

Magnitude assessment is limited too for two main reasons. Firstly, the level of the analysis is such that it is not possible to have certain computations of the time needed to substitute a supplier. It is about doing estimations and predictions based on the experience of people involved in the project and on data that can be retrieved about the market. It means that, within a model that pretends to be as much quantitative as possible, there is the presence of a qualitative measure that can take to some subjectivity. Then, in order to not have a too complex model, there is the complete absence of the evaluation of the sales perspective. In fact, impact on finished products is computed only looking at percentage of finished products that a supplier contributes to create thanks to its components. However, finished products have very different volumes among them. The model does not capture the differences between high sales and low sales products. This is especially due to the fact that different items' volumes are not easy to be predicted and they may change. Thus, it is

difficult to select a correct percentage valid for one year or to change the data inserted in the model every time the demand changes. Moreover, price too is not considered. The model is not able to capture the difference between flagship products that have a high selling price and more basic products. So, neither the different contribution margin of each product is considered. Sales perspective makes the model more complete and able to evaluate the real impact of a supplier discontinuity on company profits. However, for simplicity, the money perspective is not considered and impact on finished products has a low weight to counter these limitations.

Another limitation regards the impact on procurement mix. In fact, it strongly depends by the actual demand of the market. If sales of *PF* decreases, also the total volumes that the company requires to its suppliers decreases. Therefore, the maximum procurement mix that a supplier can reach may vary. For example, if *Supplier BO* fails, *Supplier ST* can bear between the 61% and 80% of *PF* total demand. However, if sales decrease, *Supplier ST* production capacity remain constant and it is able to provide a higher percentage. Same reasoning can be done for all those parameters that must be refreshed periodically in order to have a truthful snapshot of the situation.

Probability assessment has some limitations too. The most important regards certainly the self-assessment modality. In fact, supplier can bias answering the questionnaires sent them: they can lie and tell a story different from the reality. Moreover, if vendors' collaboration level is low, they could not answer to the questionnaires, making impossible to perform the analysis. So, with the impossibility of performing audits, the evaluation strongly depends by suppliers, increasing again model's subjectivity. However, supplier bias is not the only one that can arise. Even the buyer can bias in filling the detectability assessment, in order to show better knowledge of the market and higher ability to create profitable relationships. The difficulty in getting naked and being evaluated without conditioning is another source of subjectivity. Moreover, estimate the level of collaboration of new suppliers could be a problem too, because the relationship is still not born.

Other limitation in the probability assessments regards the dependance by third entities. In fact, *PF* has not the competences to evaluate political and credit risk connected to a certain country or to assess in such a complete way the financial risk of a firm. Thus, relying on third entities is mandatory. However, the choice was done consciously and both *SACE SIMEST* and *CERVED* are very reliable sources. Concerning the financial evaluation, a limit is set by the fact that some kinds of companies are not obliged to publish their balance sheet. In fact, in Italy, so called "*società di persone"* (i.e. companies with the denomination *s.s., s.a.s., s.n.c.*) have not this obligation. Thus, data regarding

their revenues are taken from secondary sources (e.g. websites, interviews with them) and may present errors or biases.

Summing up, limitations of the model created consist mainly in the absence of the sales perspective, also due to the lack of availability of a sales resource in the team, and in some factors that can increase the subjectivity of the analysis performed.

7.3 Open points

Project deployment leaves some open points. First of all, there is a sort of philosophical question: in the model, risk equal to zero is not considered. In fact, in each part of it, there is the possibility to choose or compute through a transcoding table a value between 1 and 5. Looking at the *Ishikawa* diagram (*Figure 26*), it's possible to note that there are some risks that cannot be avoided: accidents, unintended or random events, climatic disasters may not depend by the company or by someone, but they may be the result of randomness and casualty. Thus, there are always some degrees of incertitude that cannot be controlled: that is why risk zero does not exist.

Another important topic regards sustainability. Nowadays, the question is no more why it is important, because it is not a trend anymore. It is something that cannot be neglected and the real thing to be analyzed should be how to approach to it, trying to pursue a competitive advantage on competitors. Unsustainable behaviors are under public scrutiny and can create big damages to companies. In fact, some of the larger problems arisen in recent years are connected to this theme (e.g. *Nike*'s child labor scandal, *Foxconn* employees' suicides). In the model created, the only sustainability reference is the *ISO 14001* presence. It is a certification that regards environmental aspects. However, it is not enough. Firstly, it has the lowest weight of the supplier organization risk assessment. Secondly, it considers only one aspect of the *Triple Bottom Line*, neglecting, for example, the social point of view. The model mirrors the company for which it is developed and its little attention posed on sustainability. Considering that purchasing can have a strategic role in spreading it all over the value chain, this is a great lack of the model and of the department.

Another neglected risk is the climatic one. Due to the fact that the vast majority of mechanical suppliers comes from Italy or, more in general, Europe, it was neglected. However, there are locations in the world that are more subject to natural disasters and climatic catastrophes. Risk connected to those countries could become a strong issue. In fact, factories or logistics flow can be stopped in an easier way, increasing the probability of supply discontinuities.

Last parameter that can be added to the model regards the strength of the relationship. Inspiration comes from the *Olsen and Ellram* (1997) model that considers on its two axes supplier attractiveness and strength of the relationship. The first looks at operative evaluation, overall performance evaluation and strategic evaluation of the vendor. The second, instead, synthetizes the current status of the supply relationship, considering cooperation level, contact frequency and intensity, geographical, cultural and technological distances. The relationship between two entities can comprehend some risks: stronger it is, lower the likelihood of a supply interruption. The only reference to the relationship in the model is the collaboration level in the detectability assessment. However, it may be too few, because the strength of the relationship may impact on the probability of a supplier discontinuity. In fact, a bad relationship can cause, for example, opportunistic behaviors of the vendor or can put *PF* at the end of the queue in case of issues.

Some evidences arose in the model filling. First of all, some suppliers do not track their O.E.E. or do not want to share it. Moreover, some of them didn't even know what it is. O.E.E. is a quite simple and spread parameter to evaluate the efficiency and the effectiveness of manufacturing processes. Keep track of it should be one of the bases of the production management. Probably, vendors may need more support and knowledge exchange in order to further growth. Same reasoning can be done for the ratio between indirect and direct employees in the supplier risk organization part. In fact, lot of the 9 interviewed suppliers did not know the difference between them. Direct employees are the blue collars that works directly on the production process, while indirect are the white collar, thus, those one that do not work directly in the production process, but they make it possible performing support activities (e.g. procurement). This ratio should be explained in a clearer way.

Another open point regards the dependance rate. In fact, the way in which it is considered can take to some wrong evaluations. In fact, *PF* can know only its purchases with a certain supplier and suppliers' revenues. However, risk can be high even if the dependence rate is low: if *PF* contribution to supplier's revenues is negligible, but the other part of them comes from, for example, an unique other one customer, it means that if this customer fails, the vendor has not any kind of entry. Thus, risk probability is high. However, it is quite difficult to know the number of clients of a firm and the percentages they contribute on its revenues. Therefore, dependance rate is a good proxy.

