Prioritizing and Mitigating the Supply Chain Risks of a Dairy Company in an Unstable Economic Environment

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Abstract

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The aim of this paper is to implement the Failure Mode and Effect Analysis (FMEA) approach to assess, mitigate, and prioritize risks in the dairy industry, with a particular emphasis on a specific company. The values of occurrence (O), severity (S) and detection (D) of failures will be determined. These estimated values will be used to calculate a risk priority number (RPN), for each potential failure, ultimately allowing to us to develop a well-defined and comprehensive risk prioritization list. Through this paper, we apply a practical and refined FMEA approach, tailored specifically for the dairy industry. While our findings draws on commonalities shared with other dairy companies all around the world, it is necessary to recognize that each dairy business has distinct characteristics and challenges. Since this case study focuses on a particular dairy company in Lebanon, a country that is currently in the midst of an economic crisis, we gain valuable insights into the unique risks and corrective actions undertaken by the company. Moreover, this paper presents an innovative and enhanced version of the traditional FMEA approach by incorporating two additional factors, the application rate and the weight-based model. While the application rate (A) enriches the FMEA analysis by assessing how effectively and efficiently the studied company applies the corrective measures, the weight-based model enables a more comprehensive evaluation of the analyzed risks by taking into consideration the relative collective expertise of members involved in the supply chain. Once the most substantial threats were identified, we were able to provide and improve risk mitigation strategies for those threats. Eventually, by improving the firm's decision-making on risks, we intend to minimize potential future losses associated with specific scenarios. Moreover, future research paths are highlighted as a result of this study.

Keywords: Failure Mode and Effect Analysis (FMEA) - Dairy Industry - Case Study – Risk Prioritization - Economic Crisis - Corrective Measures - Risk Mitigation

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Table of Contents

List of Figures

List of Tables

1. Introduction

Supply chain management (SCM) has gained a growing interest from all industries, all over the world. (Li et al., 2006). The same applies for supply chain risk management (SCRM) (Tang, 2006). Supply chain risk management (SCRM) has developed into a critical topic for the success of companies, due to the mounting uncertainties concerning today's marketplace. It is considered to be a comprehensive business discipline, as it incorporates the entirety of stakeholders, with the intentions of providing a good or a service at minimum cost, while maintaining maximum customer satisfaction (Simchi-Levi et al., 2008). Successful managers are constantly searching for ways to improve long-term efficiency and effectiveness of the supply chain. To do so, it is crucial to successfully identify and mitigate the different risks and uncertainties that might arise (Juha and Pentti, 2008).

It is important to note that, even though the terms "risk" and "uncertainty" are interchangeable in the supply chain management literature, they are still dissimilar terms. Risk refers to the potential for undesirable consequences to result from an event or an activity (Rowe, 1980). Furthermore, it is described as a subjectively determined expectation of loss, in which the higher the likelihood of the harm, the higher the risk itself (Mitchell, 1999). Risks can be categorized into several types. For instance, Hager (2004) makes a distinction between personal risks and corporate risks. Lü ck and Henke (2004) identifies the difference between speculative and pure concepts. Odening et al. (2007) compare objective and subjective risks. Business uncertainties signifies circumstances in which organizations face risks that can neither be anticipated nor measured. Due to unprecedented or frequently changing occurrences, uncertainties prevent firms to correctly predict their performance. In fact, the probability of a risk might be known, however the likelihood of an uncertainty remains unknown (Siegel, 2005). Even for the most robust supply chains, risks and uncertainties can never be ruled out. Therefore, continuous attention is required to effectively manage these threats. The supply chain of an organization entangles complex bonds between multiple stakeholders; hence, dealing with risks and uncertainties at one stage might lead to distortions to the entire supply chain (Mulacahy, 2003).

Numerous research display a rising trend associated with analyzing risks in perishable food supply chains. Rijpkema et al. (2014) evaluated approaches to mitigate risks related to quality, in order to provide proper value in the supply chain of perishable foods. Agricultural produce, such as fruits, meat, milk, vegetables, eggs, and their processed foods have to cope with deterioration or decay in due course (Shukla and Jharkharia, 2013). Aysha and Athira (2020) explain the term “perishable” as a substance, that at any moment in the processing period, has to go through: (1) obvious deteriorating of the physicality of the product (i.e. spoilage, decay, or depletion); (2) decline in the product’s perceived customer value; (3) the likelihood of a drop in the functionality of the product. Notably, when it comes to perishable food supply chains, the risks involved in product waste and reduced shelf life are a problem of great concern for any organization (Rijpkema et al., 2014). Systematic risk management permits agriculturalists to identify, quantify, control and monitor different risks, as well as potential losses (Waters, 2007). The goal of these strategies is to be able to recognize risks in a supply chain, and respond in the most suitable manner (Merna and Al-Thani, 2005).

In the production of food-related processes , the term “hazard” is often discussed. It refers to a chemical, biological, or physical agent that might have negative health impacts on the consumers (Shirani et al., 2015). Whereas the term "risk" looks at, both, the probability of the hazard to occur and the significance of any potential consequences on the well-being of the end-user (Aleksić, 2020). Hazards can be documented at every stage of the supply chain, whether it is from primary production, through transportation, handling, processing, packaging, warehousing, all the way till the consumer (Motarjemi and Leliveld, 2013; Aysha and Athira 2020).

One of the major perishable food supply chains, which will be the focus of this paper, include the manufacturing of milk-derived products (i.e. cheese, yogurts, etc.). The milking process could be accomplished through a wide variety of animals, such as cows, sheep, goats, and even their mixtures. Massively nutritious, milk provides great means for the proliferation of all types of microorganisms, enabling it to be a highly perishable product (Aysha and Athira, 2020). Since the technological process of cheese production often causes a decrease in pathogenic microorganisms (organism capable of causing diseases), it is possible to use cheese as a way to conserve raw milk (Zhao, 2013). On one hand, the production of cheese can be accomplished by small artisan processing, in which manufacturers are labeled as household producers making farmhouse cheese (Aleksić, 2020). In this case, the dairy products are produced with the use of traditional methods, often derived from their own cows/goats. This kind of production usually involves a direct link between the manufacturers and the consumers. This concept is referred to as a short food supply chain (Malak-Rawlikowska et al., 2019). On the other hand, the production of cheese can be accomplished by the application of an industrial setting, in which much greater volumes of milk are being processed. By having a much more complex supply chain, larger organizations have to examine changes in food quality and safety throughout the whole supply chain, until the product reaches the consumer (Yu et al., 2013).

2. Literature Review

The goal of supply chain risk management is to identify probable causes of risks, evaluate the potential consequences, and eventually take appropriate action (Juttner et al., 2003). This notion has established growing attention in handling the security and the safety of products in industries, in which the goods' safety and reliability are essential, such as the automobile, the pharmaceutical, and the food and beverage industries (Marucheck et al., 2011). In fact, it is critical that the practice of SCRM is well controlled and organized. Recent milk contamination scandals have uncovered its liabilities (Yu & Huatuco, 2016). For instance, the 2008 milk scandal in China occurred due to the contamination of powdered milk with a toxic chemical compound called melamine, causing sickness to approximately 300,000 babies and six fatalities (Huang, 2014). Daud et al. (2015) claim that in the dairy supply chain, the fundamental causes of risks are associated with feeding accessibility, quality of milk, milk bulking practices, milk handling practices, and milk transportation.

The most common SCRM process includes five stages: identification of risks, assessment and evaluation of risks, mitigation of risks, monitoring risks and constantly improving the process (Christopher & Brian, 2008). First, the risk identification stage primarily seeks to define the potential risks an organization might face. It allows managers to have a better comprehension of the wide range of supply chain risks, their interrelationships, and their possible implications (Tummala & Schoenherr, 2011). Yu & Huatuco (2016) compare different identification frameworks and techniques such as Supply Chain Mapping (SCM), Checklists, Fault Tree Analysis (FTA), Failure Mode Effect Analysis (FMEA), Ishikawa Cause and Effect Analysis (CEA), and Supply Chain Operations Reference (SCOR). All of these techniques contribute to the risk identification of qualitative risks. However, out of all the mentioned techniques, only FTA and FMEA are able to assess quantifiable risks. Furthermore, unlike all other mentioned frameworks, FMEA is able to identify potential effects of failure, as well as provide an action plan for the managers.

Second, the risk assessment and evaluation stage encompasses the severity level of the potential consequences, the ranking of risks, and the acceptance of risks (Tummala & Schoenherr, 2011). Moreover, the consequences of risks can be classified into three categories: time-based, quality-based, and finance-based (Vilko & Hallikas, 2012). According to the notion of "as low as reasonably practicable", the possibilities can be expressed as unacceptable, tolerable, or acceptable (Yu & Huatuco, 2016). Risks analysis stresses on the quantification of the occurrence of risks, as well as its probable damage (Diederichs, 2004).

Third, the risk mitigation stage ensures that the supply chain remains operating as smooth as possible. This phases implements resources and capabilities effectively and efficiently, while obeying constraints set by laws and regulations in the industry (Waters, 2011). There are many approaches that can be implemented by a company, in response to the occurrence of a risk event, such as improving collaborations with partners, enhancing system flexibility, and producing capacity buffers (Sodhi et al., 2012). The use of collaboration to mitigate risks can be subcategorized into internal collaboration, supplier collaboration, and consumer collaboration (Chaudhuri et al., 2013). While internal collaboration refers to the coordination, collaboration, and incorporation of logistics with different functional departments within a company, external collaboration refers to the interaction between organizations' logistics and those of customers and suppliers (Stock et al., 1998). The extent of a company's collaboration has a positive influence on the supply chain agility, which refers to the capability to act quickly to disruptions (Manuj & Mentzer, 2008).

Finally, the last two stages includes the application of mitigation strategies, continuous monitoring and controlling. The goal of monitoring is to review progress, in relation to the plan, allowing executives to take corrective actions, in case of divergence from the desired performance (Yu & Huatuco, 2016). The main aim of controlling risk is to determine whether the implemented risk strategies have been effective. Also, risk control enables the organization to assess the strengths and weaknesses of the current operating structures, to identify new requirements, and to enhance the cost-benefit ratio of certain measures (Schaper et al., 2014).

A variety of frameworks have been suggested in the literature as systematic methodologies to assess risks in the supply chain, such as Hazard Analysis and Critical Control Points (HACCP), Risks Ranking (ICH, 2005), and Preliminary Hazard Analysis (PHA). After contrasting different risk mapping and prioritizing tools, we selected the Failure Mode Effect Analysis (FMEA). The FMEA is considered to be a systematic approach that develops and enhances production lines by classifying potential threats and providing mitigation approaches. This framework defines, identifies, and attempts to either remove or reduce potential failures that might arise in the process, before it reaches the following stage. It has been widely used by manufacturing organizations for quality and safety assurance, as well as tackling customer and governmental requirements (Kurt and Ozilgen, 2013). Although this framework was originally developed and implemented by the United States army in 1949, today, it is applied in numerous fields, such as the food industry (Scipioni et al., 2002). This tool allows companies to better understand product failure modes, determine the outcomes of failure, and implement the necessary mitigation approaches; moreover, it is recognized as an effective tool, as it is capable of improving quality, reliability, and the maintainability of designs and functions (Sharifi et al., 2022). Shirani & Demichela (2015) utilized the FMEA tool in the dairy supply chain, and found that human factor is the most critical cause of risks.

FMEA analysis is considered to be an appropriate strategy, due to its ability to pinpoint possible risks within a system, and to evaluate their impacts by quantitatively ranking three criteria: severity (S), occurrence (O), and detection (D) (Sharifi et al., 2022). The given value for the severity of a failure refers to the extent of the impact that a failure can potentially have on the health of the end-user; it could also be assessed through quality standards boundaries that are set by regulations (Aleksić, 2020). In addition, values given to severity can be explained relative to the direct monetary impact of each risk, as well as the indirect monetary impact (e.g. the influence on brand image). The given value for the occurrence rate defines the frequency of the failure, whereas the given value for detection indicates the possibility of noticing a potential failure either before it occurs (Kurt and Özilgen 2013), or before the defected product reaches the consumer.

The complete application of FMEA can be divided into seven steps: (1) Identifying risk categories, (2) Identifying potential risks, (3) Allocating, for each risk, its severity, its occurrence rate, and its detection rate, (4) Computing, for each risk, its risk priority number (RPN = S * O * D), (5) Evaluation of risks, (6) Taking action, if needed, (7) Reevaluating the risks, by conducting an iterated FMEA (Welborn, 2007). After the corrective measures have been taken, the values of for frequency of occurrence and detection rate needs to be assessed again, while the value of severity remains the same (Arvanitoyanis and Varzakas, 2007).

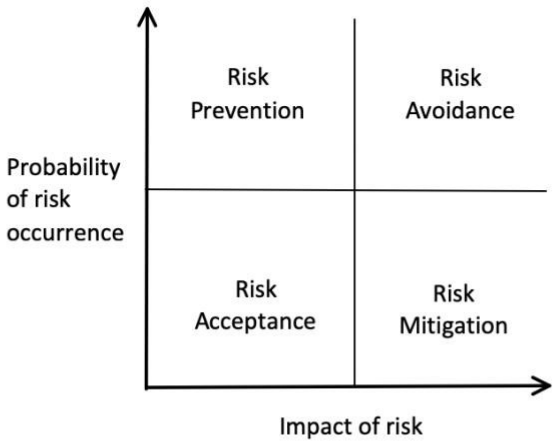
The existing mechanisms used in risk management for dairy operations can be divided into four groups: risk avoidance, risk prevention, risk mitigation, and risk acceptance. Their grouping embodies a farm's risk management strategy mix (Chapman, 2002). To begin with, risk avoidance is a procedure that diminishes a farm's exposure to risks, often by stopping some business activities (Schaper et al., 2010). On one hand, halting the production of dairy products allows the company to circumvent the risks related to milk production (Diederichs, 2004). On the other hand, this decision would lead the business wasting its revenue opportunities. As such, risk avoidance is a risk management approach that needs to be implemented in a selective manner.

