BUILDING THE RESILIENT SME:

DEVELOPING THE '4 IN A ROW' TOOL FOR SUPPLY CHAIN RISK MANAGEMENT

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I hereby declare that I am the sole author of this thesis. No other sources than those indicated have been used in the accomplishment of this work.

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Intellectuals solve problems, geniuses prevent them

Albert Einstein

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Abstract

The number of supply chain risks has sharply risen due to climate change and the increasing complexity of the 21st century business network whose firms are exporting and importing articles worldwide. Nowadays, it is not enough to ensure an effective production plant; it is high time to guarantee the perfect performance of the whole supply chain. And that means, among other issues, an intense and close relationship between suppliers and customers.

This thesis addresses some of the small and medium enterprises' concerns by developing a new procedure: '4 in a row'. '4 in a row' is unpretentious, effective and carefully designed to be implemented taking into account its users constraints. '4 in a row' is the result of a deep literature review and a passionate interaction with supply chain experts. '4 in a row' is the main contribution of a project in which I started to think about one year ago: creating something valuable to improve the small and medium enterprise's supply chain.

The thesis starts with the introduction chapter and the literature review. Then, it follows the research approach chapter in which the motives of choosing a literature review and a semi-structured interview as the main study methods are reasoned. Chapter four summarises feedback from five different supply chain experts. The core of the thesis is in chapter 5: the design of a four-step procedure with the intuitive name of '4 in a row'. The first step of '4 in a row' is the adaptation of the tool to the needs of each firm; the second step is the identification and prioritization of supply chain risks through a Failure Mode and Effect Analysis; the third step contains potential mitigation actions in order to cope with the identified high-priority risks organized in two categories, 'Lean tools' and 'best practices'; and the fourth and last step is a benefit/cost analysis which aims to assess from an economical point of view which mitigation actions are worth to implement. The core of the thesis is followed, in chapter 6, by an evaluation of the performance of '4 in a row' in a real small company. Lastly, there is a critical discussion in what could have been done better and some natural indications about how to continue with further investigation.

I wholeheartedly expect to capture your attention through this 132-page thesis and 32.980 words mostly written in the awe-inspiring Denmark Technical University facilities. It might not be the longest thesis; however, I hope you will find this text easy-to-read and above all else, profitable and constructive.

Acknowledgements

I would like to take the chance to express my gratitude to those who have given their support enabling the successful completion of my thesis.

My greatest thanks to Dr. Josef Oehmen: my DTU supervisor. His guidance as well as his fruitful feedback in the 'I don't know how to continue' moments were a truly support for the thesis.

I would also like to thanks to my family, and especially to my parents, for minimising these depressing moments when you feel 'What on Earth am I doing here instead of being at home' and their obvious financial support.

And last but not least, to my darling fiancée who has been taking care of me in Denmark from the very beginning and has made from this experience something unforgettable and unrepeatable.

1- Introduction to research motivation and goals

A few years before moving in Denmark to finish my Master I had the chance to leave my studies and start working in the family small company. My mother has a medical degree and she pushed me to develop my academic skills in a foreign University (what she considered very stimulating) whereas my father did not especially encourage me to do so. He has been quite successful by creating the family enterprise and maybe for that reason he would have preferred me to stay at home and learn there that leaving 'the only child he has' moving around the globe. However, it must be said that once he visited me and realised that in that country 'there was something to eat' and I was not living 'under a bridge', he was also proud of having 'the only child he has' involved in this experience and getting prepared to enter in the labour market. And what was my opinion? Before coming, I wanted to start working as soon as possible to have economic independence but I also wanted to challenge myself with a new language, new workmates and a new country from the northern Europe. And when I am in the verge of finishing my thesis, I can only say that it was the best decision I could have ever taken. Nowadays, I feel much more prepared, full of fulfilment and very pleased to have had this magnificent chance to study abroad.

1.1- Initial situation and motivation

Supply chains have become much more complex and difficult-to-drive whereas the number of risks has sharply risen due to globalization and capital needs. Luckily, an overwhelming increase of awareness about supply chain in the last two decades has meant a new science, Supply Chain Risk Management, which nowadays is an attractive research area to academics who wish to have impact on business (Sodhi et al., 2011).

Most large firms have specialised teams trying to cope with new daily supply chain challenges and still suffer huge losses when unexpected disruptions appears (Pisarenko and Rodkin, 2014). However, Small and Medium Enterprises (SME) are exposed to the same challenges with additional constraints (Gutierrez et al., 2006) such as very limited budgets, shortage of human resources and lack of knowledge. Hence, the main question is: How can a SME face, prioritize and mitigate supply chains risks to improve its resilience according to their constraints? There are also two subquestions which are lacking a solution: Does 'resilient supply chain' have a common meaning in SMEs and in large firms? And what kind of problems struggle most the SMEs' supply chains?

The first clue might be to take profit from the agile organization that a SME tends to have and solve problems quick and effective without an excess of bureaucracy. With around 2.5 million SMEs in Europe representing 99% of European manufacturing

businesses, it is not difficult to conclude that EU competitiveness is significantly influenced by the performance of its SMEs. It is therefore not surprising, particularly in the recent economic downturn, that sustainability of SMEs is vitally important for the global economy (Mikhailitchenko and Lundstrom, 2006; Turner et al., 2010; North, 1998).

The second clue might be the correct implementation of already existing successful technologies and philosophies applied traditionally by large firms, such as Lean, in SMEs. Many authors have developed the Toyota Production System (TPS) until defining a whole philosophy with its own principles what is today called Lean but, unfortunately, very little attention has been paid in the adaptation of Lean to manufacturing SMEs in an easy way.

As a result, this thesis is going to contribute to fill the existing gap of connecting the concepts of resilience and Lean and give a meaning to supply chain risk management within the SMEs context. The motivation is in some way being 'a small Robin Hood' by taking profit from the valuable SCRM contribution established by large firms to facilitate and spread out their knowledge among SMEs.

1.2- Research objectives and hypotheses

This thesis is going to address and verify three research hypotheses.

The first one refers to the similarity of problems and hazards between the ones confronted by SMEs and the ones handled by large firms. The first hypothesis of the thesis is that these hazards are different: SMEs worry most of the time about the survival of their business whereas large firms have the chance of improving processes and productivity since nearly any risk can challenge their existence.

H1: SMEs and large firms differ in the approach to the concept of resilience.

The second hypothesis refers to which problems challenge most a supply chain of a company. The hypothesis of the thesis is that the most problematic risks are the ones which were not previously considered by the corporation.

H2: Hidden problems are the most challenging hazards. There is a necessity of tools useful and easy to implement to mitigate these risks.

The third and last hypothesis is that Lean, the Japanese philosophy firstly adopted by *Toyota*, is something what is not worth to implement as a risk mitigation strategy since most SMEs do not have the required time and/or funds to cultivate it.

H3: Lean is mostly applicable in large firms.

By corroborating these three hypotheses, I hope to realise what the state-of-the-art is regarding the application of Supply Chain Risk Management, Lean and resilience within the small and medium enterprise context. Afterwards, I expect to contribute the existing literature by developing an online tool, accessible for whoever wants to have a glance, which can help to bring near the above mentioned concepts to SMEs. In my opinion, there is no other way to success than creating something easy-to-use and with objective benefits - exactly what I want for my contribution.

1.3- Thesis structure

This thesis is structured in 7 chapters plus an abstract, acknowledgements, references and appendixes.

Chapter 1 is the introduction to the thesis. It aims to highlight the main reasons to carry on this project and includes the research objectives and the thesis structure.

Chapter 2 is the theoretical background chapter. In 4 subchapters the main topics are introduced through a literature review. The first two subchapters are about supply chain risk management; the third subchapter covers the Lean philosophy and the last one discovers the resilience concept and its key concepts.

Chapter 3 introduces the research approach and describes the research methods used in this thesis.

Chapter 4 includes the reflections from five different supply chain experts who are interviewed. Five completely different profiles which include: a CEO of a SME selling worldwide, a Lean external consultant for SMEs, a University professor head of a research group in IT, a co-partner of a procurement consultancy and a naval manager specialised in the logistics area. Thanks to their valuable contribution, it was possible to collect different insights from different key players all working in the supply chain area.

Chapter 5 is the core of the thesis and where the tool I designed, ‘4 in a row’, is described in 4 intuitive steps. ‘4 in a row’ is a free online resource whose goal is to assess SMEs in the tough field of Supply Chain Risk Management. Until now, there was no self-assessment process, specially designed for SMEs, which aimed to measure and cope with their supply chain risks from the early stage of identifying those risks until the decision point of implementing mitigation actions based on economic facts. The first step of ‘4 in a row’ is the adaptation of ‘4 in a row’ to the needs of each manufacturing SME; the second step is the identification and prioritization of supply chain risks through a Failure Mode and Effect Analysis; the third step contains mitigation actions to cope with the identified high-priority supply chain risks organized in two categories, ‘Lean tools’ and ‘best practices’; and the

fourth step is a benefit/cost analysis which aims to assess from an economical point of view which mitigation actions are worth to implement.

Chapter 6 is an example of how ‘4 in a row’ is tested on a real SME and includes the reflections from the manager who tried the tool.

Chapter 7 is a summary of the project and includes the conclusions and a discussion based on the previous literature.

Table 1.1, reflects how the chapters are dependent on the three established hypotheses of the thesis.

		H1	H2	H3
Chapter 2	2.1	⊙		
	2.2	⊙	●	
	2.3		⊙	●
	2.4	●	⊙	
	2.5	⊙	⊙	⊙
Chapter 3	3.1			
	3.2			
	3.3			
	3.4	⊙	⊙	⊙
Chapter 4	4.1		●	
	4.2	●	●	
	4.3	●		●
	4.4	●		●
	4.5	⊙	⊙	⊙
	4.6	⊙	⊙	⊙
Chapter 5	5.1	●	⊙	⊙
	5.2	●	●	
	5.3	⊙	⊙	●
	5.4	●	⊙	
	5.5	⊙	⊙	⊙
Chapter 6		⊙	●	⊙
Chapter 7		●	●	●
● **Very relevant**			⊙**Partly relevant**	

Table 1.1: Applicability of each chapter and subchapter to the three research hypothesis

Note: In this thesis is going to be used ‘How to write a better thesis’ by Evans et al. (Evans et al., 2014) as a guide for writing the document.

2- Theory of Lean philosophy and Supply Chain Risk Management within manufacturing Small and Medium Enterprises

2.1- Supply Chain Risk processes

Not many years ago, there was no available and standardised procedure to deal with supply chain risks. SMEs, but also the large enterprises, were used to create their own supply chain risk plans or just trust in their views and a pinch of 'luck' to overcome those risks as soon as they appeared. However, in the last decade, a big number of authors and organisations have focussed their attention in such a vital activity of any manufacturing company. Today, there are many standards and papers accessible; the following lines include a review of the most relevant documents.

In 2006, Tang proposed 4 different approaches to supply chain risk management: product management, supply management, demand management and information management. He aimed to create a paper 'to unify framework for classifying supply chain risk management articles', 'serve as a practical guide for some researchers to navigate through the sea of research articles in this important area' and 'highlight the gap between theory and practice'. And basically he did it, since that paper has been reviewed for a very big number of authors afterwards (Tang, 2006).

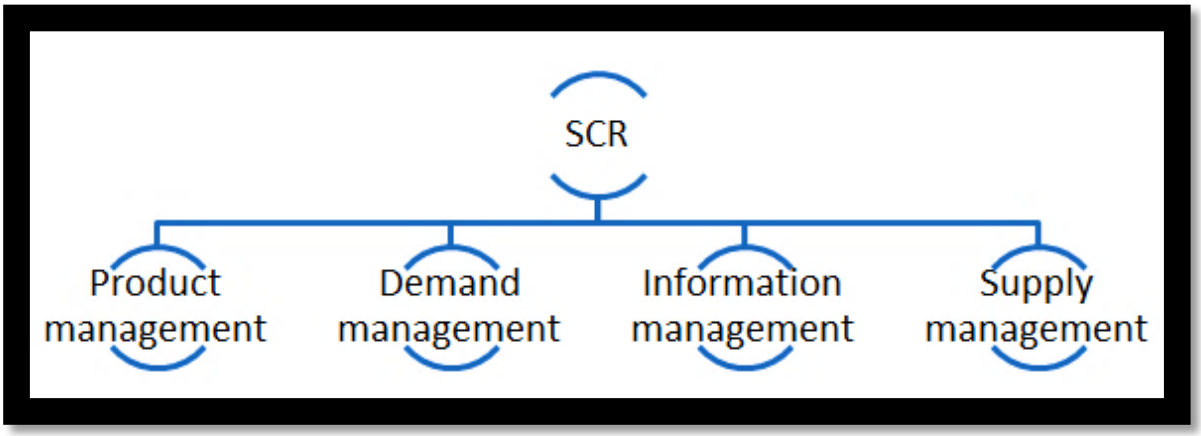


Figure 2.1: Four basic approaches for managing SCR by Tang. Based on Tang, 2006

In 2008, Olson and Wu suggested two different phases for the risk management process 'Risk Assessment' and 'Risk Response'. They created a 'The two-polar perspective' to express the fact that the risk management process 'has two main equivalent poles or columns, including risk and response' (Olson & Wu 2008).

	Level-1	Level-2	Level-3
Action	RMP start up Actuation		
Plan	Risk assessment	Risk identification Risk analysis	 Risk measurement Risk processing Risk classification
Do	Implementation		
Check	Control Shut down		

Figure 2.2: SCR process proposed by Olson and Wu. Based on Olson and Wu, 2008.

In addition, in 2008 was launched the fourth edition of the Project Management Body of Knowledge, usually referred as PMBoK. This book proposes to include in the 'Project Risk Management' the processes of 'conducting risk management planning, identification, analysis, response planning, and monitoring and control on a project'. For the authors of the book, the objectives of Project Risk Management are 'to increase the probability and impact of positive events' and 'decrease the probability and impact of negative events in the project'. The authors also distinguish in the book between 'known risks (identified and analysed)' and 'specific unknown risks (which cannot be managed proactively and need from a contingency plan)' (PMBoK 2008).

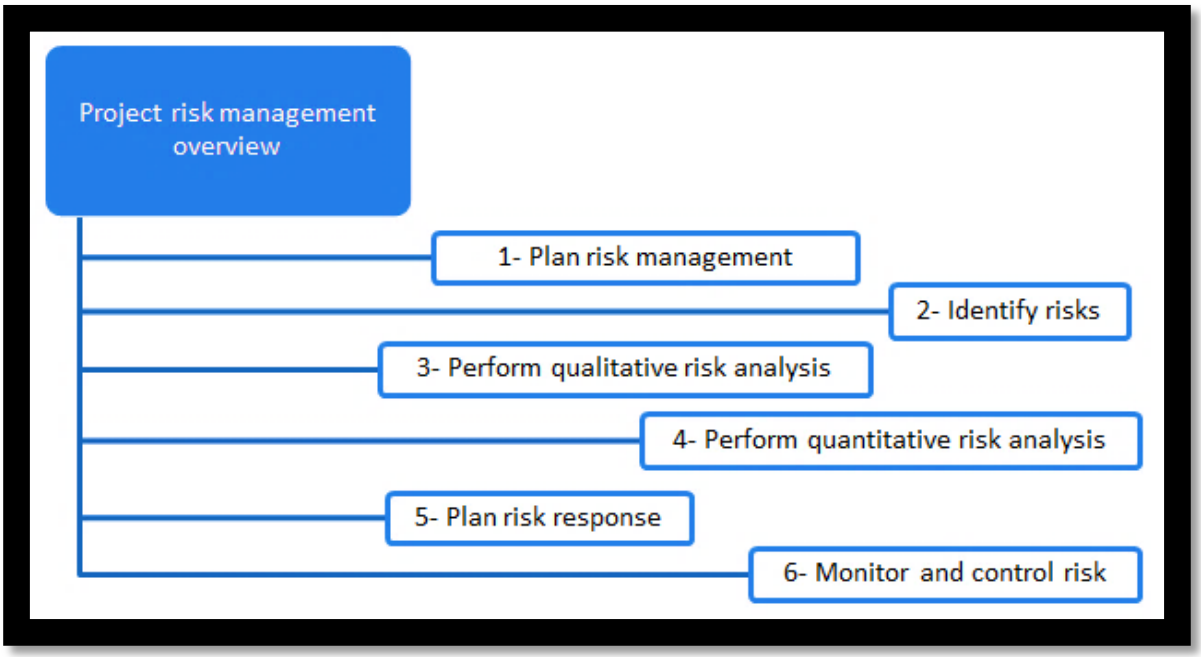


Figure 2.3: SCR process proposed by the PMBoK. Based on PMBoK, 2008

In 2009, Kleindorfer and Saad published their framework, labelled as 'SAM-SAC'. Their framework denotes the three main tasks of risk: '**S**pecification of sources and

vulnerabilities, **A**ssessment, and **M**itigation' and the proposed '**S**trategies with dual dimensions: **A**ctions and necessary **C**onditions for effective implementation'. In their paper, they also advise 'not to manage supply chain risks in the traditional manner (based on measuring outcomes and translating these into process improvements) because disruption risks belong to the low-probability, high-consequence outcomes'. They recommend 'the spirit of very high quality (Six Sigma) process management, in which the process itself is continually audited to assure a proper balance between risks and benefits of mitigation' (Kleindorfer & Saad, 2009).

Figure 2.4: SCR process proposed by Kleindorfer and Saad. Based on Kleindorfer and Saad, 2009

2009 was also the year when Oehmen et al. wrote their SC paper about their proposal of SCR process. Through a case study the authors wanted to validate their 'Dynamics Model', which is based on 'the assumption that the final states of the system, from a risk perspective, are critical failures in one or more of the target areas'.

They condense the SCR process in three main steps: 'Risk identification (or risk catalogue)', 'Risk assessment (or risk portfolio)' and 'Risk mitigation (or measures)' (Oehmen et al., 2009).

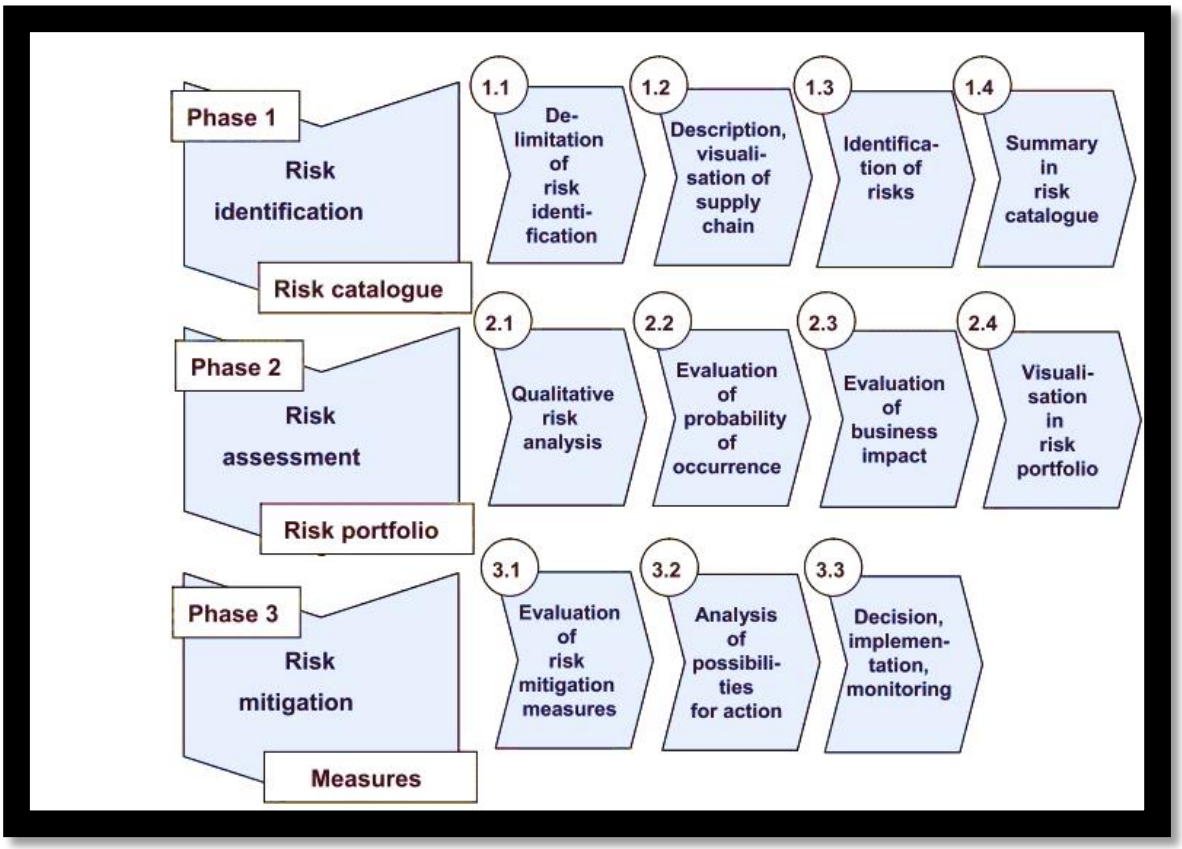


Figure 2.5: SCR process proposed by Oehmen et al. Based on Oehmen et al., 2009

ISO 31000, created by the ISO committee of experts in 2009, is a standard which also addresses the SCR process. ISO 31000 aims to ‘evaluate an organization's effectiveness in managing risk’. This standard clearly reflects the high-value of supply chain risk management as it is written ‘The risk management process should be an integral part of management, embedded in the culture and practices, and tailored to the business processes of the organization’. ISO 31000 contemplate the supply chain risk process in three main steps: ‘Establishing the context’, ‘Risk assessment (which include three sub steps: risk identification, risk analysis and risk evaluation)’ and ‘risk treatment’ (ISO 31000, 2009).

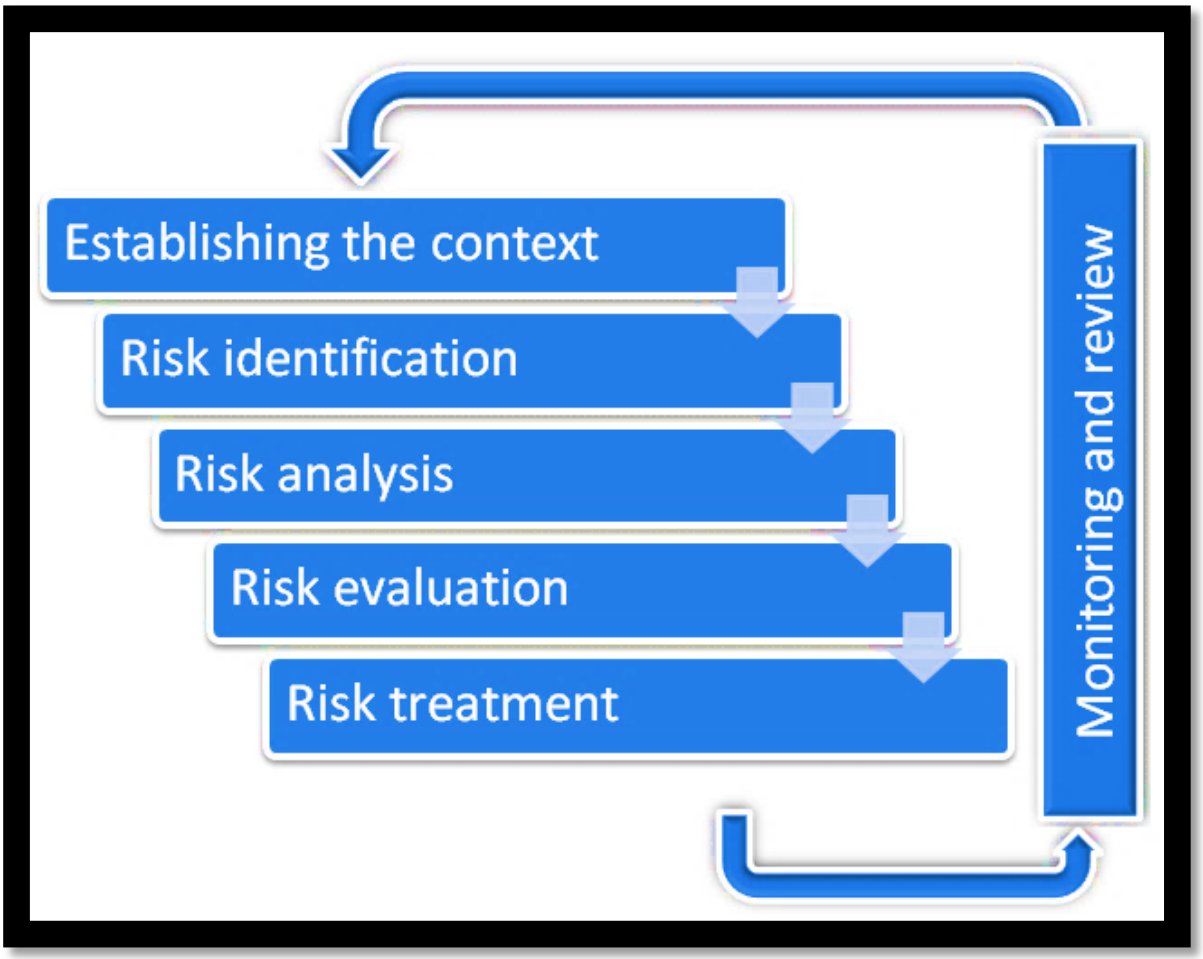


Figure 2.6: SCR process proposed by the ISO 31000. Based on ISO 31000, 2009

In 2009, the fifth edition of *Managing Successful Projects with PRINCE2* (PRINCE2, 2009) was launched. For the international organisation of PRINCE2, the supply chain risk process should contain 4 steps with the 'railing' of communication.

The first step is 'Identify context' which aims to obtain information about the project in order to understand the specific objectives in risk and formulate the risk management strategy for the project.

The second step is 'Estimate' which aims to assess the threats and opportunities for the project in terms of their probability and impact.

The third step is 'Plan' which aims to prepare specific management responses to the threats and opportunities identified (ideally to remove or reduce the threats and to maximize the opportunities).

The last step is 'Implement' which aims to ensure that the planned risk responses are actioned, their effectiveness monitored, and corrective action taken where responses do not match expectations.

Communication is a step that is carried out continually. The 'Communicate' step should ensure that information related to the threats and opportunities faced by the project is communicated both within the project and externally to stakeholders.

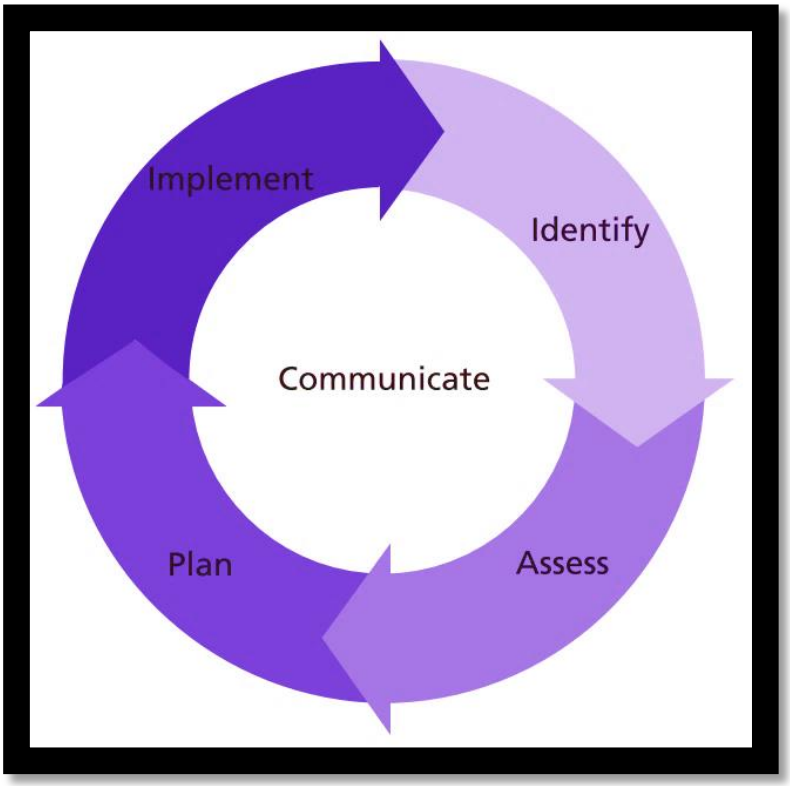


Figure 2.7: SCR process proposed by PRINCE2. Based on PRINCE2, 2009

In 2011, Kern published a paper, certifying 'the need for professional supply chain risk management activities along the risk management process: risk identification, risk assessment and risk mitigation'. They argue that companies with higher competencies in these three process steps of upstream supply chain risk management show 'superior performance' when it comes to the reduction of the frequency and impact of supply chain risks (Kern, 2011).