The model is not able to capture the randomness and the creativity that can modify things during emergencies. In fact, in case of heavy supply disruptions, some strange tricks can be found to solve the situation. This is allowed by buyer's role, that nowadays should be a creative thinker able to find solutions to problems in every possible way. In the magnitude assessment, it was difficult to imagine

this kind of scenarios in the computation of the time needed to find an alternative. Being not certain about the timings and thinking about the limitations explained in the previous sub-chapter, it is easier to understand why the evaluation is not done considering the financial impact.

In order to have a precise cost computation, several factors should be considered: competitive advantage loss, investment done to have a full supply again and opportunity costs. The first one is the difference in total costs of supply between the failed supplier and the supplier replacing it. It is necessary to identify reasons that led to the awarding of the failed supplier and to consider not only the purchase price, but any other aspect that could impact the total cost too (e.g. punctuality, compliance, payment conditions). It results very difficult to understand in anticipation which will be the supply conditions of the new vendor and, thus, it is difficult to compute the competitive advantage loss. The second one corresponds to the amount of investments to restore the supply and includes, for example, costs for new supplier's qualification, relationship development, training and purchase or transfer of equipment. However, each situation is different and cost connected can vary. Finally, opportunity costs regard the loss of margins, orders and customers resulting from the interruption of a supply. Often, this is the most impactful item, but at the same time the least considered, due to its uncertainty and figurative nature, which makes it difficult to be estimated even afterwards. Therefore, assessing the economic impact of a disruption results very difficult.

Another open point of the model regards the KRI 3D matrix (*Figure 2*). It can be a very useful tool able to classify the various kind of suppliers and suggest which is the best strategy to pursue. In the analysis of the results, it was kept in mind when the mitigation actions were suggested, but there are not references to it. Increasing the relationship between the actions suggested and the model created could be a positive factor. Moreover, the threshold that divides high and low values of detectability, magnitude or probability is set in the matrix in the middle between 1 and 5. However, a deep assessment of where to put this threshold should be done with the company in order to understand its level of risk tolerance and appetite.

The methodology chosen for the risk assessment is certainly quite complex and time consuming. In the project, only 9 suppliers were evaluated, but to be really effective it should be done on every active vendor and on possible new ones too. A department in which there is only one buyer cannot perform this analysis on such a big number of suppliers. Thus, there is the necessity of having a resource that can support him in the process. In addition, during the internship a lack of communication between strategic sourcing and *Rosate* purchasing department was observed. This kind of risk analysis should be done with their collaboration in order to save time (e.g. there can be

common suppliers for different plants) and increase the effectiveness of the results. In addition, promoting this kind of analysis can put the purchasing department of *Rosate* in the spotlight as a supplier qualification virtuous example.

Last consideration regards how the model should be approached. It is important that it is not limited to give a sort of "school report" to suppliers. It is something that can help doing a check-up on the health of a vendor. As a good doctor can suggest, doing a check-up means to understand the current status of the patient, understand the possible causes of the disease and finally suggest some treatments. Causes can be various and can lie also within *PF* boundaries. Remedies should not be only suggested, but implemented too. Implementing risk mitigation actions is the most important part of supplier risk management.

7.4 Possible improvements

Some possible improvements to the model are thought starting from limitations and open points previously identified. First of all, a climate risk evaluation can be added in the country risk analysis. There are some indexes retrievable on the internet, as the Global Climate Risk Index provided by *Germanwatch.org* that analyses to what extent countries and regions have been affected by impacts of weather-related loss events. Country risk can be expanded considering also the differences between peculiarities of each territory within the same country: political and, especially, credit risk can vary from North to South of the same nation, for example. It can be very useful especially because most of mechanical suppliers come from Italy and their risk seems the same, although it is not like this. In order to obtain this data, it is possible to sign agreements with *SACE SIMEST*.

Looking at contract risk, likely the most common issue is determined by *CGA*. Even if it did not happen with the 9 selected vendors, they are so stringent that some suppliers refuse to sign them. It would be beneficial to the company to make the legal office work on some of the clauses contained in the contracts to make them more acceptable, obviously, staying assured and covered in case of opportunistic behaviors of the supplier. However, if the number of documents signed could increase, the risk connected to less stringent document is a bit higher.

Contract could include also some protections against risk. In fact, it is possible to anticipate risk inserting bonuses and maluses in the agreements signed with vendors. Considering systematically cost implications coming from the poor quality of processes and products in the awarding process, it is possible to define economical advantages or disadvantages linked with the performances of the vendors. Their product and process performance, that are especially connected to the quality

theme, are one of the risk causes identified by the Ishikawa diagram. *PF* already started to implement this kind of initiatives with *Supplier I* in order to make increase its quality index.

Another improvement can regard the self-evaluation questionnaire modality. When *Covid-19* pandemic will be ended, there will be possible to do audits. This kind of data gathering is more reliable, because it avoids supplier bias eventuality. Despite the subjectivity of the evaluation would decrease, time consumed would increase. Thus, the involvement of other resources, also from different functions, can be beneficial.

In the magnitude assessment, transform days of impact into an economic impact would be a big boost for the model. However, as shown in the previous sub-chapter, it is very difficult. Putting as much complexity in the model would increase the time needed to fill it, making it too long to be performed with a good frequency. Same reasoning can be done for the action plan development. The cost of risk mitigation actions is expressed in number of days. Transforming this indication into the amount of money needed to perform the actions would be beneficial to the model. A possible way is multiplying the hourly wage of the resource involved for the time previously calculated, keeping in consideration also that some activities can be carried on contemporary and that other ones may need time waiting for the answer of the counterpart. In every case, the economic impact is directly proportional to the one in days, so, the latter is a reliable proxy. Moreover, there could be the involvement of sales and planning resources in order to understand margins and volumes of different items in the computation of the finished products impact.

Other improvements can regard sustainability and strength of the relationship. Some parameters can be selected to evaluate the environmental, social and economic impact of a vendor in order to understand the risk connected to its behavior. Some example can regard the carbon footprint emissions, destination of wastes, employees' treatment, support given to local. Inspiration can be taken from some common documents and standards, like the Sustainable Development Goals (SDG) or the Global Reporting Initiative (GRI). It could help monitoring and avoiding possible unsustainable disruptions. However, the shift has to be done from an overall company point of view. The firm has to raise awareness regarding this theme in every department, included the purchasing one. As explained before, introducing an index based on the strength of the relationship would add to the probability assessment something that can make it more complete. In this way, all the typologies of KPIs identified in the *Hughes* scorecard (*Figure 8*) would be taken in consideration.