Next, the risks prevention strategy, also referred to as the risk reduction strategy, involves methods that decrease the occurrence rate of a risk, as well as potential losses or damages to the company. It involves actions, such as the use of fire alarm systems, the diversification of farm activities (Lehrner, 2002), the use of multiple suppliers (Bandaly et al., 2012). These actions allow for an improved response against the variety of risks that dairy companies might face. Unlike the risk avoidance approach, the risk reduction does not involve the stoppage of an activity. Therefore, this method can be used in a far more flexible manner (Schaper et al., 2010). Actions that are able to reduce the occurrence rates of specific risks mainly deal with internal issues, such as daily manufacturing undertakings. Schaper et al., (2010) have found that, in the dairy industry, the most favorized risk reduction strategy is the use of cooperatively organized purchases of input factors, as it allows for farmers to retain the risks associated with fluctuations in pricing. Interestingly, this study has also found that, with regards to sales cooperatives, numerous groups of dairy farmers wish to reinforce such activities, as it would help them cope with future difficulties. However, several other farmers strongly disagree with the concept of handing over their entrepreneurial autonomy.

Additionally, the risk mitigation strategy reduces, or eliminate if possible, the undesirable impact of unfavorable events (Bandaly et al., 2012). Moreover, risk transfer allows for the consequences of a particular risk to be mitigated through another party, most commonly, through professional risk-taking establishments. For example, these institutions could vary from fire and crop insurance (Breustedt, G. 2004), weather derivatives (Odening et al., 2007), to the consumption of agribusiness commodity futures exchanges (Scott, 2003). Another alternative, would be to transfer the risks to the buyers, with the use of long-term contracts and price guarantees – however, this option is considered to be uncommon in the farming industry (Schulze et al., 2007).

Furthermore, the risk acceptance strategy is often used either when risks remain unidentified, or when the application of an action plan is technically impossible (Schaper et al., 2010). Nevertheless, this strategy can be implemented in order to prevent costly alternatives, such as risk avoidance, risk reduction, and risk transfer (Berges, 1998). In order to allow farmers to handle greater market pressures and increased competitiveness between other dairy farms, (Schaper et al., 2010) have found, in their empirical study, that farmers heavily employ risk acceptance strategies. Consequently, the suitable strategies can be determined through the following 2x2 matrix.

Figure 1: Risk Response Matrix



3. Case Study

3.1 Lebanese Dairy Industry

Popular among different demographics in Lebanon, dairy products are highly consumed due to their level of nutritional value (Daou et al., 2020). Milk is considered to be one of the main ingredients in the making of Middle Eastern cuisine, such as pastries and sweets (Motarjemi and Yasmine, 2014). The dairy sector in Lebanon has progressed during recent years, demonstrating its economic standing as a vital actor in the agricultural and industrial sectors. According to a 2019 report published by the Consultation & Research Institute, the size of the dairy market in Lebanon is estimated around $200M, incorporating 167 dairy factories mostly located in two governates, the Beqaa and Mount Lebanon. Since the dairy sector in Lebanon is considered to be a rather robust sector and supports the majority of farmers in the country, it is considered as one of the highest priority sector for the government (Abebe et al., 2016). According to the Lebanese Ministry of Agriculture, the dairy industry is also expected to continue its growth in the coming years, with total dairy cattle expected to increase from

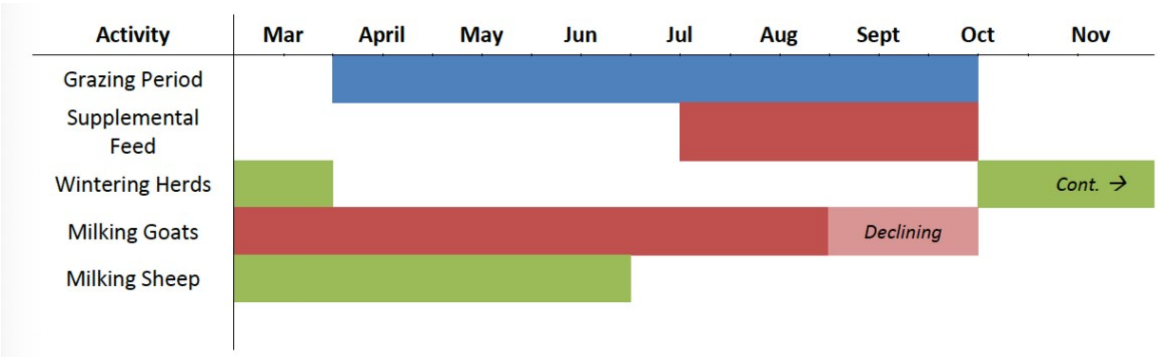
2020 till 2025 by 50,000 to 100,000. The vast influx of Syrian refugees in the past years is considered to be the main reason behind the increase in annual demand.

Dairy firms may vary from small family-owned businesses to large deep-rooted companies. Even though the country's milk production is considered to be self-sufficient, local producers have to face intense competition from international companies. Multiple missions, directed by the Lebanese government, were in place, targeting an increase in the income of agriculturalists, as well as an improvement in the quality and safety of the milk provided by marginal dairy farmers. One example in the Beqaa region is the Smallhoder Livestock Rehabilitation Project (SLRP), that is funded by the International Fund for Agricultural Development (IFAD) in 2004. It originated at a time when the nation was emerging from years of civil war. There were four main goals behind the project: (1) offer a stimulus to, once again, instate small-scale livestock production; (2) replace some of the small-scale lost stock; (3) deliver the foundation for sustainability in the development of livestock; (4) improve agricultural support services. A second example is the "Recovery and Rehabilitation of Dairy Sector in the Beqaa Valey and Hermel-Akkar Uplands" in 2014. This endeavor was financed by the Lebanon Recovery Fund (LRF) and implemented with the help of the Food and Agriculture Organization (FAO) and the Lebanese Ministry of Agriculture (MOA). The goal of this project was mainly to support the dairy producers' associations by enhancing the hygienic conditions of milk and the overall milk quality. Due to a partnership between UKAID and the MOA, funds were offered to aid in the vaccination of livestock for the small ruminant sector (predominantly sheep and goats), with the intention of preventing major diseases (The Dairy Site, 2013). According to a study conducted by BlomInvest Bank in 2021, the Beqaa region encompasses widespread dairy farming, covering over 40% of

Lebanon's entire farming properties. The report claims that, out of all the animals in the country, the Beqaa region incorporates around 80% of the cows, 45% of the goats, and 35% of the sheep, producing a total of around 188 tons of milk per day.

According to a Mercy Corps report in 2014, there are two kinds of small dairy production systems: the semi-extensive and the semi-intensive systems. On one hand, the semi-extensive system, which embodies 90% of small dairy production in the Beqaa region, includes almost no supplemental feed to the animals during the grazing period (Table 1). In agriculture, grazing refers to the ability of domestic livestock to wander around and consume wild vegetations. The system incorporates Bedouin herders that are constantly on the move, in order to graze their herds at higher altitudes. On the other hand, the semi-intensive system engages with feed supplements on a regular basis during the yearly grazing period. The semi-intensive systems tend to have well-established affiliations with large dairy processors or milk collectors. In this system, farmers often buy grains such as barley, alfalfa, and soy. Feed expenses have ranged in the past few years between $550 and $750 per ton sold. The cost is mostly influenced by the nutritional quality of the product. Each animal needs around a kg of feed per day. This approach is implemented by more developed small ruminant dairy producers, as they also engage in more complex procedures, such as the presence of improved breeds, the application of routine health inspections, and the use of appropriate stainless steel containers. In fact, the Food and Agriculture Organization of the United Nations attempts to improve nutrition and food security in the country, by providing stainless steel tanks for milk collection. However, it is improbable to assist all producers, mainly due to the substantial amount of farmers in the nation along with the relatively high-priced cost of each tank (around $130). Consequently, aluminum and plastic collection containers are still utilized by minor producers of milk. These jugs are considered as an inferior alternative, especially that they are harder to sterilize, not as smooth as stainless steel, and are not fully opaque, causing high temperatures by direct contact with the sun to hinder the quality of milk.

Table 1: Production Calendar for Small Ruminant Dairy



Source: Mercy Corps (2014)

In general, milk is gathered in the evening and sold to private collectors, who cooperate with their personal network of producers. Milk collectors have an essential part in the dairy industry, as they connect the producers to the processors. Often, milk collectors, not only gather milk from different farms, but also produce milk themselves. Hence, they are responsible for the transportation and the sale of these goods. When selling to the processors, milk collectors approximately add 20% to the price of the milk and the cost of transportation (Mercy Corps, 2014).

3.2 Laiterie Massabki

Founded in 1961, Laiterie Massabki ("Massabki" for short) is a Lebanese company that is specialized in the production of dairy products. The company is comprised of two brands: Laiterie Massabki and Karam. Primarily, the former is consisted of cow-based products (Labneh, Laban, Halloum, Ackawi, Double Crème, Ayran, etc.), while the latter is consisted of goat-based products. Together, both brands produce a total of around 40 products.
Once the production process is completed, the organization relies on two main sources of income. The primary revenue stream of the company is based on the sales of their products through (i) retailers (ranging from minor grocery stores to the largest supermarkets), (ii) hotels, (iii) restaurants, and (iv) distributors that sell the products in regions that are out of reach for the company (including clients overseas). For all four types of buyers, the transportation of the goods is accomplished daily through company-owned trucks. The final goods may be sold either in bulk or in plastic labeled containers to retailers throughout the country. In general, restaurants and hotels buy dairy products in bulk, while supermarket and mini-markets rely on commercial packaging. The secondary revenue stream of the company is through a shop located in Chtaura, Lebanon. The shop, directly connected to the main factory, is not only a convenience store that stocks a range of everyday items, along with fresh Massabki products, but it also is renowned in the Beqaa region for its tasty dairy-based sandwiches. In this study, we will mostly focus on the risks of the distributed products, rather than the risks of the store.

4. Methodology

In this study, with the help of previous research, expert opinions, and consultations from Massabki's managers: the CEO (42 years of experience), the COO (12 years of experience) the production manager (12 years of experience), the operations manager (6 years of experience), and the sales manager (9 years of experience), we will aim to uncover the main risks associated with dairy supply chains. Interviews and surveys with the managers of the company were divided into three stages. Along with an extensive literature review, the goal of first discussion was to identify the most threatening risk domains in the dairy industry worldwide, and then determine those that are associated with the company specifically. After conducting a thorough research on these specific risks in the dairy industry worldwide, we were able to shape a semi-structured interview that allowed to get elaborated qualitative and quantitative insight about the company. The final stage is composed of a carefully designed survey that allowed us to gather the needed information (severity, occurrence rate, and detection rate) to complete the FMEA analysis. Notably, for some risks, a detection value could be not given, as it is impossible for those risks to be detected before they emerge. Since these risks do not have a detection value, they cannot have a RPN value. Hence, risks that are solely analyzed based on occurrence and severity will be looked at separately.

Moreover, measuring the occurrence, severity and detection cannot always be accurate as subjectivity by the contributors impacts the results. Although the FMEA approach lacks a universal scale, we have implemented standards inspired by previously applied measures in the literature, such as Jensen et al., (2020), Curkovic et al., (2013), Liu et al., (2016), and Prakash et al., (2015). In order to standardize the results received by the interviewee, we generated appropriate scales for occurrence, severity, and detection, shown in Table 2. Even though prior research included specific criteria for severity, we have opted not to apply specific measures, due to the variety of consequences a risk can have on the company (e.g. direct monetary loss, damage to the brand image, impact on the health of the end-user, etc.).

Table 2: FMEA Occurrence, Severity and Detection Proposed Scale

Ranking	Occurrence Rate (O)	Severity (S)	Detection Rate (D)
1	Almost never (< 1 in 1,500,000)	Insignificant	Almost certain (>99.7%)
2	Rarely (1 in 150,000)	Negligible	Very high (95-99.7%)
3	Seldom (1 in 15,000)	Marginal	High (85%-94%)
4	Occasionally (1 in 2,000)	Minor	Moderately high (70%-84%)
5	Sometimes (1 in 400)	Moderate	Moderate (56%-69%)
6	Often (1 in 80)	Serious	Low (45%-55%)
7	Frequently (1 in 20)	Major	Very Low (20% to 44%)
8	Generally (1 in 8)	Severe	Remote (6% to 19%)
9	Usually (1 in 3)	Critical	Very remote (1% to 5%)
10	Almost all the time (≥ 1 in 2)	Catastrophic	Absolute uncertainty (≈ 0%)

The managers, as well as experienced company employees, conveyed their beliefs towards risks that are affiliated with their roles in the company by assigning fitting criteria scores. As seen in Table 3, a weight-based system was adapted for the FMEA, in which values of weights are reflective of the member's relative importance, as well as the member's relative knowledge and experience on the topic at hand.

Table 3: FMEA Weight-based System for Each Member

	Risk Domains					
	Economic	Market	Sourcing	Process	Logistics	Regulatory
Chief Executive Officer (CEO)	40%	20%	25%	20%	25%	35%
Chief Operations Officer (COO)	40%	20%	25%	20%	25%	35%
Operations Manager	20%	20%	25%	20%	25%	15%
Production Manager			25%	20%		15%
Sales Manager		20%				
Experienced Truck Driver/Salesman (1)		10%			12.50%	
Experienced Truck Driver/Salesman (2)		10%			12.50%	
Experienced Factory Employee (1)				10%		
Experienced Factory Employee (2)				10%		
Total	100%	100%	100%	100%	100%	100%
Participants	**3**	**6**	**4**	**6**	**5**	**4**

In addition to the previously mentioned managers, the weight-based system allowed us to incorporate experienced employees, allowing us to diversify and broaden our results. For economic, market, and regulatory risks, the CEO and the COO were given majority weights (80%, 60%, and 70% respectively) mainly due to their significant experience and decision-making input on these matters. Unlike the CEO and COO who contribute to significant decision-making, the operations manager is more involved with the daily tasks in relation to economic risks, hence he was given a 20% weight. For market risks, the remainder of the weights were divided among the sales manager (20%) and two experienced salesmen (10% each). Since the sales manager is responsible of reviewing and reporting all sales completed by the company and is in constant communication with all salesmen, he was given the higher weight. For sourcing and process risks, the weights of the operations and production manager were increased to those of the CEO and COO due to their significant contribution in relation to day-by-day activities, such as the reception and production of milk, as well as their involvement in important decisions. In order to improve our understanding of process risks, we have decided to incorporate as well non-manager factory employees, as their experience on minor day-to-day activities could still be insightful. These experienced factory employees were each given a lesser weight of 10%. Moreover, since one of the major focus of the operations manager is the smoothness of the logistics from the suppliers, all the way to the end-user, he was given a similar weight as the CEO and COO of 25% each. The last 25% were covered by two truck drivers (12.5% each), as they are responsible of delivering the products from the factory to the clients, overseeing problems that could occur on a daily basis. Finally, for regulatory risks, since the operations and production managers are responsible of overlooking conformity to standards, they need to have knowledge on specific criteria that need to be respected at all times, hence contributing to 15% each. The results were then averaged to get a comprehensive estimation. In scenarios where opinions varied significantly, we communicated with the parties involved to understand the dissimilarities in judgment, ultimately allowing for their views to be closer to each other. Furthermore, if participants lacked proper knowledge on a specific topic, we advised them to avoid filling the occurrence, severity, and detection of risks. We believe that this measure would improve the reliability and integrity of our results, as it will eliminate any response bias, whereby participants fill the answers incorrectly either due to their lack of knowledge on the matter, or due to their refusal to share the correct answers. Consequently, the weights assigned for those risks had to be adjusted accordingly.