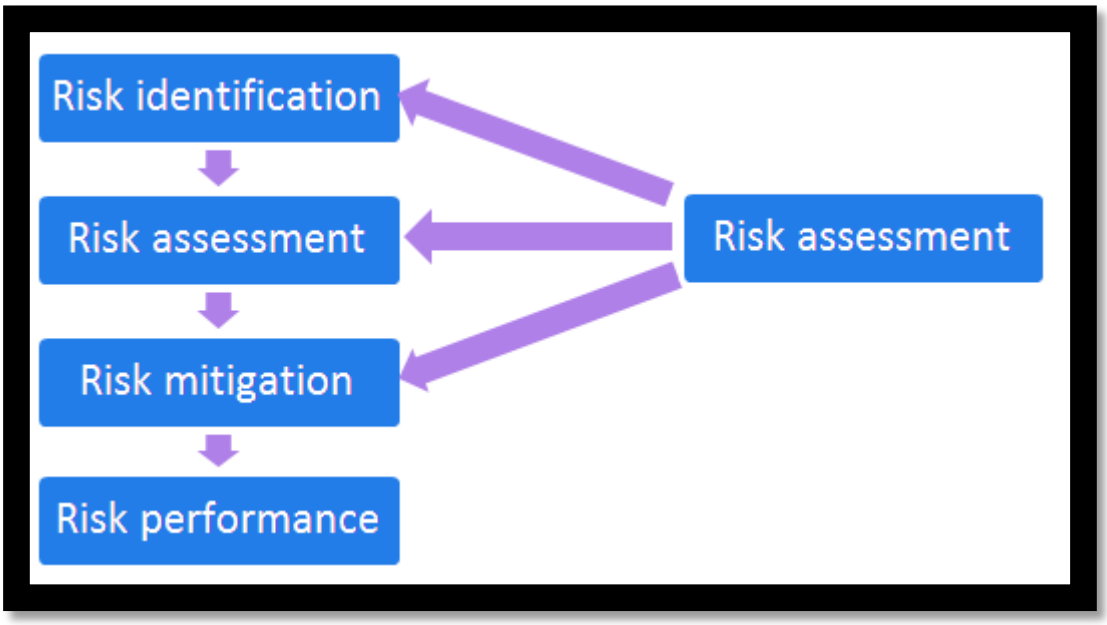


Figure 2.8: SCR process proposed by Kern. Based on Kern, 2011

In 2011, Christopher suggests a supply chain risk process considerably different from the one proposed by their supply chain colleagues, at least what refers to terminology (Christopher, 2011). He suggests a seven-step process which aims to understand, improve, control the supply chain and collaborate at the end with suppliers and customers to improve supply chain risk management procedures.

Figure 2.9: SCR process proposed by Christopher. Based on Christopher, 2011

In 2012, the ISO organisation dedicated a new standard to SCRM what reinforces the statement that SCRM is becoming an essential player for enterprises. The authors in this occasion define the SCR process in four steps: 'Identify', 'Assess', 'Treat' and 'Control' risks.

The purpose of 'Identify' risks is to determine potential risk events and their characteristics that, if they occur, may have a positive or negative impact on the project objectives. The purpose of 'Assess' risk is to measure and prioritize the risks for further action. The purpose of 'Treat' risks is to develop options and determine actions to enhance opportunities and reduce threats to project objectives. The purpose of 'Control' risks is to minimize disruption to the project by determining whether the risk responses are executed and whether they have the desired effect (ISO 21500, 2012).

Nowadays, there is also an Enterprise called 'FM Global' whose products are specifically designed to support their clients in overall risk management objectives. Their task is helping their clients in 'understanding the nature and reality of their specific risks', 'establishing sound loss prevention solutions that safeguard against loss', 'developing cost-effective insurance and risk transfer solutions backed by large, stable capacity' and 'providing the claims and loss mitigation support to minimize business disruption'.

They work with a three-phase SCR process: 'Risk identification and assessment', 'risk avoidance and reduction' and 'risk acceptance and transfer'.

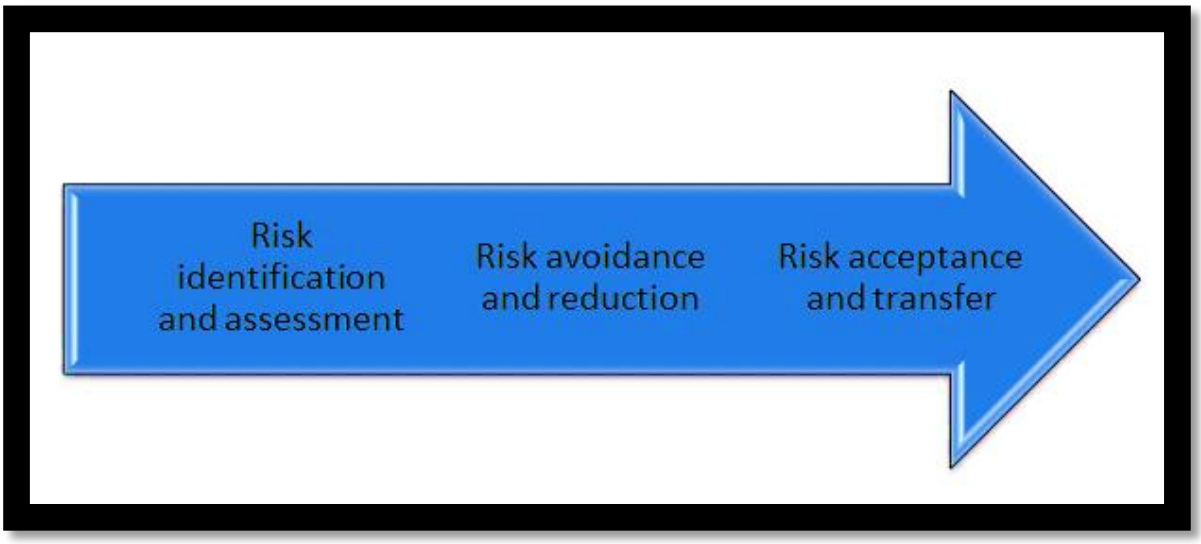


Figure 2.10: SCR process proposed by FM global. Based on FM Global, 2014

2.2- Supply Chain Risk classification

2.2.1- Overview

Risk in Supply Chain (SCR) can be defined as the potential deviation from the initial overall objective that, consequently, trigger the decrease of value-added activities at different levels (Kumar et al., 2010). Risk is always in the future and there is a thin line which separates an uncertain event or condition from a real risk. A risk must have an effect on at least one project objective (PMBoK, 2008) if not, it could not be considered as a risk.

Managing risk is a must for any organization (Ben-Daya et al., 2009). Given the high vulnerability of today's supply chains to disruptions, measuring and managing supply chain vulnerability has become critical (Wagner & Neshat, 2012). Risks are inherent in every aspect of business, and the ability of manage risks is an important aspect that differentiates successful business leaders from others (Sodhi & Tang, 2012). For this reason, in the recent decades a new science has attracted the interest of both, enterprises and academic researchers. And this new science has been commonly known as Supply Chain Risk Management (SCRM), although some authors refer to it simply as Supply Chain Management or Risk Management.

A Supply Chain (SC) is a network of organizations possibly including suppliers, manufacturers, logistics providers, wholesalers/distributors, and retailers that aims to produce and deliver products or services for the end customer (Sodhi & Tang, 2012). When working effectively and efficiently, modern SC allow goods to be produced and delivered in the right quantities, to the right places at the right time in a cost-effective manner. The key point is that modern supply chains are not simply linear chains or processes, they are complex networks. The products and information flows travel within and between nodes in a variety of networks which link organisations, industries and economies (Cranfield 2003).

Once, the definition of SC and risk are clear, it is easier to give a meaning to SCRM. Nonetheless, there is a big discussion about which definition fits better to the concept.

Tang refers to SCRM as the management of risk, material, information and financial flows through a network of organizations (i.e. suppliers, manufacturers, logistics providers, wholesalers/distributors and retailers) that aims to produce and deliver products or services for the consumers (Tang, 2006). The IPMA foundation denotes SCRM as an early warning system for the organisation to give it timely and accurate information to prepare risk management interventions when needed (IPMA, 2006). There are other authors who also address the definition of SCRM in their papers or books. For example, SCRM is for the ISO foundation a group of coordinated activities to direct and control an organization with regard to risk (ISO 31000, 2009). For Sodhi

and Tang, SCRM is the management of material, information and financial flows through the supply chain and includes the coordination and collaboration of processes and activities across different functions such as marketing, sales, production, product design, procurement, logistics, finance, and information technology within the supply chain (Sodhi & Tang, 2012). For Wieland, SCRM is defined as the implementation of strategies to manage both every day and exceptional risks along the supply chain based on continuous risk assessment with the objective of reducing vulnerability and ensuring continuity. Thus, SCRM extends traditional risk management approaches by integrating risks of partners upstream and downstream the supply chain (Wieland, 2012).

In this thesis, SCRM is going to be addressed as 'a science which aims to identify, assess, mitigate and control SCR in order to increase the resilience of these enterprises who apply it meticulously'.

There is also a big discussion between SCRM authors regarding a possible classification of SCR. Table 2.1 summarise some of these SCR.

Author(s)	Year	Supply Chain Risk classification	
Chopra & Sodhi	2004	System	
		Forecast	
		Intellectual property	
		Receivable	
		Inventory	
		Capacity	
Kleindorfer & Saad	2005	Operational contingencies	
		Natural hazards	
		Terrorism and political instability	
Paulsson & Nilsson	2008	Product design	
		Production process design	
		Product flow design	
		Product flow supporting systems	
		Risk management systems and actions	
		Human resources	
Ritchie & Bob	2008	Supply	Supply cost
			Supply commitment
			Supply continuity
		Process	
		Demand	
		Rare-but-severe disruption	
		Other	Intellectual property
			Behavioural
			Political
			Social
Wagner & Bode	2008	Demand side	
		Supply side	
		Regulatory, legal and bureaucratic	
		Infrastructure	
		Catastrophic	
Hopkin	2010	Upside or opportunity (help an organization to achieve desired objectives)	
		Downside or hazard (inhibit achieving these objectives)	
		Other or control (create uncertainty about outcomes)	
Kumar et al.	2010	Demand	
		Production and distribution	
		Supply	
		Interaction	

Author(s)	Year	Supply Chain Risk classification	
Christopher	2011	Supply	
		Demand	
		Process	
		Risk	
		Environmental	
Wakolbinger & Cruz	2012	Supply–demand coordination	
		Disruption	
Simangunsong et al.	2012	Product characteristics	
		Process/manufacturing	
		Control/chaos/response uncertainty	
		Supplier	
		Decision complexity	
		Organisation structure and human behaviour	
		IT/IS complexity	
		End customer demand	
		Demand amplification	
		Parallel interaction	
		Order forecast horizon/ lead-time gap	
		Chain configuration, infrastructure and facilities	
		Environment	
		Disruption/natural uncertainties	
Sodhi & Tang	2012	Supply	Supplier failure
			Supply commitment
			Supply cost
		Process	Design
			Yield
			Inventory
			Capacity
		Demand	Forecasting
			Change in technology or in consumer preference
			Receivable
		Corporate-level risks	Financial
			SC visibility
			Political/Social
			IT systems
			Intellectual property
			Exchange rate
Chen et al.	2013	Supply	
		Demand	
		Process	

Table 2.1: SCR classification through a literature review

After considering the above mentions categories, in this thesis the SCR classification is based in six threats, the five proposed by Christopher (Christopher, 2011) plus an additional 'Other risks' which are not considered by him.

1. Demand risks
2. Supply risks
3. Process risks
4. Control risks
5. Environmental risks
6. Other risks

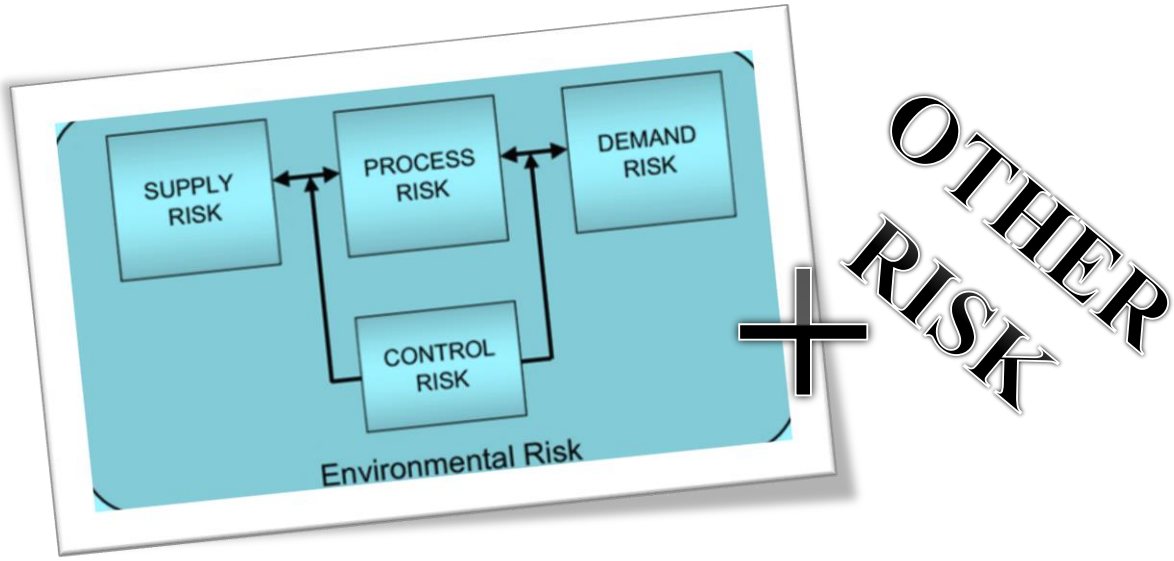


Figure 2.11: SCR classification proposed. Based on Christopher, 2011

There are two main reasons to consider Christopher as the main reference. Firstly, for his very deep knowledge and experience in the logistics area in which he has co-foundered the International Journal of Logistics Management, written several SC books and offered a large contribution in conferences and workshops around the world. And secondly, because Christopher's categorisation is direct, instinctual and very suitable for the majority of SMEs.

Even though the six-risk classification covers all the potentially detectable SCR, there is always an additional threat of those risks that have not been detected yet. This risk is considered by Sodhi and Tang as 'Residual risk'. Residual risk is the level of risk that remains after taking the company's prevention and responsiveness efforts into account (Sodhi & Tang, 2012).

2.2.2- Demand risk

Demand risk is the potential deviation of the forecasted demand from the actual demand (Kumar et al., 2010). Demand risk occur here as a result of a mismatch between a company's projections and actual demand as well as from poor supply chain coordination. The consequences of such disruptions are costly shortages, obsolescence, and inefficient capacity utilization (Wagner & Bode, 2008).

Tang summarises demand risk in three categories: shifting demand across time; shifting demand across markets; and shifting demand across products. For the first category, Tang suggests the mitigation action of offering different prices at different times. That enables the firm to increase the profit generated from a fixed supply capacity by capturing customers in different segments who are willing to pay different prices for the service offered in different times. For the second category, Tang calls for selling the new product in different markets with non-overlapping selling seasons. And for the third category, Tang suggests the product substitution (selling products with similar features increasing the product substitutability) or the product bundling (selling packs of computers and printers, for example) (Tang, 2006).

Nevertheless, other authors include in the demand category other SCRs. One of the most challenging demand risks for a few authors is the bullwhip effect. Bullwhip effect is the magnification of demand as orders move up the supply chain away from the original point of order. Small changes in demand can result in large variations in orders placed upstream. The bullwhip effect can result in increased cost and reduced service (Cranfield, 2003).

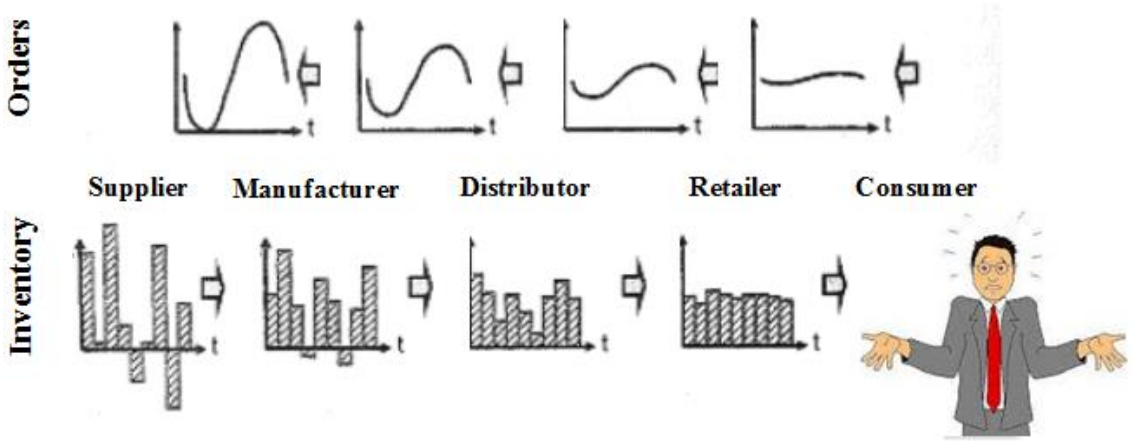


Figure 2.12: The bullwhip effect. Based on Sheffi, 2005

Other causes of demand risk correspond also with information distortion such as promotions or incentives that lead to forward buying batching of purchases that leads to

higher volatility in orders and lack of knowledge of end-customer demand at upstream locations (Sodhi & Tang, 2012).

More than a few SC experts have addressed the issue of how to mitigate demand SCR. Sodhi and Tang suggest three actions to mitigate inventory SCR: pooling inventory; creating common components across products and postponing or delaying until the receipt of orders the last stage of production from which emerges product variety (Sodhi & Tang, 2012). Chopra and Sodhi gives the Toyota example of how to cope with demand risks 'By running plants at 80% utilization, Toyota can handle demand variation without having to hold inventory' (Chopra & Sodhi, 2004). KPMG audit suggests turning to a scenario-based forecasting in which managers define alternative scenarios and identify a range of possible outcomes. Some of the key steps of the scenario-based they propose is to determine the focus of the evaluation and the key factors and events affecting the focal area; identify the driving forces behind the key factors; rank critical uncertainties and begin to develop different outcome scenarios; identify early indicators of a probable outcome and integrate the results of the developed scenario, which is currently evolving, into the planning cycle (KPMG Audit, 2009).

One demand SCR example occurred in 2003. Product shortages in Western Europe led Nokia customers to order more than they needed so they would be able to meet demand in case Nokia began rationing or allocations. These exaggerated figures distorted Nokia's reading of the market, causing the company to inaccurately forecast sales (Sodhi & Tang, 2012).

2.2.3- Supply risk

Supply risk is the potential deviation in the inbound supply in terms of time, quality and quantity that may result in uncompleted orders (Kumar et al. 2010). Due to the practice of outsourcing, the capability of the suppliers to assure supply is critical for the buying companies (Chen et al., 2013).

Supply side risks reside most in purchasing, suppliers, supplier relationships, and supply networks (Wagner & Bode, 2008).

One of the topics which is more widely addressed by SC authors is the suitability of a single-or-several-source of supplied components to mitigate SCR. More than one supplier is a suggestion formulated by Sodhi and Tang about countering disruptions in material: 'after all, it is unlikely that all suppliers would be disrupted at the same time' (Sodhi & Tang, 2012). An example of how to use effectively two suppliers for one product is the example proposed by Kouvelis and Dong about Adidas. One of their suppliers is in East-Asia and another is in Germany. A large order is placed with the Asian supplier. In addition, if the demand is higher than expected, then Adidas places a

rush order with the local supplier, which is more expensive but allows the retailer to avoid stocking out (Kouvelis and Dong, 2012). There are also numerical studies which indicate that dual sourcing provides a higher service level and results in higher order quantities than single sourcing (Glock & Ries, 2013). However, according to Sheffi (Sheffi, 2005), a single supplier must be enough if there is a deep relationship with that specific supplier. A study proposed by Lockström has found that a close and intense collaboration and interaction between buyers and suppliers is required in order to cope with the challenges in the industry (Lockström et al., 2010). Trust, information and continuing profitability are the basic glue that makes supply chain partnerships a reality. Continuous coordination, cooperation, and collaboration among supply chain partners are needed for risk avoidance, reduction, and mitigation such that the value and benefits generated are maximized and shared fairly (Kleindofer & Saad, 2009).

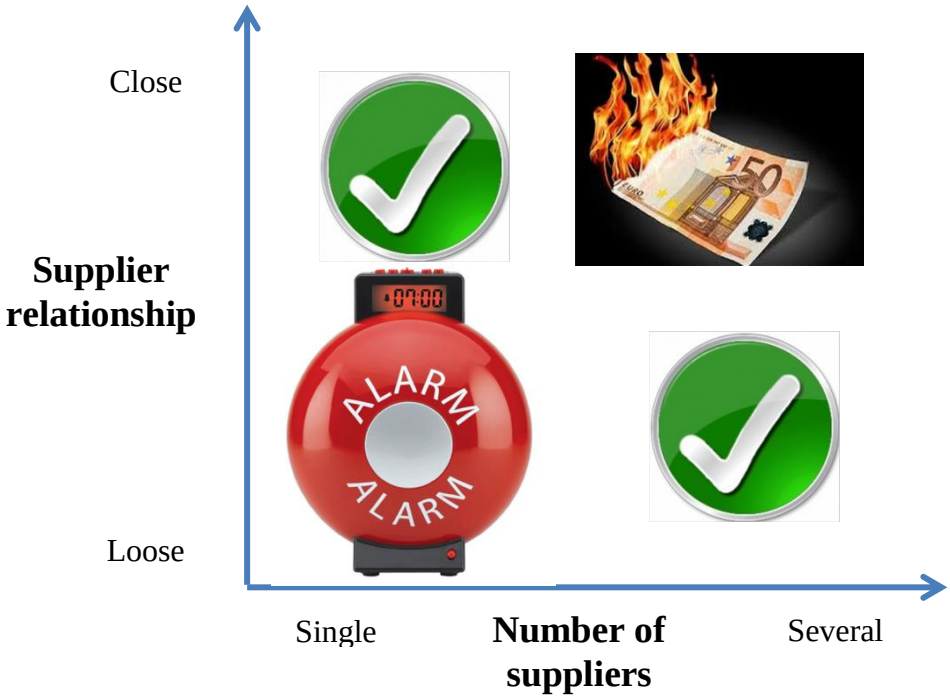
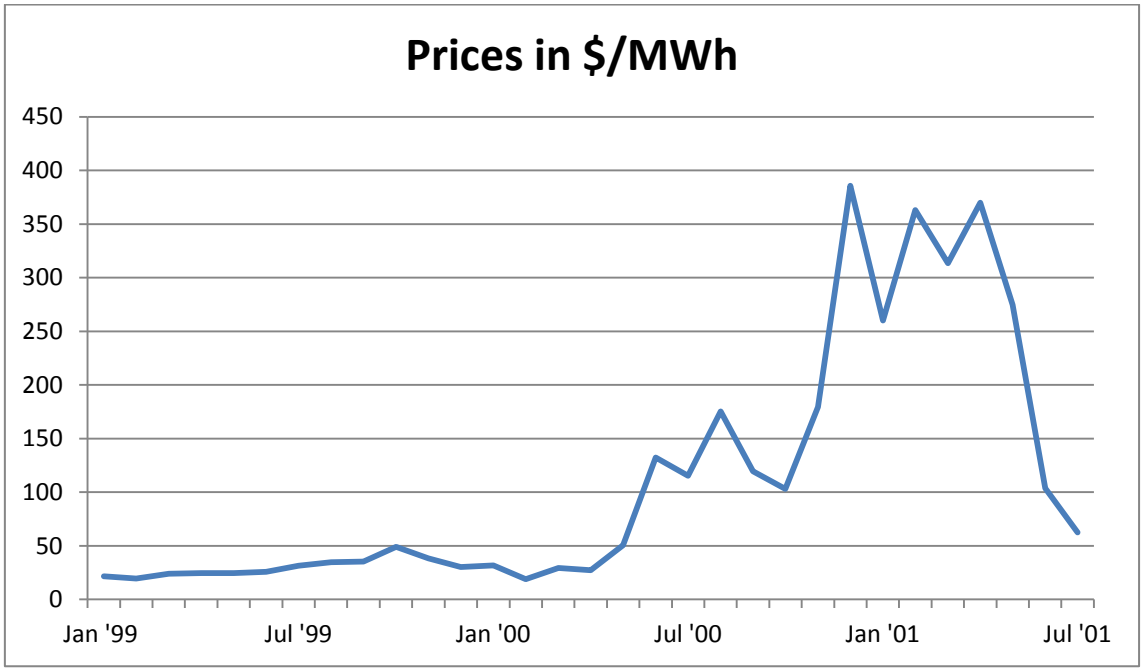


Figure 2.13: Number of suppliers recommended based on the strength of the relationships. Based on Sheffi, 2005

An example of a supply risk is the California electricity crisis in 2000. This year, California had a shortage of electricity caused by market influences and illegal blackouts. Drought, delays in approval of new power plants, and market manipulation decreased supply resulting in very low electricity reserves. Some firms took advantage from it by closing their plants for "maintenance" and forcing California to purchase electricity on the spot market, thus causing an 800% increase in wholesale prices from April 2000 to December 2000 (Joskow, 2002).

	1999	2000	2001
January	21.6	31.8	260.2
February	19.6	18.8	363.0
March	24.0	29.3	313.5
April	24.7	27.4	370.0
May	24.7	50.4	274.7
June	25.8	132.4	103.8
July	31.5	115.3	62.6
August	34.7	175.2	
September	35.2	119.6	
October	49.0	103.2	
November	38.3	179.4	
December	30.2	385.6	
Average	30	115.0	

Figure 2.14: Electricity prices in $/MWh during the California electricity crisis. Based on Joskow, 2002



Graph 2.1: Electricity prices in $/MWh during the California electricity crisis. Based on data from Joskow, 2002

2.2.4- Process risk

Process risk is the potential deviation from producing the desired quality and quantity at the right time (Kumar et al., 2010). Process risk might be influenced by the design of a product, the variation of a process, the yield or the capacity constraints of a production plant and the inventory adopted by a firm (Sodhi & Tang, 2012).

A design which does not satisfy the customers' expectation might mean a huge impact in an enterprise. For example, Samsung accepted the resignation of Chang Dong-hoon, head of design of their smartphones, in April 2014. That reason was none other than the poor reception of their new device design, the Galaxy S5. Although it seems that the Galaxy S5 is selling better than the previous S4, the critics for the texture points in the back of the phone and the resemblance between the S5 models with a plaster definitely meant the resignation of the responsible.

Variability is also a SCR to consider. There are two main types of variability in a manufacturing system and none of them is desirable. One is process variability which is mainly caused by various detractors such as machine downtime, setups or operator unavailability. The other is flow variability which is caused by the way the work is released to the system and the movement between stations (Chen et al., 2013).

One example of process SCR was the one faced by IBM in 2004. That year, IBM announced that yield problems in their East Fishkill plant (New York), contributed to the $150 million first-quarter loss by its microelectronics division. The lower-than-expected yields reduced the plant's effective capacity and limited IBM's ability to meet customer demand (Ritchie & Bob, 2008).

Singhal discusses in his paper the performance of an enterprise based on the SCR caused by a surplus of inventory. Based on an analysis of more than 900 excess inventory announcements made by publicly traded firms during 1990-2002, he documents that firms that experience excess inventory situations substantially underperform a sample of matched firms from the same industry and of similar size. He estimates that the mean abnormal return due to excess inventory is -37.22%. The evidence he presents in his paper highlights the need for firms to be fully aware of what is happening in their supply chain so that inventory build-ups can be avoided or dealt with earlier rather than later (Singhal, 2005).

2.2.5- Control risk

The control risk is the risk of bad products continuing to join the flow of goods in the supply chain (Bogataj & Bogataj, 2007). Control risks might also be understood as disturbances and distortions of real demand caused by own internal control systems such as safety stocks policies and batch sizes (Christopher, 2011). In both circumstances, it is worth to have a look at Six Sigma.

Six Sigma is a systematic and robust approach to improvement, based on a reduction of variability. Originally, six sigma meant producing no more than 2 defects per million (see figure). Sigma (or standard deviation) is in statistics a measure of the amount of variability from the average of a sample and six is the number of standard deviations where the 99,999998% of goods produced should be. To define the standard deviation, it should be applied the following formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{i=n}(X_i - \bar{X})}{n-1}}$$

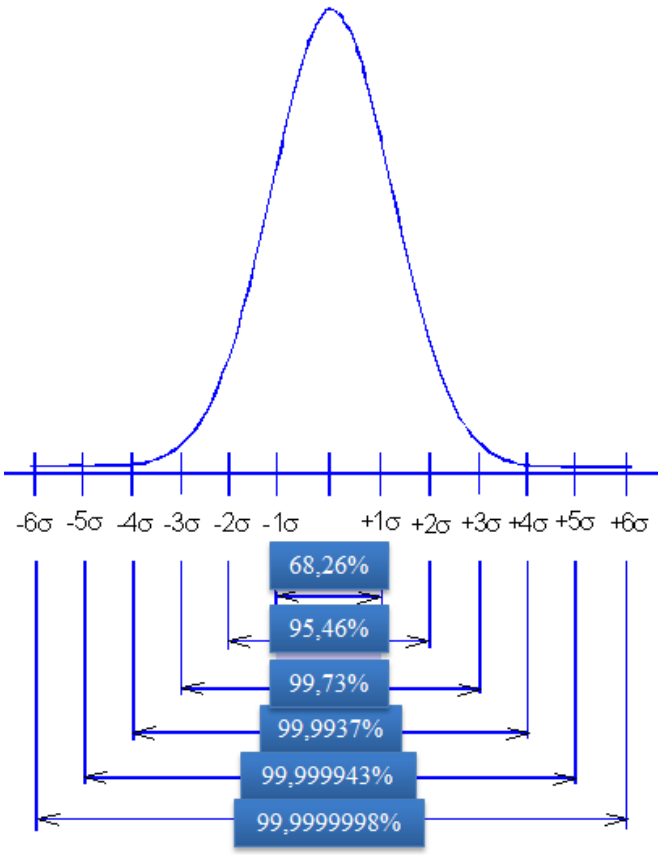


Figure 2.15: Relationship between standard deviation and percentage of goods satisfying the requirements. Based on Morgan & Brenig-Jones, 2009

Nowadays, referring to Six Sigma is not only that measure of variability. Implementing Six Sigma is synonym of referring to a five-step process, known as the DMAIC cycle, which aims to improve quality.