Talking about the algorithm used for the computation of the model, probably a more scientific approach in the weight definition could increase its objectivity. Having more time available and the

possibility to consult more actors can make possible to rely on the AHP methodology. Transcoding tables were draft through the experience and the personal knowledge of people involved in the project. However, it would be possible to find a scientific proof of the relationship between answers and scores or to correct them: with more suppliers evaluated and more data available, the model can be trained and correspondences can be verified. In order to increase the uniformity of the model, scores that can be given are between 1 and 5. Nevertheless, purchasing constraints are evaluated only with three different possibilities. Trying to complete the spectrum of the possibilities enlarging the range of answers can increase completeness and uniformity of the model.

In order to always have a truthful snapshot of the reality, a monitoring tool can be developed. It may be a precious support for the model, because it can keep track of various parameters as age of machines, stock level in *PF* or in vendor's warehouse, eventual stoppages of machines that can extend lead times due to the necessity to retool machines to get them back up to speed, certification expiry date. Modifications to the monitoring tool can be put automatically in the model created, diminishing the refreshment frequency and allowing to always have updated KRIs.

Finally, some further analysis can be done on the results. For example, a fragmentation analysis can be promoted in order to understand the percentage of suppliers or purchases belonging to each category of the KRI 3D matrix (*Figure 27*). It can be useful to understand the current state of risk of *PF* purchases. A fragmentation analysis can be done also in order to understand the breakdown of the risk items for every supplier, in order to understand graphically which are the main responsible for the risk linked to a vendor. In every case, space for analyzing data retrieved and coming from the risk mitigation actions launched is quite infinite and each person involved in the project can find the information he needs managing data to his liking and willing.

8. Conclusions

8.1 What next

Once completed the analysis descripted in the paper, it is important to do not stop and continue on the path of continuous improvement traced by the lean philosophy. Surely, the first things to do are the accomplishment of the tasks identified by the action plan (*Annex 9*) and the promotion of the actions suggested in *Chapter 7.4* in order to increase objectivity and completeness of the model. Then, suppliers' risk evaluation should not become a *una tantum* activity. It should be refreshed at least every year, in order to catch possible changes to *PF* supply network, products, processes, vendors financials and characteristics.

It is not enough to consider it as a tool detached from the context: supplier risk analysis should become integrated in qualification and evaluation processes. In the qualification phase, vendors should present themselves and fill at least the questionnaire regarding the supplier organization risk. Then, the product/process questionnaire can be filled through audits. The other parts of the model can be completed autonomously by the buyer. The preventive computation of the KRI allows to consider risk perspective in the awarding phase: risk may become a parameter to select a supplier as price and quality. The result can be represented by a preliminary GO/NOT GO about suppliers' eligibility or by some improvement suggestions that can be imposed to the supplier in order to find an agreement.

In the evaluation phase, instead, it allows to comprehend the current risk connected to each purchasing category and vendor. Starting from this snapshot, the department can find mitigation strategies connected to dangerous elements. Virtuous suppliers can be taken as an example and their processes can be shared to the other ones in order to increase their performances.

Certainly, to be really effective, the model should become a standard and formalized procedure in the company's vendor rating. A massive launch is needed to have a proper evaluation about all *PF* suppliers' portfolio. In fact, in the action plan suggested to the firm, some other purchasing categories to analyze were identified. The process could be long, but the objective should be to have a continuous and complete evaluation of the risk connected to each vendor and each category.

It should be always updated and periodically refreshed, through the monitoring of some key parameters. Risk will always exist, but monitoring is the only way to keep it under control, allowing detectability of risk items, identification of possible risk areas and promotion of mitigation actions. Planning meetings in which discuss about these activities becomes fundamental, in order to not put less important activities before. In fact, people should not be dragged into doing urgent but not

important tasks: focus should be on programming time leaving some space for important things, even if they are not strictly urgent.

8.2 Final considerations

At the end of this challenging period in *Pietro Fiorentini*, it is possible to assess that all objectives of both internship and thesis were accomplished. A lot of new concepts have been learned, hands-on experience in the purchasing department has been gained and arguments studied in different courses of the Master of Science at *Politecnico di Milano* have been applied into the development of a successful project that may took to decrease supplier risk of about 42%. Some final considerations can be done on what has been done.

The project conducted was important for the company because allowed to do a step forward in the qualification and evaluation of suppliers. As previously stated, risk equal to zero does not exist. Thus, a proper analysis of the riskiness of the actors that are part of *PF* chain has to be done in order to keep it under control. Only what is measured, can be managed. A research from *Laboratiorio RISE* of *Brescia* University and *IQ-Consulting*, showed that in 2018 only 50% of interviewed companies has a supplier risk management system. Therefore, apply this kind of analysis could be a competitive advantage, that can help overwhelming competitors, avoiding the menace linked to dangerous vendors. In order to exploit as much as possible this kind of advantage, include the model in the ITC system of the company can automatize the process and give a great boost to the effectiveness of the computations.

The main final goal of the project was to build and maintain a resilient supply chain. Resilience can be a differentiator for being a successful company. However, its connected costs are not negligible, both in term of efforts and consequences of the actions identified to mitigate danger. First of all, there is the cost of the resources: supplier risk analysis is quite complex and time consuming, so a unique buyer cannot do it alone. Support from a back-up figure or from other functions (e.g. strategic purchasing, risk management) can help him in these tasks. Then, trying to avoid the single-sourcing situation, competition between vendors can decrease the price. However, there can be also the case in which only one supplier is able to provide a component at a certain valuable economic condition. Thus, shifting from single to dual or parallel sourcing can take to the rise of some opportunity costs linked to the higher price offered by the second vendor.

Supplier risk management cannot finish with the analysis performed in the paper. It should be integrated into firm's procedures in a formalized way and it should be done systematically,

periodically and massively. Evaluations should not be a “school report”, but a deep check up on the status of the supplier. Once identified actions for mitigating risk, performing them is the key for decreeing the success of everything that has been done previously. Collaboration between different functions and accountability of the various tasks can help in achieving goals chosen. Just looking at numbers is not enough, because supplier management is about people management: a firm should be transparent and should share information and corrective actions.

The complexity and globally outsourced nature of today’s supply chains combined with techniques as lean manufacturing and JIT has increased supply chain vulnerabilities to even minor supply disruptions. More competences are needed in order to manage such a context, where continuity of supply is the key of the business, even with an higher relevance than cost items. Especially in the *Covid-19* period, risk is something that cannot be neglected. Qualification and evaluation of suppliers is shifting towards a proper risk analysis, where potential hazards have to be detected in a preventive way and mitigation actions are launched proactively. Therefore, role of the buyer is changing again: negotiator, problem solver, creative thinker and, now, risk manager.