As we aim to enhance the traditional FMEA process, we decided to integrate an supplementary factor, denoted as “A”, which represents the application rate of the corrective actions implemented by the business. The main goal of introducing this factor is to profit from a more comprehensive understanding of the company’s application and effectiveness in undertaking the corrective actions for the assigned risks. By incorporating the application rate (A) into the assessment, we can establish the degree to which the mentioned corrective actions effectively and actually mitigate the different risks. On one hand, this aspect of the approach becomes specifically critical when the RPN is initially high and decreases considerably after the corrective action takes place, all while having a low application rate. This case could ultimately reveal critical problems for the company being studied, revealing potential failures that could occur in the future. On the other hand, if the RPNs before and after the corrective action are low, and the application rate is also low, the threat of the risk may be relatively less concerning. Although the optimization of all the application rates is desirable for the company’s development, the risks associated with these specific failure modes are not significant threats. The implementation of a grade classification ranging from 1 to 10 will offer a better understanding of how the company actually apply the corresponding corrective measure for each risk (Table 4). With the use of this grade system, we believe that it will be easier to evaluate the effectiveness of the correction actions that need take place by the company. Also, such metric could be useful to track progress over time and recognize areas of improvement.

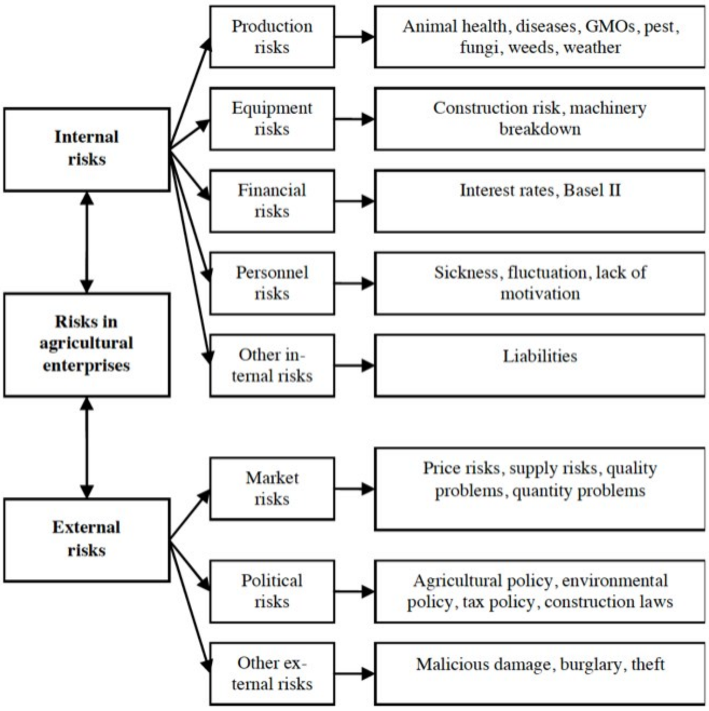
Table 4: Application Rate (A) Grading System

Grade	Description
1	The company does not apply this corrective measure at all.
2-3	The company rarely applies this corrective measure.
4-5	The company irregularly or inconsistently apply this corrective measure.
6-7	The company moderately applies this corrective measure.
8-9	The company frequently applies this corrective measure.
10	The company consistently applies this corrective measures at all times.

5. Risk Domains

Lehrner (2002), classifies the most common agricultural risks into internal and external risks (Figure 2). On one hand, production, equipment, financial, and personnel, are positioned mainly within the farm and the factory; hence, they can mostly be managed through internal channels. On the other hand, since market and political risks, among other risks, are engrained in an organization’s ecosystem, in a way that cannot be controlled by managers, they are considered as external risks.

Figure 2: Risks in Agricultural Enterprises



Source (in German): Lehrner (2002)
English Translation by: Schaper et al., (2009)

By conducting an extensive literature review and by reaching out to experts in the dairy industry, we were able to identify the six main risks associated with the management of a dairy supply chain: economic risks, market risks, sourcing risks, process risks, logistics risks, and regulatory risks.

5.1 Economic risks

5.1.1 Impact of Covid-19

Since the food supply chain incorporates a wide array of interconnected actors, it is vital that these actors' partnership and cooperation remain as trouble-free as possible. However, the Covid-19 pandemic caused severe economic consequences in all industries, all over the world

(Nicola et al., 2020). According to the Food and Agriculture Organization of the United Nations, widespread restrictions on the circulation of goods and people across and within regions were in place, causing disruptions in supply chains, markets, and trade. The temporary and permanent termination of restaurants and other food services triggered a severe drop in demand for perishable goods, such as dairy products, fruits and vegetables, chocolates, and high-end cuts of meat (HLPE, 2020b). The waste was considered to be particularly serious in the dairy industry, especially that cows are continually getting milked, irrespective of fluctuations in demand. Major purchasers of dairy products, such as schools and coffeehouses, were obliged to close down. This phenomenon caused milk producers to have less customers, in periods where cows produce milk at their highest rate (Yaffe-Bellany and Corkery, 2020). Consequently, dairy farmers that did not own appropriate cold storage facilities had to throw away the unwanted surplus of milk.

As a company that is ISO certified, Massabki gives high value to cleanliness and hygiene in the workplace. Subsequently, the company has to rely on large amount of daily supplies, such as gloves, masks, and covers. Due to disruptions in the supply chain caused by Covid-19, each of these items were not available at some point in time, therefore inventory buffers had to be introduced. Due to the radical increase in demand for these items, their prices increased drastically. According to the operations manager, the prices of nitrile gloves that were worn by all employees in the factory, increased from approximately $3/box to $15/box.

The fact that Massabki's employees had to abide by strict precautionary measures regarding Covid-19, such as continuously wearing masks and maintaining social distance as much as possible, there was no large contaminations within the company. Up until now, the two times an employee tested positive for Covid-19, they were successfully able to quarantine themselves early on, preventing further spread of the virus. However, other companies were forced to temporarily close down due to excessive contamination. For instance, a plastic company providing packaging products for Massabki had to close down for as long as two weeks. Due to the following development, Massabki ran out of packaging for a specific item and could no longer sell it to their clients, causing a noticeable disruption in the supply chain of the company.

As we looked at the impact Covid-19 had in terms of sales for the company, we noticed that the amount of items sold in stores, which represent 80% of sales, were not significantly affected. However, sales that were concerned with hotels and restaurants, which represents 20% of sales, considerably decreased. Due to governmental restrictions, restaurants had to completely close down, while hotels had to reduce their total occupancy rate and had to stop providing the buffet breakfast. These constraints had a significant impact on the amount of guests a hotel can accommodate. Subsequently, the total amount of dairy products consumed by hotel members were reduced during that time. In fact, the occupancy rate in Beirut's 4-star and 5-star hotels slipped from 65% in February 2020 (first Covid-19 case in Lebanon reported during that time) to 28% one year later (Yacoub & El Hajjar, 2021).

5.1.2 Impact of the Economic Crisis on the Lebanese Population

Several studies have been conducted on the influence of the pandemic on food insecurity. According to research, the latter could be divided into multiple variables such as the availability, utilization, sustainability, agency, and stability of the food in question (HLPE, 2020a). Although the burdens that COVID-19 posed were global, the implications were not encountered similarly across different nations (Zurayk, 2020). Countries with weak economic structures and those that are involved in extended wars are predominantly vulnerable to the consequences of the virus. According to the United Nations Economic and Social Commission for Western Asia (ESCWA), by 2020, over 8 million Arab citizens are predicted to fall from the middle-income class into poverty; the amount of unsafe food and undernourished individuals was estimated to radically increase. Moreover, Arab countries tend to have a high reliance on food imports, causing further danger to their food safety and their resilience to COVID-19 (FAO, 2020).

Specifically, Lebanon, a relatively small country that is located in the Middle East, has had a prolonged history of political and economic uncertainties and insecurities. Unfortunately, the timing of the pandemic overlapped with one of the largest economic crisis in history. In the past decades, Lebanon has faced large economic hardships, due to sectarian conflicts, collective dictatorship, institutional corruption, unsuccessful or unproductive fiscal policies, and the possession of illegitimate weapons (Malaeb, 2018). Incompetence, negligence, and the absence of accountability by the people in power caused Lebanon to form a debt of over $80 billion, causing the country to have one of the largest debt to GDP ratio (Collard, 2019). Due to the accumulation of challenges, national protests erupted on 17 October 2019 demanding major reforms, such as the increase in transparency and financial stability, in addition to the reduction in corruption and tax evasion (Assouad, 2021). By the end of 2019, banks imposed capital control prohibiting their customers from withdrawing large amounts. The Lebanese economy collapsed, as the country defaulted on its commitments, triggering hyperinflation. From then on, Lebanon has experienced a substantial fallout, causing more than half of the population to be trapped below the poverty line (ESCWA, 2020). Inflation rates have reached 88.2% in 2021; forecasts predicts this number to continue to grow in the near future due the current political gridlock and the financial slump (Kharroubi et al., 2021). The main reason behind the astounding upsurge in inflation is the spiral devaluation of the Lebanese Pound against the US dollar, which has lost over 90% of its value (Daher, 2022). This has caused a significant increase in food prices (prices in the food and non-alcoholic beverages industry increased by 395.29% yearly), affecting the purchasing power of the Lebanese consumers, as well as their dietary selections (BlomInvest, 2021). As for Massabki, inflation impacted the pricing of supplies both, directly and indirectly, such as the packaging of products and the basic supplies needed for the day to day activities. Due to the collapse of the local currency, inflation seems to be inevitable. Therefore, major players in the market have started to resort to the use of the USD in their dealings, as it is considered to be a stable currency. Despite the government fighting dollarization, the use of the USD instead of the domestic currency is rising between client and supplier transactions.

In the years prior to the economic crisis and the pandemic, the food industry was considered to be relatively stable and safe. In 2016, Lebanon was among the nations with the lowest levels of food insecurity (5.2%), compared to its neighboring counterparts, such as Egypt (29.8%) and Jordan (27.3%) (Kharroubi et al., 2021). The reason behind the relatively superior food security for Lebanon was due to the favorable weather, water, and soil characteristics of the country. These particular conditions allowed for growth in the diversity of food production, as opposed to some MENA countries that experience dry and arid conditions (Harrigan, 2014). Moreover, the Lebanese economy has been predominantly dependent on tourism, remittances from migrant oil workers in the Gulf, and investments from foreign countries (Abosedra and Fakih, 2017; Chapkanosvska, 2020). The injection of foreign money into the economy had been beneficial in retaining a low food insecurity. However, the pandemic and its financial ramifications are posing a threat to further aggravate food insecurities in nations that are enduring political unrest among other distressing challenges, such as the case in Lebanon. After taking into consideration the accumulation of misfortunes witnessed in Lebanon since 2019, Kharroubi et al. (2021), estimates food insecurity to significantly increase from 5.2% to an alarming average of 36% to 39%.

While discussing dairy customer behavior in relation to the economic crisis, we noted that the increased cost of living has pushed the Lebanese to switch from their accustomed way of living to a rather more affordable lifestyle. Products sold by Massabki are considered to be common commodities, in that the Lebanese people consume Labneh, as well as Massabki's traditional Middle Eastern cheeses, on a regular basis. Households moved from purchasing imported to locally produced cheeses, benefiting Lebanese dairy companies. "The rich class became middle class, while the middle class turned into the poor class". On one hand, Massabki's products, considered to have good quality (100% fresh, no added additives or preservatives), were able to attract the consumers that used to buy more expensive imported cheeses. On the other hand, some clients that used to buy Massabki products switched to cheaper alternatives that do not provide the same quality and taste. All in all, even though the consumers changed their dietary preferences, total volumes sold were not significantly affected.

5.1.3 Payment Methods

On a related note, as economic struggles increase in a country, bankruptcy and the lack of liquidation of many organizations increase simultaneously. The following causes the upsurge of a risk: receivable risk. The risk of a client not being able to collect on receivables can potentially cause heavy damages to a company (Chopra and Sodhi, 2004). Understandably, such risk has been present long before the economic crisis. In fact, a client that went bankrupt in the early 2000's owed Massabki the equivalent of approximately $150,000, which was unsalvageable and written-off as a loss for the company.

According to the operations manager, the most frustrating and recurrent costs is unfortunately one that is unmeasurable. He clarifies the statement by giving an example of a dilemma the company currently faces on a regular basis. "Let's say, we are due 200,000,000 LBP on the 10th of the month and that the LBP/USD rate that day was 20,000. Suppose the client delays the payment by a few days, in which the exchange rate has become 22,000. Due to the relatively short delay, the amount that was due goes from $10,000 to $9,090, causing a loss of $910 (9%)". Since organizations have no control over the high volatility of the exchange rate, the most they could do to hedge against such issue is to assert strict on-time payment policies on their clients.