Figure 2.16: DMAIC cycle

- **D**efine means understanding what the problem is.
- **M**easure means employing a quality tool to collect data.
- **A**nalyse means finding the roots of the problem.
- **I**mprove means generating and implementing solutions
- **C**ontrol means ensuring a positive long-term effect of the solution

2.2.6- Environmental risk

Environmental SCR might be understood as a two-side term; a hazard caused to a firm due to a natural disaster or a threat instigated by the own activity of an enterprise to the environment.

In the first case, there are many regions of the world were tsunamis, droughts, earthquakes, hurricanes, and floods are a constant threat to their societies in general and to their firms in particular. The negative consequences on supply chains are obvious since production facilities and transportation systems are highly vulnerable to natural disasters. Due to the globalization of markets and a surge in globe-spanning supply chain operations, local catastrophes have increasingly indirect global repercussions. (Wagner & Bode, 2008)

In the second case, is the own firm the guilty of an environmental SCR due to a lack of responsibility when ensuring the firm's safety and the social responsibility they have with the society. Polluting water, contaminating air or not taking measures to ensure the sustainability of a process can be considered as SCR or hazards.

A very frequent environmental risk is thunderstorms. Although there is not usually a critical impact in SCs, nearly every year there is a major tempest which can cause (at least) delays. For example, in October 2013 the northern Europe suffered very strong winds which forced to close airports (such as Heathrow, in London), prevent passage in international roads (e.g. Øresund Bridge which connects Sweden with Denmark), meant electrical shut downs and caused 13 deaths.

A less-frequent but widely-known example of environmental risk for its impact on population took place in Chernobyl, in 1996. That year, due to some electrical tests, the nuclear reactor overheated resulting in a hydrogen explosion. That meant the death of 31 people, over 600 thousand people with high rates of radioactivity and more than 5 million of inhabitants directly affected (IAEA, 2006).

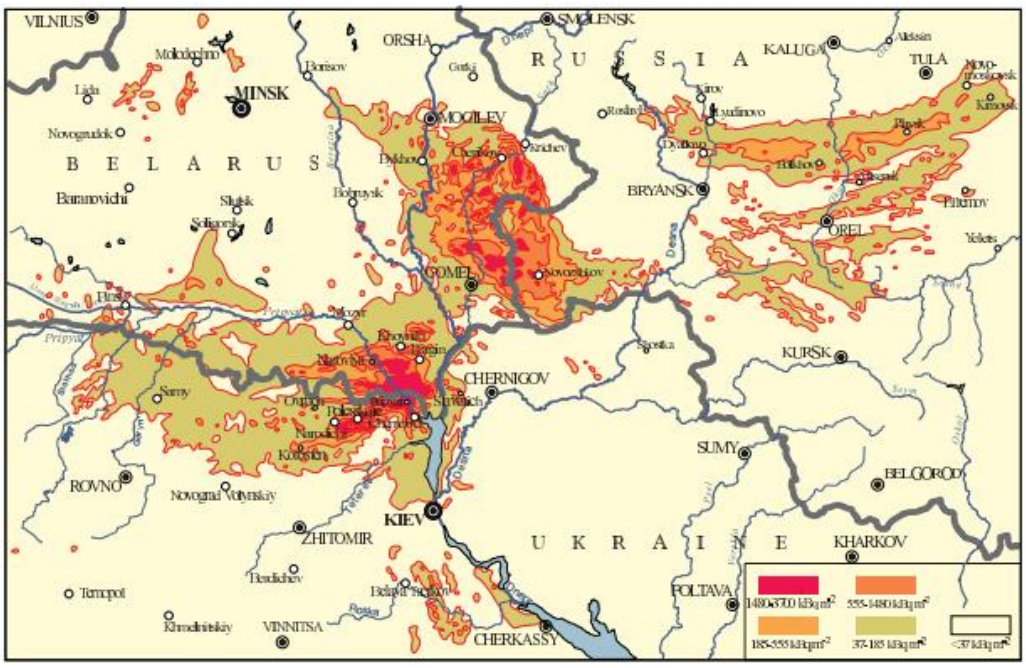


Figure 2.17: Surface ground deposition of ^{137}Cs after the Chernobyl accident. Based on IAEA, 2006

2.2.7- Other risk

There are other SCR which can damage an enterprise, depending very much in its activity. For example, Governmental instability, intellectual property, financial constraints, exchange rate risks or long bureaucratic procedures must be taken into account by worldwide-oriented firms.

One example of governmental risk was the YPF nationalisation, in May 2012. In that year, Argentina announced the nationalisation of an oil company, YPF, by the expropriation of a 51% of the shares belonging to the Spanish firm Repsol. That caused a huge impact not only in Repsol itself, but also in other international relationships

between Spain and Argentina such as cancelling the importation contracts of Argentinian lamb by the Spanish government as a response. A legal battle was then initiated and it was not until February 2014 when Argentina decided to pay USD5.000.000.000 in Argentinian bonds for the 51% of the YPF shares (REPSOL SA, 2014).

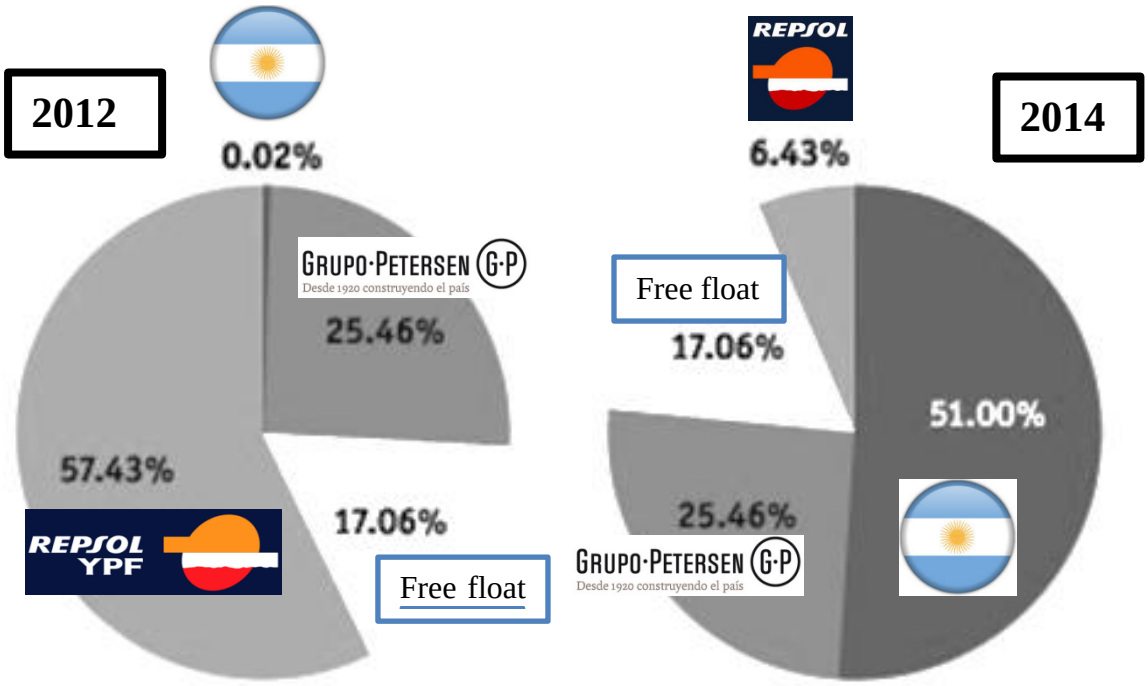


Figure 2.18: YPF ownership before (left) and after (right) the nationalisation. Based on Spanish press 2014

One example of intellectual property risk is the legal battle between Apple and Samsung regarding some patents of the Apple device, IPhone. A judge has condemned Samsung to pay USD199.600.000 for violating Apple patents in May 2014. Although, that is only a 5,5% of the USD2.200.000.000 Apple had asked for, the sentence means an impact on Samsung reputation (since that means the public recognition of copying Apple).

One example of financial and exchange SCR is offered by Weissensteiner regarding a Company called Toolco. Toolco, a machine tool manufacturer that produces and sells highly specialized equipment to customers who rely on the company to honour warranties, provide ongoing service, technical assistance and supply spare parts. Southeast Asia and Europe are both major markets for Toolco with German and South Korean manufacturing firms being major customers. Toolco prepares bids, quotes prices, and bills customers in local currency- German euros and South Korean won. In case the U.S. dollar appreciate substantially relative to the German mark and Korean won, Toolco's overall competitive position will weaken relative to its foreign competitors. The strengthening of the U.S. dollar will cause a substantial reduction in

Toolco's profits and cash flows, a reduction that will affect its ability to service its debt. Toolco can use risk management strategies to mitigate the potential financial problems associated with currency risks. It can hedge its exchange rate exposures and adopt other exchange rate exposure strategies-such as currency swaps for financing its foreign operations-that reduce the likelihood of Toolco experiencing severe financial problems from unexpected exchange rate movements. Managing currency risk may also lead to an increased willingness of customers to buy from Toolco because of its ability to withstand financial difficulties (Weissensteiner, 2014).

2.2.8 – Supply Chain Risk impact of disruptions in enterprises

A SC disruption is the combination of (1) an unintended, anomalous triggering event that materializes somewhere in the supply chain or its environment, and (2) a consequential situation which significantly threatens normal business operations of the firms in the supply chain (Wagner & Bode, 2006).

The chances of experiencing disruptions are higher now, and in the future than in the past because of some recent trends and practices in managing SC (Gurnani et al., 2012):

- Increased complexity: the complexity of supply chains has increased due to global sourcing, managing large number of supply chain partners, the need to co-ordinate across many tiers of supply chains, and dealing with long lead times.
- Outsourcing and partnerships: increased reliance on outsourcing and partnering has heightened interdependencies among different nodes of the global supply networks and increased the chances that a disruption or problem in one link of the supply chain can quickly ripple through the rest of the chain, bringing the whole supply chain to a quick halt.
- Single sourcing: single sourcing strategies have reduced the purchase price and the administrative costs of managing the supplier base, but may have also increased the vulnerability of supply chains if the single-source supplier is unable to deliver on time.
- Limited buffers: focus on reducing inventory and excess capacity and squeezing slack in supply chains has more tightly coupled the various links leaving little room for errors.
- Focus on efficiency: supply chains have focused too much on improving efficiency (reducing costs) at the expense of increasing the risk of disruptions.
- Over-concentration of operations: in their drive to take advantage of economies of scale, volume discounts, and lower transaction cost, firms have over-concentrated their operations at a particular location, thus reducing their flexibility.

- Poor planning and execution: poor planning and execution capabilities result in more incidents of demand-supply mismatches.

A survey carried on by Glendon and Lindon in 2013 (see figure 2.19), reinforces the Gurnani et al. statement about the increase in the number of disruptions in the recent years. According to that survey, 75% of organizations recognise to have suffered at least one disruption in their past 12 months and the 22% of them, claim to have suffered more than six disruptions.

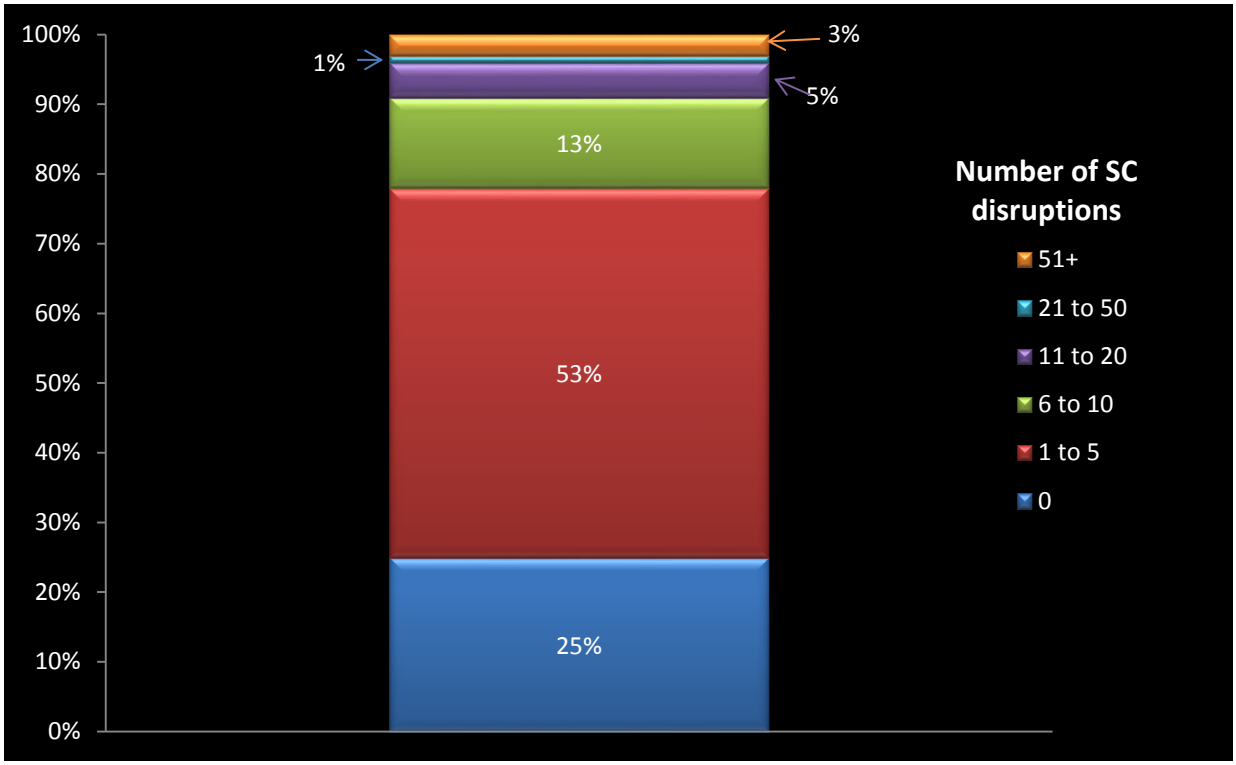


Figure 2.19: Percentage of respondents which has suffered SC disruptions in the past 12 months. Based on the survey developed by Glendon and Lindon and included in the 5th annual Zurich Insurance survey for Supply Chain Resilience 2013 (Glendon & Lindon, 2013).

How the severity of disruptions in a SC is matched by the disruption probability is a topic discussed by Sheffi in his book (Sheffi, 2005). According to him, the most severe and frequent SC disruption is due to the loss of a key supplier.

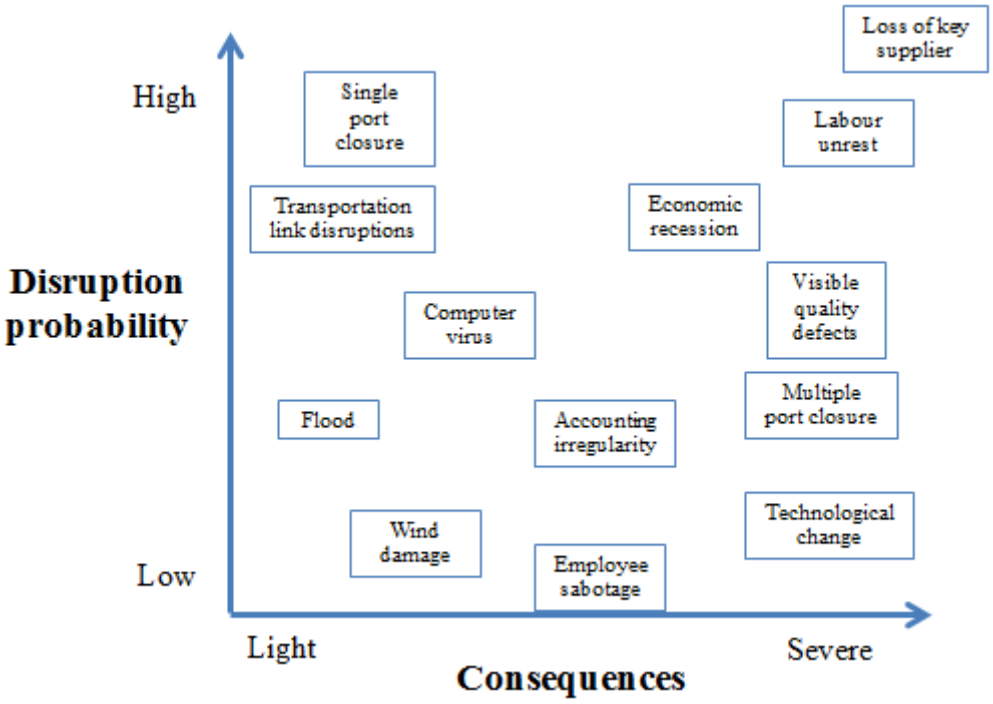


Figure 2.20: Enterprise vulnerability to SC disruptions. Based on Sheffi, 2005

According to Tang, SC disruptions can have significant impact on a firm's short-term performance (Tang, 2006). Nevertheless, disruptions can have also a huge impact in the long-term performance of an enterprise. Based on a sample of more than 800 supply chain disruption announcements, Gurnani et al. discuss in their paper the fact that firms which suffer supply chain disruptions experience 33–40% lower stock returns relative to their benchmarks, 13.5% increase in share price volatility, 107% drop in operating income, 7% lower sales growth, and 11% increase in costs in the following two years of a major disruption (Gurnani et al., 2012).

Under the above mentioned circumstances, new philosophies, tools and best practices have been introduced successfully to mitigate the effect of disruptions. In the following subchapter, Lean is presented as the most revolutionary and widespread philosophy introduced in the last 50 years between large enterprises.

2.3- Lean philosophy

In the early 1988, Toyota's Chief Engineer, Taiichi Ohno (Ohno, 1988) identified 7 ways of waste as part of the Toyota Production System (TPS):

- **T**ransportation → Each time a product is moved it stands the risk of being damaged, lost or delayed what means a cost for no-added value. Transportation

does not make any transformation to the product that the consumer is willing to pay for.

- **I**nventory → Inventory, be it in the form of raw materials, work-in-progress or finished goods, represents a capital outlay that has not yet produced an income either by the producer or for the consumer. Any of these three items not being actively processed to add value is waste.
- **M**otion → Motion refers to the damage that the production process causes on the entity that creates the product, either over time (wear and tear for equipment and repetitive strain injuries for workers) or during discrete events (accidents that damage equipment and/or injure workers).
- **W**aiting → Whenever goods are not in transport or being processed, they are waiting.
- **O**verprocessing→ Overprocessing occurs any time more work is done on a piece than is required by the customer. This also includes using components that are more precise, complex, higher quality or expensive than absolutely required.
- **O**verproduction → Overproduction occurs when more products are produced than is required at that time by your customers (e.g. larger batches than required). It leads to excess inventory, which then means expending resources on storage, space and preservation activities that do not benefit the customer.
- **D**efects → Whenever defects occur, extra costs are incurred re-working the part, re-scheduling production, etc. Defects in practice can sometimes double the cost of one single product. This should not be passed on to the consumer and should be taken as a loss.

It is easy not to forget that 7 kinds of waste by remembering 'TIMWOOD'.

Several authors have later added an additional form of waste, connected with the suitability of an employee to his workplace.

- Intellect/People → Over use or under use of human resources, such as not having enough staff to carry out duties; using over qualified people to carry out certain works or using extra human resources to assist fully automated processes

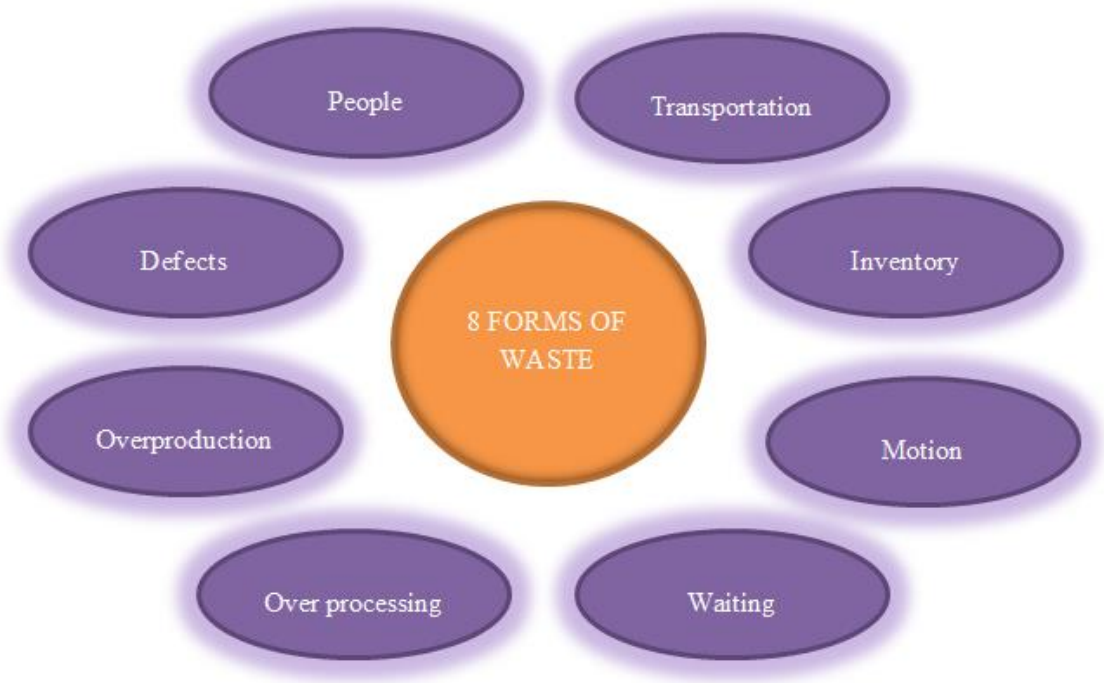


Figure 2.21: 8 forms of waste. Based on Chiarini, 2013

One of the key steps in Lean and TPS is to identify which steps add value and which can be considered as a kind of waste. Much in Lean is about knowing how to look at processes and improve them (Lacey, 2007). In some way, popular initiatives like outsourcing, reduction of inventories, just-in-time concepts, and increasing inter-firm cooperation have helped to create much leaner SCs (Kern, 2011) although the person who was in charge might not be aware he was applying some Lean concepts. But there is still a huge margin for improvement through Lean, especially in SMEs and their production plants. But it is remarkable that the implementation of Lean concepts within SCs must be accompanied by SC risk management concepts (Kern, 2005; Wieland, 2012) and vice versa. There is no point in implementing a Lean tool without a clear SCR process giving a reason to do that. But there is neither a SCR process which aims not to increase productivity while reducing non-value activities, what in the end means 'Leaner'.

2.3.1-Definition

According to Marchwinski, communication director of *Lean Enterprise Institute, Inc.*, Lean management is a series of practices that develops people to understand and own their problems, and aligns resources to achieve the purpose of the organization. Lean management engages everyone in designing processes to continuously solve problems, improve performance, and achieve purpose while consuming the fewest possible resources (Marchwinki, 2014).

In a similar way, Ruffa describes Lean as a system of management that creates and sustains strong, steady bottom-line value for corporations and their customers even as they encounter severe, dynamic conditions (Ruffa, 2008)

In this thesis, Lean is defined as a 'philosophy embracing the whole organisation which aims to reduce non-adding activities and waste, pursue perfection and guarantee the employees' satisfaction in order to increase the overall production while decreasing the total cost'

2.3.2- Lean principles

The categorisation of Lean principles is slightly different according to the author you read. However, all of them pursue the same objective: be more cost-effective.

Womack and Jones (Womack & Jones, 2003), one of the reference books for Lean manufacturing, defines 5 principles: *value, value stream, flow, pull and perfection*. Oehmen (Oehmen, 2012) suggests adding one to the 5 principles of Womack and Jones, *respect for people*. And Sayer and Williams (Sayer & Williams, 2012) proposed 6 principles: *customer value, value-stream analysis, everyday improvement, flow, pull and perfection*.

In this thesis, it is going to be adopted the six-principle Lean categorisation proposed by Oehmen. Especially for SMEs, the criticality of the satisfaction and the performance of every single employee is maximum and that is why I think that categorisation fits better than the given by Womack and Jones, for example.

Principle 1: Value

Capture the value defined by the customer stakeholders, who may be either external or internal. The external customer who pays for the system or service defines the final value for the deliverable. Internal customers receive the output of a task or activity and usually do not explicitly pay. In both cases, the customer stakeholder is the one who defines what constitutes value.

Principle 2: Value stream

Map the value stream (plan the program) and eliminate waste. Map all end to end linked tasks, control/decision nodes, and the interconnecting flows necessary to realize customer value. During the mapping process, identify and eliminate all non-value added activities, minimize all necessary non value activities, and enable the remaining activities to flow without rework, backflow, or stopping.

Principle 3: Flow

Flow the work through planned and streamlined value adding steps and processes, without stopping or idle time, unplanned rework, or backflow. To optimize flow, plan for the maximum concurrency of tasks up to near capacity of an enterprise.

Principle 4: Pull

Let customer stakeholders pull value. In manufacturing, the ideal pull principle is implemented as the Just in Time (JIT) delivery of parts and materials to the needing station and to the external customer.

Principle 5: Perfection

Pursue perfection in all processes. Global competition is a brutal 'race without a finish line,' requiring continuous improvements of processes and products.

Principle 6: Respect for People

A Lean enterprise is an organization that recognizes its people are the most important resource and is one that adopts high performance work practices. In Lean, people are encouraged to identify problems and imperfections honestly and openly in real time, and plan effective solutions together by consensus.

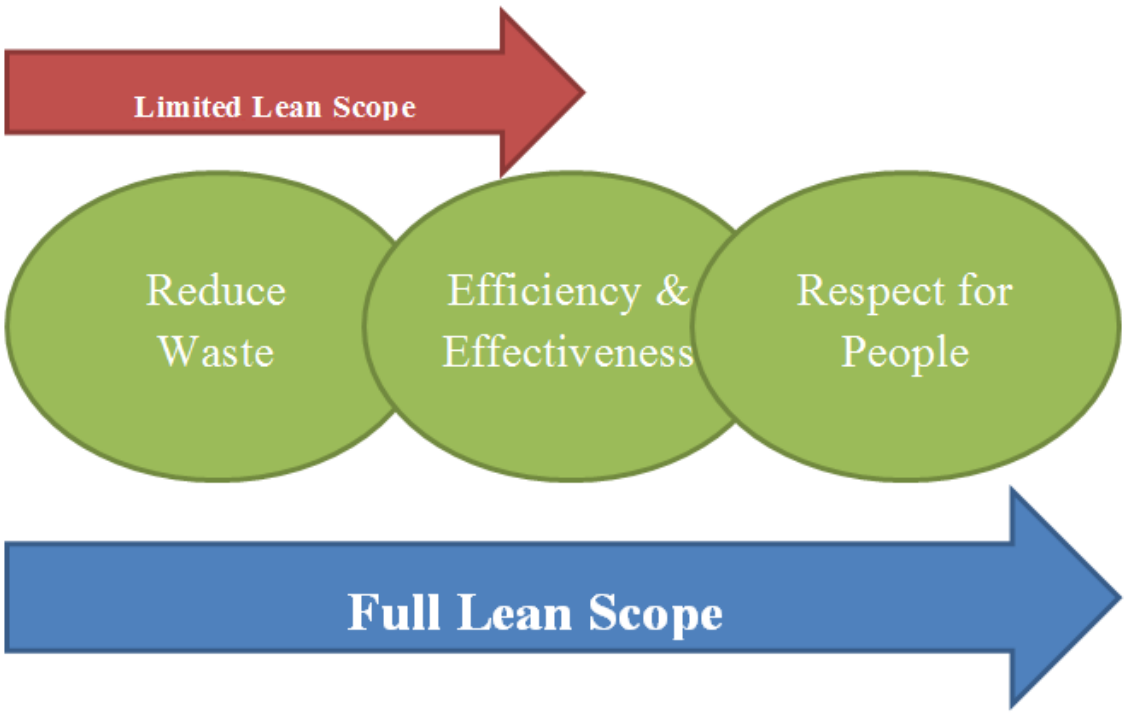


Figure 2.22: Limited vs. Full scope of the Lean philosophy

2.4- Resilience

The concept of business resilience is still relatively new. Except for those companies that have learned to expect continuous business disruptions, many are still struggling with the idea. There is a tendency to look for the cause of the disruption and tackle survival that way, which can be helpful. But it is not as important as other activities such as researching how companies with frequently disrupted SC plan ahead and recover without driving up costs. If your business is not prepared to handle disruption or disaster, then it will suffer. It may not even survive (Tompkins, 2007). Resilience of SC is therefore, critical for individual organisations, the economy and the wellbeing of society as a whole (Rural affairs, 2010). Each individual link of a SC is not likely to suffer a particular rare event, but the chances are that the chain as a whole will be disrupted somehow (Sheffi, 2005).

Resilience is more important today than ever. The pace of business has accelerated, and the velocity of events is greater. This makes organizations more vulnerable to disruptions, unexpected surges, and declines in demand (Sheffi, 2005; Tompkins, 2007; Pettit et al., 2013). Only by increasing their resilience, these enterprises are likely to continue with their activity in a long-term horizon.