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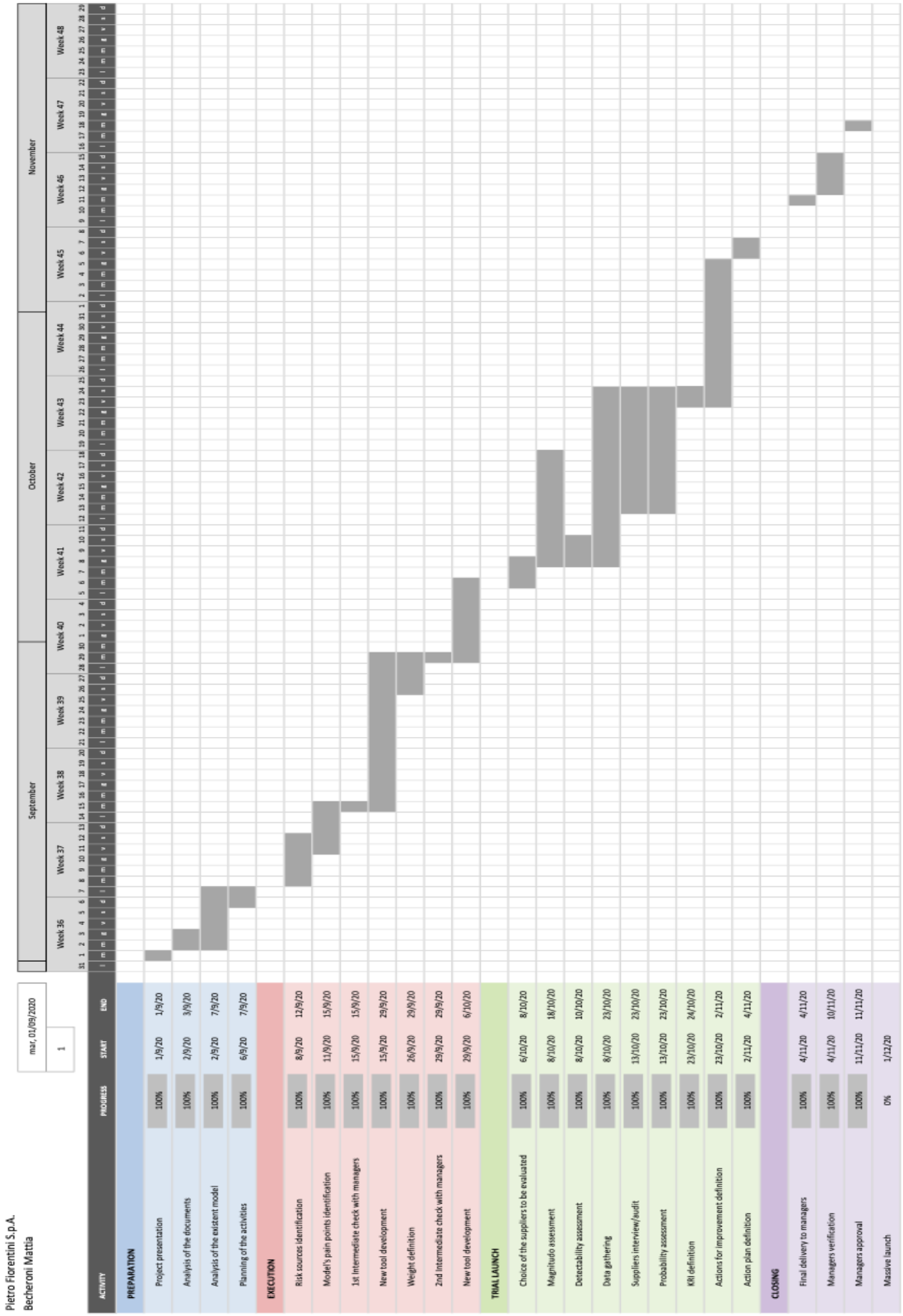
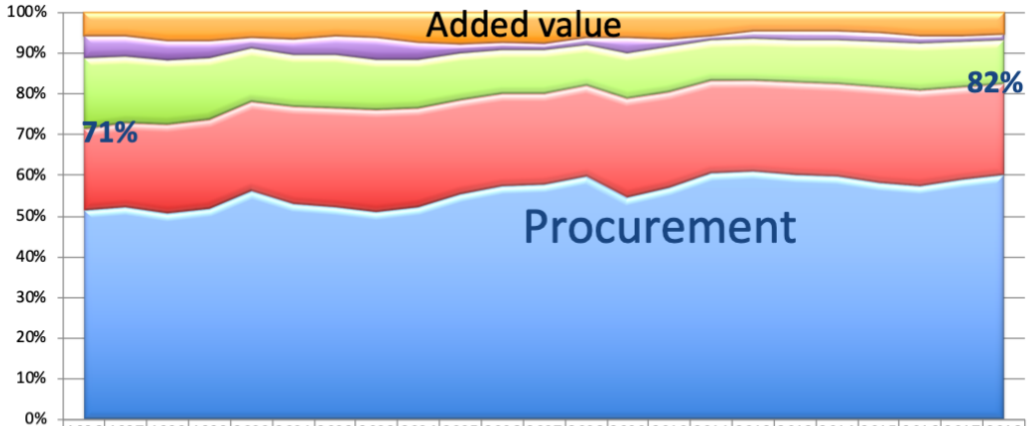
10. Annexes

Annex 1: GANTT of the project

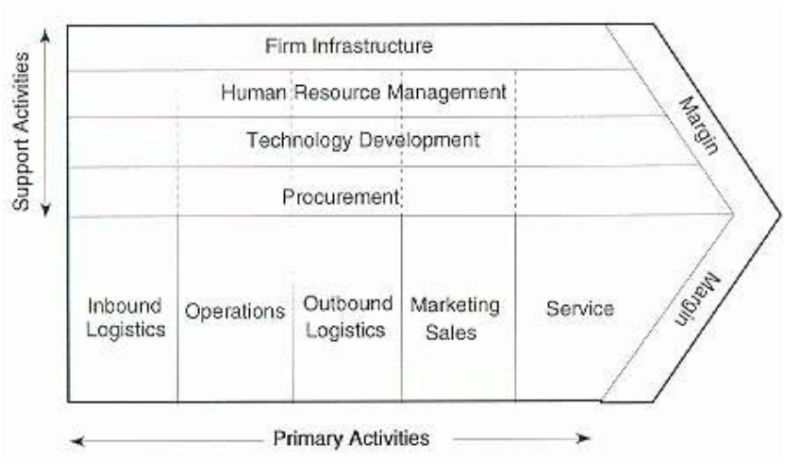


Annex 2: elaboration of Mediobanca data on Italian companies to show off purchasing relevance



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EBIT	5%	6%	7%	7%	6%	6%	6%	6%	7%	7%	7%	7%	6%	6%	6%	5%	4%	4%	4%	5%	5%	5%	5%
Depreciation	5%	5%	5%	4%	3%	4%	5%	5%	4%	3%	2%	2%	2%	4%	2%	1%	2%	2%	2%	2%	2%	2%	2%
Labor Cost	18%	17%	16%	15%	13%	13%	13%	13%	12%	11%	11%	10%	10%	11%	11%	10%	10%	10%	11%	11%	11%	11%	11%
Services	20%	20%	22%	22%	22%	24%	25%	25%	25%	23%	23%	22%	22%	24%	23%	22%	22%	23%	23%	24%	24%	23%	22%
Goods	51%	52%	51%	52%	56%	53%	52%	51%	52%	55%	57%	58%	60%	55%	57%	61%	61%	60%	60%	58%	57%	59%	60%