Most dairy companies in Lebanon used to have a policy, in which, they would provide either 30 or 60 days to their clients in order to allow them to close their debts. However, as they ran deeper into the crisis, these delays had to become shorter. According to the operations manager, Massabki had to switch around 80% of their clients to pay cash on delivery, while others had to pay every two weeks. Very few were requested to pay within a couple of days of the monthly statement. Previous to the crisis, there was no major differences between the different payment methods (cash, bank check, different currencies). This is no longer the case during the economic crisis. Currently, the percentage you would get out of money in the bank in USD is around 12% of the total amount. Whereas in Lebanese Pound, money in the bank is estimated to be worth around 35% less than its counterpart in cash. Consequently, you would get $12 cash for every $100 in the bank and 65,000 LBP for every 100,000 LBP in the bank. Understandably, firms no longer have interest in receiving payments directly to their accounts in Lebanese banks, as they would rather receive the payments in cash. In fact, Massabki's payment terms with their clients are regularly under negotiation, with the goal of reducing payment delays and increasing the percentage paid in cash compared to the amount allocated to checks that need to be deposited in the banks. According to the operations manager, at the time of the interview (July 2022), the largest and most recognized supermarkets are paying in LBP between 20% and 40% of the amount in the form of checks and the remainder in cash. On the other hand, payments related to clients outside the country are usually paid in cash in USD.

5.1.4 Impact of Fuel Price Fluctuations

Moreover, the increase in fuel price fluctuations is considered to be an economic threat to organizations worldwide. In Lebanon, fuel prices used to be set every Tuesday for the following week. However, due to the rise of fuel prices globally, prices are changing almost every few days. According to the operations manager, these recurring changes are highly influenced by black market practices whereby prices are increased earlier than expected in anticipation of increases in pricing. He added that even though gas prices increased due to inflation, the most impactful and noticeable upsurge in the price of gas is mainly due to the current war in Ukraine. For instance, prices increased from ± $600/m^3$ in January 2022 to ± $1,300/m^3$ in June 2022 raising the cost to run the factory and keep the electricity running, especially considering the lack of electricity provided by the government. In the period of only one month between June 2022 and July 2022, the price decreased by around 20% (± $1,050/m³). The following fluctuations demonstrates the potential significance of international conflicts on the price of fuel.

5.1.5 Frequency of Price Changes

While discussing the frequency of price changes for products sold by the company, we noted a significant difference between the frequency prior and following the 2019 crisis. In fact, prices remained constant from January 2012 till 7th of December 2019. Whereas in the following two years, Laiterie Massabki has changed their price lists a total of 33 times. According to the operations manager, altering prices is an incredibly tough process, considering you need to take into consideration the right time and the right amount to change the prices of your products, which is more or less impossible in such a volatile market. It is relatively easy to calculate the price you would like to apply for your products, in order to keep a stable profit margin as the valuation of the Lebanese Pound fluctuates. However, in such a competitive market, organizations no longer have the luxury of being flexible with their pricing. Therefore, prices of competition is a major constraint to look into, while attempting to find the optimal price. The operations manager claims that the company attempts to position themselves in the market, not as the most expensive item, nor the cheapest among similar products. Taking into consideration the amount your competition is going to increase or decrease their prices complicates the pricing dilemma. On one hand, if you wait for the competition to be the first to increase prices, then you are waiting a longer time to implement the price change you originally planned to go with. "At times, we anticipate a rise in prices by 10%, but competitors increase their prices by 5%, so we adapt our prices so that we don't price our items too far from others in the market". At first, some retailers built a resistance to change, as they would not allow price adjustments without notice. “For example, if we saw our costs increase by 10% simply because of a change in the exchange rate, it would take us around 24 hours to make sure that the increase in the black market is actually real and not just made up, and maybe another 24 hours to make sure the increase stabilized at around 10%”. Therefore, the company waits for at least two days before preparing a new pricelist that will be sent to the clients.” In due course, these clients will also require a couple of days before implementing the price adjustment. Fortunately, as the Lebanese community got used to the continuous alterations to prices in all industries, the process has become more tolerable and more rapid for retailers. Nevertheless, the procedure remains extremely tough to manage. “We already had to face a situation where we raised prices by 10% and by the time we were notifying our clients and sending emails with the new pricelists, the exchange rate increased by another 10%”.

5.2 Market risks

5.2.1 Demand Risks

Due to the fluctuations in the popularity of products, organizations face demand risks. These risks involve uncertainties coming from the downstream of the supply chain that could potentially cause disturbances to the business. This kind of risk might surface due to increased economic swings, consumer migration, developments of new market segments, incorrect or imprecise information sharing by vendors (Lu, 2021), data error caused by point of sales (Wagner and Bode, 2008), and improper demand forecasting (Wu et al., 2006).

5.2.2 Price Risks

For large milk processing plants, the cost of raw milk from farmers is primarily contingent to the relationship of supply and demand. On one hand, whenever the supply is superior to the demand, the price of raw milk tends to decrease, allowing the large manufacturers to benefit. On the other hand, if the supply is inferior to the demand, farmers are able to raise their prices. Such occurrence would negatively impact the firms' profit margin, and therefore the overall profit of the company. With the use of a risk map for dairy farms in Germany, Schaper et al. (2009), have shown that price risks on input markets is the primary priority for farmers. Since a rise in feed prices is considered to be highly probable and has a high loss potential, growing feed prices was seen as the most significant risk.

In the Beqaa region, most farmers agree on a set price for milk on a weekly basis. Since the value of the LBP fluctuates significantly, some farmers attempt to take advantage of the situation. At times, government officials have intervened in order to avoid exploitation by the farmers. According to the operations manager, "There is no particular rule of thumb for these prices. They were almost always negotiated between the farmers and the factories up until the last day. Currently, most of the set price is correlated with the volatility of the exchange rate". The price of milk was stable around 850 LBP equivalent to $0.57 per liter until the end of 2019. As of then, the price in LBP kept increasing as a result of the increasing exchange rate. Up until March 2022, when government officials required prices to set the prices in USD at $0.43, disregarding the current rates. However, prices kept increasing in the months to follow due to increases in feed prices caused by the Russia-Ukraine conflict, especially that Ukraine is considered to be a main provider of animal feeds. In fact, prices increased in April 2022 to $0.55 per liter, and to $0.70 in May 2022. In the three months to follow prices have become relatively stable at around $0.67 per liter. Even though the dollarization of the price of milk in March 2022 was intended to stabilize the price of milk, international conflicts are still a significant factor in the cost of raw material.

5.2.3 Competitive Risks

Competitive risk refers to possible activities by competitors to negatively influence your business. Competitive markets can sometimes be considered beneficial, as it might lead to improvements such as reduced cost and increased quality. The pricing strategies of competitors could potentially turn into significant threats to a business, such as the application of large discounts. Furthermore, promotions employed by competitors have the power to take away the company's customers. According to the CEO, the large dairy manufacturing companies in Lebanon rely mostly on two methods to promote their products in supermarkets. Firstly, companies resort to product bundling, in which an assortment of products is sold in one bag for a cheaper collective price. Since such promotion method significantly reduces the profit margin of the company, it cannot be applicable throughout the entire year. Secondly, companies resort to friendly and well-engaged individuals, who provide free tastings of the organization's products in the supermarket.

In addition, the availability of intellectual property, as well as the implementation of innovation by a competitor can be considered as a threat for an organization. New product development (NPD), labeled as one of the riskiest measures in the food sector, is defined as the procedure that a company takes into account using its resources and capabilities to either generate a novel product or enhance an already existing product (Sharifi et al., 2022). The most severe impediments to new product development are the high cost of NPD processes, as well as the uncertainties in relation to market acceptance (Ahmed et al., 2007). Although products have been quite similar in the Lebanese dairy industry, some competitors were able to incorporate new flavored products and lactose free alternatives, which are becoming more popular. On the other hand, some competitors were unsuccessful in the implementation of new products, such as Greek yogurt, into the market.

The market in Lebanon for dairy products is particularly diverse and includes widespread consumers that are extremely demanding on the products' taste, quality, and price. It is extremely difficult for new players to enter the industry and compete with the medium to large companies that have established well-known brands throughout the years. According to Massabki's CEO, the threat of new entrants in recent years has been negligible, considering there has not been any new major players in over 10 years. The main reason for that is due to the saturation of the market. Notably, every year, there are still a few newcomers in the market that work on a small-scale that join the industry, while others are forced to quit.

5.2.4 Substitutes Risks

According to the literature, the demand side of supply chain is heavily influenced by the accessibility and availability of substitutes (Zubair, 2015). Along with environmental and ethical concerns, the main reason behind the avoidance of cow milk is due to milk allergy or lactose intolerance, leading to an emergent interest for alternatives (Sethi, 2016). Plant-based substitutes, which are able to imitate the sensory characteristics of animal products, are considered to be a continuously growing market (Boukid, 2021; Salomé et al., 2021). Dairy alternatives are prepared by extracting the plant material in water, isolating the liquid, and can then be fermented to produce dairy-type products, such as yogurt (Mä kinen, 2016). Differences in nutritional characteristics of dairy substitutes is an often debated and researched topic. Astolfi et al., (2020) compared animal milk to plant-based alternatives (such as soy, rice, oat, spelt, almond, coconut, hazelnut, walnut, cashew, hemp, and quinoa) and found that plant-based milk substitutes are reasonably safe, with a relatively low level of contamination from toxic components. In addition, the study has found that out of all the examined options, cow and goat milks were the only alternatives to have a substantial source of key minerals (calcium, potassium, magnesium, sodium, and phosphorus). For instance, Salomé et al. (2021) has found that, dairy goods that were regarded as calcium-fortified substitutes, were able to preserve the required calcium adequacy; yet, these products had a greater risk of iodine deficiency. In Lebanon, even though plant-based products are becoming more popular in recent years, they are still considered to be a niche market.

Massabki, as well as their direct competitors, use 100% fresh milk for their products. A lower cost option would be cheeses originating from constructed milk. The latter is made out of artificial ingredients, such as casein, protein, vegetable fat, etc. Even though the taste of such products is considered to be inferior, some people lean towards such substitutes, as they are inexpensive relative to cheeses made of fresh milk.

Moreover, powdered milk is also considered to be a substitute to fresh milk. Likewise, fresh milk gives a better taste and is more liked by consumers. Powdered milk tends to be cheaper alternative. However, due to the Lebanese economic crisis, powdered milk has become even more expensive than fresh milk because it is imported, compared to the extraction of fresh milk which is locally produced.

5.2.5 Forecasting Risks

Alternatively, another demand risk associated with dairy producers is the fluctuation in demand for dairy products in the consumer market. Forecast risks are the outcome of a mismatch between projections and actual demand. On one hand, if the company's predictions are lower than actual demand, some products might not be available to be sold. On the other hand, if the company's predictions are higher than actual demand, there will be an excess of inventories. Such scenario is especially problematic in the dairy industry due to the fast deterioration in the quality of the products. Factors that have a high influence on forecast errors include lengthy lead times, seasonal demand, a large array of products, and reduced product life cycles (Chopra and Sodhi, 2004).

Often, demand forecasts are predictable due to the large amount of historical data. However, it is an unfeasible option to adjust the productivity of cows in generating raw milk to accommodate the demand in the consumer market. Therefore, it is crucial to predict the variability as reliably as possible. According to the production manager, even though there are many external uncontrollable variables, weekly forecasts tend to be reliable. Moreover, there are times where external variables cause significant shifts in consumer demand. For example, the occurrence of a large increase in the daily exchange rate would cause a sudden rush to the supermarkets, in the goal of buying prior to the anticipated increased adjustments to prices. Contrarily, if the exchange rate suddenly decreases, people tend to withhold large purchases from the supermarkets until prices adjust.

There are many reasons for demand to vary during a year. For instance, at the beginning of the month, the consumption of the consumers tends to be higher than at the end of the month. The following is undoubtedly correlated with the people receiving their salaries. It is important to note that the demand on products are affected by seasonality. With the help of large set of historical data, the company is capable of identifying trends. For instance, there are periods of fasting, such as Ramadan, that causes shifts in demand compared to other periods. According to the production manager, during the month of fasting, the sales of cheese lines is reduced, whereas the sales of yogurt lines (e.g. Laban) rises. Since the tourism sector has been one of Lebanon's leading economic sectors, another example of demand seasonality is the increased sales during summer, compared to other months of the year. According to EcomNews Med, expected arrivals of up to 1.5 million visitors are expected for Summer 2022, which is highly significant considering the total population of Lebanon is estimated around 6 to 7 million people. In fact, Massabki's CEO has stated that he expects increases of around 20% in sales during June, July, and August.

5.3 Sourcing Risks

5.3.1 Supplier Risks

An individual failure by the supplier might lead to a broad variety of concerns to an organization, such as product quality, brand reputation, delays, dissatisfied consumers, decrease in demand (Prakash et al., 2015). In the domain of perishable goods, the upstream risks are comprised of the suppliers' qualities and capabilities (Lockamy, 2011), their reliability (Norman and Jansson, 2004), and the infrastructure of information and communications technology (ICT) (Wagner and Bode, 2008). Quality problems of raw materials have been perceived as a risk component by many scholars (Manuj and Mentzer, 2008; Scott et al., 2011; Punniyamoorthy, 2013). Particularly, the quality of milk has been established and developed as a predominantly significant supply risk (Zubair et al., 2015). For Massabki, milk suppliers contribute up to 70% of the total costs, making it the most critical expense to look into. The collection of milk from the suppliers has become routine work, considering that the factory receives milk on a daily basis. If supply quantities need to be increased or decreased, it is usually easily doable. However, other suppliers, such as packaging-related suppliers are not as flexible. For instance, the packaging company that provides Massabki with polypropylene boxes requires approximately three weeks from the time of order to the arrival to the factory. However, according to the CEO, the variability in lead time is an issue that always needs to be considered, as they sometimes send the products later than expected. Hence, it is necessary to undergo precautionary measures by ordering in advance and storing additional supplies in the available warehouses.

Incorrect and inaccurate ordering mechanism can have negative impacts on the supply side (Pujawan, 2009). In addition, unforeseen changes in design and technology might potentially lead to difficulties on the supply side (Monczka, 2009). Another potential supply-related issue that might arise, is the ability of suppliers to create monopolies, causing multiple companies to partner with the same supplier (Pfohl et al., 2011). Notably, if the majority of manufacturers rely on the same supplier, it is expected for the cost of the raw material to increase. In order to avoid such issues, a possible solution is to implement backward integration, whereby an organization might get complete control of its supplies (Zubair, 2015). Nevertheless, dominant and powerful control by large farmers is relatively rare and difficult to achieve in the dairy industry, especially that farms tend to be composed of an abundance of decentralized minor farmers. In Lebanon, farmers retain different kinds of goat breeds. The baladi breed constitutes the vast majority of goats in Lebanon. Although the breed strongly suits the Lebanese environment, its milk production is relatively low, which may consequently have an impact on the amount of supply. According to the FAO, the baladi breed produces 0.5 to 1 kg of milk per day, whereas improved breeds such as the shami goat produces up to 5 kg of milk per day. Notably, such improved breeds are usually found with larger farmers. Responsible for the care and supervision of a flock of animals in open pasture, herders are often on the move. Nevertheless, in 2014, a noteworthy transition occurred, in which herders have become less active either due to the inaccessibility or the lack of productivity in grazing lands (Mercy Corps, 2014).