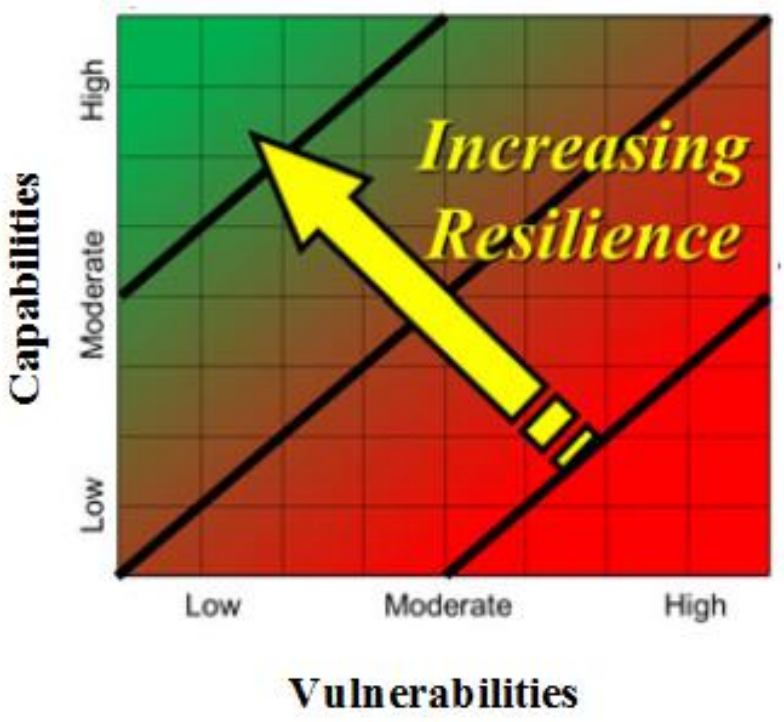


Figure 2.23: Moving from high-vulnerabilities-low-capabilities to low-vulnerabilities-high-capacities. Based on Pettit et al., 2013

2.4.1- Definition

Numerous authors have addressed the question of how to define the concept of resilience within SC. And there is quite an agreement between them. Resilience, as a pure concept, is the capacity to recover quickly from difficulties; toughness (Oxford Dictionaries, 2010). Within the concept of SC, Ritchie and Bob say 'resilience may be defined as a system's ability to return to a new stable situation after an accidental event' (Ritchie & Bob, 2008). For Ates and Bititci, resilience is 'the capacity of an organisation to survive, adapt and sustain the business in the face of turbulent change' (Ates & Bititci, 2011). For Christopher, resilience refers to the ability of the SC to cope with unexpected disturbances (Christopher, 2011). And very similarly, for Pettit et al. 'resilience is the ability to survive, adapt, and grow in the face of turbulent change' (Pettit et al., 2013).

In this thesis, resilience must be understood as the capacity of a firm to prevent and overcome SCR quickly, effectively and resourcefully, thus guaranteeing its existence in the long-term.

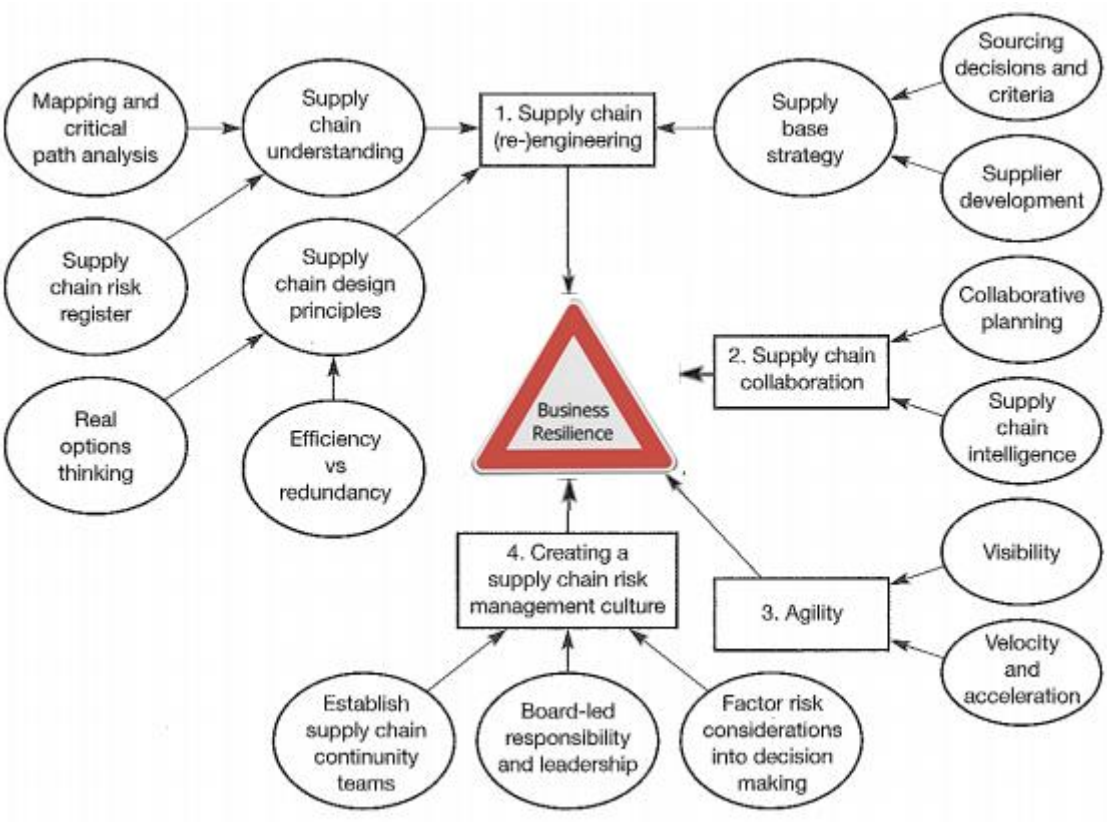


Figure 2.24: Creating the resilient SC. Based on Christopher, 2011

2.4.2- Key aspects of resilience

SME managers perceive their challenges as being different to those experienced by larger organisations, especially in the meaning of an extreme event. Sullivan-Taylor and Branicki collect some relevant managers' impressions in their paper (Sullivan-Taylor & Branicki, 2011). For example,

- 'An extreme event is anything which is particularly life threatening' (Managing Director, Manufacturing).
- 'An extreme event could be a major non-payment of an invoice, or flooding, or a failure in our electronic facilities in our workshop' (Director, Manufacturing).
- 'There are events that happen in small businesses that just totally challenge the existence of the organisation, which you don't get in big ones. For example, the death of a key person in the organisation, I've had that' (Chairman, Enterprise Board)

There had been an implicit assumption that organisational theories, models and conceptual frameworks developed in large organisations were relevant and directly applicable to SMEs (Kumar et al., 2011). Sullivan-Taylor and Branicki (Sullivan-Taylor & Branicki, 2011) highpoint in their paper the fact that SMEs do not hold the resources and technical systems often equated with resilience capabilities. They also write an excerpt from a chairman interview: 'We just ignore them (referring to resilience activities) because we don't have the resources to do it. It's the difference between a big business and a small business. Big business, you make a decision on the basis of what is value, the small business you make a business decision on the basis of what you can afford'.

But even the obvious restrictions managers claim to have, managers' concerns should desirably not cover the opportunities they have to increase their SMEs resilience.

There are some cost-effective and potentially applicable concepts which can help to create resilience. Soft managerial practices such as effective communication and relationships within the organisation, with key customers and stakeholders are all fundamental to enabling firms to be resilient (Ates & Bititci, 2011). Resilience is dependent on a set of collaborative relationships with trading partners, since each enterprise is only as resilient as the weakest link in its supply chain (Sheffi, 2005). In addition, firms can inexpensively reduce their vulnerability by investing in training and culture, organizing for action, reducing the likelihood of disruptions, collaborating for security and building in redundancies (Sheffi, 2005). That last point is somehow controversial: redundancies clearly increase resilience by enhancing the SMEs performance in case of unexpected demand, but an excess of inventory can damage the profitability of the business. Petit et al. perfectly define the area in which SMEs should aim to be, the 'zone of balanced resilience' (Pettit et al., 2013). It is also remarkable that

once a disruption has happened, is important to give customers as much information as possible in order to help them to recover from it. Which customers should be supported first is a vital decision that can be based on costumer vulnerability or on more internally focused criteria such as how profitable the customer is (Sheffi, 2005).

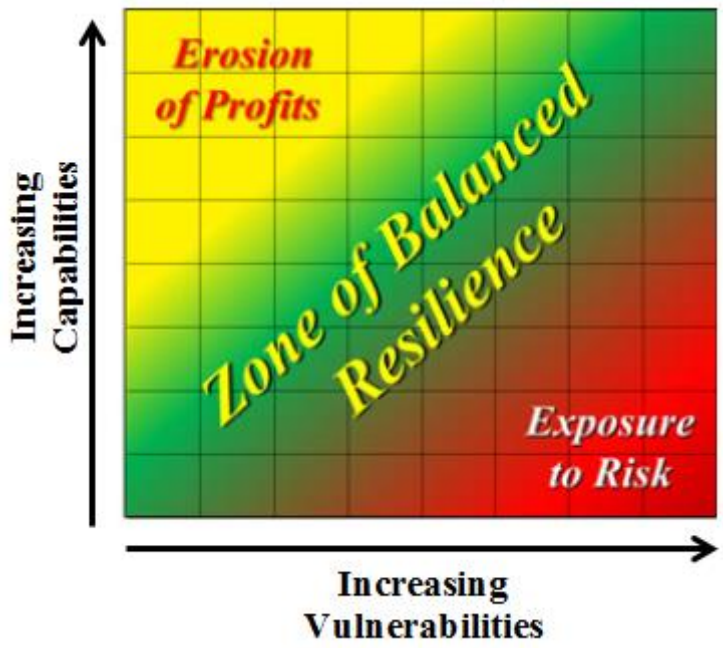


Figure 2.25: The resilience fitness space. Based on Pettit et al., 2013

2.4.3- Nine principles to build a resilient SME

There have been detected nine main principles in the literature which definitely contribute to create resilience in a SME.

- Principle 1 → Create and maintain SC resilience is not a one-time event - it is a process (Pettit et al., 2013).
- Principle 2 → Standardize parts, processes and productions systems so that these elements are interchangeable. That creates options for using them when there is a shortfall (Sheffi, 2005).
- Principle 3 → Do not focus all the attention to operational, hard and internal aspects of change management with a short-term and reactive behaviour, whilst neglecting strategic, long-term and soft requirements of organisational change process (Ates & Bititci, 2011).
- Principle 4 → Increase your operational flexibility. That involves a close partnership with suppliers who can be called upon to help; flexible contracts allowing for changes in quantities and delivery time; flexible manufacturing

facilities that can be used to multiple products; a multi skilled work force with empowered employees who can move quickly from one task to another and strong customer relationships ensuring continuity when troubled times. (Sheffi, 2005)

- Principle 5 → Redundancy does not always mean waste. Safety stocks are a part of most resilience and business continuity plans although companies should take care not to reverse the gains of such Lean SC operations (Ritchie & Bob, 2008).
- Principle 6 → Work with aggregate forecasts since they are more accurate than disaggregate forecast (principle of risk pooling) and also work with short-time horizons because they are more accurate than long ones (Sheffi, 2005). To increase the accuracy of these forecasts, promote the collaborative efforts based on Lean such as Vendor-managed-inventory (VMI) which is aimed to reduce the bullwhip effect (Oehmen et al., 2009).
- Principle 7 → Win from competitors disruptions. When a competitor stumbles, quick response can lead to increased market share when new customers try your products or services and stay with you (Sheffi, 2005).
- Principle 8 → Share risks with suppliers and customers to mitigate the consequences of a wrong forecast (by buyback agreements, for instance); numerical examples reinforce the statement (Wakolbinger & Cruz, 2011).
- Principle 9 → Employees must possess a feeling of ownership in the business and the freedom to make decisions according to their responsibility area (Ates & Bititci, 2011)

2.5- Summary and currents gaps in the literature

In this chapter, an extensive literature review has been developed as a preliminary step to design and decide how my contribution was going to look like. In the first part of the chapter, there were defined the research hypothesis for the thesis. Then, a study of the current literature was offered in order to obtain a depth view on the discussion of what structure should the SCRs follow and how a disruption might affect to a firm. In addition, it was introduced the Lean philosophy and the main principles which drive that way of thinking and proceeding. A bit later, it was introduced the concept of resilience and which concepts are suggested by SC authors to create resilience. The last step of that chapter was offering a broad perspective about the different manner of approaching the SCR procedure, since every author has his own attitude towards the route to address that process.

It was not until books, surveys and papers were examined when I was capable to identify the current gaps of the literature. It was then when I truly understood how my

contribution could fit in order to have an impact not only academically, but also in SMEs.

My contribution wants to cover the missing gap of an entire procedure easy to implement by SMEs, capable to identify, assess and give an economical perspective of the impact of a measure within a SME. Until now, there was no author who combined the SCR identification with the Lean philosophy in order to mitigate these SCRs and create resilience in the enterprise. Obviously, no one also combined that strategy to a study of which measures should be implemented first basing the decision on economic facts.

3- Research approach

This section highlights the research approach of the thesis. Basically, two main techniques have been used to gain knowledge about current gaps in the literature and recognize the necessities of the manufacturing industry. Firstly, it has been done a literature review to check the state-of-the-art and secondly, a group of interviews and frameworks have been conducted to understand what kind of challenges are CEOs and SC managers facing today. Therefore, this thesis aims to be interesting from the academic point of view but also from the point of view of SMEs and industry.

According to Frankel et al. (Frankel et al., 2005) both research methods used during the thesis are objective and one of them do involve the researcher (interviews) and one do not (literature review).

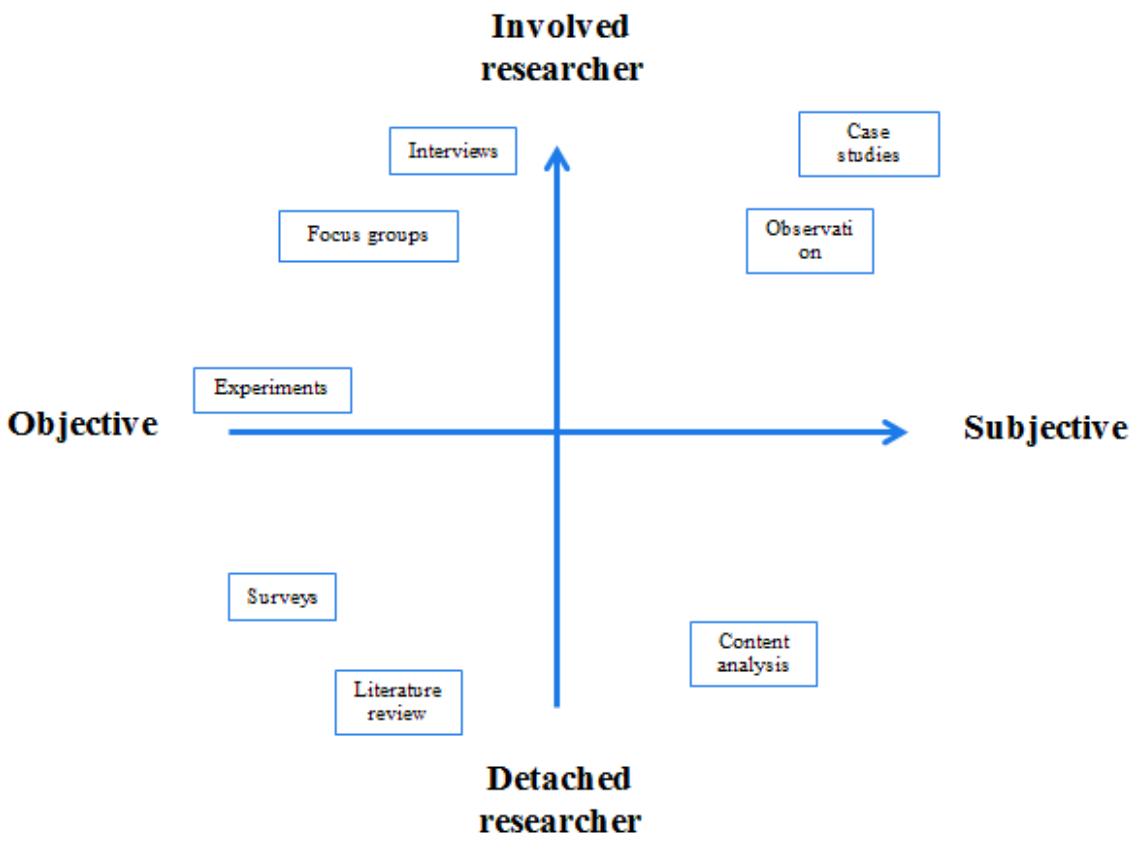


Figure 3.1: Characterization of logistics research methods. Based on Frankel et al., 2005

3.1- Definitions

Literature gap → A gap in the literature is a research question relevant to a given field that has not been answered properly or at all in existing documents.

Search engine → A program that searches for and identifies items in a database that correspond to keywords or characters specified by the user, used especially for finding particular sites on the World Wide Web (Oxford Dictionaries, 2010).

State-of-the-art → The most recent stage in the development of a product, incorporating the newest ideas and features (Oxford Dictionaries, 2010).

3.2- Literature review

A literature review is the comprehensive study and interpretation of literature that relates to a particular topic (Aveyard, 2007). Literature reviews involve an in-depth analysis and critical summary of previously collected data (e.g., secondary data) for the purpose of identifying a research "gap" that needs to be addressed through future studies (Frankel et al., 2005). Literature reviews are important because they seek to summarise the literature that is available on any one topic (Aveyard, 2007).

For this thesis, I did a wide literature review about different topics such as SCRM, SC best practices, SCR mitigation tools, Lean philosophy, the concept of resilience, Failure Mode and Effect analysis, organization of a thesis and preparation of an interview and how to develop a case study. It was not until many different papers and books were studied and analysed when I found a key gap where the contribution could be relevant. Therefore, the literature review definitely contributed to decide which key questions this thesis was going to formulate and which tool could offer a broader positive impact for the Industry.

Since there were thousands of papers and books which could potentially be appropriate for this project, there were used three different search engines: Amazon (http://www.amazon.com), Google Scholar (http://scholar.google.com/) and DTU Findit – Your digital library (http://libguides.dtu.dk/content.php?pid=466792&sid=3821475#13937966). Amazon offers an introduction to all the books, most of the product details and a rating with some comments edited by readers. It was really useful especially in the beginning where the key words introduced were offering a full range of possibilities and ranking these books by readers' opinion was fairly interesting. Google Scholar offers a very accurate research through papers and books. Some of them could be obtained after a payment fee and some of them could be obtained for free. Lastly, DTU Findit – Your digital library was definitely the best engine I could have used ever. It combines a similar technology as Google Scholar

with the vast majority of books and papers which I considered relevant from Amazon but (nearly) all for free.

3.3- Semi-structured interview

The purpose of an interview is to contribute to a body of knowledge that is conceptual and theoretical and is based on the meanings that life experiences hold for the interviewees. (DiCicco-Bloom & Crabtree, 2006). Nevertheless, interviews are often criticised for its high propensity to encourage interviewer and respondent bias and are often insightful. (Frankel et al., 2005)

There are three main ways of conducting an interview: fully structured, semi-structured and unstructured. The fully structured interview tends to be very formal in which the questions asked by the interviewer are carefully prepared before going through them. The interviewer is supposed not to have opportunity to ask more in-depth details after a response of the interviewee. The semi-structured interview has a few questions or areas to cover. This kind of interview brings the interviewer the option to ask what the interviewee really means in an answer by creating an interaction through 'question-response'. The unstructured interview is often informal and in which the researcher formulate his following question based in the previous answer of the respondent. It is a way of creating new ideas in every new interview and where probably the participant feels much more relaxed and have a tendency to be more trustworthy. However, the interview might finish in a point of no interest for the study.

Fully Structured	Semi-Structured	Unstructured
Very Formal	Formal	Informal
Prepared answers with bias/no clarification for topics in which the participant does not want to offer more information	The topic might be prepared but the interview might be addressed to the interest of the researcher	Spontaneous answers, as a chat more than an interview
Questions carefully prepared	Areas to cover thought before the interview	Natural conversation with vague preparation
Tense conversation	Relaxed conversation but keeping an atmosphere of formality	Relaxed conversation, usually with jokes and bad words

Table 3.1: Classification of interviews

For this thesis, semi-structured interviews are chosen to realise what the needs of supply chain managers and presidents of SMEs are. Semi-structured interviews were selected as a data collection method because of a main consideration: they are well-suited for the exploration of beliefs and opinions of respondents regarding complex and sometimes sensitive topics, but maintaining a necessary formality. By creating an honest atmosphere, I could obtain some helpful data which I would have probably not acquired in any other research. In addition, I could drive the interview to the topics in which the participants were more reluctant to talk about. By doing that, I discovered their problems and consequently the opportunities the tool proposed in this thesis might have. I therefore assume my tool to be useful as reflect the necessities of my interviewees, since according to Grindsted 'from the very moment a participant has accepted to engage in a research interview, they will most likely make every effort to produce true and accurate responses' (Grindsted, 2005).

The contribution of participants in the interviews was vital for the development of the tool proposed. I completely share the Baumbusch opinion who claims that her participants felt that by sharing their experiences, they might be able to have a positive impact for future industries in similar circumstances (Baumbusch, 2010).

3.4- Summary

This chapter wanted to defend and justify the reasons that drove me to adopt the tools chosen and why other tools were refused.

For instance, a survey was also considered as a method to approach the opinions of managers who worked in the SC area to the thesis. It was refused for two main reasons. The first one is because it is a method in which those managers who answer the survey cannot offer their insights in an extended manner. They would have been limited to answer a close question with a number and I would not have gained their experience and the way they believe SCRs must be addressed, an issue in which I was especially interested in. The second reason is the low percentage of respondents and the low contact author-respondent a survey tends to have.

The idea of a structured interview was also valued and refused when deciding the research approach. Although the structure interview would have forced the different SC experts to answer the same carefully-though questions, the interviewed SC experts would have not been capable of extending in their explanations as the topic required. Additionally, I could have not reformulated the queries in order to understand what they really meant with their words and struggle them 'just a bit' to obtain a reliable feedback.

Consequently, the methods I considered to fit better were the literature review and the semi-structured interview. The first one allowed me to obtain some expertise and knowledge to prepare the semi-structured interviews, what at the same time resulted in giving a mean to this thesis and contribute, at least an inch, to the available literature.

4- Constraints, necessities and opportunities of manufacturing SMEs based on Supply Chain managers' interviews

This section highlights the beliefs and experiences of five different SC experts interviewed regarding SCRM.

Expert one (E1): Manager of a naval organization (a 'society of members'), who works in the logistics area. He works in the development of the naval value chain in Denmark by promoting European projects and establishing connections between Universities and the Industry. E1 also give conferences and prepare frameworks. His organization is self-financed by members fees and European projects funds. The oral semi-structured interview was conducted the 3rd of April 2014.

Expert two (E2): President of a Danish SME who works in the area of emergency fire pumps for ships and offshore plants. It is an enterprise selling worldwide where the SC is a basic piece for their activity. The turnover is over 10 million Euros and the number of employees is 15. The oral semi-structured interview was conducted the 2nd of April 2014.

Expert three (E3): He is an external Spanish Lean consultant working in the implementation of that philosophy in Spanish SMEs. He usually works from 1 to 6 months in a SME in which he tries to reduce the unnecessary waste and increase de consciousness about the value creation. The written semi-structured interview was answered the 22nd of April 2014.

Expert four (E4): He is co-partner of a SC consultancy based in Denmark. They specifically work in this area of consultancy. The firm was created in 2008 and today they are employing more than 20 people, most of them engineers and business experts. I assisted to one of their invitational events where I obtained most of the information. After the framework, I personally talked with him about this thesis. The framework was developed the 3rd of April 2014.

Expert five (E5): He is a professor and Head of Research Group in IT-Innovation at Roskilde University. I met him in a conference organized by the Project Management Institute about Agile Project Management. He has written more than 20 articles and books on agile development and agile project management with special interest in SCRUM, an iterative tool for managing product or application development. The framework was developed the 8th of April 2014.

4.1- Supply chain most challenging risks

E1: He states that in his experience, each and every SME should disclose their own risks and consider first the ones which are priority. E1 stresses the fact that the classification of risks depends very much in the kind of good each SME is selling, the warehouse cost, the opportunity cost and the obsolescence of the product shipped. E1 considers, in a global view, the supply risks to be the most hazardous. 'Without the pieces or raw material required, no activity can be done in your enterprise' he suggests. Process risks are considered by E1 in some way 'stimulating' from the management point of view. He puts the example of the construction sector in which, from 25% to 50% of the time employed in building a house is wasted by waiting for some raw materials and having the builder looking for a hammer or screwdriver.

E2: He declares the supply SC risks to be the most tough to cope with. One of the most critical parts in his SME equipment is engines. They are imported from the USA (to Denmark) from three different well-known suppliers. The supplier who used to be the cheapest is currently having some disorganization and some orders are not in time, causing clear problems to E2.

Time-frame for E2 is vital. The company he presides usually signs contracts in which it is specifically written 'the equipment must be delivered in 32 weeks'. In the first 16 weeks they assemble most of their equipment parts and then, they expect to receive the engine. It the engine suffers a delay, all the assembling process has to be stopped, endangering one of their premises: over 95% of on time deliveries.

About process risks E2 is not particularly worried about. He proudly says that his employees 'feel a responsibility with the Enterprise' and 'are flexible in the schedule'. 'Employees spend more hours working than what they are supposed to when necessary' he remarks. 'As a reward, they usually enjoy more free time when there are not orders. Having flexibility in the working hours is part of the game'.

Demand risks are something he is neither specifically concerned about. They are the second largest company in the sector with not many competitors in the market. And there are neither many customers, not more than 200 worldwide (between shipyards, offshore plants, large consulting firms and operators). He adds 'I am in a market in which everybody knows everybody in some way'. The only marketing action they develop is calling to shipyards after reading in the specialised magazines that they got an order and express E2 availability to cooperate.

E3: He suggests that there should be a differentiation between internal and external processes.

In external processes, the most painful risks are, in his opinion, delays in the delivery date due to incoordination between the capabilities and reality of the supplier with the real necessities of the client.

In internal processes, E3 recognises the lack of tools to manage the daily decisions that needs to be taken in a production plant as a main problem. These decisions usually involve problems in machine's breakdowns. And these breakdowns are frequently related with the 'low knowledge about the real yield and capacity of the production plant', finally adds.

E4: He claims that 'supply' risks are the ones most challenging, since they are in a vastly undiscovered area for many SC managers and is full of opportunities. In his experience, there is a 'hole in many SMEs pockets' regarding the procurement, so reshuffling the supply department is one of the very first suggestions in more than 75% of manufacturing enterprises which ask for E4 help.

Another main risk E4 is used to face is 'the inability to manage pressure', what could be categorised as process risk. E4 ensures that most manufacturing SMEs have for a long time been facing declining margins and earnings while increasing pressure from retailers and end customers demanding higher quality and lower costs. 'And not all the companies have been capable to front that properly', he remarks.

E4 justifies the reasons why it has been increasingly difficult to manage complexity. 'It is basically due to inadequate control mechanisms, processes, or a lack of strategic cooperation between business units; a high degree of complexity often results in excessively high costs for producers' he guarantees.

E5: He basically suggests an internal factor to be the most challenging, 'the awareness of your enterprise performance'. 'There is no easy tool to value the 5 critical points of a project: the requirements stability, how many people is going to participate during the entire project, the complexity of the project, the motivation and education of your team and the criticality of a defect' E5 suggests.

4.2- Mitigation of Key Supply Chain Risks

E1: He naughty laughs when talking about mitigation actions. 'If only we had a magic wand to choose the best actions!' E1 claims.

Between the mitigation actions to cope with demand risks, he reinforces the one followed by many technological designers to avoid obsolescence. That is externalising the production to a common supplier and keep focused where they are truly creating value, the design.

Between the mitigation actions for supply risks E1 puts the example of IKEA, a company which has at least two suppliers for each and every good they are selling to avoid dependence of any of them. He also recommends sharing perspectives among the different companies who work in the same area, although sometimes is difficult.

Other improvement actions he enumerates are

1) Reducing cost by lowering stocks, like Toyota in the Scandinavian countries who have centralised their warehouses from four to one.
2) Re-check which way of transport is optimal for your company. E1 believes there is a huge margin to improve the efficiency by train transportation of products in which you pay for the volume used and not for tone like in trucks (what makes it especially interesting for materials like sheets of paper, low cost and high weigh).
3) If one of the values of your Enterprise is the reliability, capitalize it like Maersk, a company which is currently working in how to do it.
4) Short-distance journeys by truck are very inefficient. Work in minimizing them, maybe externalizing your logistics department.

E2: From the supply point of view, the E2 enterprise is for example reducing their engines orders from the unreliable supplier to another one a bit more expensive but to meets satisfactorily the time frame. They also have a third alternative, also very reliable supplier, but much more expensive which is used occasionally.

To mitigate other possible supply risks, they have a very close relationship with what he calls the "2600 district", a very close cluster in distance. This group of enterprises cooperates with each other having an employee rotating across the members for two months when he is hired. They argue that by doing that, the employee is given a general view of the philosophy of the district and the sector.

About process risks, he is only slightly worried about the current capacity of the plant. He is conscious that they have a very limited space to work in, and E2 is looking for a

new location, very close to the current one. He defends this last point because for him, 'the staff and their know-how is the most valuable aspect of my Enterprise'. He mentions that because he particularly rejected an option they had to move to China a couple of years ago. Their current labour cost is only about 6-7% of the total costs while in China it is estimated to be around 3%. For him is, therefore, no point in moving there and missing the 'very experienced and fully professional team' he proudly claims to have.