Annex 3: Porter's value chain



Annex 4: Maturity model

	Clerical	Developing	Supportive	Strategic contributor
Drivers	**1**	**2**	**3**	**4**
PSM strategy	None	Emerging, informal	Formal supportive to corporate strategy	PSM integral part of corporate strategy
Global sourcing	None or ad hoc	International sourcing developing	Global sourcing strategies integrated across worldwide locations	Global sourcing strategy integrated across worldwide locations and functional groups
Organizational visibility and influence	Low, cost saving function	Gaining indirect visibility	Direct visibility at senior level, but limited influence	Direct influence at senior strategic level, CPO position
Data, communication & organization	Low level of spend information, decentralized organization, basic ICT	Improving information, change towards ICT, centralized organization	Cross-functional & ICT-enabled, hybrid organization	Full spend information, ICT-enabled, centre-led organization
KPIs	Price savings	Small set of easy-to-measure KPIs	Range of KPIs aligned with PSM strategy	Range of KPIs aligned with PSM strategy, including soft behavioral factors
Skills training and development	Minimal, low level tactical	Current popular best practice	Cross-functional	Cross-functional, leadership, change management
Basis of supplier selection & evaluation	Price & availability	Change towards TCO, but ultimately cost driven	Multiple weighted criteria	Multiple weighted criteria aligned with PSM strategy
Supplier involvement in NPD	None, suppliers approached during prototyping	Attempts at early involvement (i.e. early design, development planning)	Close early involvement of key suppliers also in concept development	Close early involvement of key suppliers, including between NPD projects
Supplier development	None	External accreditation, reactive problem solving	Systematic vertical supplier development (assistance, training, one-way approach)	Systematic development extending beyond direct suppliers, horizontal supplier collaboration, two-way mutual improvement approach
Supplier relationships	Mostly adversarial	Emerging partnerships	High proportion of partnerships, SRM	Portfolio of appropriate varied relationships, SRM
Sustainability strategy	No consideration	Partial and emerging	Integrated sustainability and PSM strategy	Integrated sustainability and PSM strategy
Sustainability implementation	None or limited	Some initiatives to avoid negative exposure	Ethical SC evaluation mostly focused on direct suppliers	Deeper ethical SC evaluation extended also to indirect supplier
Sustainability reporting	None	Ad hoc mention of sustainability policy or code of conduct	Some disclosure including online reports	Fully transparent reporting including online reports, video clips form suppliers

Annex 5: magnitude assessment tool

Compilare solamente le celle di colore verde chiaro come questa cella

Pietro Fiorentini

Valutazione del Rischio FORNITORE: MAGNITUDO

DATA COMPILAZIONE:	01/03/19	
COMPILATO DA:	Nome Buyer	
FORNITORE :	**NOME FORNITORE**	
VALUTAZIONE MAGNITUDO	**0,8**	
IMPATTO RICERCA E VALIDAZIONE SOLUZIONE ALTERNATIVA	**peso 40%**	**1**
Quanto tempo occorrrebbe per sostituire il fornitore?	**0**	giorni
Comprensione del bisogno	0	giorni
Definizione delle specifiche	0	giorni
Identificazione dei mercati di ricerca	0	giorni
Scouting	0	giorni
Attivazione/ Omologazione del fornitore	0	giorni
Analisi dell'offerta economica (mascherato)	0	giorni
Campionatura	0	giorni
Benestare inizio fornitura	0	giorni
Emissione ODA	0	giorni
LT Fornitore	0	giorni
Copertura in PF	0	giorni
Copertura fornitore	0	giorni
Copertura subfornitore	0	giorni
IMPATTO SUL PRODOTTO FINITO	**peso 10%**	**1**
Incidenza dei componenti sui prodotti finiti	**0%**	%
Numero prodotti finiti di Pietro Fiorentini	37	prodotti
Numero massimo di prodotti finiti in cui sono usati i componenenti del fornitore valutato	0	prodotti
IMPATTO SUL MIX DI APPROVVIGIONAMENTO	**peso 50%**	**0,5**
Massima % del mix di approvvigionamento del fornitore valutato	**0%**	1
Volume totale acquistato della categoria merceologica più usata dal fornitore	1,00 €	€
Volume acquistato dal singolo fornitore valutato di quella categoria	- €	€

Percentuale del mix di approvvigionamento che il fornitore alternativo (se presente) può assorbire al massimo	**1**	**2**	**3**	**4**	**5**	0
	81-100%	61-80%	41-60%	21-40%	0-20%	

Annex 6: probability assessment tool

Compilare solamente le celle di colore verde chiaro come questa cella

Pietro Fiorentini

Valutazione del Rischio FORNITORE: PROBABILITA' A (acquisti diretti su commessa)