The milking process for cows occur all year long, whereas the milking of goats is seasonal. Primarily, the milking season for goats ranges from March to August. Massabki starts to receive small quantities of goat milk at the end of March. The supply of goat milk keeps increasing and peaks during the months of June, July and August. In September, supply gradually decreases. By October, there is close to zero supply of goat milk. In order to find a solution for the lack of goat milk during the rest of the year, the company produces Goat Labneh out of goat milk and stores the finished good for months. As a finished product, Goat Labneh benefits from a characteristic that enables it to be stored up to one year, provided the product is significantly dried, conserved in an hermetically sealed packaging, and kept at 0 degrees Celsius.

In general, milk collectors complete their payments to the producers (farms) within two weeks. This allows them time to receive their compensation from the processors (factories). Milk collectors often have long-term relationships with well-established factories. Such affiliations can be considered to be beneficial for both players. The supplier takes advantage of guaranteed future demand, while the buyer guarantees future supply and decent quality of milk. According to the operations manager, farmers are quite harder to deal with, since most of them lack proper education, not having completed their school degrees. In Massabki's case, the company mostly deals directly with distributors, who collect and deliver the milk for them. When questioned about their relationship, the COO emphasized the importance of long-term partnerships and mutual respect, that has been passed down for many generations. "Our long-term relationship with the milk suppliers has put us in a trustworthy situation, in which we very rarely come across any issues with quality". However, he also noted a disadvantage that comes with dealing with one main supplier, which is the reduction in competition. This setting causes price negotiations to be tougher, benefiting milk collectors. Therefore, the CEO emphasizes the importance of having supplier contingency plans, as well as multiple suppliers of milk at the same time. "We try to deal with at least two to three suppliers for each raw material, at any time".

5.3.2 Hazard Risks Associated With Milk Farming

Physical Hazards

As previously mentioned, major food-related hazards can be categorized into three groups: physical, chemical, and biological. The availability of foreign substances in milk is the most common physical hazards. These foreign matters may involve soil particles, insects, hair, metals, glass, among other substances (Aysha and Athira, 2020). The presence of such elements in milk, especially hard objects, may lead to the impairment of the consumer's teeth or their internal organs. Such incident could even cause choking incidents, especially among children. In order to either, avoid or minimize the dangers associated with the contamination of milk by these physical hazards, protective measures should be established by the company. The presence of sharp-edged entities is more common in raw milk, rather than processed milk. Fortunately, it is considered relatively easy for physical hazards to be spotted, and for their source to be traced. Upon reception of milk, the first step employed by Massabki is filtration. This procedure allows them to eliminate any physical hazard at the beginning of the process.

Chemical Hazards

It is extremely difficult to avoid and control incidence of chemical hazards, in particular, environment-borne chemical hazards (Aysha and Athira, 2020). The use of chemicals in the milking process increases the probability of chemical hazards in finalized milk. Unsanitary and falsified procedures completed in the farming stage increases incidences of chemical hazards in milk. Chemical hazards in milk-related products may be linked to several factors: (1) remainders of chemicals in different animal practices, such as drugs, pesticides, and hormones; (2) incompetent activities, such as the use of contaminated elements; (3) residues of environmental pollutants, such as heavy metals (high density, toxic, poisonous), dioxins (persistent environmental pollutant POP – primarily in the fatty tissue of animals), and radionuclides (atoms that emit radiation); (4) cleaning-related chemicals, such as sanitizers, bleachers, and detergents (Aysha and Athira, 2020).

Biological Hazards

In general, biological hazards in the dairy industry are comprised of pathogenic microorganisms that access milk either through the milking process, the workers, or the environment itself (Aysha and Athira, 2020). Evidently, the lack of hygienic practices is the main reason behind a high probability of a biological hazard to occur. The preliminary presence of microorganism in the supply chain can be heavily diminished by the application of good hygienic practices (GHP). Reducing the amount of pathogenic microorganisms at an early stage of the dairy process avoids future additional increments in microbial populations (Anand et al., 2006). Iyer et al. (2010) recognizes that the poor design of dairy systems is the root for high bacterial count, making the organization of dairy processes highly influential for the quality of milk. Exposure to spoilage and pathogenic microorganisms are the root cause behind human poisoning due to milk-related products. The amount of microorganisms in a final good is mostly associated with the characteristics of the nutrients in the product, such as the quantity of water available, the level of oxygen, the extent of the acidity, the temperature, etc. (Boor, 1997). Furthermore, molds and yeasts are microorganisms that can grow in dairy goods if storage conditions are not effectively managed. These molds can potentially produce mycotoxins, which can be harmful if consumed. Moreover, parasites can contaminate water sources used in dairy production, also leading to potential health issues.

Testing milk for fat content is a necessary task in the processing of dairy products. For instance, it is conceivable for certain milk producers to conduct unethical actions, such as adding water to their milk, allowing them to sell at higher prices. Dairy processors have to be cautious by engaging in fat content testing that is achieved through specialized equipment. The use of testing strips for medications is a crucial aspect of dairy processing, as antibiotics and penicillin may hamper the quality of milk (Mercy Corps, 2014). Milk collectors conduct their own milk quality examinations upon collection. It is considered to be extremely risky for milk collectors to mix milk from different farms without conducting the required tests, since one batch of bad milk (containing water or probiotics) would damage the rest. Testing is also necessary for large dairy manufactures. Due to their ISO certification, Massabki are compelled to test every batch upon reception at the factory. The “milkoscan” device, available at reception, allows the company to test the transported milk for fat content, water percentage, density, total acidity (pH), proteins, total solids, critic acids, urea, casein, etc. Other mandatory tests include the inspection of antibiotics, penicillin, and bacterial content in the raw material. Another way of detecting biological hazards in the milk is during the pasteurization process. If the milk is poorly conserved, the milk can collapse due to the high temperatures of the pasteurization process (85 degrees Celsius). Evidently, the manufacturing process will not continue with the batch; the milk will be rejected and returned to the suppliers. According to the production manager, as a last resort, experts in the factory are sometimes even capable of distinguishing different quality of milk by their color and smell. According to the production manager, around once every six months (~0.5% of all milk receptions), Massabki rejects the raw milk due to biological hazards.

Hayes and Boor (2001) identify the bacteria that are generally associated with milk, as well as their potential consequent diseases (Table 5). In addition to microorganisms, toxins formed by certain microbial pathogens, such as enterotoxins, can cause an inflammation of the stomach and intestinal lining, which may result in diarrhea and vomiting. Due to their strong stability in relation to variation in temperature, these microbes usually do not dissolve during standard heat treatments. The care and attention associated with the animals, such as the different feeding procedures of cattle that are in place, should maintain proper hygienic measures, especially that the procedures influence the chemical and biological quality of milk (Torkar and Teger, 2008). The use of unsafe water for the washing of milking machines can increase the amount of pathogenic organisms in raw milk (Bramley and McKinnon, 1990). Since the raw milk that is provided from the suppliers is sold without any thermal processing, the probability of a biological hazard to occur is more likely to occur on the supplier side than on the production side. The hygienic condition of employees is an important factor that may impact the quality of raw milk. Lelieveld et al., (2003) identifies unhealthy personnel in the milking process as a major source of biological hazards in milk. An effective way to enhance the quality of milk of milk acquired from small-scale farmers, is by building awareness concerning the different hazards and their impacts.

Table 5: Human Microbial Pathogens Associated with Milk and Milk Products

Organism	Disease
Enterobacteriaceae	
Escherichia coli, including O157:H7	Gastroenteritis, hemolytic uremic syndrome
Salmonella	Gastroenteritis, typhoid fever
Yersinia enterocolitica (psychrotrophic)	Gastroenteritis
Other gram-negative bacteria	
Aeromonas hydrophila (psychrotrophic)	Gastroenteritis
Brucella spp.	Brucellosis (Bang's disease)
Campylobacter jejuni	Gastroenteritis
Pseudomonas aeruginosa	Gastroenteritis
Gram-positive spore formers	
Bacillus cereus (some strains are psychrotrophic)	Gastroenteritis
Bacillus anthracis	Anthrax
Clostridium perfringens	Gastroenteritis
Clostridium botulinum (type E is psychrotrophic)	Botulism
Gram-positive cocci	
Staphylococcus aureus	Emetic intoxication
Streptococcus agalactiae	Sore throat
Streptococcus pyogenes	Scarlet fever/sore throat
Streptococcus zooepidemicus	Pharyngitis, nephritic sequelae
Miscellaneous gram-positive bacteria	
Corynebacterium spp.	Diphtheria
Listeria monocytogenes (psychrotrophic)	Listeriosis
Mycobacterium bovis	Tuberculosis
Mycobacterium tuberculosis	Tuberculosis
Mycobacterium paratuberculosis	Johne's disease (ruminants)
Rickettsia	
Coxiella burnetii	Q fever
Viruses	
Enterovirus, including polioviruses, rotaviruses, Coxsackie viruses	Enteric infection
FMD virus	Foot-and-mouth disease
Hepatitis virus	Infectious hepatitis
Fungi	
Molds	Mycotoxicoses
Protozoa	
Entamoeba histolytica	Amebiasis
Giardia lamblia	Giardiasis
Toxoplasma gondii	Toxoplasmosis

Source: Hayes and Boor, 2001
Adapted from: Boor, 1997 and Johnson et al., 1990

5.3.3 Bullwhip Effect

The bullwhip effect is described as the demand distortion that transfers from the downstream to the upstream section of the supply chain; the phenomenon implies swings in inventory with regards to consumer demand, causing supply chain inefficiencies (Metters, 1997). In relation to perishable products, these inefficiencies are associated with quality in the supply chain, as well as product waste (Peña, 2021). The phenomenon is particularly challenging in the food supply chain, and especially for the case of fresh products.

The reasons behind the occurrence of the bullwhip effect are multifold. Lee al., (1997) pinpoint some of the principal causes of the bullwhip effect such as demand signaling, order batching, fluctuating prices, and supply shortage. Moreover, Garge and Srinivasan (2014) also looked at some of the roots of the bullwhip effect and identified causes, such as the lack of supply chain coordination, the lack of trust among different actors in the supply chain, the lack of information sharing, the lack of training in the sales force, and the lack of a proper incentive scheme. For supply chains to be effective, developing a smooth flow of information is vital (Harland et al., 2003). One of the reasons for information distortion might include promotions or incentives that lead to forward buying, whereby purchases are made in quantities larger than demand to hedge against expected increases in pricing. Such high volatility in sales causes a lack of upstream awareness of actual demand. Information sharing has been identified as a variable that isolates successful from unsuccessful supply chains (Cavinato and Joseph, 2004). Cavinato and Joseph (2004) identify essential threats related to informational risks, such as improper market knowledge, the lack of access to key information, and the lack of smooth data movement. In addition, distorted information can halt the smoothness of a supply chain (Fakhar, 2006).

Since the bullwhip effect generates a negative impact on the efficiency of the supply chain, scholars have implemented simulation techniques to assess the outcome of possible strategies to mitigate this issue. For instance, Naghavi et al. (2020) propose solutions, such as (i) the need for suppliers to communicate and constantly share inventory and capacity information to their clients; (ii) the need to use identical information between different members of the supply chain, in order to forecast demand; (iii) the need to reduce time delays for the movement of goods, as well as for the circulation of information; (iv) the need for upstream and downstream members of the supply chain to regularly interchange information about consumer demand.

5.4 Process risks

5.4.1 Types of Processing Risks

Processing risks involves risks in the day-to-day operations of a manufacturing company. Risks that originate all the way from the processing of raw material to the finished products are labeled as process risks. The threats that arise from this type of risk can vary from production issues, transportation issues, and labor issues (Wu et al., 2006). The milk processing line integrates plenty of steps during the transportation of raw milk into the final product. Any slip-up or error in any of the operational steps could cause the entire processing line down. According to the production manager, "Failures happen. At the end of the day, it is a factory. We can only try to maintain the equipment, follow procedures and guidelines to avoid problems as much as possible. For example, during packing, if the machine that fills a certain product encounters a problem, it needs to be resolved quickly and efficiently, or else we would not be able to provide the product to our clients until it is fixed". Conveniently, the company employs workers that are also mechanics. Hence, they are often capable of taking care of such issues. Rarely, these mechanics are not capable of solving the problem at hand, in which the production manager relies on outsourced technicians that have more expertise with the needed parts. Machine breakdown can be categorized into two types: wear and tear breakdown (common) and complete breakdown (extremely rare). Wear and tear breakdowns can slow down the process, but does not stop it completely. In that case, the company can control the repair time during idle times, avoiding any delays in the supply chain. For example, the vacuum machine for packaging could potentially show weaknesses by slowing down its production rate. Usually, such issues are associated with maintenance problems that are repairable through the use of spare parts, ultimately avoiding discontinuity in the production lines. When it is time for the company to cover the maintenance of a specific machine, it is important for them validate that there are enough goods to cover the needed period. According to the production manager “out of experience, we have learned to always keep overhaul kits, which contain commonly used replaceable parts, such as cylinder kits, filters, gaskets kits, seals and bearings, ultimately significantly reducing delays in repair”. Complete breakdowns have not happened in the past decade, mainly due to good quality machines and proper maintenance throughout the years.

In Lebanon, power failures have become common for businesses and households, as the government is only capable of offering electricity for a few hours a day. In order to defy the lack of electricity, the use a local generator provider is a more expensive option. However, this option still does not provide electricity permanently. In order to do so, the people need to install their own generator, which is an even more expensive alternative to operate. For factories such as Massabki, power failures are not an option, due to the significance of retaining a cold chain. Since the lack of electricity for a short time could deteriorate all the products in refrigeration, the company relies on three private generators, in addition to the electricity provided by the government. The three generators (150kVA, 100kVA, and 60kVa) are synchronized to efficiently cover the needed level of power at any time. According to the production manager, “The electricity interruption is limited to the few seconds the electricity changes from one source to the other, which is highly negligible”.