E3: Under his opinion, there are three main risk mitigation actions which are applicable to most of the Enterprises he has collaborated with. The first one is to ease the flow of information and conscious all the departments about the time-frame they have for a project or order. The second one is to generate a commitment culture across the company. And the third one is to spread the problems and consequences that have meant (or could potentially mean) the breach of objectives in the Enterprise.

E4: In his opinion, it is high time to stop wasting resources and time on inefficient processes by optimizing both purchasing and supply chain of most manufacturing enterprises to ensure competitiveness. E4 considers management as the key department which should place a renewed focus on the specific challenges and opportunities they have.

E4 suggests the cost reduction and an optimization of the supply chain or portfolio as the best mitigation actions to cope with the main risk they have found, the declining margins. He also mentions the case of industrial and manufacturing companies in particular, in which it may be relevant to optimize the purchasing function as this often accounts for 50% or more of the firm's total cost base. 'Typically by optimising purchasing, savings of between 10-15% can be realised' finally adds.

E5: He reinforces the thesis of implementing in an enterprise an own philosophy, with a mission and vision clearly defined and a written procedure in how to cope with major daily problems (like delays in supplied materials) but also the very eventual challenges (like a fire). He believes that especially the SMEs are lacking of a clear attitude and a way of understanding the value which makes them different from the competitors.

He recommends building relations and networks within the project team, 'building trust, even at a distance' to give the project a common language shared by all the employees. He also states that short and long term targets are necessary, including simple but effective mechanisms for tracking project progress. Lastly, he considers necessary a

certain meeting structure that works well for communication in the project team and puts the example of a tool called Scrum as an instrument to implement.

4.3- Experts work philosophy and their approach to Lean

E1: He relies on a main statement, which is keeping your client informed about the occasional problems your enterprise could suffer. E1 also highlights that this information should be given as soon as you detect it. 'It is vital to tell your client the truth and not to say everything is working fine if that does not fit your reality' he emphasizes.

In addition, E1 mentions the undesirable common problem with pieces imported from China. 'It is nearly the rule, and one of the main risks of importing things from Asian countries, to open a container and check there is something shabby, broken or missing' he ensures.

E1 also shares the idea of flexibility. 'Employees should make an effort and adapt their schedule to the Enterprise requirements, thus working harder when necessary' he considers.

Lastly, he recognises that not everything is about cost reduction. Many finance managers only work in reducing expenses and E1 disagrees in that way of proceeding. 'To help your Enterprise to gain value, it is also important to take measured risks; and that usually involves increasing expenses in machinery or human resources' he points.

E2: He strongly believes to have an own philosophy of quality. Although he is applying some Lean principles in the enterprise, he is not especially interested in knowing and implementing fully the Lean. 'I do not have time to implement costly Lean tools! That is for large companies like Mercedes!' he claims.

His work philosophy can be summarised in four main points.

1) They work by 'make to order' what means essentially manufacturing 'Just in Time'.
2) A good working atmosphere. Employees work hard but also have time to make some jokes when a foreigner like me is visiting their plant. And to see that, it is paramount the respect the more experienced labours maintain to newcomers.
3) Responsibility with the client. A sole man is in charge of the whole SC process. This employee is responsible for the order from the moment of signing de contract to the moment the bill is fully paid the bill.

4) Job satisfaction. E2 promises that all they employees ‘feel part of the Enterprise’ and nobody would say that they are working there only ‘for 200kr/h’.

E3: It would be difficult to find someone who knows more about the implementation of Lean in SMEs, since as an external Lean consultant is a specialist on the topic and the common reluctances and fears when introducing it in a new Enterprise.

E3 states that ‘there is not a unique way to apply Lean in an enterprise’ and ‘Lean should be customized to the processes of each SME to see all the benefits the Lean implementation could bring them’. E3 is also a very robust defender of ‘the right procedure will drive you to right result, although some difficulties and cost increases might appear in the short term’. Moreover, E3 draws attention in incorporating ‘visual methods’ to SMEs and thus creating a consciousness among the staff about the important of the ‘flow’ and ‘keeping an eye in value creating’

To achieve a satisfactory end, E3 emphasizes that in SMEs is unquestionably vital to appropriately define and write down the current processes. Subsequently, try to standardise some processes and reduce the production batch size to create the sought ‘flow’.

E4: His philosophy is that by reinforcing all the strategic and organizational areas of whichever SMEs, they will be ‘a new SME’ capable to meet their goals. E4 clarifies achieving that is not an easy task and is why he has job as a SC consultant. His company and he work hard in creating customized purchasing strategies and shaping the overall sourcing strategy. At the same time, they analyse the organizational structure of the SME and assess whether changes are necessary in order to achieve the maximum potential performance.

E5: Question not addressed.

4.4- Lean principles and resilience

E1: He thinks that resilience is in some way connected with reliability. ‘A customer will probably rely in you again if he is satisfied with the service you provided him and you have a similar price to your competitors. And of course, you should meet the standards and not produce Monday cars’. Just after, E1 clarifies that ‘Monday car’ is an old

expression referring to some car assemblers which had some production problems every Monday morning because of some machinery mismatches.

The Lean principle E1 most likes is ‘capture the value’. He utterly agrees that is essential for whichever SME to know what ‘makes you different’ and ‘what reasons do they have to make you an order the following day’. Another Lean principle he supports is ‘map the value’. For him is important to reduce all the unnecessary waste, but having special care to ensure that all the requirements are met satisfactorily. He suggests the example of the short-distance ships transporting goods. ‘30% of these short-distance ships arrive 7’5 hours before they can enter to the harbour and wait until is their time to release their products. Obviously, that can be seen as an unnecessary waste, but you should also consider that this ship might be transporting engines to Mercedes and half an hour delay might mean stopping all the assembly line, causing huge loses’. As a result, he considers indispensable to compare the transportation cost with the whole value of the product before taking some risky decisions.

The Lean principle E1 slightly disagrees is the JIT, as it is seen in Europe. In his opinion, European JIT is understood as ‘phoning your supplier and asking him to bring you something immediately’ as a result of a lack of organization. ‘And in case your supplier agrees to do it, it means a special shipment causing also waste’ he criticises.

E2: In his opinion, his company is resilient (they are working since 1903) because they have been employing the right staff. React quickly and offer reliability to his clients are also important facts that make his enterprise even more resilient.

When he has a look at Lean, he entirely agrees on the ‘Respect for people’ principle. It is an imperative for him to keep his employees motivated by giving them a certain responsibility. He also agrees on the principle of ‘capture the value’ although he considers that to be ‘common sense’ more than an innovative philosophy.

E3: Be resilient means for E3 to ‘improve continually, non-stop’. It is therefore essential for E3 to standardise as many processes as possible and have all the little process details written down, as a preliminary step to achieve that constant improvement.

E3 chiefly agrees on all the Lean principles, with special approval with ‘respect for people’. The key aspects which differentiates a great boss from an excellent one is ‘listen, value, offer autonomy, teach self-motivation and recognise your employees’ effort’ he joyfully articulates word by word.

E4: He says that ‘there is no tool that fit all the necessities’ when talking about Lean. His consulting company and he do not consider Lean to be something priority to introduce in a SME. They prefer to develop other operational strategies to ensure that overall objectives are reached and, at the same time, introduce best practice management processes in production and procurement. That is the point, in his opinion, to reach resilience in a SME.

E5: For E5, resilience is obtained by an accurate planning of all the activities which are developed in a SME. He differentiates between six levels of plans in a SME working by processes: ‘Daily, for this iteration, release, product, portfolio and strategy’. In his opinion, for each 100 SMEs which have all the six levels of plans written down, a Business Continuity Plan and a risk assessment manager, 99 SMEs will continue with their activity in more than 20 years, thus achieving what resilience is for him.

Lean principles were not addressed in this framework.

4.5- Main key points for a successful Supply Chain

E1: Consider risk as something that lets you gain value, but having a risk assessment plan which differentiates the ‘interesting risk’ from the ‘useless risk’.

Keep a close and trustful relationship with all the key suppliers which could potentially damage your supply chain if something goes wrong.

E2: Deliver on time your products.

Ensure quality at a reasonable price.

Work from the day one you sign up a contract.

E3: Believe, trust and help your employees.

Defence the chosen business philosophy (whichever it is), taking into account you might need to modify it during the time. And even more important, learn to sell its advantages not only to your customers but also to your suppliers.

Plan in the long, but decide in the short term. Consider all the alternatives and take the minimum risks to get the biggest opportunity.

Overcome reluctance to changes.

E4: Establish effective Key Performance Indicators (KPIs) and make sure what your real situation is.

Ensure that all your employees have the right capabilities for their task.

Work with True Pocket Margin (TPM). That is the profit the company earns on a product, when all of the direct and indirect costs such as storage, transport, marketing, etc. are included.

E5: Be agile, be 'QQR'. Quick, Resourceful, and Ready for change

Plan, check and then, decide.

4.6- Summary and main challenges

Five different SC experts have discussed five SCRM categories and have exposed their attitudes and opinions regarding these topics. Opposed approaches can be seen by reading these five experts abstracts, thus contributing to create even a broader view.

On the one hand, there are some experts, for instance E3 (the Lean consultant), who considers Lean as a requisite for the continuous improvement. He also thinks that this philosophy is applicable to all kind of SMEs once it is customised to their necessities. It is fairly remarkable the point he makes about how an 'excellent' boss would drive their employees: by teaching them to self-motivate and believing in their capabilities. Furthermore, he makes a coherent differentiation in SCR between internal and external factors, which later in this thesis is used to develop the proposed tool.

On the other hand, there are some experts like. E2 (SME president) and E4 (SC consultant), who do not consider Lean as something relevant for a great number of SMEs. In E2 opinion, managers should create an 'own work philosophy' like he has created in the SME he presides. 'It is not necessary to use very sophisticated tools or revolutionise an Enterprise to have a continuous improvement' in his opinion. It is more about 'working with responsibility and common sense' E2 says. In addition, he suggests that by working hard from the very first day a contract is signed (or an order submitted)

there should be no problem to create a resilient SME. E4 maintains a similar speech regarding the implementation of Lean in SMEs. He prefers to talk about 'best practice management processes' and 'improving the SMEs management department' to obtain some visible improvements rather than working with Lean. Besides E2 and E4 fears and disagreements regarding Lean, they both agree in saying that 'supply' (or 'procurement' as E4 prefers to call) risks are the most challenging for a SME. For E2, supply risks are something particularly important to keep under control since components produced by third enterprises are indispensable for their activity. For E4, procurement is an activity with a very large margin for improvement which could save lot of resources.

E2 has neither a very positive impression nor reluctance to the implementation of Lean. He does not disagree with nearly any of the Lean principles, but he has some conditions or 'disagreement details' regarding that philosophy. Not 'all kind of waste' should be removed since there is 'a positive waste' which is necessary. For example, to guarantee that something very valuable is on time, a vehicle might arrive to its destination a few hours before; in case an unexpected event happens, there is some manoeuvring time. E2 also stresses the supply risks to be the most challenging for most SMEs, although he considers that differentiating between various sectors is a need.

E5 did not address the Lean question very in-depth. However, his opinion is especially interesting for obtaining an academic point of view, since the remaining experts are more connected with the Industry. For him, it is essential to plan each and every decision carefully in order to minimise errors while creating a written procedure which indicates what to do when something unpredicted occurs. It is also important for him to focus in 'what can go wrong in your SME' as internal risks are the most challenging in his opinion.

Summarising their feedback, there are three main concerns which could be considered as opportunities for an improvement.

The first concern is the lack of a tool which could guide the SMEs through the mitigation of SCRs. E1 wishes to have a 'magic wand' which could tell you which mitigation actions should be implemented in order to avoid all SCRs. Although there is not such an invention available in the market, there are some best practices and some procedures which could help to mitigate the most hazardous SCRs.

The second concern is the vague knowledge about the benefits Lean could bring to a SME. There are some experts, e.g. E2, who considers this philosophy 'expensive' and requiring 'a lot of time'. Or other experts, for instance E4, who prefer to take some 'management decisions' and 'assess in order relevant areas, like procurement' in these SMEs who ask for his help. However, one of the main reasons why E2 refuses Lean might be the ignorance as he himself recognises, 'I used to work in a large consulting company which did not work with Lean and now I prefer to help our clients in what I

am really experienced about, which definitely is not Lean'. Therefore, it could be considered the spread of the Lean benefits a preliminary step to decide whether or not to implement 'a customized Lean' as E3 recommends.

The third concern is the perception about resilience these experts have. Resilience is not only 'reliability' as E1 suggests, 'employing the right staff' as E2 proposes or 'keep everything planned' as E5 recommends. Resilience is synonym of overcoming problems quick and resourceful, having a long-term effect after a major incident close to 0. Resilience also means taking measures to avoid potential problems by preventing them and using some resources to ensure the best possible performance of an Enterprise after an incident. Therefore, the concept is clearly misunderstood or underestimated among many of the SC experts interviewed.

5-Overcoming Supply Chain problems to create a resilient SME – ‘4 in a row’

There is a recognised necessity between the consulted SC experts of a tool which allow them to decide how to overcome SCRs with a low budget, if possible.

There is also a gap in the literature about a holistic procedure which covers from the early detection phase of SCR to the moment where a solution is adopted based on cash facts. For example, Ittner and Larcker claim there is a ‘lack of integration between financial and managerial research’ (Ittner & Larcker, 2001). Maybe, that is a result of the wrong beliefs of some SMEs: ‘Most organizations stop at the completion of the FMEA and assume that the work is done and it is not always the case since there is a significant amount of work before and after an FMEA’ (Bidokhti, 2009).

Therefore, my contribution is going to cover these two big concerns by the development of an innovative SC tool, which is going to be called ‘4 in a row’. This tool is going to base the improvement stage in the Lean philosophy and is going to act as a ‘Mythbuster’ for all the fears and mysteries Lean is surrounded by. This tool is going to be published in the Internet and is going to have free access for whoever wants to implement it. The address is the following

http://4inarowforsmes.wix.com/4inarow

This chapter is going to be mainly addressed in second person. Hopefully, ‘4 in a row’ is going to be used as a self-assessment tool by SC managers or CEOs and I consider this chapter much easier-to-read if written in this way.

5.1- Step one: Tailoring ‘four in a row’

In this step, you should tailor the tool to the necessities of your SME.

The adaptation of the FMEA, an analysis which is going to be developed in the following step, is suggested to be through a very intuitive 5-question self-survey which can reveal the key aspects for the analysis.

Question 1 aims to recommend who should be responsible of the analysis and its following updates.

Question 2 purpose is to disclose the level of detail of the analysis. That means going very in-depth in the reason of the failure mode (e.g. stop production by the wear and

tear of a screw in the engine of machine 3 of subsystem A) or stay in the surface (e.g. stop production by machine 2 breakdown)

Question 3, 4 and 5 objective is to assess in the level of time, investment and effort to be put in the FMEA throughout a categorization in three intuitive levels: green (or 'easy'), yellow (or 'medium') and red (or 'hard').

5.1.1- Self-questionnaire

Question 1: How many employees does your enterprise have?

a) From 1 to 10

b) From 10 to 50

c) More than 50

Question 2: How long has the activity or process you are checking being done in the same way?

a) It is a new or relatively new activity or process, with most of the employees working in this way for less than 3 months - 8 hours per day in use (approx. 600h)

b) Most of the employees have been working in the same way with this activity or process between 3 and 18 months - 8 hours per day (approx. 600h to 3600h)

c) All the employees have been working in this activity or process for more than 18 months

Question 3: Do you have detailed data of how often most of the incidents you are analysing occur?

a) Not at all. It is a new activity or process and we do not have any similar previous experience

b) Not really. We have been doing this activity for a time but without measuring how often the incidents are happening or it is very difficult to obtain this data.

c) Yes. We have historical data of all the incidents we have suffered and/or experienced employees who can approximately tell us the frequency of most of the incidents under study

Question 4: How critical are your SC errors?

a) Very critical. We are selling a very high-quality and unique good, very differentiated from the one our competitors are proposing (in case there are competitors) (e. g. Ferrari, Apple).

b) Critical. Although we are selling a common product in the market, our brand and quality are very well-known in the market. And of course, our costumers value that (e.g. Carlsberg, Danone).

c) Not especially critical. We are selling (in some way) the same as our competitors, working with low/very low margins and competing with them basically in price (e.g. Ryanair, generic medical products).

Question 5: Do you have any previous experience in Supply Chain Risk Management?

a) Not really… What does exactly Supply Chain Risk Management mean?

b) We are aware of the importance of SCRM and we have at least a bit of experience in the field

c) We are familiar with SCRM and we have previously been working in the field

5.1.2- Self-questionnaire results

Question 1

a) If that is your answer, the FMEA should be introduced and developed by a sole person, the CEO if possible. Since you are working in a SME very reduced in the number of employees, the CEO is probably high-capable to explain all the processes of the production plant without problem and hence, their SCR (in the majority cases he is also the owner). In addition, since the SMEs usually have limited human resources, there is no point in employing additional people who might be worth to keep working in their task.

b) If that is your answer, the FMEA should be implemented by a team of two to four people, including if possible the CEO. Although it is very likely that the CEO knows most of his SME processes, he might not be aware of the technical details of the production plant. For that reason, it is important for him to have some technical support from engineers or operators who work daily with the equipment and someone from the sales or supply department who works daily in the upstream and downstream communication

c) If that is your answer, the FMEA should be settled in the SME by a specialised team. Your SME may have different production plants and very low contact between project or process managers may occur. Consequently, it would be beneficial for your SME to create a team with components from different areas and an external consultant capable to moderate and drive the discussion to cover all the SCR.

Question 2

a) If that is your answer a low categorization is suggested to implement. Your SME is very new in the process and do not have previous data to do the analysis. Therefore, it would be interesting to learn how the process works while collecting as much data as possible. Once there is more data available, your '4 in a row' can be updated with a more detailed specification of failure modes.

b) If that is your answer, a medium categorization is recommended to implement. Although your SME is relatively new, the most common failure modes might have already happened at least once. Obviously, you should keep collecting data but… since you are interested in '4 in a row' you are in a first step to create a resilient SME!

c) If that is your answer, a very detailed categorization and specification of failure modes is suggested to implement. The main reason is because the SME can take profit from their experience in working in the same processes for a time and the FMEA designer/s is/are probably capable to say, based on facts, which specific components tend to cause a failure mode.

Question 3 (look at 'the secret revealing' cube)

a) If that is your answer, your data is very low or close to 0. It is important to collect data in order to develop a more accurate '4 in a row' study and obtain all the benefits. Your data is low in 'the secret revealing' cube.

b) If that is your answer, you are supposed to have previous experience in the work process and/or some data about the failure modes and failure causes. '4 in a row' is definitely going to help you to create a resilient SME, although it is important to collect more data and update your FMEA analysis. Your data is medium in 'the secret revealing' cube.

c) If that is your answer, you are supposed to be a data-fan and/or a certain maturity in the process operation. Everything is measured and control in your SME, and that is an excellent point. Your data is high in 'the secret revealing' cube.

Question 4 (look at ‘the secret revealing’ cube)

a) If that is your answer, do not hesitate to quickly implement ‘4 in a row’. Your customers are probably paying for your high-quality products and they are undoubtedly asking for your best performance. Your SC criticality challenges the resilience of your SME and there is no doubt in saying you must consider this tool as an opportunity to safeguard your business. Your criticality is high in ‘the secret revealing’ cube.

b) If that is your answer, your SC is critical for your business. You are differentiated from your competitors in a competitive market for your brand and performance, so you cannot deceive them. For this reason, it is important to pay attention to how a failure mode can occur and what is its failure cause. ‘4 in a row’ is definitely your tool. Your criticality is medium in ‘the secret revealing’ cube.

c) If that is your answer, your SC is probably not critical enough to challenge the survival of your SME. Your customers are probably very interested in keeping very low prices even though a delay or not having all their requirements properly satisfied. Although you will probably not obtain all the potential of ‘4 in a row’, there are some best practices and Lean tools which surely can help you to decrease your waste and make you even more competitive. Your criticality is low in ‘the secret revealing’ cube.

Question 5 (look at ‘the secret revealing’ cube)

a) If that is your answer, you are probably a novice in the SC and do not really know how to face its problems. It is going to be challenging for you to discover how a delay or a disruption can affect your resilience. Be prepared to learn quick and effectively. Experience will come by itself. Your experience is low in ‘the secret revealing’ cube.

b) If that is your answer, you are supposed to be aware of how SCR can damage your SME. You are also supposed to be familiar with the reasons why mitigation actions are constructive. Feel free to investigate further in the SC area to be even more prepared to help your enterprise. Your experience is medium in ‘the secret revealing’ cube.

c) If that is your answer, you are supposed to have read some SCRM books and/or have previous experience in that area. You are going to be a vital piece in ‘4 in a row’ and for sure, your SME is very fortunate to have hired such a prepared worker as you. Your experience is high in ‘the secret revealing’ cube.

You are now prepared to look at ‘the secret revealing’ cube. Review your answers, compare them with the cube sides and pick the most critical result. That means choosing the yellow level if one side is yellow and the other two are green, for example.

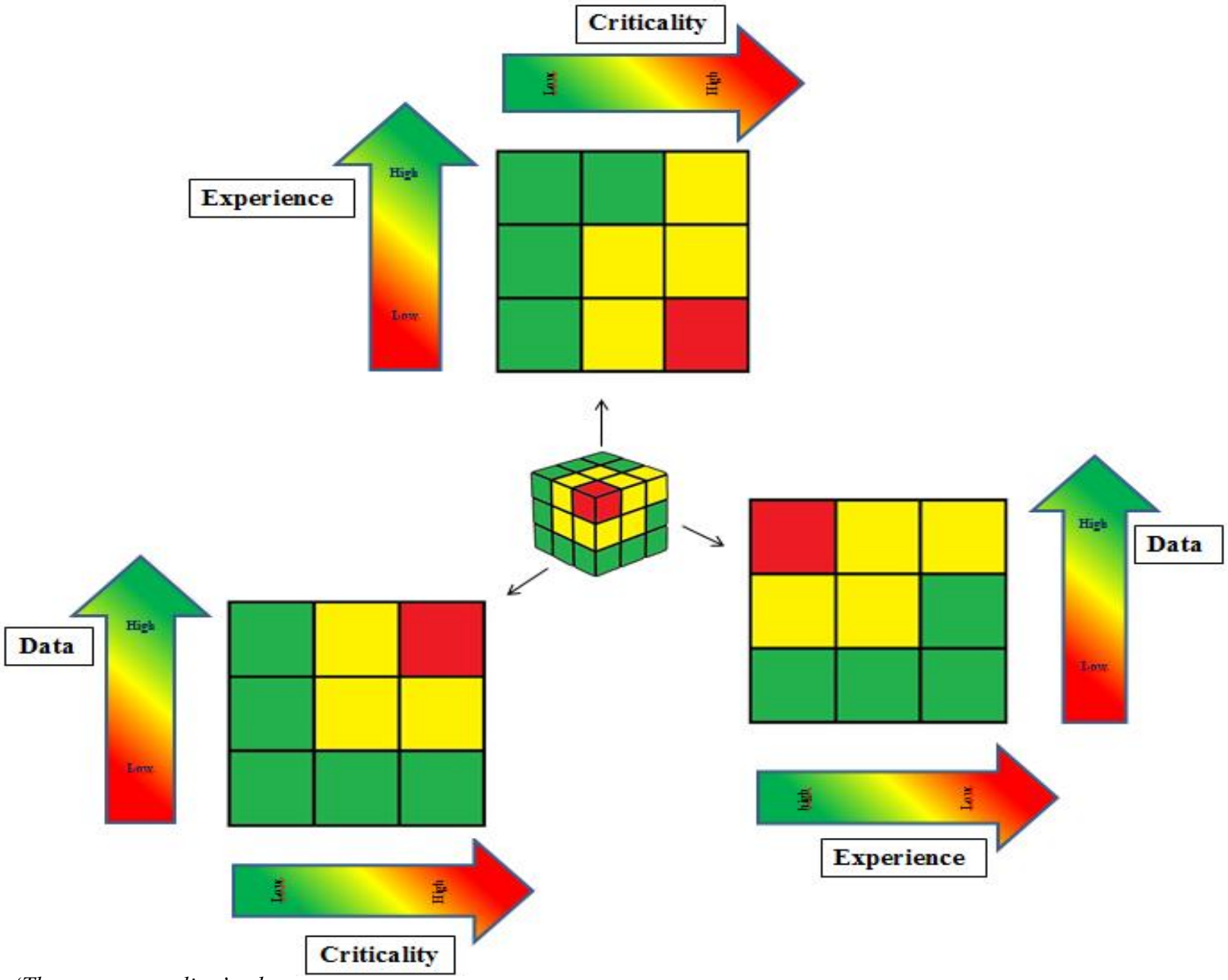


Figure 5.1: 'The secret revealing' cube

Green level

If that is your situation, you should develop the easiest '4 in a row'. That means categorising severity, probability and level of detection from 1 to 4. Green level also means you can develop all the tools which are in green from table 5.12 in step three.

Level	Probability	Description
4	Almost certain	Catastrophic - The failure mode is very likely to happen. Over 90% of chances
3	Highly probable	Critical - The failure mode is likely to happen. Probability over 50%
2	Unremarkably probable	Major - The failure mode is not likely to happen. Probability under 50%
1	Rare event	Minor – The failure mode is not expected to happen. Less than 10% of chances

Table 5.1: Notional example of a 1-to-4 probability classification for an electrical power cut in a FMEA

Level	Severity	Description
4	Catastrophic	SC disrupted and orders cancelled
3	Critical	Critical delay in an order
2	Major	Non-critical delay in an order
1	Minor	Small mismatches in the SC causing minor problems

Table 5.2: Notional example of a 1-to-4 severity classification for a natural disaster in a FMEA

Level	Severity	Description
4	Very remote (+5%)	Very remote chance to detect the potential cause and subsequent failure mode
3	Moderately low (+30%)	Low chance to detect the potential cause and subsequent failure mode
2	Moderately high (+70%)	Mod. high chance to detect the potential cause and subsequent failure mode
1	Very high (+95%)	Very high chance to detect the potential cause and subsequent failure mode

Table 5.3: Notional example of a 1-to-4 detection classification for an automotive supplier in a FMEA. Based on IEC 60812, 2006

Fortunately, you will probably need very few economic resources and time to obtain the first benefits from the '4 in a row' implementation.

Yellow level

If that is your situation, you should develop the medium '4 in a row'. That means categorising severity, probability and level of detection from 1 to 6. Yellow level also means you can develop all the tools which are in green or yellow from table 5.12 in step three.

Level	Probability	Description
6	Almost certain	The failure mode is very likely to happen. Over 95% of chances
5	Highly probable	The failure mode is likely to happen. Probability around 75%
4	Probable	The failure mode might happen. Probability over 50%
3	Moderately Probable	The failure mode might happen. Probability under 50%
2	Unremarkably probable	The failure mode is not likely to happen. Probability around 25%
1	Rare event	The failure mode is not expected to happen. Less than 5% of chances

Table 5.4: Notional example of a 1-to-6 probability classification for an electrical power cut in a FMEA

Level	Severity	Description
6	Catastrophic	SC disrupted and orders cancelled
5	Very Critical	Penalties for a severe delay
4	Critical	Critical delay in an order
3	Major	Non-critical delay in an order
2	Minor	Small mismatches in the SC causing minor problems
1	Negligible	Temporally stoppage of the production without consequences

Table 5.5: Notional example of a 1-to-6 severity classification for a natural disaster in a FMEA

Level	Detection	Description
6	Very remote (+5%)	Very remote chance to detect the potential cause and subsequent failure mode
5	Remote (+20%)	Remote chance to detect the potential cause and subsequent failure mode
4	Low (+40%)	Low chance to detect the potential cause and subsequent failure mode
3	Moderate (+60%)	Moderate chance to detect the potential cause and subsequent failure mode
2	High (+80%)	High chance to detect the potential cause and subsequent failure mode
1	Very high (+95%)	Very high chance to detect the potential cause and subsequent failure mode

Table 5.6: Notional example of a 1-to-6 detection classification for an automotive supplier in a FMEA. Based on IEC 60812, 2006

You will probably not need many economic resources and time to implement ‘4 in a row’.

Red level

If that is your situation, you should develop the hardest and longest ‘4 in a row’. That means categorising severity, probability and level of detection from 1 to 10. Red level also means you can develop all the tools which are in green, yellow or red from table 5.12 in step three.