DATA COMPILAZIONE:	01/03/19					
COMPILATO DA:	Nome Buyer					
FORNITORE :	**NOME FORNITORE**					
VALUTAZIONE PROBABILITA'	**2,0**					
RISCHIO PAESE	**peso**		**5%**			**1**
Punteggio RISCHIO POLITICO assegnato da SACE del paese sede produttiva del fornitore esaminato	0					1
Punteggio RISCHIO CREDITO assegnato da SACE del paese sede produttiva del fornitore esaminato	0					1
RISCHIO CATEGORIA MERCEOLOGICA	**peso**		**15%**			**1**
Somma delle valutazioni dei rischi derivanti da vincoli esterni e interni						0
VINCOLI ESTERNI DETERMINATI DAL MERCATO	**1**		**3**		**5**	0
Esistono accordi sul mercato (cartelli, monopoli)?	No		Cartello		Monopolio	0
La domanda è superiore all'offerta?	No		A volte		Si	0
Il fornitore detiene un brevetto o un know-how specifico?	No		Know-how		Brevetto	0
Il cliente impone il fornitore?	No		Consigliato		Si	0
Il fornitore deve essere vicino alla azienda?	No		Consigliato		Si	0
La tecnologia è in rapida evoluzione?	No		Lenta		Si	0
Esiste un monopolio tecnologico?	No		Oligopolio		Si	0
Il fornitore richiede lotti minimi di produzione?	No		Non vincolante		Vincolanti	0
Il ciclo di vita del prodotto è vincolante?	No		Potrebbe diventarlo		Si	0
Il fornitore necessita di una tecnologia particolare?	No		Non specifica		Si	0
La legislazione vigente è vincolante?	No		Si, ma non è ostacolo		Si ed è bloccante	0
E' necessario sviluppare pratiche di protezione politica o sociale?	No		Sociale		Sociale e politica	0
Esistono differenze culturali tra noi e il fornitore?	No		Si, trascurabili		Si, bloccanti	0
Il fornitore deve essere flessibile?	No		Nel mix produttivo		In mix e volume	0
Sono richiesti investimenti per accedere alla fornitura?	No		Contenuti		Si	0
VINCOLI INTERNI DETERMINATI DA PIETRO FIORENTINI	**1**		**3**		**5**	0
Il Fornitore e la Politica d'acquisto è imposta da Pietro Fiorentini?	No		Consigliato		Si	0
Il Fornitore ritiene che le specifiche e le tolleranza previste da PF sono sovrastimate?	No		Medie		Alte	0
I tempi di approvvigionamento richiesti sono brevi?	< 1 mese		Tra 1 e 3 mesi		> 3 mesi	0
Il Fornitore esaminato è imposto dall'organizzazione interna di PF?	No		Dall'ufficio tecnico		Si	0
Si ritiene ci sia scarsa conoscenza del prodotto e mancanza di know how da parte di PF?	No		Nell'ufficio acquisti		Uff. Acquisti e Tecnico	0
Le Specifiche d'acquisto sono chiare ed esaustive?	Si		Non chiare		No	0
Sono richieste Certificazioni Specifiche?	No		Non vincolanti		Si	0
Qual è il tempo stimato necessario per l'omologazione del fornitore?	< 1 mese		Tra 1 e 3 mesi		> 3 mesi	0
Il prodotto/i acquistati godono di un segreto aziendale?	No		Divulgabile		Non divulgabile	0
Il livello di qualità richiesto è maggiore di quanto offerto mediamente dal mercato?	No		Nella media		Superiore all'offerta	0
Esistono strumenti di controllo (qualità, deriva dei prezzi, performance fornitori)?	Si		Non formalizzati		No	0
Esistono procedure amministrative che appesantiscono il processo?	No		Alcune		Si	0
Pietro Fiorentini ha potere d'acquisto rispetto al fornitore?	Si		Parità		No	0
Il livello di comunicazione interna è sufficiente?	Si		Non adeguato		Inesistente	0
Si prevede un impegno tecnico (supporto) preliminare da parte del fornitore?	No		Bassi		Alti	0

RISCHIO SOCIETARIO	peso	15%				1
Somma delle valutazioni dei rischi societari						0
ORGANICO AZIENDALE	1	2	3	4	5	0
Organizzazione padronale, famigliare o manageriale?	Manageriale	Padronale/famigliare con presenza di alcuni manager	Famigliare	Famigliare con eredi disinteressati	Padronale senza eredi	0
Esistono distinte le figure: Direzione Commerciale, Tecnica, Qualità, di Produzione, ecc?	Si con back-up	Si	Solo alcune	Poche, livello non sufficiente	No	0
Rapporto lavoratori diretti/indiretti	>2	Tra 1 e 2	1	Tra 0,1 e 1	< 0,1	0
Analisi su età dei dipendenti e grado di fidelizzazione	Giovani e fidelizzati	Mix giovani-anziani fidelizzati	Mix giovani-anziani non fidelizzati	Giovani non fidelizzati	Anziani non fidelizzati	0
Azienda storica	>50 anni	20-50 anni	10-20 anni	5-9 anni	< 4 anni	0
Capacità di innovarsi e di stare al passo coi tempi (R&D, nuove tecnologie...)	R&D traino che propone innovazione (first mover)	R&D segue il mercato innovazione proattivamente	R&D reagisce all'innovazione sul mercato	Solo se obbligato, con fatica	R&D assente, in contrasto	0
SISTEMA QUALITA'	1	2	3	4	5	0
Esiste il certificato ISO 9001?	Si	Aspetta il certificato	Audit nei prossimi 12 mesi	No, ma intenionato	No e non intende	0
Esiste una struttura di controllo ben definita?	Direzione qualità con obiettivi di miglioramento continuo	Responsabile qualità con obiettivi di continuo miglioramento	Direzione qualità senza obiettivi di miglioramento continuo	Responsabile qualità senza obiettivi di miglioramento	No	0
Le azioni Qualità previste da Pietro Fiorentini sono effettivamente messe in pratica?	Formalizzate e applicate	Applicate ma non formalizzate	Formalizzate ma saltuarie	Formalizzate ma non attuate	No	0
SISTEMA SICUREZZA	1	2	3	4	5	0
Esiste il certificato BS OHSAS 18001?	Si	Aspetta il certificato	Audit nei prossimi 12 mesi	No, ma intenionato	No e non intende	0
Le procedure sono realmente effettuate	Formalizzate e applicate	Applicate ma non formalizzate	Formalizzate ma saltuarie	Formalizzate ma non attuate	No	0
SISTEMA AMBIENTE	1	2	3	4	5	0
Esiste il certificato ISO 14001/EMAS?	Si	Aspetta il certificato	Audit nei prossimi 12 mesi	No, ma intenionato	No e non intende	0
Le procedure sono realmente effettuate	Formalizzate e applicate	Applicate ma non formalizzate	Formalizzate ma saltuarie	Formalizzate ma non attuate	No	0
RISCHIO FINANZIARIO	**peso**	**15%**				**5**
Valutazione sintetica di affidabilità CERVED			0			punti
DIPENDENZA ECONOMICA	**peso**	**10%**				**1**
Fatturato totale anno precedente del fornitore			1			€
Fatturato del fornitore solo con Pietro Fiorentini nell'anno precedente			0			€
Dependance Rate			0%			%
RISCHIO CONTRATTUALE	**peso**	**10%**				**5**
Il fornitore ha sottoscritto le DSRG?		Si		No		
Il fornitore ha sottoscritto le CGA?		Si		No		
Il fornitore invia le conferme d'ordine (ODA) controfirmate?		Si		No		
RISCHIO PRODOTTO/PROCESSO	**peso**	**30%**				**1**
Somma delle valutazioni dei rischi riguardanti prodotto/processo						4
PARCO MACCHINE	1	2	3	4	5	20
Anzianità del parco macchine	Meno di 5 anni	5-10 anni	10-20 anni	20-25 anni	Oltre 25 anni	0
Livello di adeguatezza di macchine e strumentazione	Adeguata e tarata	Adeguata	Adeguate, ma non sufficienti	Non adeguata	Insufficiente	0
Censimento macchine	Esiste completo	Esiste incompleto	No, ma ci sono le informazioni	Non esiste e c'è resistenza nel fornire informazioni	Non esiste e non ci sono info	0
Piano di gestione/manutenzione di attrezzature e macchine	Esiste e viene rispettato	Esiste, ma non rispettato	Non esiste ma ci sono azioni puntuali	Non esiste e azioni saltuarie	Non esiste e nessuna azione	0
O.E.E. (Rendimento globale d'impianto)	85-100%	70-84%	50-70%	25-49%	0-24%	5
Disponibilità = tempo di funzionamento lordo / tempo disponibile effettivo			0			0
Prime tre cause di fermo macchine						
Efficienza delle prestazioni = (tempo ciclo teorico * volume) / tempo di funzionamento lordo			0			
Tasso di qualità = (produzione totale - produzione difettosa) / produzione totale			0			
CONTROLLO IN ACCETTAZIONE	1	2	3	4	5	0
Il Fornitore utilizza fornitori terzi (2-tier suppliers)?	No	Si con audit fatto da PF per tutti	Si con audit fatto da PF per alcuni	Si con comunicazione a noi	Si senza comunicazione	0
Il fornitore adotta un sistema di valutazione dei Fornitori (vendor rating)?	Formalizzato e sistematico	Formalizzato ma non sistematico	Non formalizzato ma sistematico	Non formalizzato e saltuario	No	0
Il Fornitore ha un sistema di controllo qualità in ingresso?	Si standardizzato e documentato	Standardizzato, ma non documentato	Documentato, ma non standardizzato	Non sempre documentato e non standardizzato	No	0
I materiali non conformi in entrata sono segregati?	Identificati, segregati e azione fatta con fornitori documentata	Identificati, segregati e azione fatta con fornitori non	Identificati e segregati	Segregati ma non identificati	No	0
MATERIALE IN CONTO LAVORO	1	2	3	4	5	0
Il materiale fornito da Pietro Fiorentini è gestito correttamente e facilmente rintracciabile?	Identificato, segregato	Segregato	Identificato	Non sempre identificato	No	0
CONTROLLO DEL PROCESSO DI PRODUZIONE	1	2	3	4	5	0
Esiste un piano di controllo con indicate tutte le attività e le fasi del processo?	Esiste in tutte le fasi e ci sono controlli	Esiste per alcune fasi e ci sono controlli	Esiste solo a fine produzione	Non esiste ma ci sono controlli	Non esiste	0
Quando vengono effettuati i controlli?	Durante e alla fine del processo	Durante	Alla fine	Su richiesta	Non effettuato	0
Come vengono registrati i controlli effettuati?	Automatizzato in linea	Sistema gestionale	Tabellare	Cartacea	Non effettuato	0
Vengono raccolte e analizzate le non conformità?	Raccolte e analizzate con piani di miglioramento	Raccolte su gestionale	Raccolte su fogli di calcolo	Raccolte cartacee	Non raccolte	0
CERTIFICAZIONE PRODOTTO	1	2	3	4	5	0
Esiste una certificazione specifica di prodotto?	Esiste	Attesa certificato	In conseguimento	Intenzionato	Non esiste e non è intenzionato	0
STRUMENTI, FORMAZIONE E MANUTENZIONE	1	2	3	4	5	0
Esiste un Piano di controllo e taratura degli strumenti?	Esiste in tute le fasi	Esiste in tutte le fasi ma non viene sempre seguito da tutti	Parziale	Non esiste ma le attività vengono svolte	Non esiste e le attività non vengono svolte	0
Il personale che esegue attività relative alla qualità del prodotto ha un piano specifico di addestramento?	Esiste in tute le fasi	Esiste in tutte le fasi ma non viene sempre seguito da tutti	Parziale	Non esiste ma le attività vengono svolte	Non esiste e le attività non vengono svolte	0
Esiste un Piano di manutenzione programmata?	Esiste in tute le fasi	Esiste in tutte le fasi ma non viene sempre seguito da tutti	Parziale	Non esiste ma le attività vengono svolte	Non esiste e le attività non vengono svolte	0
GESTIONE DELLA PIANIFICAZIONE E PROGRAMMAZIONE DELLA PRODUZIONE	1	2	3	4	5	0
Come vengono determinati i Lead Time (LT)?	Determinati oggettivamente considerando approvvigionamento,	Determinati oggettivamente considerando attesa standard	Determinati con Capacità produttiva infinita	LT standard	Non determinati	0
Come viene gestita la conferma delle date di produzione/consegna?	Comunicata su calcolo oggettivo e conferma firmata inviata	Comunicata su calcolo oggettivo senza conferma	Comunicata senza calcolo oggettivo con conferma	Comunicata senza calcolo oggettivo senza conferma	Non comunicata	0
Come viene fatta la programmazione della produzione?	Software	Fogli di calcolo non a sistema	Manualmente	Esperienza	Non viene fatta mai	0
Come viene fatto il controllo di avanzamento?	Controllo fase per fase automatizzato	Controllo fase per fase manuale	Controllo automatizzato solo a fine processo	Controllo manuale solo a fine processo	Non viene fatto	0
Come vengono gestite le giacenze a magazzino?	Automatizzato	Sistema gestionale	Fogli di calcolo non a sistema	A vista	Non vengono gestite	0