Another processing risk an organization might face is the loss of workers due to an accident or an illness. Schaper et al. (2010) labels such misfortune as one the most significant production risk in dairy farms, especially for smaller organizations. Recognizably, the greater the number of employees, the easier to manage such issues.

5.4.2 Factory Physical Hazards

As previously discussed, suppliers may cause physical hazards during the milking process, such as accidently releasing foreign matters into milk. However, this issue might also happen in large and organized factories, causing a wide variety of threats to the end-user. According to the production manager, in extremely rare occasions, strands of hair are found inside packaged goods. Such physical hazard can reach the final product during the manufacturing the product, during resting period (very unlikely), during the packaging process, or it could be embedded in the plastic all the way from the packaging company. After packaging, the product is completely sealed and becomes highly unlikely to get contaminated. In each step of the procedure, the product will pass by the supervision of different employees, hoping to eliminate any slip-up. Even following the packaging and storing phases, employees are still capable of detecting a defect in future stages, such as during the transportation from the warehouse to the trucks, during the delivery of items to clients, and during reception from clients. Since the product passes through various individuals before reaching the shelves, it highly reduces the chances of a physical hazard to reach the end-user. The production manager emphasized on the importance of the rigorous hygiene protocols employed to reduce the occurrence of a physical hazard, such as the mandatory wear of masks, gloves, sleeves, hairnets, and beard covers. In addition, they do not allow their factory employees to have neither long hair, nor long beards.

Once the delivery of milk from the farms to the factory is completed, the goods can be passed through metal detectors, in order to either reduce or eliminate the occurrence of such metallic objects. Another way to identify physical foreign substances in milk would be for manufacturing companies to install a X-ray machine at the last step of the processing line (Aysha and S. Athira, 2020). However, the cost of such machinery is usually not considered to be practical for household farmers that provide unpacked milk marketing channels, and that manage the sales themselves (Molins et al., 2001).

ISO standards require companies such as Massabki to have many countermeasures to significantly reduce physical hazards. Positive pressure ventilation systems fans push air into the inside, creating higher static pressure. This allows unfiltered air to depart the factory through openings in doors and windows. Moreover, all 3 doors giving access to the production area are covered by air curtains, forbidding any insects, flies, dust, debris, to enter. Ultimately, all 3 air curtains generate an air barrier between the outside air and the inside conditioned air. Furthermore, the factory contains 12 UV fly traps, each protecting a specific area of the manufacturing plant. The powerful beams of Ultraviolet A from LED lights in UV fly traps lures flies, as they are sensitive to light at that specific wavelength. In addition, 20 mouse traps are used as protection from rodents. They are all strategically located on the outside of the factory, which is essential as the inserted poison must remain separated from the factory. A pest and insect control company visits the factory twice a month, in order to conduct the necessary maintenance to eradicate flies, insects, and rodents. The ISO audit requires complete periodical reports of all measures carried by the pest control company, such as replacing the glue boards located in the UV fly traps, replacing the mouse traps if needed, spraying all the gutters with food-approved pesticides.

5.4.3 Factory Chemical Hazards

Similar to the farming process, it is vital for chemicals hazards to be addressed in the dairy factory. The use of certain substances in processing plants may lead to a proliferation of chemical hazards in milk. For instance, severe consequences might arise due to faulty practices, such as the adulteration of neutralizers, which is the material that is added to milk, allowing the dairy company to regulate the acidity (pH) of milk. Furthermore, the use of detergents and disinfectants need to be applied in the correct manner in order to avoid contamination. Moreover, it is important to be aware of elements that are formed throughout the processing phase and how to control their presence. For instance, neoformed contaminants, also known as NFCs, may be formed during high temperature procedures, such as pasteurization (Birlouez-Aragon, 2010). According to the production manager, chemical hazards is the least common hazard to occur in their factory. Employees use quaternary ammonium compounds, which are found in cleaning products, to eradicate different kinds of bacteria, viruses, and mold. All detergents and disinfectants used in the factory have technical datasheets, showing the proper dosage of safe usage, as well as proper rinsing instructions. These solutions must have a specific concentration that is considered safe for food manufacturing plants. “It is necessary to always follow the instructions of the datasheet to avoid any chemical hazard”.

5.4.4 Factory Biological Hazards

By conducting the FMEA approach and allocating risk priority numbers to hazards in a dairy company, Kurt and Ozilgen (2013) found that biological failures had the highest RPN, followed by chemical and physical failures. According to the authors, companies that were operating obsolete machineries, implementing rigorous human handling, and hiring employees with no proper training, were the ones that encountered the most hazards.

The presence of pathogenic microorganisms in raw milk could signify the animals' damaged health condition, or improper milking procedures. Since raw milk might include pathogens that can remain in the whole dairy process, dairy products have a substantial role in the manifestation of foodborne diseases for the end-user. The best way for a dairy company to decrease the chances of a biological hazard is the engagement in thermal processing machinery (e.g. pasteurization and sterilization). This kind of procedure is essential as it would reduce the pathogenic microorganisms prior to the production of toxins. In order to avoid biological hazards, simple, yet essential hygienic exercises need to be constantly reinforced. Well-exercised sanitization of all the equipment needs to be done to avoid the occurrence of biological hazards. ISO standards require employees in the production area to follow strict procedures concerning the use of safety accessories, such as gloves, aprons, sleeves, hairnets, shoe covers, whenever they enter the production area. The whole clothing safety kit needs to be replaced each time the employee leaves the production area and comes back. These measures are meant to avoid contamination from the external environment to the production area.

5.5 Logistics risks

5.5.1 Transportation Risks

According to the Basel Committee on Banking Supervision, operational risk refers to "the risk of loss resulting from inadequate or failed internal processes, people or from external events". The threats might surface from internal processes or from exchanges with external members. Moreover, control risks are generally linked with the implementation of rules, policies, or procedures that oversee the operational activities (Yu and Huatuco, 2016). In comparison to traditional supply chains, the logistics of perishable products often takes into consideration many more factors, allowing for a more complex system. These factors include the deterioration of the products, extremely short useful life of the products, seasonality of milk production, inconsistency of quality and quantity, effectiveness of cold warehousing, and transportation requirements, considering the operation of a set of trucks over long routes. All of these dynamics generate an increase in complexity, cost, and unpredictability (Peña, 2021). A transportation disruption might happen as an outcome of potential triggers, including natural disasters, war and terrorist activities, infrastructure breakdowns, and labor disputes (Chopra and Sodhi, 2006).

Milk kettles that are used for transportation by suppliers to the factory need to be sufficiently cleaned after each use. Appropriate disinfecting procedures should be applied in the transportation of milk. Direct and indirect adulteration should be prevented in order to retain the quality of the milk. Prior to being packed into finished goods at Massabki, internal transportation of goods is supported by high safety guidelines. Once, the items are sealed in their packaging, they are placed into crates, moved into large fridges, relocated into trucks depending on the size of the orders, and delivered to the stores by the truck drivers. During these steps, it is highly unlikely that a sealed package gets contaminated. According to the operations manager, one issue that might arise is a cheese pack filling with air, which could cause contamination and faster deterioration of the product. Employees are instructed not deliver a pack of cheese that is not properly vacuum sealed (air passing through). Fortunately, it is easy for the truck employees to identify such issue, as the structure of the product changes significantly when in contact with air.

Furthermore, risks associated with truck-related failures are considered to have a low occurrence rate, especially that the maintenance of all company vehicles are thoroughly applied. According to the operations manager company trucks encounter problems around once a year. Usually, these issues are fixable on the spot. Most of the time, the problem is related to bad currents while charging that causes the burst of fuses, which are easily and inexpensively replaceable. However, in the rare occasion of truck failures, it is important to note that, the impact of such risk is highly significant, considering the potential loss of all goods placed in the truck, equivalent to approximately $10,000 at full capacity. In order to avoid a scenario whereby, the effectiveness of refrigeration might be affected unknowingly, it is recommended for the company to install sensors and dataloggers for all trucks that are capable of notifying the drivers when the temperatures exceed 10 degrees Celsius. This countermeasure allows for the company to react in a quick manner, as to avoid losing valuable products. If the issue is not fixed immediately, the company either sends the nearest active truck or an idle truck to recuperate and transfer all the goods from one truck to the other.

Additionally, an issue that might happen to the products during the transportation is related to their the tolerance of sudden movements. If the truck driver does a sudden movement or runs over potholes, products could be ruined by tumbling down, which would make it unsellable. According to the sales manager, this mainly happens with the larger (2Kg) Laban boxes, which has the texture of yoghurt. Notably, this issue does not occur with experienced drivers. Highly trained drivers and their helpers learn the best way to stack items in the trucks, as to avoid these situations. According to the sales manager, these mistakes only happen if the company hires new employees or new helpers, that are less familiar with these slip-ups. Therefore, the company highly advises drivers to notify helpers or new recruits of all the different possible scenarios that might cause damage to the products while driving.

In relation to the economic crisis in Lebanon, organizations may potentially find themselves vulnerable to transportation issues concerning the arrival of raw materials and the departure of finished goods. The transportation of these items might be problematic due to interferences, such as disruptions in fuel supply or roadblocks. In 2021 and 2022, Lebanon was challenged by a fuel shortage crisis. The latter caused excessively long queues and prolonged waiting times for the consumers at the gas stations (Lewis, 2021). The main cause behind these circumstances was the deteriorating value of the Lebanese currency, the illegal smuggling of subsidized petrol to Syria, and the government's financial incapacity to provide sufficient amount of fuel (Reuters, 2021). Such events will have a direct impact on the logistics of many businesses, including dairy companies that are responsible of delivering products on a daily basis to their clients.

5.5.2 Storage Risks

The storage and the transportation of goods have been addressed as potential sources of risks to be considered (Rodrigues et al., 2008). Dairy products also need to be stored and handled cautiously and rapidly to retain both, their hygiene and their safety, until they reach the end-user. Temperature management is an extremely important concern for the dairy companies. Since milk is highly perishable, it is required for its temperature to remain at a safe range through the supply chain, also termed as a cold chain (Aung and Chang, 2014). If the milk is exposed to relatively high temperatures at any point in the supply chain, shelf life and quality of the final good are expected to significantly decrease. Storing the milk at a higher temperature than recommended will cause a rise in the microbial loads, leading to a worsen quality of milk (O'Connell, 2016). Moreover, the safety and healthiness of milk also revolves around the end-user's abidance to the required temperature storage of the product (Valeeva et al., 2005). Therefore, it is important for the end-user to ensure products bought from the supermarkets reach their refrigerators as quick as possible, are kept far from high temperatures (no straight access to the sun), and are stored back in the fridge after use.

Since the Lebanese economic crisis lead to a significant increase in the interruption of electricity in the country, the limited supply of power throughout the day meant some supermarkets, hotels, and restaurants stored dairy products without providing 24/7 cooling. Dairy products are extremely sensitive to increases in temperature (recommended to be stored between 1 and 5 degrees Celsius). Some stores were caught cutting electricity at night, as to avoid the high price of maintenance for private generators. Due to these unethical actions by clients, Massabki started receiving complaints from customers, claiming that the product purchased either had a bad taste, or a bad smell upon unpacking. In order to avoid such issue, the company was able to locate the stores that provided such immoral engagements in two ways. Firstly, the company questions the end-user that complained and figure out the store in which the purchase was made. Once identified, the company sends the driver responsible of sales in that specific store to examine the temperature of their fridge at different timings of the day. Secondly, the company enforced a policy on truck drivers to examine the temperatures of all stores, at least once a month. This plan allowed the company not only to detect intentional cut-offs of electricity, but also refrigerators that are no longer performing optimal temperatures. If the temperatures are above the standard range, truck drivers are asked to return all the goods from that store. Delivery for that store restarts only once the problem is fixed.

As previously mentioned as a supplier risks, a proper contingency plan for suppliers lacking the needed amount of raw materials at the time of order, would be to keep large quantities of inventory (buffer inventory strategy). However, it is important to note that excess inventory can create storage issues, as excess stock takes up valuable warehousing space. In addition, excess inventory can potentially be more costly due to increases in rent, maintenance, utilities, insurance, and salaries (to manage the additional goods). Massabki are forced to hold thousands of polypropylene boxes and polyamide vacuum bags among other packaging suppliers. Fortunately, the packaging material is not bulky, especially that all boxes are stackable, avoiding unused space. According to the CEO, “we require our suppliers to keep printed labeled material for us in their stock too”. This strategy is beneficial as it allows, not only for future orders to be ready in time, but also to reduce the organization’s storage costs.

5.6 Regulatory Risks

Food Safety Management Systems (FSMS) is a systematic methodology to monitor food safety hazards in a food-related business, certifying that the end result is safe for the consumer (Babeker et al., 2022). In Lebanon, food safety concerns have been tackled by multiple legislative and regulatory restrictions. The implementation of these restrictions follow a multi-agency system, whereby accountabilities are distributed among several institutions. For example, the Ministry of Agriculture oversees production and distribution; the Ministry of Public Health is responsible for monitoring the hygiene applied in factories, by executing occasional inspections; the Ministry of Industry is accountable for the control of dairy manufacturing ; the Ministry of Economy is liable for the circulation in food chain, as well as running inspection activities (Abebe et al., 2016). The Lebanese Standards Institution, also known as LIBNOR, is a national public organization that is directly involved with the Ministry of Industry. The institution has the authority to create and to modify national standards, as well as to verify the compliance of products to the national standards. It is important to note that although standards all over the world consider similar factors, the exact criteria vary between countries and regions. According to Massabki's CEO, the government periodically takes samples for testing; the Ministry of Economy examines samples directly from the factory, while the Ministry of Agriculture randomly examines products from the market. In the case of exceeding the standards provided by the government, consequences may vary. The company might get a warning for its first minor misconduct, a fine for a larger offence, or might be forced to close down due to repetition of wrongdoings.

6. FMEA Results, Analysis, and Mitigation Approaches

We can find below the calculated weighted values for occurrence, severity, and detection for all risks, separated by the risk domains, as they were provided to all the members. While the risks filled in red refer to risks that are only influenced by two factors: occurrence and severity, the risks filled in green refer to the risks that are influenced by three factors: occurrence, severity, and detection. Hence, only the risks in green can provide a RPN value.