Level	Probability	Description
10	Absolutely certain	The failure mode is going to happen. Around 100% of chances
9	Almost certain	The failure mode is very likely to happen. Over 95% of chances
8	Highly probable	The failure mode is likely to happen. Probability around 80% of chances
7	Quite probable	The failure mode might happen. Probability over 60% of chances
6	Probable	The failure mode might happen. Probability over 50% of chances
5	Moderately Probable	The failure mode might happen. Probability under 50% of chances
4	Unremarkably Probable	The failure mode might happen. Probability under 40% of chances
3	Not probable	The failure mode is not likely to happen. Probability around 20% of chances
2	Rare event	The failure mode is not expected to happen. Less than 15% of chances
1	Extremely rare event	The failure mode is not going to happen. Less than 5% of chances

Table 5.7: Notional example of a 1-to-10 probability classification for an electrical power cut in a FMEA

Level	Severity	Description
10	Catastrophic	SC disrupted and orders cancelled
9	Extremely critical	Penalties for a severe delay
8	Very critical	Very critical delay in an order with complains
7	Remarkably Critical	Critical delay in an order with complains
6	Critical	Critical delay in an order without complains
5	Major	Non-critical delay in an order
4	Unremarkably critical	Mismatches in the SC causing internal problems without affecting the delivering time
4	Not Critical	Small mismatches in the SC causing not critical problems
2	Minor	Small mismatches in the SC causing very small problems
1	Negligible	Any consequences

Table 5.8: Notional example of a 1-to-10 severity classification for a natural disaster in a FMEA

Level	Detection	Description
10	Absolutely uncertain (+/- 0%)	Design control cannot detect the potential cause and subsequent failure mode
9	Very remote (+5%)	Very remote chance to detect the potential cause and subsequent failure mode
8	Remote (+20%)	Remote chance to detect the potential cause and subsequent failure mode
7	Very Low (+30%)	Very low chance to detect the potential cause and subsequent failure mode
6	Low (+40%)	Low chance to detect the potential cause and subsequent failure mode
5	Moderate (+60%)	Moderate chance to detect the potential cause and subsequent failure mode
4	Moderately high (+70%)	Mod. high chance to detect the potential cause and subsequent failure mode
3	High (+80%)	High chance to detect the potential cause and subsequent failure mode
2	Very high (+95%)	Very high chance to detect the potential cause and subsequent failure mode
1	Almost certain (100%)	Almost sure to detect the potential cause and subsequent failure mode

Table 5.9: Notional example of a 1-to-10 detection classification for an automotive supplier in a FMEA. Based on IEC 60812, 2006

Unfortunately, you will probably need to invest a significant part of your budget in the implementation of '4 in a row'. But there is a reason, probably the criticality of your SC, which requires from that effort. But there are also good news: you can fully obtain the benefits of '4 in a row'.

5.2- Step two: Identification and prioritization of risks through Failure Mode and Effect Analysis (FMEA)

The second step of '4 in a row' is the identification of the top-priority SCRs which require a quicker solution. This early stage is going to be based in an already existing methodology called Failure Mode and Effect Analysis (FMEA) adapted to the SMEs context.

5.2.1- Background to FMEA

5.2.1.1- Definition and scope

The definition of FMEA has evolved since it was first used in a USA Military standard in 1980. FMEA was first defined as ‘a procedure by which each potential failure mode in a system is analysed to determine the results or effects thereof on the system and to classify each potential failure mode according to its severity’ (Military standard, 1980). In 1992, Sematech projected FMEA as a ‘technique for systematically identifying, analysing, and documenting the possible failure modes within a design and the effects of such failures on equipment performance’ (Technology transfer – Sematech, 1992). In 2003, the Cranfield University proposes FMEA as ‘a quality improvement tool that can be applied equally to physical systems (vehicles, aircraft, electronic devices and so forth) and non-physical systems such as supply chain processes. The purpose of FMEA is to prevent process and product problems during the design phase. However, conducting an FMEA on existing processes is also hugely beneficial; unlike products, processes can be re-engineered more easily’ (Cranfield, 2003). In 2006, Vosniakos and Barla simplified the definition and wrote ‘Failure mode and effect analysis (FMEA) is a technique to systematically record problems, their criticality, and possible alleviation’ (Vosniakos & Barla, 2006). Also in 2006, there was a new standard introduced which defines FMEA as ‘a systematic procedure for the analysis of a system to identify the potential failure modes, their causes and effects on system performance (performance of the immediate assembly and the entire system or a process)’ (IEC, 2006). In 2012, Jensen et al. defined FMEA as a tool that exists in the larger framework of quality and reliability processes: ‘FMEA is a method designed to identify and fully understand potential failure modes, their causes and effects; assess the risk associated with the identified failure modes; prioritize issues for corrective action and identify and carry out corrective actions to address the most serious concerns’ (Jensen et al., 2012).

Summarizing most of the definitions, the proposed definition and scope for a FMEA in this thesis is ‘systematic procedure, based on the analysis of potential failure modes in processes or physical systems thorough a classification of risks by severity, probability and detection which helps to understand causes and effects, prioritize risks and propose mitigation actions’.

5.2.1.2- International Standard IEC 60812

One of the main documents I have used for developing ‘4 in a row’ is the International Standard 60812. It has been used as a guide to understand the critical points for the design of a FMEA and therefore, propose a foolproof and unswervingly, but also easy-to-implement tool, to improve processes in SMEs.

The organization of the standard is the following:

1) Definitions
2) Reasons for the implementation of FMEA
3) Tasks to be done before the analysis
4) Structure of FMEA: definitions and what to take in consideration about
    - Levels of analysis
    - Failure mode determination
    - Failure causes
    - Failure effects
    - Detection methods
    - Severity classification
    - Probability of occurrence
5) How to use RPN
6) Criticality matrix
7) RPN deficiencies
8) Common-cause failure
9) Applications

The standard also suggests some strengths and weaknesses of FMEA.
On the one hand, strengths to be considered are

1) Early identification of risks and failure modes
2) Focus on quality control, inspection and process control
3) Helps to ensure the fulfilment of specifications

On the other hand, weaknesses to be considered are

1) The RPN deficiencies → RPN classification must not be understood linear; RPN is very sensitive to small changes when larger numbers; there are gaps in the RPN ranges
2) Awkwardness to implement in complex systems which multiple functions.
3) It is not possible to represent relationships between failure modes (based on the assumption of interdependency)

5.2.1.3- FMEA procedure

An FMEA (or a series of FMEAs) is usually indicated when a new product or process is underway…If existing designs or processes are changed, FMEAs may be needed to ensure the changes are safe, reliable, and cost-effective. There is no standard method for the sequence of steps (Jensen et al., 2012); however, many experienced FMEA teams use the following strategy:

1. Enter all the primary functions for the item under analysis.

2. Beginning with the first function, enter all the failure modes and corresponding effects, with severity rankings for the most serious effect of each failure mode.

3. For each failure mode, enter all of the causes, with occurrence rankings for each cause.

4. For each cause, enter prevention-type controls and detection-type controls, with detection rankings for the best detection-type control.

5. Enter the next function and continue until all the functions are analysed through Risk Priority Numbers (RPNs).

6. Review the high severities and high RPNs, and develop all needed recommended actions that will reduce risk to an acceptable level.

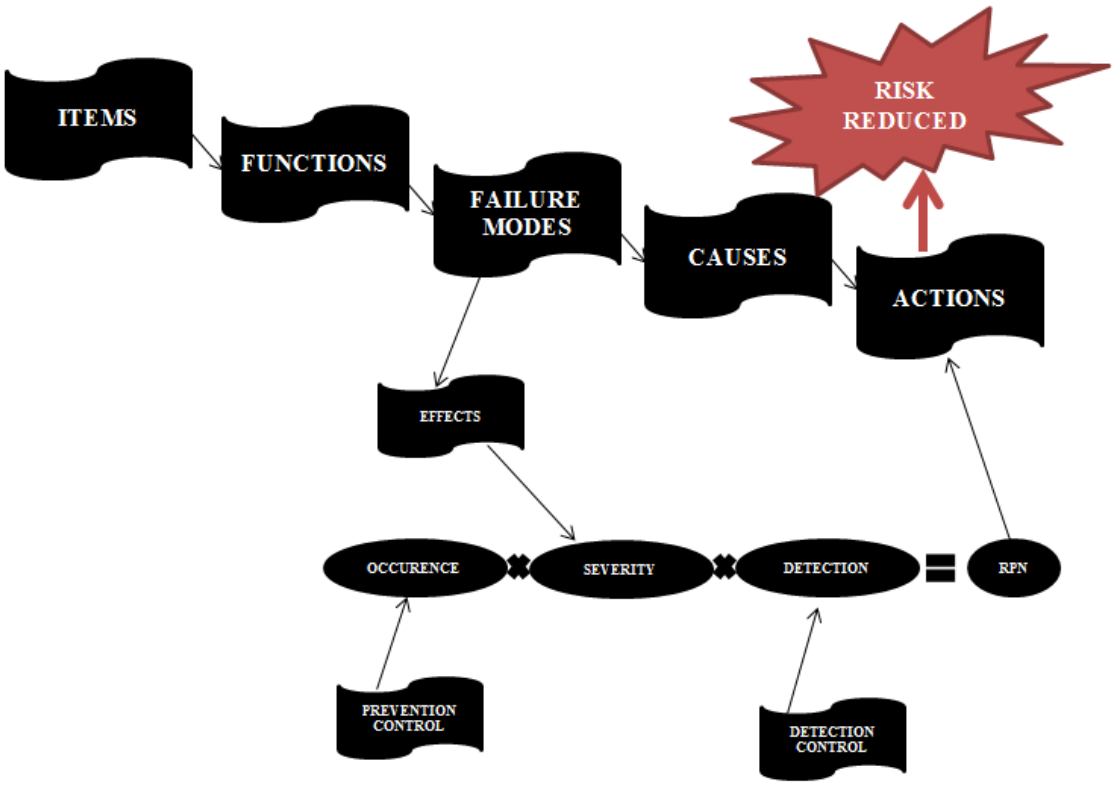


Figure 5.2: FMEA procedure.

Category	Item to check	Failure mode	Failure effect	Severity	Potential failure cause	Detection action	Detection	Key element	Occurrence	RPN

Table 5.10: Suggested FMEA table

5.2.2- Six categories for Supply Chain challenges

‘4 in a row’ has been designed to include the most challenging SCRs a manufacturing SME must take into consideration. Since each SME is a completely differentiated case and have to cope with individual and complex SCRs, it has not been possible to create a whole list of risks. However, ‘4 in a row’ presents a six-level categorization which aim to summarise these SCRs.

SMEs who want to implement ‘4 in a row’ must feel free to add an additional category which they consider relevant for their activity or delete any SCR if the existing ones do not concern their production.

The six-level categorization of SCRs is split in factors which affect external stakeholders, factors which affect internal stakeholders and factors which affect both, internal and external. There are three reasons why it has been adopted that division. Firstly, because Oehmen (Oehmen, 2012) suggests this division as the most suitable way to organize Lean principles (he refers to them as Lean enablers) and therefore, that division would result very appropriate for step 3 (which implies the Lean implementation) of ‘4 in a row’. Secondly, because E5 asserts SCRs should be categorised in that way for an accurate analysis of them. And thirdly, because I consider that division a simple and natural way of understanding the different stakeholders approach to whichever SME. In addition, that categorization helps to realise when the FMEA should be updated as a result of a major change in any of the factors.

5.2.2.1- Two External factors

There are two factors which affect most to external stakeholders. These external stakeholders must be understood as suppliers and customers. Therefore, two extensive categories can be defined according to the interests of the already mentioned stakeholders: ‘Supply Security’ and ‘Customer Satisfaction’

The FMEA should be updated periodically and when a major change affect to any of the categories. Examples of big changes can be the acquisition of a new supplier, a new monitoring control or an increase in the price of supplied components.

Supply Security (SS)

This category encloses all the activities required for the procurement of raw materials, pieces and other resources to guarantee the precise operation of SMEs processes. The override subcategories to be checked are the followings:

- Reliability of suppliers (including suitability of supplied components and spares)
- Availability of resources
- Price stability

- Geographical location of suppliers
- Flexibility (including quantities and lead time)
- Grade of communication with your supplier (from personal friendship to very low contact)

Each supplier will probably have special characteristics, hence is important to check every subcategory according to the individualities of these suppliers.

Customer Satisfaction (CS)

This category encloses all the mandatory activities for the satisfaction of ALL the requirements imposed by customers. The override subcategories to be checked are the followings:

- Suitability of the price
- On-time deliveries
- Sales monitoring and accurate forecast
- Quality of the product
- Complaints treatment
- Presentation of the product
- Overall satisfaction
- Grade of communication with your customer (from personal friendship to very low contact)

Each customer will probably have special characteristics, hence is important to check every subcategory according to the individualities of these customers.

5.2.2.2- Two Internal factors

There are two factors which affect most to internal stakeholders. These internal stakeholders must be understood as employees and people involved in the production process. Therefore, two extensive categories can be defined according to the interests of the already mentioned stakeholders: 'Working facilities and production management' and 'Equipment'

The FMEA should be updated periodically and when a major change affect to any of the categories. Examples of big changes can be the introduction of new equipment, a new equipment layout and the implementation of optimisation tools.

Working Facilities and Production Management (WF & PM)

This category encloses the management of the SC basic components within the production plant. The override subcategories to be checked are the followings:

- Required space for the equipment operation
- Grade of efficiency and effectiveness
- Satisfaction of the staff with the facilities
- Fire and other protection against hazardous events
- Implementation and correct utilisation of security measures
- Quality control
- Standard satisfaction (if applies)

Each production plan will probably have special characteristics, hence is important to check every subcategory according to the individualities of these plants.

Equipment (E)

This category encloses the management of the machinery and the technical aspects of the production plant. The override subcategories to be checked are the followings:

- Equipment maintenance
- Machinery depreciation
- Suitability of the equipment
- Availability of data in the frequency and severity of working interruptions
- A comparison with processes carried on by similar competitors
- Variety in the process

Each key component of the equipment will probably have special characteristics, hence is important to check every subcategory according to the individualities of these mechanisms.

5.2.2.3- Two factors that affects both internal and external

There are two factors which affect both internal and external stakeholders. Two extensive categories can be defined according to the interests of the already mentioned stakeholders: 'Team quality' and 'Decision making'.

The FMEA should be updated periodically and when a major change affect to any of the categories. Examples of big changes can be the retirement of a key component of the team, the introduction of new bureaucracy and the reorganization of departments/projects.

Team quality (TQ)

This category encloses all the activities which safeguard the suitability for a task, the required formation and the diffusion of know-how among the workmates. The override subcategories to be checked are the followings:

- Employees satisfaction

- Suitable-for-the-job-position employee availability
- Formation and recycling of the staff
- Easy flow of knowledge across the company
- Diversification of know-how across all the members of the team, without any process dependent in a sole working man
- Effective communication between departments/processes

Each department or project will probably have special characteristics, hence is important to check every subcategory according to the individualities of these departments/projects.

Decision-Making (DM)

This category encloses the way in which decisions are taken, plans are designed and tools are implemented. The override subcategories to be checked are the followings:

- Reactivity towards problems
- Agility to find clever solutions
- Accuracy in the implementation of plans
- Procedure to assume the responsibility and manage the DM

Each decision unit will probably have special characteristics, hence is important to check every subcategory according to the individualities of these units.

5.2.3- Benefits and handicaps of the implementation of a systematic FMEA in SMEs

In chapter 5.2.1, it has been written down some strengths and weaknesses suggested by the standard 60812. However, this standard does not mention in which way the implementation of a systematic FMEA helps a SME to increase its resilience.

A systematic FMEA has to be understood as the introduction and update of this tool according to the requirements of each SME and its performance in each of the six proposed categories.

After the literature review and the opinion of some SC experts, their views but also mine can be recapitulated in the table 5.11:

ADVANTAGES	DISADVANTAGES
FMEA increases the awareness of already studied SCRs and helps to discover those which might not have been realised yet	FMEA requires some time to develop the analysis and fully-expand its benefits
FMEA is an easy tool to prioritize risks and order the introduction of mitigation actions to achieve a resilient SME	There is no linearity in the RPN scale (200 RPN does not necessarily mean to worry double about a 100 RPN risk)
FMEA is a relatively cheap and effective tool to detect failure modes and failure causes	The FMEA analysis do not ensure the detection of all the possible failure modes
The presentation of a FMEA helps the management of decision based on facts, not in intuitions	To obtain all the benefits of the FMEA, the analysis should be developed periodically and with major changes. And that might be cumbersome in the time, especially for SMEs

Table 5.11: Advantages and disadvantages of the implementation of a systematic FMEA in a SME

5.3- Step three: Mitigation actions for identified and high-priority risks

Once you know the top SCRs to deal with, it is high time to introduce some mitigation actions to reduce the potential hazards of these SCRs. A mitigation action can be defined as an action which aims to reduce the severity, seriousness, or painfulness of something (Oxford Dictionaries, 2010). In the context of this thesis, that 'something' must be understood as a SCR.

In this step three of '4 in a row', a compilation of mitigation actions are described and suggested to be implemented in your SME according to your budget and requirements. This thesis presents two alternatives of mitigation actions: Lean tools and Best practices. Ideally, you should choose from both alternatives the tools which fit better with your SME necessities.

5.3.1- Lean tools

The following tools are a compilation of procedures and measures suggested by: Plenert, 2006; Ben-Daya, 2009; Meran et al., 2013; Elbert, 2013; Chiarini 2013; Thuesen, 2013; E4, 2014; E5, 2014. The compilation is edited, extended and organised by the own author.

5.3.1.1- Using lean tools in a clever way

You might not have time, budget or intention to implement simultaneously all the Lean tools. And even if you have all three constraints, your SME is still plenty of opportunities to become more resilient. Table 5.12 organizes Lean tools according to the six categories defined in chapter 5.2.2 and categorizes them according to 'the secret revealing' cube. For each category, there are a big number of proposals which can be helpful to your case.

And remember, 'to really be able to use the complete set of tools… we need to understand which tool(s) are best utilised to solve a particular type of problem' (Frankel et al., 2005).

EXTERNAL FACTORS		INTERNAL FACTORS		BOTH	
SUPPLY SECURITY	CUSTOMER SATISFACTION	WORKING FACILITIES & PRODUCTION MANAGEMENT	EQUIPMENT	TEAM QUALITY	DECISION MAKING
Effort benefit matrix	Must criteria	SCAMPER	Effort benefit matrix	Brainstorming	Brainstorming
SCAMPER	Effort benefit matrix	Cross functional diagram	Total productive maintenance	Anti-solution brainstorming	Anti-solution brainstorming
Determination of batch size	Determination of batch size	Effort benefit matrix	SCAMPER	The six thinking hats	The six thinking hats
Brainstorming	Brainstorming	Process flow and process logic	Must criteria	Glass wall management	SCAMPER
Anti-solution brainstorming	Anti-solution brainstorming	Generic pull system	Spaghetti diagram	SCRUM	Cross functional diagram
The six thinking hats	The six thinking hats	Replenishment pull system	Should be process map		Affinity diagram
Replenishment pull system	SCAMPER	Setup time reduction	Control chart		Effort benefit matrix
Reaction plan	Generic pull system	5 S	Total cost of ownership		N/3 method
Clean sheet modelling	Replenishment pull system	Value Stream mapping	Poka Yoke		Nominal group technique
	Reaction plan	Process control	Process control		Pugh matrix
		Workplace layout			Should be process map
		Theory of constraints			Value stream mapping
					Reaction plan
					Implementation plan
					Process control
					SCRUM

Table 5.12: Classification of Lean tools according to the six proposed categories in chapter 5.2

5.3.1.2- Lean tools description

5S (Seiri, Seiton, Seiso, Seiketsu, Shitsuke)

It is a five-step procedure which aims to create an efficient working environment and minimize defects.

- Seiri: It could be translated as sort. It consists in marking all the items with a red tag in the working environment and get rid of them after a specified period of time without being used
- Seiton: It could be translated as storing. It is based on marking all the tools and working objects with a card, specifying where should be deposited these items after using them. Thereby, the following employee does not have to waste time looking around for the tools.
- Seiso: It could be translated as sanitising. It refers to have the entire working environment clean.
- Seiketsu: It could be translated as standardising. It refers to implement the previous concepts as a daily activity.
- Shitsuke: It could be translated as sustaining. It consists in maintaining the improvement philosophy by integrating the Lean culture in the enterprise.

Japanese	Definition	English	Example
Seiri	Tidiness	Sorting	Throw away rubbish
Seiton	Organization	Storing	30 sec. doc. Retrieval
Seiso	Cleanliness	Sanitising	Individual responsibility
Seiketsu	Neatness	Standardising	Clear written instructions
Shitsuke	Discipline	Sustaining	Do 5S activities daily

Figure 5.3: 5S definition and example. Based on Elbert, 2011

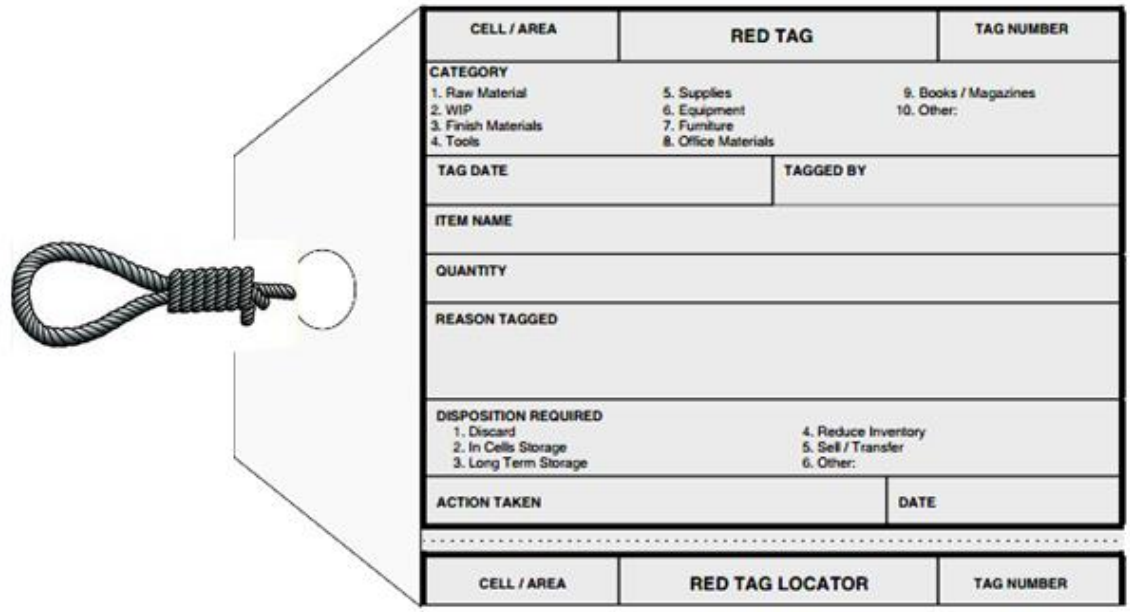


Figure 5.4: Red tag example used in the Seiri stage. Based on Plenert, 2006

Affinity diagram (Clustering)

The object of this diagram is grouping ideas collectively without criticism among the participants. To organise these ideas, some post-its can be stuck in the wall to find how the proposals are interrelated.

Figure 5.5: Affinity diagram example in the Project Management 2.0 (2014) course in DTU

Antisolution brainstorming

The procedure is very similar to the usual brainstorming. Nevertheless, in this case the participants have to answer the question of 'what can go wrong or even worse?' Afterwards, these participants should find some mitigation action to these potential circumstances.

Brainstorming

The idea of that widely known tool is to find solutions for a problem or improve an activity. Although there are several methodologies, most of them can be summarised in writing down (in silence) the proposals of all the members, collect them and see which suggestions fit better to the problem.

Clean sheet modelling

The purpose to develop such a tool is to pressure your supplier to decrease the cost of a supplied component, especially if you have the sensation the relationship price-quality is very low. It is a tool suggested by E4 which helps to increase the competitiveness in the market as your enterprise can face lower costs.

To develop that clean sheet, true data must be obtained for the cost of each component of the piece supplied and include to that number an approximation for the cost of electricity, taxes, distribution, labour, packaging and an operating margin.

If there is a big difference to the purchase price for your enterprise, it is better to have a talk with the supplier and show him the clean sheet.

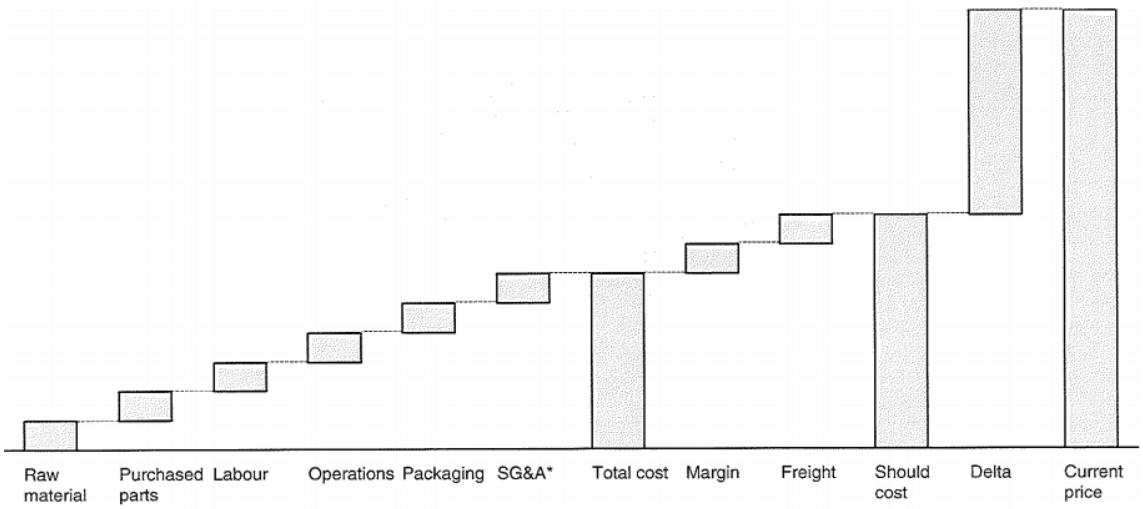


Figure 5.6: Clean sheet notional example from E4 (E4, 2014). Data in Euros per unit

Cross Functional Diagram (CFD)

The object of this diagram is to have a visual representation of a process and identify areas for improvement. The six-step plan involves:

- Identifying people involved in the process
- Marking start and stop points
- Sorting the process steps according to their actual sequence

- Assigning the steps to their respective function
- Mapping decisions and loops
- Identifying weak points

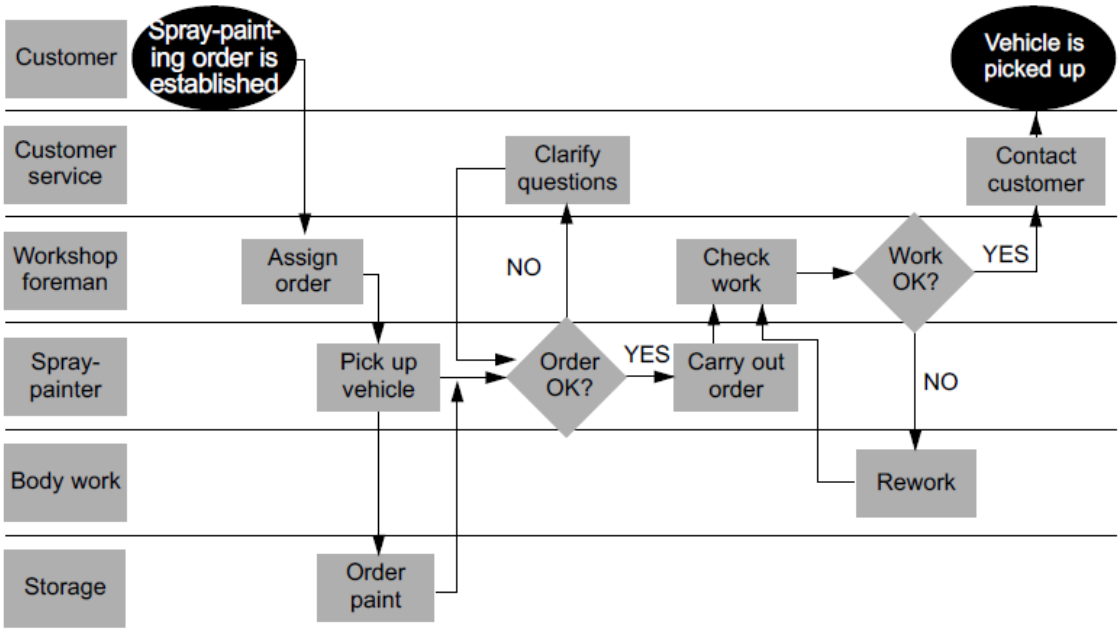


Figure 5.7: Notional CFD example. Based on Meran et al., 2013

<u>*Determination of batch size*</u>

The objective of that method is to estimate the optimal batch size to achieve the highest quality with the lowest total cost. There are some formulas which are commonly used in the industry for a product p with a unique raw material, such as:

$$Q_p^* = \sqrt{\frac{2D_p \cdot (A_p + A_1)}{H_p + r_1 \cdot H_1}}$$

Where Q_p = production lot size; D_p = demand rate; H_p = Inventory holding cost; A_p = setup cost; r_i = amount/quantity of raw material i required in producing one unit of a product p; A_i = ordering cost of a raw material i; H_i = annual inventory holding cost for raw material i.

For other cases, there are also specific formulas.

Effort-Benefit matrix

The intention of this tool is to provide a visual method showing the relationship between the effort involved in implementing a proposal and the benefit it could potentially bring to the enterprise. By rating all the ideas, a matrix could be drawn to decide which concepts are High-benefit-Low-effort and consequently, are worth to introduce in the company.

Generic pull system (flow pull system)

The target of that production thinking is to re-orient the manufacturing process to avoid overproduction, reduce the lead time and increase the process flexibility. The 4-step process is the following:

- Introduce a very straightforward FIFO (First-in-First-out)
- Connect an alarm that announces the end of a batch to allow the following batch to start. Reduce the variability in lead time
- The inventories can be progressively cut down by process efficiency and process lead time
- Start a process control

Glass Wall management

The aim of this method is to motivate the working teams by exposing publically (in key figures) the most relevant results of each team or department. Each and every employee must have access to that information and see how his team and their workmates performance look like.

It is vital to reflect reliable information and award the success of the best teams to motivate the internal competition, thus improving the productiveness of the enterprise

Implementation plan

It is a technique to map the activities and responsibilities to ensure the execution of the idea according to a timeframe. The procedure is based in three steps:

- Set the scope for the implementation
- Define solution blocks and assign the concrete actions to an employee
- Develop a change management strategy to ensure there is no reluctance to the acceptance of the implementation.