Annex 7: possible answers for supplier organization risk questionnaire

SUPPLIER ORGANIZATION RISK					
ORGANIZATIONAL CHART	1	2	3	4	5
Managerial, familiar or single owner organization?	Managerial	Manor/familiar with some managers	Familiar	Familiar with disinterested heirs	Manor without heirs
Presence of commercial, technical, quality, production directors	Yes with back-up	Yes	Only some	Few, not enough	No
Indirect/direct employees ratio	>2	Between 1 and 2	1	Between 0,1 and 1	< 0,1
Age and fidelity of employees analysis	Young and loyal	Mix young-old loyal	Mix young-old not loyal	Young not loyal	Old not loyal
Historical firm	>50 years	20-50 years	10-20 years	5-9 years	< 4 years
Innovation capabilities	R&D drivies innovation (first mover)	R&D follows the innovation market proactively	R&D reacts to innovation on the market	Innovation only if forced, with difficulty	No R&D department and no innovation
QUALITY	1	2	3	4	5
Certification ISO 9001	Yes	Waiting for the ceritification	Audit within 12 months	No, but willing	No and not willing
Well defined control structure	Quality management with continuous improvement objectives	Quality manager with goals of continuous improvement	Quality management without continuous improvement objectives	Quality manager without goals of continuous improvement	No
Procedure from Pietro Fiorentini are really implemented?	Formalized and applied	Applied but not formalized	Formalized but occasional	Formalized but not applied	No
SAFETY	1	2	3	4	5
Certification BS OHSAS 18001	Yes	Waiting for the ceritification	Audit within 12 months	No, but willing	No and not willing
Procedure are really implemented?	Formalized and applied	Applied but not formalized	Formalized but occasional	Formalized but not applied	No
ENVIRONMENT	1	2	3	4	5
Certification ISO 14001/EMAS	Yes	Waiting for the ceritification	Audit within 12 months	No, but willing	No and not willing
Procedure are really implemented?	Formalized and applied	Applied but not formalized	Formalized but occasional	Formalized but not applied	No