Table 6: FMEA Results - Economic Risks (Part 1/3)

ECONOMIC RISKS (25)												
Subdomain		**Risk**	**O**	**S**	**D**	**RPN**	**Corrective actions**	**O**	**S**	**D**	**RPN**	**A**
Fuel price	**R 1**	Sudden increases in global fuel price (due to international conflicts or other reasons)	5.20	4.60		N/A	-	5.20	4.40		N/A	
Interest rates	**R 2**	Mismanagement of bank interest rates	3.80	3.60		N/A	Borrowing should be carefuly studied, if needed. Use company capital instead of bank loans, if possible.	3.40	3.20		N/A	9.60
Tax rates	**R 3**	Governmental changes in tax rates (e.g. an increase in income tax might reduce the consumer's disposable income, resulting in lower revenues for the business)	2.40	4.60		N/A	-	2.40	4.60		N/A	
Inflation (USD)	**R 4**	Inflation of the US Dollar, causing sales revenues to decrease	2.80	5.20		N/A	-	2.80	5.20		N/A	
	R 5	Inflation of the US Dollar, causing an increase in the price of milk	3.00	5.80		N/A	-	3.00	5.80		N/A	
	R 6	Inflation of the USD Dollar, causing an increase in packaging material	3.00	4.40		N/A	-	3.00	4.40		N/A	
	R 7	Inflation of the US Dollar, causing an increase in the price of basic supplies needed for day to day activities	3.40	4.00		N/A	-	3.40	4.00		N/A	
	R 8	Inflation of the US Dollar, causing increases in the the company's pricing	3.00	3.80		N/A	-	3.00	3.80		N/A	

Table 7: FMEA Results - Economic Risks (Part 2/3)

Inflation (LBP)	**R 9**	Inflation of the Lebanese Pound, causing sales revenues to decrease (in dollars).	7.40	6.40		N/A	-	7.40	6.40		N/A	
	R 10	Inflation of the Lebanese Pound, causing an increase in the price of basic supplies needed for day to day activities	7.40	4.00		N/A	-	7.40	4.00		N/A	
	R 11	Inflation of the Lebanese Pound, causing increases in the company's pricing	7.80	4.80		N/A	-	7.80	4.80		N/A	
Currency	**R 12**	Significant decreases in the value of the national currency (LBP) against the US dollar	8.60	7.80		N/A	Minimize holdings of currencies that are susceptible to inflation by converting the money to more stable foreign currencies. Continiously keep track of currency fluctuations.	6.20	6.00		N/A	5.40
	R 13	Continuous volatility of the Lebanese Pound against the US Dollar (i.e. lack of stability)	8.40	7.80		N/A		6.00	7.20		N/A	5.40
Recession	**R 14**	Global recessions, negatively impacting sales revenues	5.40	2.80		N/A	-	5.40	2.80		N/A	
Security	**R 15**	Regional political instability, negatively impacting sales revenues	5.00	2.80		N/A	-	5.00	2.80		N/A	
	R 16	Lack of security during large cash collections from clients (i.e. vulnerable to robberies), considering the country's recent transition to a cash economy	2.20	7.40		N/A	Cash should be collected on a daily basis by the drivers. Collections should not be set on specific days, as to avoid large collections to accumulate on a certain day.	2.20	5.20		N/A	5.40

Table 8: FMEA Results - Economic Risks (Part 3/3)

Revenue fluctuations due to Covid-19	**R 17**	Decreases in sales revenues in retail stores during the Covid-19 pandemic	3.60	3.20		N/A	-	3.60	3.20		N/A	
	R 18	Decreases in sales revenues in restaurants during the Covid-19 pandemic	5.60	4.00		N/A	-	5.60	4.00		N/A	
	R 19	Decreases in sales revenues in hotels during the Covid-19 pandemic	6.00	3.80		N/A	-	6.00	3.80		N/A	
Volatility of sales	**R 20**	Volatility of sales in retail stores (excluding Covid-19 scenario)	3.80	3.20		N/A	-	3.80	3.20		N/A	
	R 21	Volatility of sales in restaurants (excluding Covid-19 scenario)	4.40	2.40		N/A	-	4.40	2.40		N/A	
	R 22	Volatility of sales in hotels (excluding Covid-19 scenario)	5.00			N/A	-	5.00	2.40		N/A	
Food insecurity	**R 23**	Increased food insecurity of company products due to the economic crisis	3.20	7.40		N/A	Act in accordance with the manufacturing standard operating procedures (SOP) at all times.	1.40	7.40		N/A	8.20
Receivables	**R 24**	Clients exceeding payment deadlines	7.20	7.40	4.20	**223.78**	Push clients to pay on the same day of receival of goods, reducing credit balances. Persist on clients that do have credit balances to pay as soon as possible. Continuously track clients payment delays and act accordingly if deadlines are not repected.	6.00	7.00	3.20	**134.40**	3.80
	R 25	Clients declaring bankruptcy with unsettled payments	2.20	8.40	5.40	**99.79**	Stop delivering products to clients that exceed payment deadlines. Properly track clients payment delays.	2.20	6.00	3.60	**47.52**	8.40

Table 9: FMEA Results - Market Risks (Part 1/2)

MARKET RISKS (24)												
Phase		**Risk**	**O**	**S**	**D**	**RPN**	**Corrective actions**	**O**	**S**	**D**	**RPN**	**A**
Demand risks / Forecasting risks	**R 26**	Consumer migration (e.g. regular consumers either switching to imported cheeses or to low-quality alternatives)	5.20	5.30	4.80	**132.29**	Improve brand loyalty and brand image through quality maintenance and promotions. Continuosly monitoring pricing policy versus competition.	4.00	5.30	4.60	**97.52**	8.25
	R 27	Development of new dairy market segments by the competition	4.30	3.80		N/A	Stay up to date with relevant industry information and react accordingly.	3.90	3.40		N/A	7.60
	R 28	Incorrect/Imprecise information sharing by vendors	3.80	2.90		N/A	Improve data collection from the market.	2.80	2.70		N/A	6.70
	R 29	Data error caused by point of sales	4.10	2.70		N/A	-	3.50	2.70		N/A	
	R 30	Improper demand forecasting	5.00	5.00		N/A	Improve internal communication between the production and sales deparments. Optimize demand forecasting techniques.	3.70	4.60		N/A	7.60
	R 31	Demand fluctuation in consumer market	4.90	3.00		N/A	-	4.90	3.00		N/A	
	R 32	Reduction of demand due to to closures/restrictions caused by Covid-19	4.60	4.00		N/A	-	4.60	4.00		N/A	
Price risks	**R 33**	Price volatility of dairy suppliers	5.30	5.50		N/A	Establish contingency plan.	4.90	5.50		N/A	5.20
	R 34	Price votality of packaging suppliers	4.10	4.10		N/A		3.70	4.10		N/A	7.70
	R 35	Price volatility of fuel	6.20	4.90		N/A		5.80	4.70		N/A	4.60
	R 36	Scarcity of raw milk	3.50	7.90		N/A		3.10	7.70		N/A	5.50
	R 37	Scarcity of packaging raw materials	3.60	5.80		N/A		3.20	5.30		N/A	
	R 38	Sudden large spikes in prices of raw material due to unexpected events (e.g. Increases in prices of nitrile gloves due to increased demand during Covid-19 / Impact of Russia-Ukraine conflict on price of animal feeds).	2.70	7.00		N/A	-	2.70	7.00		N/A	

Table 10: FMEA Results - Market Risks (Part 2/2)

Competitive risks / Substitutes risks	**R 39**	Large discounts/promotions by competitors	6.50	5.70		N/A	Keep track of competitors marketing strategies and react accordingly if needed.	6.40	4.60		N/A	4.80
	R 40	Innovations by competitors (e.g. implementation of new products by competitors, implementation of new machinery)	4.50	5.10		N/A	Stay up to date with innovations by competitors and react accordingly.	4.10	4.70		N/A	4.80
	R 41	Accessibility of substitutes (plant-based dairy, cheaper low-quality alternatives, international cheeses, powdered milk alternatives, etc.)	6.70	5.20		N/A	-	6.70	5.20		N/A	
	R 42	Availability of substitutes (plant-based dairy, cheaper low-quality alternatives, international cheeses, powdered milk alternatives, etc.)	6.70	5.40		N/A	-	6.70	5.40		N/A	
	R 43	Entrants of medium to large-scaled competitors in the market	2.90	6.50		N/A	-	2.90	6.50		N/A	
	R 44	Entrants of new small-scaled competitors in the market	5.40	3.90		N/A	-	5.40	3.90		N/A	
	R 45	Ineffective promotion actvities	3.90	4.50		N/A	Improve marketing involvements. Increase promotion budget.	2.90	4.10		N/A	4.30
	R 46	Neglect of promotional activities	6.70	4.60		N/A	-	6.70	4.60		N/A	
	R 47	Lack of consistency causing decreases in quality of product and services	4.30	7.60		N/A	Verify the application of a manufacturing standard operation procedure (SOP) by employees.	2.90	7.40		N/A	8.00
	R 48	Low ability to launch new products	5.20	4.50		N/A	Continuous market research must take place. Research development opportunities for new goods and services.	4.60	4.20		N/A	5.70
	R 49	Decreased sales due to lack of customer loyalty	2.70	5.70		N/A	Improve product consistency. Listen and consider customer feedback more often. Provide personalized customer service when possible.	1.90	5.50		N/A	8.40

Table 11: FMEA Results - Sourcing Risks (Part 1/5)

SOURCING RISKS (39)												
Phase		**Failure**	**O**	**S**	**D**	**RPN**	**Corrective actions**	**O**	**S**	**D**	**RPN**	**A**
Informational risks	**R 50**	Bullwhip effect due to the lack of information or information distortion within the company	6.50	5.00		N/A	Suppliers should communicate and constantly share inventory and capacity information. Use identifcal information between different members of the supply chain,in order to properly forecast demand. Reduce time delays for the movement of goods, as well as for the circulation of information. Upstream and downsteam members of the supply should regularly interchange information about consumer demand. (Naghavi et a., 2020)	4.25	5.50		N/A	8.50
	R 51	Bullwhip effect due to the lack of information or information distortion with suppliers	5.00	4.75		N/A		3.75	5.00		N/A	8.50
	R 52	Lack of trust/reliability among different actors in the supply chain	3.75	6.00		N/A		3.00	5.50		N/A	8.50
	R 53	Lack of supply chain coordination (in reference to independent entitites working together by sharing resources and information to achieve common objectives)	4.50	4.50		N/A		4.00	4.50		N/A	8.50
	R 54	Lack of smooth data movement	5.75	4.50		N/A		3.25	4.25		N/A	8.50
	R 55	Lack of access to key information in the industry / Improper market knowledge	5.25	5.00		N/A	Ensure that your market knowledge is up-to-date	4.50	4.50		N/A	7.50
Supplier monopolies	**R 56**	Market structure whereby milk suppliers assume a dominant position in the industry	4.75	7.50		N/A	Establish vertical integration / partial vertical integration.	3.50	7.00		N/A	3.00
	R 57	Market structure whereby packaging suppliers assume a dominant position in the industry	4.25	6.50		N/A		3.25	6.00		N/A	3.00

Table 12: FMEA Results - Sourcing Risks (Part 2/5)

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Purchase of raw material	**R 58**	Lack of milk by suppliers / inability of milk suppliers to meet customer's demand	5.50	7.00		N/A	Establish contingency plan (multiple suppliers). Establish clear communication with milk suppliers.	4.75	6.50		N/A	5.75
	R 59	Lack of productivity in grazing lands for farmers	3.50	6.00		N/A	-	3.50	6.00		N/A	
	R 60	Lack of packaging materials / inability of packaging suppliers to meet customer's demand	4.75	6.50		N/A	Establish contingency plan (multiple suppliers). Establish clear communication with packaging suppliers. Keep additional inventory of packaging in storage. Keep printed and labeled raw material with your suppliers.	4.00	6.25		N/A	8.00
	R 61	Distruptions in the purchase of raw materials due to Covid-19	5.00	6.00		N/A	Establish contingency plan (multiple suppliers)	4.00	4.50		N/A	7.75
	R 62	Global increases in the price of feeds for farmers	5.00	6.75		N/A	-	5.00	6.75		N/A	
	R 63	Global increases in the price of livestock (i.e. cows and goats), causing inceases in the price of raw milk	3.50	4.50		N/A	-	3.50	4.50		N/A	
	R 64	Global increases in the price of fuel	5.50	6.50		N/A	-	5.50	6.50		N/A	
	R 65	Delays by milk suppliers, causing delays throughout the supply chain	2.75	7.75		N/A	Economic Order Quantity (EOQ) should be optimized. Get reliable suppliers.	2.00	7.75		N/A	7.50
	R 66	Delays with packaging suppliers, causing delays throughout the supply chain	5.00	7.50		N/A		4.25	7.50		N/A	7.50
	R 67	Presence of defected packaging materials due such as spots on packaging, changes in the color of the labeling, etc.	5.50	5.75	3.75	**118.59**	Get reliable suppliers. Long-term partners are advised. Staff must be trained to recognize deffected packaging material. Guarantee claim from packaging supplier for each defected product.	4.75	6.00	2.60	**74.10**	8.25

Table 13: FMEA Results - Sourcing Risks (Part 3/5)