Must criteria

This method could be applied both to ideas and processes. It involves the review of all the requirements of a procedure/order and decide a posteriori, if all of them are satisfied by the current process or proposed idea.

To organise the requirements, all the parameters (legal and safety regulations, standards, environmental issues and corporate strategy) are suggested to be included in a table.

N/3 Method

The end of this method is to simplify the selection of a proposal by a group of managers/employees.

Each component should vote for $\frac{N}{3}$ of the ideas. The alternatives with the majority of points are pursued further. After a first round, the procedure can be initialised again.

Note: N is the number of alternatives which could potentially be implemented.

Nominal group technique

It is another way of finding the best alternative for projects or ideas. Each member of the group should rank the proposals with 1, 2 or 3 points. The highest-ranked options are the nominees to be implemented or analysed deeper.

Poka Yoke (Error proofing)

It is a five-step procedure which aims to produce with 100% of quality, eliminating all kind of mistakes. The USB connection is a clear example of Poka-yoke implementation, as it can only be introduced in one direction.

- Step one: Detection of defects (by an inspection method such as statistical or traditional examination)
- Step two: Check if Poka Yoke is a tool applicable for this defect
- Step three: Evaluation of defects and their causes
- Step four: Development and selection of a solution. Different methods, such as contact identification (by size or shape), fixed-value (an alarm warns the operator if a concrete number of movements are not made) or sequence (an alarm warns the operator if there is a missing step)
- Step five. Implementation of the selected idea and provide a method to guarantee the long-term effect of the solution

Process control

It consists in defining which measures are going to be executed in order to ensure the sustainability of the benefits of the new proposal. The procedure involves

- Selecting which key figures and key parameter are going to be used
- Preparing the data collection
- Selecting which Key Performance Indicators (KPI) are more suitable for the studied parameter
- Defining target for the KPIs
- Develop a RACI Chart (who is responsible, accountable, consulted and informed about the process)
- Monitoring the whole process

Process flow and process logic

The object of this process is to maximize the degree of value addition and minimise the necessary resources to do that. The procedure is relatively simple:

- Decide which tasks are currently being done in the manufacturing process
- Categorize the criticality of the previous tasks in 1) main, 2) important and 3) support activity
- Investigate if there is process logic in these activities and the 'flow' of the SC
- Introduce control tools to safeguard the requirements satisfaction

Pugh matrix

The objective of this tool is to prioritise solutions by ranking them according to some technical and weighted criteria. A previous benchmark can be used as a standard for the comparison. Once there is a ordering among the alternatives, strengths and weaknesses can also be discussed.

Reaction plan

The goal of planning this procedure is to describe specific and pre-agreed action to take when some specifications or requirements are not fulfilled.

First, Critical to Business (CTB) and Critical to Customer (CTC) requirement targets have to be adopted. Second, specific measures should be defined in case the alarm warns a CTB or CTC is violated. Third, identification of who is the responsible for the implementation of the measures must be carried on.

This tool might be very helpful to organize the mitigation actions decided to cope with the SCR.

Replenishment Pull System (RPS)

The intention of that tool is to remove the delivery constraints, enable short-terms orders and relocate the investment of unneeded stocks in other places. It is a prerequisite to have a non-seasonal demand a variation coefficient $\left(\frac{s}{\bar{x}}\right)$ lower than one.

To calculate the adequate inventory, there are four items to take into account:

- Replenishment time for purchase and manufacturing pull
- Accurate forecast
- Safety factor
- Send a new order when the sum of inventory plus non-delivered orders is higher than the re-order level

SCAMPER

The goal of this tool is to generate a further development of an idea and encourage the creativity to flourish in 7 phases.

- Substitute: Is it possible to re-design the process and substitute the less efficient activities?
- Combine: How can activities be combined to increase the productivity?
- Adapt: Is it possible to adjust an external solution to the case under study?
- Modify: How can the current situation be improved to minimise the waste?
- Put to other uses: Is the idea applicable for another use?
- Eliminate: Could any activity be erased?
- Reverse: If rearranging activities, would the process be more cost-efficient?

SCRUM

The aim of the tool is to be more reactive and increase the agility in the decision-making. It was firstly introduced for software development, but today it has been demonstrated the applicability in other kind of industries. SCRUM is specially indicated for SMEs, as they tend to be more capable of having a faster adaptation to changes.

SCRUM essentially consists of a series of sprint loops, in which activities are organised in a SCRUM board and the whole process is directed by the SCRUM master

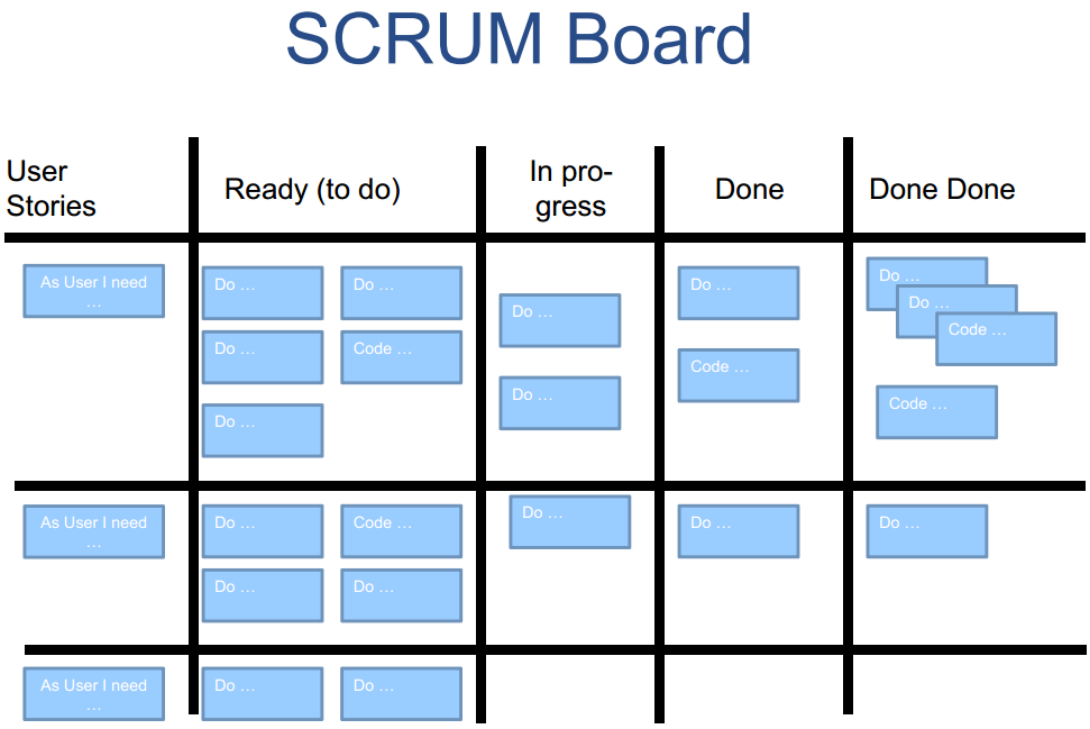


Figure 5.8: SCRUM board example. Based on a notional example by E5, 2014.

Setup time reduction (or SMED)

The objective of this methodology is to reduce setup times (interval between the last piece of a batch and the following piece of a new batch) and increase the percentage of theoretical capacity of a bottleneck in 4 steps.

- Identify internal setup times (activities which can only be done when the machine is switched off) and external setup times (activities which can be done when the machine is switched on)
- Brainstorming how to convert internal into external setup times
- Coordinate and simplify (as far as possible) the residual internal setup times
- Eliminate setup estimation times and use visual mechanisms to reduce non-productive time

Spaghetti diagram

The goal of this tool is to identify the movement of raw material, employees and goods in a plant to optimise the flow of the process by eliminating non-value-adding activities.

To implement this tool is necessary a detailed map of the plant, including the machinery and raw materials situation. Then, the spaghetti diagram responsible must draw all the movements involved in the process and remark all the waste activities. Finally, it might be necessary to take some decisions regarding the eradication of unnecessary actions.

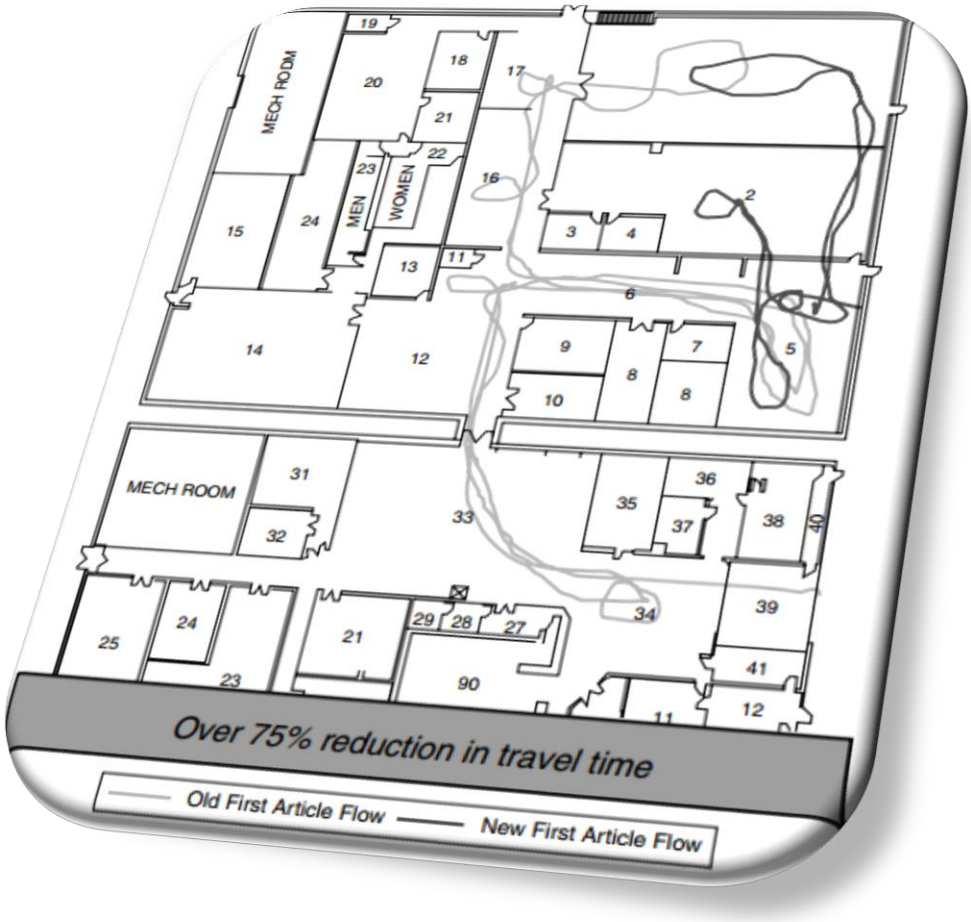


Figure 5.9: Spaghetti diagram. Based on Plenert, 2006

<u>*Should be process map*</u>

The purpose of this technique is to visualize graphically how the implementation of an idea should take place.

The procedure involves de 'should be' definition, the designation of responsibilities and the determination of the visual method to use. Then, the result can be scored with the formula

$$R = (Q \cdot A)^{M}$$

where R is for the result; Q for the quality achieved regarding the complexity of the process; A for the availability of resources for the new process/idea and M for the management of the selected components who will implement the proposal.

The six thinking hats

The aim of the tool is to increase the complexity of an idea while decreasing the uncertainty of the problem. Therefore, better and more accurate the implementation of a proposal can be.

The procedure is discussing the idea by changing the 'hat' of the members in no more than 3 minutes. Each hat has a meaning: blue is for the presentation, yellow is for positive aspects of the idea, black is for negative aspects of the idea, green is for improvement, red is for gut feeling and white is for information/data.

Theory of constraints

This theory is based in two premises: the goal of a business is to generate cash and a system's constraints determine its output. It recommends taking a global perspective of decision making by considering three economic measures (Throughput, inventory and operating expense).

To implement the theory, 5 steps should be considered.

- Identify bottlenecks
- Plan to maximize outputs from the constraint
- Improve reliability in everything else (non-constraints) to have a potential effect on the constraint
- Invest in elevating the technical capacity of constraints
- Re-identify new bottlenecks

Total cost of ownership (TCO)

The reason to develop such an activity is to understand the real cost of the equipment. It is a tool suggested by E4 which allows a decision-making based in facts.

The procedure involves obtaining data about the overall cost of running a machine (or a part of it, like a conveyor belt) to decide if it is worth to substitute the current mechanism for a new one. Such data should include all the cost e.g. purchase price; maintenance; electricity; depreciation; opportunity cost for cleaning stops; opportunity cost for change-over-time and spillage.

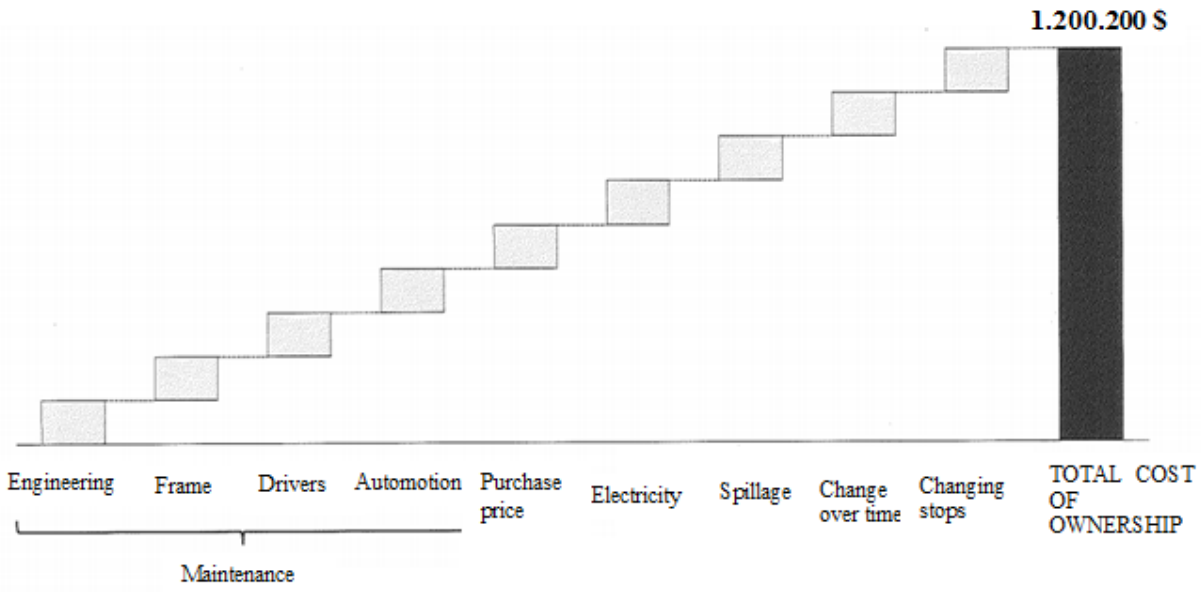


Figure 5.10: Total productive maintenance example with notional data from E4. Data in Euros

Total productive maintenance

TPM is a combination of American preventive maintenance and Japanese concepts of total quality management and total employee involvement'. TPM is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by operators through day-to-day activities involving total workforce. Consequently, the purpose of this plan is to reduce the maintenance costs and decrease the inventories in three stages.

- Stage one: analyse the current situation and determine the overall equipment effectiveness
- Stage two: introduce rapid inspections to ensure the correct operation of the machinery
- Stage three: introduce the concept of planned maintenance taking preventive actions.

By guaranteeing the right maintenance of the machinery, it could be avoided expensive reparations and decreased the stock (the rate of unexpected breakdowns is supposed to decrease)

Value stream mapping (VSM)

VSM is probably the most well-known Lean tool presented by Toyota a few decades ago. It is widely used to identify opportunities to eliminate waste, increase value added, and improve flow main stream. VSM method can be divided in current state VSM (as

is) and future state VSM (as should be) after applying Lean. Both VSM should include the KPIs relevant for the process such as lead time, number of products finished and partial cycle times.

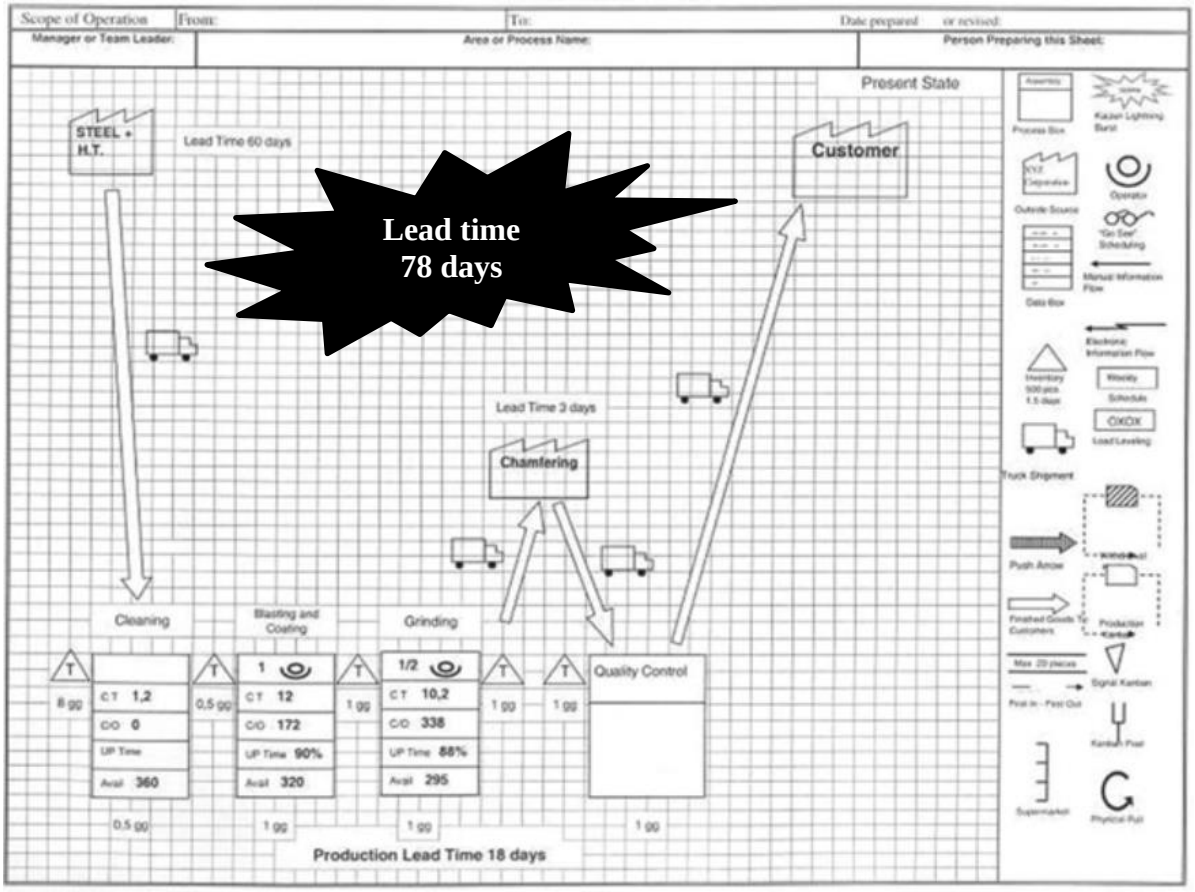


Figure 5.11: Visual Stream Mapping 'as is today'. Based on Chiarini, 2013

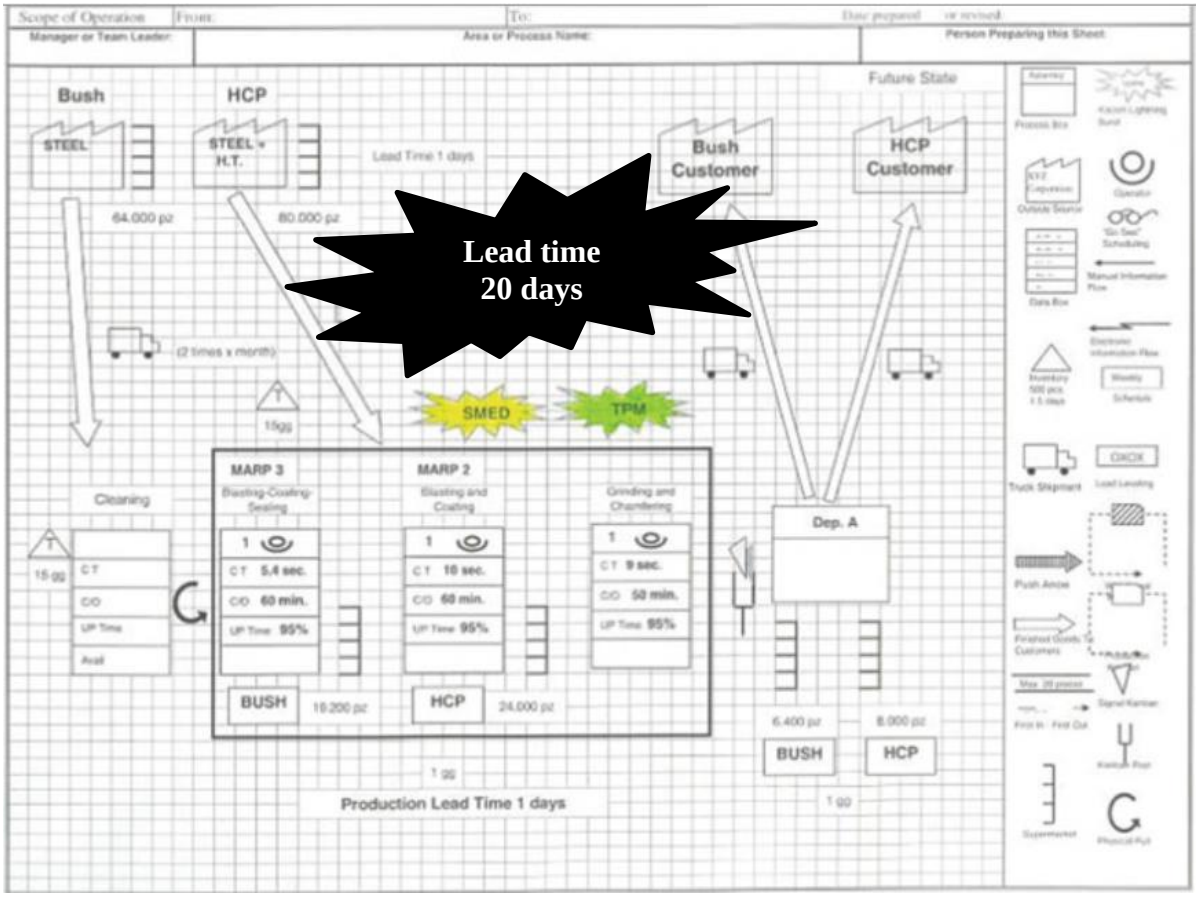


Figure 5.12: Visual Stream Map 'as should be'. Based on Chiarini, 2013

<u>*Workplace Layout*</u>

The goal of that tool is to re-design the workplace in order to reduce the idle time and the production time to improve the efficiency and be narrowly adjusted to TAKT time (the forecasted production per hour to satisfy the demand).

The designer should locate closely the similar work operations and introduce, if necessary, cost-effective equipment. It is highly recommendable for the engineer to visit the physical location ('Gemba' in Lean terms) to choose the best possible flow during the process.

5.3.2- Best practices

The following best practices are a compilation of tips and recommendations suggested by: Srinivasan, 2004; Wincel, 2004; Oehmen, 2012; SCRLC, 2011; Jensen et al. 2012; Meran et al., 2013; E1, 2014; E2, 2014; E3, 2014; E4, 2014; E5, 2014. The compilation is edited, extended and organised by the own author.

Category SS

Build partnerships and alliances with members of the SC strategically, with the goal of reducing the total cost of providing goods and services.

Work with suppliers to proactively avoid conflict and anticipate and mitigate program risk.

Keep a close and trustful relationship with all the key suppliers which could potentially damage your supply chain if something goes wrong.

Work as partners imply a cooperative effort in obtaining performance improvements.

Procurement and supply chain organizations should not be treated as cost centres support services, but as potential profit centres (See table 5.13).

Change per $100 in sales	Standard price / Profit model	$1 decrease to material content	$ increase in sales
Sales	$100	$100	$101
Material	($50)	($49)	($50.5)
Labour / OH	($30)	($30)	($30.3)
Gross profit	$20	$21	$20.2
Gross profit improvement		+5%	+1%
SG / A	($10)	($10)	($10.1)
RD & E	($5)	($5)	($5.05)
Pre-tax profit	$5	$6	$5.05
Profit improvement		+20%	+1%

Table 5.13: Profit improvement per $1 sales increase or material decrease. Based on Wincel, 2004

Category CS

Focus on customer needs and process considerations when designing a product. Enterprises can gain a tremendous competitive advantage through best-in-class practices that cut across industries.

Use forecasts to plan and pull to execute. A system that reacts to pull signals will have less variation than a comparable system that adopts a push mode of operation.

Develop high-quality program requirements among customer stakeholders before bidding and execution process begins.

Pull tasks and outputs based on need, and reject others as waste.

Establish effective contracting vehicles in the program that support the program in achieving the planned benefits and create effective pull for value.

Deliver on time your products.

Category WF & PM

Maximize external variety while minimizing internal variety. Maintain inventories in an undifferentiated form as long as it is economically feasible to do so.

Time lost at al bottleneck resource results in a loss of productivity for the whole enterprise (entire SC). Time saved at a non-bottleneck is a mirage.

Focus on bottleneck resources because they control the flow. Synchronize flow by first scheduling the bottleneck resources to support the bottleneck resources.

Do not focus on balancing capacities. Focus on synchronising the flow.

Map the management and engineering value streams and eliminate non-value added elements.

Use Lean Thinking to promote smooth flow.

Category E

Reduce variation in the system. Reduced variation allows the SC to generate higher throughput with lower inventory and lower operating expense.

Manage Technology Readiness Levels and protect program from Low-TRL delays and cost overruns.

Category TQ

Build a program culture based on respect for people.

Motivate by making the higher purpose of the program and program elements transparent.

Support an autonomous working style.

Expect and support people as they strive for professional excellence and promote their careers.

Promote the ability to rapidly learn and continuously improve.

Encourage personal networks and interactions.

Strive for perfect communication, coordination and collaboration across people and processes.

Believe, trust and help your employees.

Overcome reluctance to changes.

Ensure that all your employees have the right capabilities for their task.

Category DM

Buffer variation in demand with capacity, not inventory.

Focus on improving the performance of the Lean SC - but do not ignore the SC's business ecosystem.

Formulate performance measures that allow the enterprise to better align functions and move from a functional to a process orientation.

Decisions should promote a growth strategy. While enterprises should attempt to simultaneously increase throughput, decrease inventory, and decrease operating expenses, the focus must be on improving throughput.

Clarify, derive and prioritize requirements early, often and proactively.

Actively minimize the bureaucratic, regulatory and compliance burden on the program and sub-projects.

Plan leading indicators and metrics to manage the program.

Develop an Integrated Program Schedule at the level of detail for which you have dependable information.

Develop a Communication Plan.

Pursue collaborative and inclusive decision making that resolves the root causes of issues.

Plan in the long, but decide in the short term. Consider all the alternatives and take the minimum risks to get the biggest opportunity.

Establish effective Key Performance Indicators (KPIs) and make sure what your real situation is.

Applicable to all six categories

Improving the performance of every subsystem does not necessarily improve system performance. Improvements in subsystem performance must be gauged only through their impact on the whole system.

The role of operations strategy is to give the enterprise the ability to cope with changing customer preferences. Products and processes should be designed to promote strategic flexibility.

Pursue Lean for the long term.

Strive for excellence of program management and systems engineering.

Use lessons learned to make the next project better than the last.

Promote complementary continuous improvement methods to draw best energy and creativity from all stakeholders.

Consider risk as something that lets you gain value, but having a risk assessment plan which differentiates the 'interesting risk' from the 'useless risk'.

Ensure quality at a reasonable price.

Work from the day one you sign up a contract.

5.4- Step 4: Benefit/Cost analysis

As soon as you arrive to step four, you are supposed to be conscious of your top priority SCRs and have read a compilation of tools and best practices you can adopt. However, there is a last step in '4 in a row': the benefit/cost analysis.

A benefit/cost analysis is a method to compare the expected financial benefits of a solution with the budgeted costs in order to confirm the business benefit of proceeding. It is also a technique that allows the comparison between the final alternatives expressed in cash.

Description	Cost ($)	Benefit ($)	Benefit - Cost	Worth to do it?
Proposal 1	800	1500	+700	Yes
Proposal 2	1200	900	-300	No

Figure 5.13: Notional benefit/cost example

The aim of this benefit/cost analysis is to choose the alternative(s) that offers higher net benefit. The net benefit can be calculated as the gross benefit minus all the expenses (including among others the operating expenses, the required investment and the training costs).

Potential Costs	Potential Benefits
Required funds for the employees formation	Increase in the satisfaction of employees with the firm
Maintenance	Increase in the productivity
Purchase cost of an element	Decrease in the absenteeism rate
Electricity / Water / Fuel	Increase in the labour flexibility
Increase in the number of non-programed stops	Reduction in the number of customer complaints
Increase in the number of required employees for an already existing task	Reduction in the number of supplier complaints
Employees reluctance to the implementation	Decrease in the needs of the safety inventory
Lower control resulting in an increase of defects	Decrease in short term debts
Increase in the number of injuries	Increase of the quality of the debt
Increase of bureaucracy	Decrease of bureaucracy
Increase in the complexity	Decrease of shortages
Opportunity cost	Increase of on-time deliveries
Underutilisation of the equipment / capacity	Increase of the employees safety
Increase in the debt	Decrease of spillages

Table 5.14: List of potential costs and benefits as a result of the implementation of a new process / tool / machinery

This thesis cannot provide further assessment on how to do a benefit/cost analysis since each SME is a specific case not transposable as a general principle. However, the last suggestion '4 in a row' proposes is to develop a heat map.