PRODUCT/PROCESS RISK					
FLEET OF MACHINES	1	2	3	4	5
Machines age	Less than 5 years	5-10 years	10-20 years	20-25 years	Moe than 25 years
Level of adequacy of machines and instrumentation	Adequate and calibrated	Adequate	Adequate, but insufficent	Not adequate	Not adequate and insufficient
Machines census	Exists, complete	Exists, incomplete	No, but information available	No and information sharing resistance	No and informaation do not exist
Management/maintenance plan for equipment and machines	Exists and is respected	Exists but not respected	It does not exist but specific actions are done	It does not exist and occasional actions are done	It does not exist and no actions are done
CHECK IN ACCEPTANCE	1	2	3	4	5
Does the Supplier use 2-tier suppliers?	No	Yes with PF audit for everyone	Yes, with PF audit for some	Yes, with communication	Yes, without communication
Does the supplier adopt a vendor rating system?	Formalized and systematic	Formalized but not systematic	Not formalized but systematic	Not formalized and occasional	No
Does the Supplier have an incoming quality control system?	Yes standardized and documented	Standardized, but not documented	Documented, but not standardized	Not always documented and not standardized	No
Are incoming non-compliant materials segregated?	Identified, segregated and documented action done with suppliers	Identified, segregated and not documented action done with suppliers	Identified and segregated	Segregated but not identified	No
MATERIAL IN WORK ACCOUNT (CONTO-LAVORO)	1	2	3	4	5
Is the material provided by Pietro Fiorentini managed correctly and easily traceable?	Identified and segregated	Segregated	Identified	Not always identified	No
CONTROL OF THE PRODUCTION PROCESS	1	2	3	4	5
Is there a control plan indicating all the activities and phases of the process?	It exists at all stages and there are controls	It exists only at the end of the production	It exists at some stages and there are controls	It doesn't exist but there are controls	Doesn't exist
When are the checks carried out?	During and at the end of the process	During	At the end	On request	Not done
How are the checks carried out recorded?	Automated on the line	ITC management system	Tabular	Paper collections	Not done
Are non-conformities collected and analyzed?	Collected and analyzed with improvement plans	Collected on ITC management sytem	Collected on Excel spreadsheet	Paper collections	Not collected
PRODUCT CERTIFICATIONS	1	2	3	4	5
Is there a specific product certification?	Yes	Waiting for the ceritification	Audit within 12 months	No, but willing	No and not willing
TOOLS, TRAINING AND MAINTENANCE	1	2	3	4	5
Is there an instrument control and calibration plan?	Exists in every phase	Exists in every phase, but not always followed by everyone	Partial	Doesn't exist, but activity are carried out	Doesn't exist and activities are not carried out
Do the personnel performing product quality activities have a specific training plan?	Exists in every phase	Exists in every phase, but not always followed by everyone	Partial	Doesn't exist, but activity are carried out	Doesn't exist and activities are not carried out
Is there a scheduled maintenance plan?	Exists in every phase	Exists in every phase, but not always followed by everyone	Partial	Doesn't exist, but activity are carried out	Doesn't exist and activities are not carried out
MANAGEMENT OF PLANNING AND PRODUCTION PROGRAMMING	1	2	3	4	5
How are Lead Times (LT) determined?	Objectively determined considering supply, wait and production	Determined objectively considering standard waiting	Determined with infinite production capacity	LT standard	Not detemined
How is the confirmation of production / delivery dates managed?	Communication on objective calculation and signed confirmation sent	Communicated on objective calculation without confirmation	Communicated without objective calculation with confirmation	Communicated without objective calculation without confirmation	Not communicated
How is production planning done?	Software	Excel spreadsheets	Manually	Experience	Not done
How is the progress check done?	Automated step by step control	Manual step by step control	Automated control only at the end of the process	Manual control only at the end of the process	Not done
How are warehouse stocks managed?	Automated	ITC management system	Excel spreadsheet	At sight	Not managed

Supplier	Purchasing category	Area of improvement	Actions aimed at mitigate risk	Responsible	Days	Deadline
Supplier D	Packaging	Supply network	Introduce new supplier	Buyer	48	30/11/20
Supplier EJ	Special Screws	Specifications	Comprehend status/existence of the patent.	Buyer	14	31/12/20
Supplier I	Painting	Quality	Verify that quality index is increased.	Quality Dep.	60	31/12/20
Supplier D	Packaging	Specifications	Identify specs in laboratory. Verify eventual sovrastimation. Define new and clear specs in drawings.	Tech. Office	21	31/12/20
Supplier S, E, SI	Sheet metal stamping	Continuous improvement	Supplier risk analysis and identification of actions.	Buyer	15	31/01/21
All	All	Continuous	Formalize internal procedures for different purchasing categories to apply in case of disruption	Buyer	30	31/01/21
Supplier EJ	Special Screws	Specifications	Try to find and alternative solution (i.e. product management)	Tech. Office	60	28/02/21
Supplier EJ	Special Screws	Vendor List	Scouting. Identify 1/2 possible suppliers suitable for PF and start their qualification.	Buyer	7	28/02/21
Supplier N, C, M, NI	Plastic molding	Continuous improvement	Supplier risk analysis and identification of actions.	Buyer	15	28/02/21
Supplier P	Turning from wire	Vendor List	Scouting. Identify 1/2 possible suppliers suitable for PF and start their qualification.	Buyer	7	31/03/21
Supplier ST	Serigraphy	Continuous improvement	Introduce entry quality checks	Supplier	60	31/03/21
Supplier CO, B, P	Multi-spindle turning	Continuous improvement	Supplier risk analysis and identification of actions.	Buyer	15	31/03/21
Supplier ST, BO	Serigraphy	Vendor List	Scouting. Identify 1/2 possible suppliers suitable for PF and start their qualification.	Buyer	7	30/04/21
Supplier L, NE, TO, SA, EL, PA, R, FR	Small metal turned parts	Continuous improvement	Supplier risk analysis and identification of actions.	Buyer	15	30/04/21
All	All	Continuous improvement	Create a monitoring tool able to control the paramters of the risk assessment continuously	Buyer	30	31/05/21
Supplier I, V	Painting	Vendor List	Scouting. Identify 1/2 possible suppliers suitable for PF and start their qualification.	Buyer	7	31/05/21
Supplier D	Packaging	Vendor List	Scouting. Identify 1/2 possible suppliers suitable for PF and start their qualification.	Buyer	7	30/06/21
Supplier EJ	Special Screws	Supply network	1/2 new suppliers introduction	Buyer	170	31/07/21
Supplier I, V	Painting	Supply network	New supplier introduciton	Buyer	130	31/07/21
Supplier D	Packaging	Certifications	Require ISO 140001 certifications when obtained	Buyer	1	31/07/21
Supplier V	Painting	Certifications	Require ISO 90001 certifications when obtained	Buyer	1	31/07/21
Supplier V	Painting	Certifications	Require product certifications when obtained	Buyer	1	31/07/21
Supplier GU, GA	Special gaskets	Vendor List	Scouting. Identify 1/2 possible suppliers suitable for PF and start their qualification.	Buyer	7	31/07/21

11. List of Figures

12. List of Tables