A heat map is a graphical representation of data where the individual values for the x-axis (in this case, how much the SCRs are mitigated) and y-axis (in this case, net benefit) are represented in a colour-matrix. The best proposals are the ones located in the green zone, what means a big net benefit as well as a big SCRs reduction.

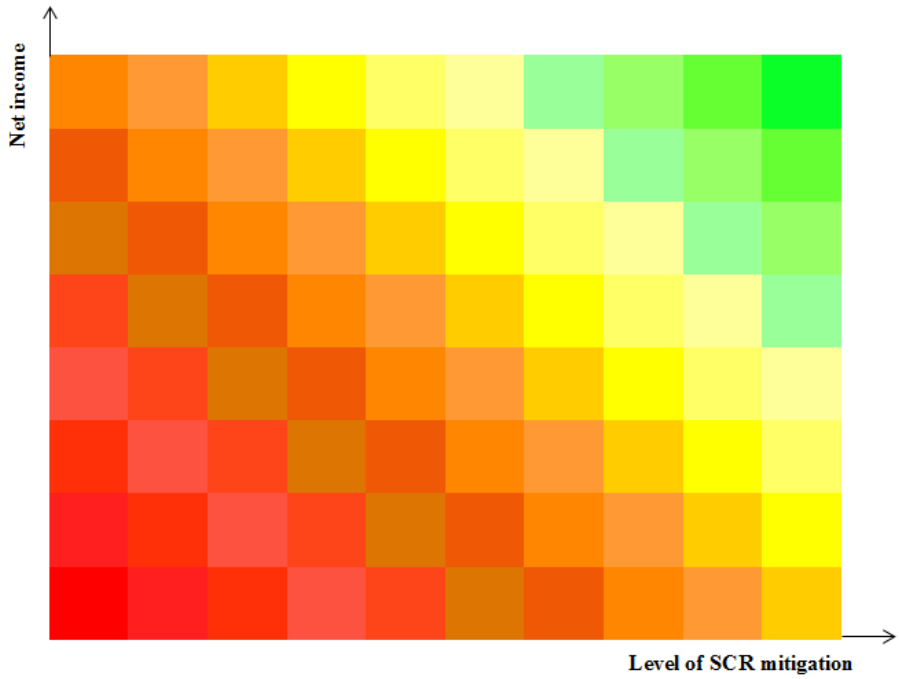


Figure 5.14: Heat map recommendation for step four of 'four in a row'

5.5- Summary

This chapter includes the real contribution of the thesis not only to literature, but also to whoever wants to have a look on the webpage to implement '4 in a row'. In 4 steps, a manager should be capable of taking decisions concerning the security of his business SC based on facts and having compared the different alternatives/proposals between them in order to select the most suitable.

The first step was tailoring '4 in a row'. Every SME has its own characteristics and therefore this step is essential to fit the tool to the different requirements of each firm. The second step was introducing the FMEA, its advantages and reasons to execute such an analysis. There are no chances of improvement if there is not an identification and prioritization of SCR. The third step was a large compilation of tools and proposals in

order to mitigate SCR. Not all the tools are necessary to all the SMEs and that is why 'The secret revealing' cube was the key to the success of '4 in a row'. And the fourth and last step was a benefit/cost analysis which aimed to assess which tools to implement according to the budget and necessities of each and every SME.

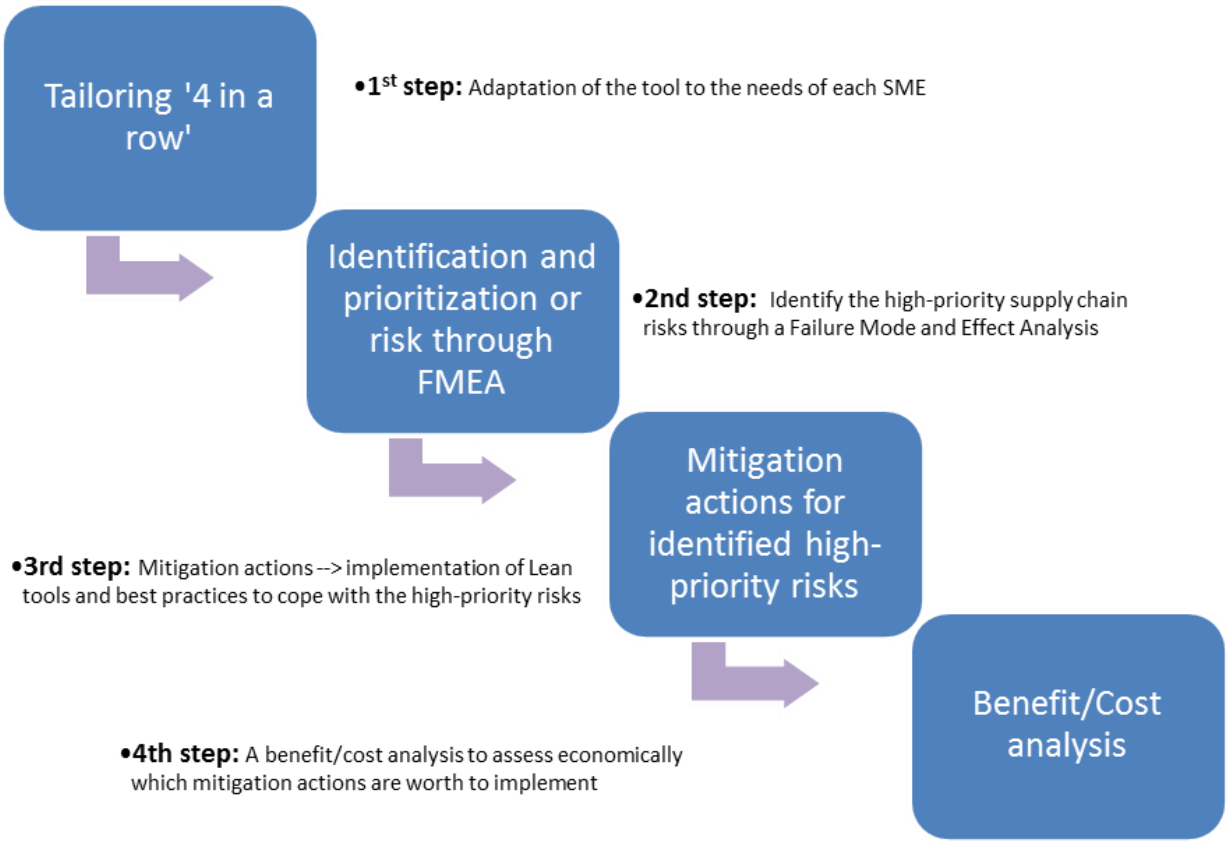


Figure 5.15: Summary of '4 in a row'

6- Implementation of the proposed procedure in a SME

In this chapter, it is going to be tested the proposed '4 in a row' in a real SME whose president is E2. The test implementation took place the 6th of June, 2014 in around 150 minutes.

6.1- Step one of '4 in a row': Tailoring the tool

In this step, '4 in a row' is going to be tailored to the E2 SME needs through the self-questionnaire.

Question 1: How many employees does your enterprise have?

a) From 1 to 10

b) From 10 to 50 → The FMEA should be implemented by a team of two to four people, including if possible the CEO

c) More than 50

Question 2: How long has the activity or process you are checking being done in the same way?

a) It is a new or relatively new activity or process, with most of the employees working in this way for less than 3 months - 8 hours per day in use (approx. 600h)

b) Most of the employees have been working in the same way with this activity or process between 3 and 18 months - 8 hours per day (approx. 600h to 3600h)

c) All the employees have been working in this activity or process for more than 18 months → A very detailed categorization and specification of failure mode is suggested to implement

Question 3: Do you have detailed data of how often most of the incidents you are analysing occur?

a) Not at all. It is a new activity or process and we do not have any similar previous experience

b) Not really. We have been doing this activity for a time but without measuring how often the incidents are happening or it is very difficult to obtain this data.

c) Yes. We have historical data of all the incidents we have suffered and/or experienced employees who can approximately tell us the frequency of most of the incidents under study → The SME has a certain maturity in the process operation and that is an excellent point

Question 4: How critical are your SC errors?

a) Very critical. We are selling a very high-quality and unique good, very differentiated from the one our competitors are proposing (in case there are competitors) (e. g. Ferrari, Apple) → The SME customers are probably paying for your high-quality products and they are undoubtedly asking for their best performance. Your SC criticality is high

b) Critical. Although we are selling a common product in the market, our brand and quality are very well-known in the market. And of course, our costumers value that (e.g. Carlsberg, Danone)

c) Not especially critical. We are selling (in some way) the same as our competitors, working with low/very low margins and competing with them basically in price (e.g. Ryanair, generic medical products)

Question 5: Do you have any previous experience in Supply Chain Risk Management?

a) Not really… What does exactly Supply Chain Risk Management mean?

b) We are aware of the importance of SCRM and we have at least a bit of experience in the field → You are supposed to be familiar with the reasons why mitigation actions are constructive and their experience is medium

c) We are familiar with SCRM and we have previously been working in the field

Looking at 'the secret revealing' cube, this SME is supposed to adopt the red level (the hardest one) because there are 2 yellows and 1 red in the cube sides. In addition, in the FMEA is supposed to take part a team of two to four people and include a very detailed categorization of the failure modes. However, as this example was only relevant to test the proposed tool and the SME president was not interested in spending the resources

required to obtain the full benefits of ‘4 in a row’, we are going to consider they are in the green level and the president is the only person required to be in charge of the analysis.

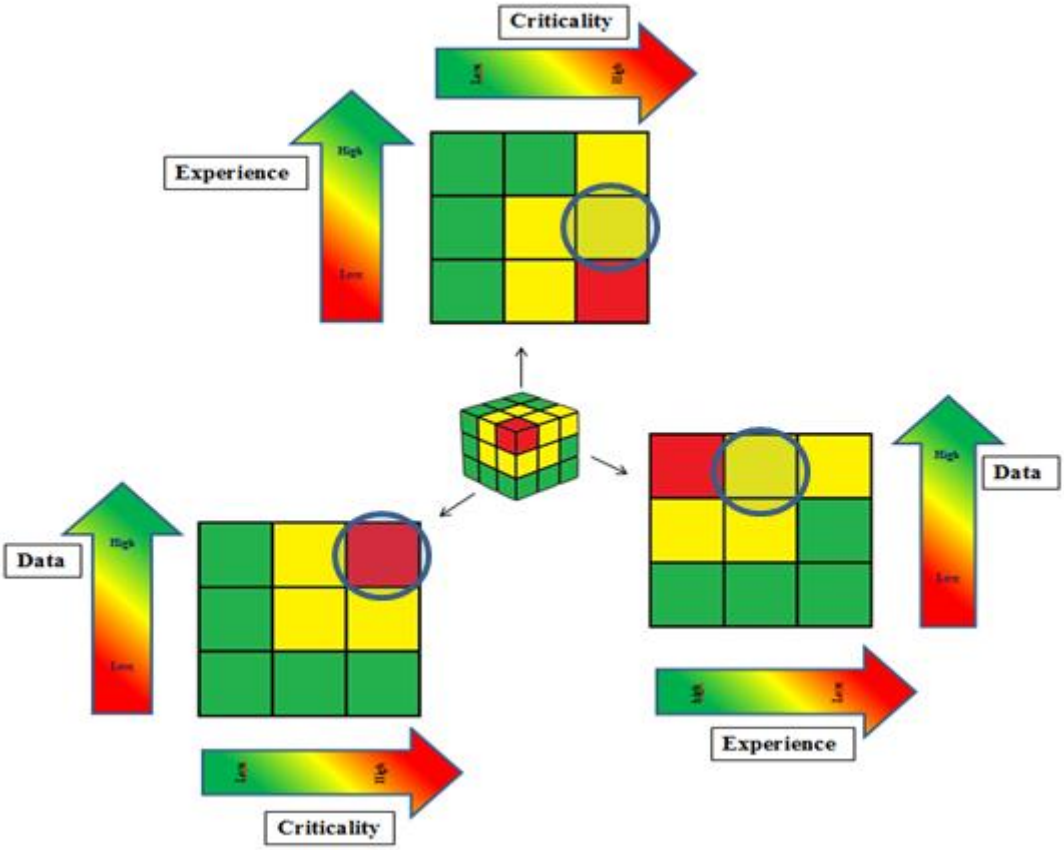


Figure 6.1: The ‘secret revealing cube’ applied in the E2 SME.

6.2- Step two of ‘4 in a row’: Identification and prioritization of risks through Failure Mode and Effect Analysis (FMEA)

In this step the FMEA is going to be developed. Due to time constraints, there are only going to be checked the two most relevant options for each category according to E2 preferences.

Category	Item to check	Failure mode	Failure effect	Severity	Potential failure cause	Detection action	Detection	Key element	Occurrence	RPN
SS	Price stability	Increase in the price of supplied components	Decrease in the sales margin	1	Currency exchange	Contact with the bank	2	Supplier 1	1	2
								Supplier 2	1	2
								Supplier 3	1	2
					Increase in the supplier margin	Contact with the supplier	1	Supplier 1	1	1
								Supplier 2	1	1
								Supplier 3	3	3
	Reliability of the supplier	Spares and components not suitable	Modify the design	3	Component not according to established measures	Contact with the supplier	3	Supplier 1	1	9
								Supplier 2	1	9
								Supplier 3	1	9
			Delay in the shipment of an order	4	Component not according to established measures	Contact with the supplier	3	Supplier 1	1	12
								Supplier 2	2	24
								Supplier 3	1	12

Category	Item to check	Failure mode	Failure effect	Severity	Potential failure cause	Detection action	Detection	Key element	Occurrence	RPN
CS	Customer dissatisfaction	Lower quality than expected	Rejection of an order	4	Component not tested	Two independent verifications	1	Customer segment 1	1	4
								Customer segment 2	1	4
								Customer segment 3	1	4
		Delay in an order	Economic penalizations	4	Lack of organization	A single employee in charge of controlling the entire production process	1	Customer segment 1	1	4
								Customer segment 2	1	4
								Customer segment 3	1	4
	Product damaged during the shipment	Item broken down	Rejection of an order	4	External operators do not take enough care with the product	1st class shipment operator in quality and protective packaging	2	Customer segment 1	1	8
								Customer segment 2	1	8
								Customer segment 3	1	8
WF & PM	Lower yield than expected	Less operators than required	Less productivity	3	Operators on holidays or ill	Schedule flexibility among the rest of operators	3	Production plant 1	1	9
	Fire protection	Fire in the production plant	Disruption in the SC	4	Electric spark	Periodic maintenance	1	Production plant 1	1	4
					Cigarette	Smoking forbidden in the production plant	1	Production plant 1	1	4

Category	Item to check	Failure mode	Failure effect	Severity	Potential failure cause	Detection action	Detection	Key element	Occurrence	RPN
E	Equipment maintenance	Component 1 not working	Quality control interrupted	3	Wear and tear in internal component	Periodic maintenance	1	Key component 1	2	6
	Variety in the process	Mismatches in the equipment	Required adjustments on the produced good	1	Production process	Components already prepared to be readjusted	1	Process	4	4
TQ	Employees satisfaction	Employees dissatisfied	Increase in the absenteeism rate	3	Excessive time pressure	Close relationship with operators	1	Production area	2	6
								Procurement and sales department	1	3
	Know-how diversification	The president is sick or has an accident	SC without clear direction	4	The president is quite old	-	4	Top management	2	32
		An operator is ill or has an accident	Time pressure	1	Many reasons	-	4	Production department	2	8
		The sales man or has an accident	The president has an additional task	2	Many reasons	-	4	Procurement and sales department	2	16

Category	Item to check	Failure mode	Failure effect	Severity	Potential failure cause	Detection action	Detection	Key element	Occurrence	RPN
DM	Decision accountable	Nobody has the capability to take management decisions	SME without anybody accountable to sign contracts	4	The president used to be the unique decision maker	Notify the team when the president is ill or cannot take decisions	2	Management	1	8
		Any implementation plan for new activities	No control in the innovation process	2	Not given any relevance to the topic	Trial and error process	4	Management	2	16
		Decisions are not taken in the production line	Delays in the SC	3	The most experienced engineers are not in the line	Ensure a right schedule	1	Production line	2	6
	Low reactivity toward offers by competitors	Loss of clients due to more competitive offers by competitors	Decrease in sales	3	The president does not want to compete in price	Close contact with customers	2	Sales department	1	6

Table 6.1: FMEA based on the E2 SME

As it can be checked in table 6.1, the highest RPN belongs to the team quality category. The hazard is about the danger that can cause an illness or an accident in the most critical position of the SME, the presidency. That is something usual in the vast majority of SMEs, since the power is basically given to a sole person who manages the whole SME.

6.3- Step three of '4 in a row': Mitigation actions for identified and high-priority risks

In this step, E2 had the chance to look at the proposed Lean tools and the compilation of best practices according to the TQ category. It is important not to forget that this category was the result of doing the FMEA in the previous step.

Build a program culture based on respect for people.

Motivate by making the higher purpose of the program and program elements transparent.

Support an autonomous working style.

Expect and support people as they strive for professional excellence and promote their careers.

Promote the ability to rapidly learn and continuously improve.

Encourage personal networks and interactions.

Strive for perfect communication, coordination and collaboration across people and processes.

Believe, trust and help your employees.

Overcome reluctance to changes.

Ensure that all your employees have the right capabilities for their task.

Table 6.2: Lean tools and best practices potentially applicable to E2 SME

From the proposed green Lean tools, E2 considers motivating (and he is especially curious about) the six thinking hats.

From the proposed best practices, E2 considers ‘Overcome reluctance to changes’, ‘Ensure that all your employees have the right capabilities for their task’ and ‘Promote the ability to rapidly learn and continuously improve’ as the most interesting for his SME.

6.4- Step four of ‘4 in a row’: Benefit/Cost analysis

Since there is no other applicable Lean tool in this example, E2 proceeds to value if it is worth to implement the Six thinking hats.

Detailed cost and benefit	Cost (Euros/week)	Benefit (Euros/week)	Benefit - Cost	Worth to do it?
Opportunity cost of 1 hour of the chief production engineer	35			
Opportunity cost of 1 hour of the president	50			
Opportunity cost of 1 hour of the secretary	15			
Opportunity cost of 1 hour of the sales responsible	30			
Employees formation/ maintenance/ other costs	Non-applicable			
Decrease in the president dependence		+120		
The team members are taken into account when taking decisions		+30		
Increase in innovation and idea-sharing		+100		
Total	-130	+250	+120	Yes

Table 6.3: Six thinking hats benefit/cost analysis for E2 SME

6.5- Summary

In this chapter is summarised the implementation of ‘4 in a row’ in a real SME whose president was E2. Although it was not possible to test the whole procedure with the real step one suggestions, results were really promising.

On the one hand, in this test application there have been three very obvious limitations. The first one was the E2 understandable reluctances to call an important part of his team to leave their jobs and join the meeting to test ‘4 in a row’. The second one was the time constraint in the ‘4 in a row’ test since E2 had not plan to spent more time with me and

it was not possible to examine all the FMEA categories exhaustively. And the last limitation was the inability to base the benefit/cost analysis in real facts since it was difficult to measure accurately the potential benefits.

On the other hand, the test allowed me to obtain very valuable feedback. It seems ‘4 in a row’ is perfectly designed to be a self-assessment tool since E2 did not need any clarification different from how to limit the scope of the tool due to his constraints. In addition, it seems E2 overcome his initial reluctances to test ‘4 in a row’; in the end, he promised me to seriously value the results and think about introducing the Six thinking hats in his SME. He had been previously thinking in how to reduce the dependence of his SME in his own decisions to ensure the SME resilience in the long term. And it seems that this tool can help him. Lastly, E2 gave me his approval, congratulated me for the work done in ‘4 in a row’ and told me not to hesitate in contacting him if I develop any other project with such a remarkable applicability as ‘4 in a row’ has for his SME.

7- Discussion and Conclusion

The aim of this thesis has been to create a holistic tool capable to fit in the previous literature and help to SMEs to overcome their challenges. In addition, throughout the whole study, I have tried to verify the three research hypothesis established in the very beginning.

7.1- Hypotheses verification

Hypothesis 1 can be considered as TRUE. Experts (E1, 2014; E2, 2014; E3, 2014; E4, 2014; E5, 2014) in chapter 4 clearly verify that assumption. In their opinion, they work and they solve the problems basically as soon as difficulties appear contrary to what large firms tends to do. For them is not possible to establish a long-term and detailed plan of how their company is going to look like in 10 years due to their constraints; principally because it would have no sense. Their necessities are mainly in the short-term (e.g. to have all their invoices paid or to sign a new contract) and they look resilience as a quotidian activity necessary to keep the SME in the market at least one more year. On the other side and according to chapter 2 literature, large firm could focus more in the long term since a non-paid invoice is not as critical as it is in a SME. Large firms can establish costly optimisation processes to see results in possibly three years, what is not possible at all for the majority of SMEs.

Hypothesis 2 can also be considered as TRUE. SMEs tend to discover complications when these hazards are chiefly in the production plant. For example, E2 (E2, 2014) hinted that all what they could do with a supply delay was complaining and being reactive as soon as he realised that something was going wrong. And being reactive means for E2 to ask their employees to work extra time and switch the supplier for another more reliable in the future. In addition, E1 (E1, 2014) also mentioned in that chapter the necessity of a ‘magic wand’ which can potentially help to identify risks before the occurrence. And literature also highlights the necessity of solving small risks before they grow: ‘Doing the right things before doing things right is important’ (Ho & Cheng, 1999; Hahn & Kuhn, 2012; Gurnani et al., 2012; Wagner & Neshat, 2012; Silverman et al., 2013).

Hypothesis 3 can be considered as FALSE. E3 (E3, 2014) claimed in his interview that Lean was a potential treasure for most SMEs he had assessed when correctly adapted to the each company’s needs and constraints. In fact, Lean is basically a philosophy with the object of maximizing value in suppliers, firms and buyers (Koller, 1994; Brandenburguer & Stuart, 1996; Plenert, 2006; Morgan & Brenig-Jones, 2009) which has no limitations regarding the size or the revenue of a firm.

7.2- Limitations of the research

I have tried during the entire project to develop a tool which can cover as many SME circumstances as possible. For example, it was chosen a Lean consultant from Spain (E3) in order not to narrow the scope of the project to Denmark. In addition, I assisted to different frameworks and interviewed people with a very distinct view on how to manage a SC. That meant for example assisting to a framework by a very well-known SC researcher, E5 (with a vast number of publications about the topic but very few experience in real firms), but also asking for an opinion to a SME president (with no interest at all in the literature but with an experience of over 40 years in SC). Therefore, I personally consider I have covered not only the concerns of the industry but also the worries of SC literature authors with an investigation of the topic in at least, two very different countries. However, this study has some limitations.

The main limitation is the low number of SMEs in which has been tested '4 in a row'. I would have loved to try the tool in a much bigger amount of SMEs to verify that all the effort put in developing this tool was worth to do it. There were two reasons why it has not been possible. First and foremost, because SMEs tend to say 'no' when contacting them from a University research; they have their own business constraints and they do not specially like to share data/information with people they do not really trust in. Secondly, because of the University rules which limited theoretically the research period to 5 months.

There was another limitation in the project: the number of people interviewed. In order to create even a better tool, it would have been very interesting to have access to additional 15 or 20 SC experts (and I personally would have enjoyed very much). As above mentioned, SME are reluctant to participate in studies and it is incredibly difficult to obtain their insights.

7.3- Future research

It would be possible to extend the scope of the research by testing '4 in a row' under new peculiarities and check if it works. It would also be a point to obtain feedback on how the implementation of the tool is seen by different SC experts and modify, if necessary, some of the steps proposed.

It would also be possible to add an additional step to '4 in a row' in case there is poor quality in the existent data of the SMEs by the Six Sigma methodology. Six sigma is a field, slightly introduced in this thesis, which I personally consider has also a huge potential when talking about improving SME process.

Last but not least, it would also be possible to research what can go wrong when doing a FMEA. Some authors (for instance Jensen et al., 2012) have given their interpretations about that but in my opinion, ‘What can go wrong in a FMEA’ is still an area full of opportunities for further research.

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Appendix

Appendix 1: Semi-structured interview on risk, resilience and the role of lean management techniques in supply chains – Overview of Questions

DTU Management Engineering

DTU

Date: 02/04/2014

1. - Which supply chain risks do you consider most significant, for example in the categories of demand, supply and/or internal processes? Are you familiar with Supply Chain Risk Management approaches?

2. - What approaches do you use to mitigate your key supply chains risks, or create general resilience in your supply chain?

3. - Are you familiar with the Lean Management philosophy? If yes, do you think it could be useful for your company? In case it is applied, how? In case it is not, do you follow an alternative improvement philosophy?

4. - Which concepts of Lean Management can contribute to create a resilient company / supply chain from your perspective? What Lean Management practices weaken the resilience of your company / supply chain from your point of view?

5. - (To sum up,) could you give me a couple of tips to become a successful SC manager?

Appendix 2: Informed Consent for the participation in a research study

Study Title: KEY CONCEPTS TO BUILD A RESILIENT SME: SUPPLY CHAIN IMPROVEMENT THROUGH LEAN PHILOSOPHY

You are asked to participate in a research study by the Technical University of Denmark. You were selected as a possible participant in this study because of your current position in your organization. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

PARTICIPATION AND WITHDRAWAL

Your participation in this study is completely voluntary and you are free to choose whether to be in it or not. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

PROCEDURES

There are no specific procedures. Participants will be asked to answer a series of questions about your organization and/or processes in one or more short (about 1-hour) interview(s).

PURPOSE OF THE STUDY

The purpose of this study is to conduct new and original research to investigate the concept of resilient supply chain in SMEs. This study is going to analyse the impact of supply chain risks in the organization and how to cope with them in order to create an enterprise that last in the time.

POTENTIAL BENEFITS

A successful execution of the research study should provide the following benefits:

- Discover key concepts to be a resilient SME
- Define what kind of risks are more challenging for an organization
- Define how Lean can contribute to create a resilient Supply Chain in a SME

PAYMENT FOR PARTICIPATION

There is no payment for participation.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Data will be stored securely until research is complete, at which time any attributable data will be destroyed. Reported data will be non-attributable.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact:

Antonio Dominguez Garrido
Technical University of Denmark
Department of Management Engineering
Building 424

2800 Kongens Lyngby, Denmark

Email:
[redacted]
Phone: [redacted]

RIGHTS OF RESEARCH SUBJECTS

You are not waiving any legal claims, rights or remedies because of your participation in this research study.

SIGNATURE OF INVESTIGATOR

In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

_____

Printed Name

_____ _____

Signature Date

Appendix 3: TAGXEDO of the thesis

Appendix 4: Initial project and task description

1. Motivation and problem statement

According to the most recent reports (http://www.ipyme.org/Publicaciones/Retrato_PYME_2013.pdf), SMEs cope more than the 99.8% of enterprises in some well developed countries like Spain. Most of them have very strong limitations in resources, not only in money but also in human resources. For that reason, as soon as an engineer is enrolled in a SME, he often struggles to articulate the most relevant aspects to start working in. There are usually a big amount of challenges and not as many resources as desired. How to identify the proposals that can offer higher revenue with minimum risk is not an easy task, and this Master Thesis is going to have a deep inside view in that problem through some tools such as LEAN and RISK MANAGEMENT. In order to ensure a high-quality research in a limited time, only the Supply Chain challenges are going to be under study.

2. Background

It is widely assumed that SME are the engine of an economy. If they fail, the GNP of a country is strongly affected. However, most of the news we can read in a newspaper or hear in the radio only affect the biggest companies and do not pay any attention to that SMEs situation. Since I come from a family which has driven a SME and I have some knowledge about common problems faced by that kind of enterprises, I would focus on how that emerging tools (Lean & risk management) can help SMEs to improve their situation and make them grow in a sustainable way, with a specific attention to the Supply Chain aspects.

3. Academic and industry impact

That Thesis wants to offer a new perspective of LEAN&RISK MANAGEMENT in the field of Supply Chain by using it in SMEs, where limited resources are their biggest constrain. Some of the aspects analysed might be hopefully a great help for junior engineers facing that kind of challenges and even a better help for enterprises which want to increase their competitiveness.

4. Task description (e.g. list of steps) & Project plan

	1-15 February	16- 28 February	1-15 March	16-31 March	1-15 April	16-30 April	1-15 May	16-31 May	1-15 June	16-30 June
‘First’ title decided, some starting references chosen and tasks for the following 3 weeks										
Talk about what I learned doing the review, what areas are covered and what aspects should be analysed with more detail. Decide the 2-3 research questions that are going to be solved by doing the thesis. Is it a survey neccessary?										
At least prepare (and if possible, answer) a couple of interviews on how SME are working in Project Management and discover any successful improvement cases										
We should have obtained a general view (via reviews) about some improvement techniques in SMEs, and seen the state-of-the-art in ‘real’ enterprises.										
We should have an idea of the Thesis’ table of contents. Keep working in the idea of selecting high revenue & low risk projects.										
Hopefully, some experts would validate a method for chosing high revenue & low risk projects. Interviews? Final table of contents and start writing the thesis										
Thesis written										
If everything is on time, we should be able to start focusing in the final presentation										
The end of the thesis										