Physical Hazards

Milking Procedure	**R 68**	The presence of foreign elements deriving from damaged equipment in the farm (pieces of metal, strand wire, cloth parts, etc.)	3.00	7.75	3.00	**69.75**	Equipments used must be in good condition. Damaged appliances must be replaced. Filtration of raw milk must be completed.	2.25	7.75	2.20	**38.36**	8.50
	R 69	The presence of hairs, mud, insects, etc. due to poor hygiene and improper farm handling	3.00	7.75	3.50	**81.38**	Both, hygiene and breeding practices, must be applied correctly. Protection of raw milk from pest must be done correctly. Filtration of raw milk must be completed.	2.50	7.75	2.60	**50.38**	8.00
	R 70	The presence of foreign bodies originating from a person handling raw milk (hair, buttons, jewelry, etc.)	2.75	7.75	3.75	**79.92**	Good hygiene must be implemented by the farmers. Adequate education of farmers handling raw milk is recommended. Farmers training of proper raw milk handling must take place.	2.00	7.75	2.20	**34.10**	7.25
	R 71	The presence of physical contaminants or small fragments from the packaging materials (e.g. containers)	2.50	7.75	3.75	**72.66**	Supplier must be reliable. The implementation of food grade materials only. Regular quality control of packaging materials.	1.75	7.75	2.80	**37.98**	8.50
Salt	**R 72**	Physical impurities from purchased salt	3.75	7.25	4.25	**115.55**	Supplier must be reliable. Periodic salt tests must take place. Each batch needs to be dissolved in water during receiving to safeguard the purity of the salt.	3.25	7.25	2.20	**51.84**	8.00
Packaging Company	**R 73**	The presence of foreign elements (hair, spots, etc.) in polypropylene boxes	3.25	8.00	3.50	**91.00**	Get reliable suppliers. Periodic assessment and control of hygiene in packaging factory must take place. Employees throughout the supply chain should be trained to detect and eliminate products containing foreign elements.	2.00	8.00	2.80	**44.80**	8.25
	R 74	The presence of foreign elements (hair, spots, etc.) in polyamide vacuum bags	5.00	8.25	4.25	**175.31**		3.75	8.25	3.00	**92.81**	8.25

Table 14: FMEA Results - Sourcing Risks (Part 4/5)

Chemical Hazards												
Milking Procedure	**R 75**	The presence of remains from veterinary drugs, such as antibiotics, hormones, growth stimulants, due to non-compliance towards recommended veterinary practices	4.25	7.50	5.75	**183.28**	Supplier must be reliable. Antibiotics analysis must be carried out for each batch with antibiotic kits. Applied medicines should be given based on commands from the veterinarian.	3.25	7.25	2.60	**61.26**	9.00
	R 76	High level of aflatoxins (or other kinds of agricultural toxins) in raw milk due to inadequate agricultural practices (including contaminated animal feed)	3.75	8.25	4.50	**139.22**	Supplier must be reliable. Aflatoxin analysis must be carried out for each batch with aflatoxin kits. The application of decent agricultural practices should be implemented. Animal nutrition should be based on authorized/verified animal feed.	2.75	8.00	4.40	**96.80**	7.50
	R 77	The presence of chemical contaminants, such as pesticides, dioxins, etc.) in raw milk or water due to inadequate agricultural practices (including contaminated animal feed)	3.75	8.25	5.50	**170.16**		2.50	8.00	4.60	**92.00**	7.50
	R 78	The presence of detergents/disinfectants in raw milk due to improper washing and rinsing	3.50	8.25	5.00	**144.38**	The implementation of certified agents for washing and disinfection should take place (follow instructions) Proper rinsing must be done.	2.50	7.75	5.00	**96.88**	9.00
	R 79	The migration of chemicals from the packaging materials to the raw milk	3.25	8.50	5.25	**145.03**	Supplier must be reliable. The implementation of food grade materials only must take place. Regular quality control of packaging materials must take palce by getting migration lab results at the Industrial Research Institute (IRI).	2.00	8.00	3.80	**60.80**	8.00
	R 80	Chemicals residues in raw milk due to adulteration of raw milk (such as alkaline addition)	2.97	7.92	4.62	**108.67**	Supplier must be reliable. Alkaline analysis must be carried out for each batch.	2.31	7.59	2.80	**49.09**	7.92

Table 15: FMEA Results - Sourcing Risks (Part 5/5)

Biological Hazards													
Milking Procedure	**R 81**	Contamination with a significant amount of pathogenic microorganisms (E. coli, Salmonella spp., Mb. tuberculosis, Shigella dysenteria, Listeria monocytogenes, Staphylococcus aureus, etc.) due to improper milk handling	4.50	9.00	6.75	**273.38**	Milk supplier must be reliable. Periodic veterinary control must take place. Immediate cooling below 5 degrees Celcius is required upon receiving and throughout the cold chain. Control for pH and acidity must be done for each batch. Periodic pathogen analysis must be done.	3.00	9.00	4.40	**118.80**	8.25
	R 82	Contamination of raw milk by pathogenic microorganisms in the equipment due to usage of contaminated water	4.00	8.50	5.75	**195.50**	Periodic control of water quality. Proper washing of the used equipment.	2.50	8.25	3.80	**78.38**	8.75
	R 83	Contamination of raw milk by pathogenic microorganisms in the equipment due to inadequate cleaning procedures.	4.50	8.00	4.25	**153.00**	Proper staff training must be in place.	3.00	8.00	4.00	**96.00**	9.00
	R 84	Contamination of raw milk by pathogenic microorganisms in the equipment due to poor storage conditions of washed equipment (including utensils such as measuring cups, blades, etc.).	4.25	8.50	3.25	**117.41**	Proper cleaning procedure must be applied. The storage room for milk-contacted equipment must remain clean.	3.00	8.50	3.00	**76.50**	8.25
	R 85	Contamination of raw milk by pathogenic microorganisms due to farmer unhealthiness	3.25	8.00	5.25	**136.50**	Education of farmers handling raw milk is recommended. Proper hygiene protocols should be in place. Workers with signs of illness should not be allowed in the farm.	2.25	8.00	4.20	**75.60**	8.00
	R 86	Raw milk contamination due to migration from the packaging materials	3.50	8.00	4.00	**112.00**	Supplier must be reliable. Periodic microbiological analysis must be carried out (swab controls) for verification	2.75	8.00	3.20	**70.40**	6.50
	R 87	Microbiological contamination from purchased salt	3.50	8.00	4.50	**126.00**	Supplier must be reliable. Periodic microbiological analysis should be in place.	3.00	8.00	3.40	**81.60**	6.75
	R 88	Presence of parasites (Protozoa – Cryptosporidium spp., etc.) in raw milk from contaminated animal sources (water/food)	2.75	8.75	5.25	**126.33**	Periodic parasite analysis must take place. Periodic veterinary controls should take place in the farms.	2.50	8.75	3.20	**70.00**	7.25

Table 16: FMEA Results - Process Risks (Part 1/7)

PROCESS RISKS (47)													
Phase		**Failure /cause**	**O**	**S**	**D**	**RPN**	**Corrective actions**	**O**	**S**	**D**	**RPN**	**A**
Power failures	**R 89**	Power failures in the factory	6.40	7.50		N/A	Use private generators to cover electricity interruptions.	1.50	7.50		N/A	9.10
Health of Workers	**R 90**	Illness of factory workers	3.00	3.90	3.00	**35.10**	Establish contingency plan for unexpected absence of employees (appropriate replacement). Periodically undergo health tests on employees.	2.60	3.10	2.60	**20.96**	8.40
	R 91	Minor injury (painful accdient that does not threaten your life, mobility or long-term survival) due to machinery or equipment used by factory workers	3.60	3.80		N/A	Rigourous abidance to the company's policy and rules on safety (such as the use of protective gloves, if needed)	2.80	3.50		N/A	8.90
	R 92	Major injury (could potentially lead to death, prolonged disability or permanently diminished quality of life) due to machinery or equipment used by factory workers	1.40	7.40		N/A		1.20	7.40		N/A	8.90
Labor Issues	**R 93**	Labor strikes by factory workers	2.50	6.10		N/A	Provide a friendly working environment. Recognize and incentivize staff efforts. Maintain open-door policy.	1.40	6.10		N/A	7.90
	R 94	Labor strikes by employees outside the factory (administrative, distribution, etc.)	2.20	6.10		N/A		1.40	6.10		N/A	7.90
Fire Risks	**R 95**	Fire occuring in the factory	1.00	8.60		N/A	Implement fire alarm systems. Get fire insurance.	1.00	7.90		N/A	4.10

Table 17: FMEA Results - Process Risks (Part 2/7)

Packaging	**R 96**	Absence or error in production/expiry date of finished goods	4.50	7.20	3.50	**113.40**	Proper staff training must take place.	3.60	7.20	2.80	**72.58**	8.80
	R 97	Production/Expiry date unclear on packaging	5.10	6.30	4.20	**134.95**	Proper ink maintenance must take place. Packaging must be completely dried out on the outside when adding expiry dates.	3.70	6.30	3.00	**69.93**	8.30
Internal Transportation	**R 98**	Imroper wrapping by vaccuum machine	4.70	4.60	2.80	**60.54**	Proper vacuum machine setting must be used at all times. Proper sanitization of machinery must take place.	4.10	4.60	2.60	**49.04**	9.00
	R 99	Damage of goods during transportation of goods in the factory due to mishandling	2.80	5.00	3.40	**47.60**	Proper staff training must take place.	2.00	5.00	2.60	**26.00**	8.20
	R 100	Interruption of cold chain for long periods during loading and unloading of goods in the factory	6.40	6.20	3.50	**138.88**		3.90	6.20	3.20	**77.38**	8.20
Machine Breakdowns	**R 101**	Machine requiring maintenance due to wear and tear	6.90	4.10	3.50	**99.02**	Get good quality machinery.	5.90	4.10	3.20	**77.41**	7.40
	R 102	Complete breakdown of machinery, causing the purchase of a whole new machine	3.70	7.40	1.00	**27.38**	Keep overhaul kits allowing to fix minor issues with the machinery.	2.70	7.40	1.00	**19.98**	7.40

Table 18: FMEA Results - Process Risks (Part 3/7)

Physical Hazards (1 of 2)

Coagulation	**R 103**	The presence of external elements (such as insects, glass, metal parts, hair) in utensils	3.00	8.60	3.40	**87.72**	The use of glass materials must be avoided. Protection from insects must take place in the factory. Proper hygiene for the workers is required.	2.20	8.60	3.00	**56.76**	9.00
Curd Treatment	**R 104**	The presence of external elements (such as strains of hair, buttons, jewelry) from the worker who cuts curd into slices	3.90	8.60	3.80	**127.45**	Proper hygiene must be in place. The use of protective gears such as gloves, masks, arm sleeves, and hairnets must always be in place.	2.40	8.60	3.00	**61.92**	9.00
Salting	**R 105**	The presence of external elements in salt	4.30	8.50	3.10	**113.31**	Reliable and certified salt supplier is required.	3.30	8.50	3.40	**95.37**	7.90
	R 106	Lack of consistency in salt quantities and moisture content (optimum at 39%)	5.60	5.20	4.50	**131.04**	Proper staff training must take place. Salt measurement should regularly take place.	4.20	4.80	3.80	**76.61**	7.80
Internal Transportation	**R 107**	The presence of external elements (such as glass, metal, hair, dust, insects) due to poor vehicle hygiene	2.60	9.00	2.60	**60.84**	Constant vehicle hygiene check-ups must be done. The use of confined boxes is recommended.	1.60	9.00	2.80	**40.32**	7.50
Packaging	**R 108**	The presence of external elements (such as glass, metal, hair, dust, insects) orginating from packaging suppliers	3.90	8.40	3.40	**111.38**	Quality control of packaging materials must be done periodically.	2.90	8.40	3.20	**77.95**	7.20
Cleaning Procedure	**R 109**	The presence of external elements from cleaning materials, such as sponge parts.	2.80	8.60	3.60	**86.69**	Replace worn out cleaning material.	1.60	8.60	3.80	**52.29**	7.30

Table 19: FMEA Results - Process Risks (Part 4/7)

Physical Hazards (2 of 2)													
Factory Environment	**R 110**	Rusty metal particles from the air ventilation system in the factory	3.60	6.10	4.90	**107.60**	Periodical maintenance and control of ventilation system must take place. The use of stainless steel is highly recommended in the production area.	2.60	6.10	3.00	**47.58**	8.20
	R 111	Physical contamination from torn or damaged filtration equipment	3.50	7.40	3.50	**90.65**	Replace damaged filtration equipement when needed.	2.50	7.40	3.60	**66.60**	8.80
	R 112	Physical contamination originating from the use of damaged equipments	3.50	7.60	3.00	**79.80**	Replace old/damaged equipment when needed.	2.80	7.60	2.60	**55.33**	8.10
	R 113	Entry of unfiltered air in the production area	5.60	4.90	4.50	**123.48**	Installation and control of proper positive pressure ventilation systems.	3.70	4.90	4.00	**72.52**	8.80
	R 114	Entry of insects, flies, dust, debris in the production area	5.50	7.50	3.40	**140.25**	Installation and control of air curtains for each door giving access to the production area. Installation of fly traps in all production area.	3.60	7.50	3.20	**86.40**	9.00
	R 115	Entry of rodents in the production area	2.40	8.50	2.00	**40.80**	Installation and replacement of mouse traps in all possible entries. Spraying all the gutters with food-approved pesticides.	1.20	8.50	2.00	**20.40**	8.50

Table 20: FMEA Results - Process Risks (Part 5/7)

Chemical Hazards													
Coagulation	**R 116**	Contamination due to faulty storage of cleaning and disinfecting products	3.70	7.20	4.70	**125.21**	Proper and regular cleaning and disinfection must be done. Cleaning products must remain isolated from milk.	2.60	7.20	4.80	**89.86**	9.00
Curd Treatment	**R 117**	The presence of mycotoxins (naturally occuring toxins produced by mold development) due to poor hygiene of the pressing table	4.00	8.34	3.66	**122.10**	Proper cleaning and disinfection of pressing table must be done.	2.66	8.34	3.20	**70.99**	8.56
Salting	**R 118**	Chemical contamination due to the presence of heavy metals (such as mercury, lead, arsenic, etc.) in salt	3.20	8.10	4.40	**114.05**	Salt needs to be purchased from reliable verified suppliers	2.00	8.10	4.40	**71.28**	8.50
Packaging	**R 119**	Chemical contamination from hand sanitizers that are placed close to the packaging lines	3.50	6.70	4.00	**93.80**	Proper training is required. Hand sanitizers must be located away from the packaging lines	1.60	6.90	4.20	**46.37**	8.80
	R 120	Chemical contamination due to the use of empty food containters to store chemicals (can occur due to mistakes such as mislabeling of factory containers)	2.90	7.00	3.40	**69.02**	Proper handling and labeling training is required. Label control must be done on a regular basis. Foods and chemicals must be kept apart at all times.	1.70	7.00	3.00	**35.70**	8.60
Water Addition	**R 121**	Residues of chemical contaminants from water (inclduing heavy metal, such as arsenic, antimony, boron, cadmium, chrome, copper, lead, mercury)	4.40	8.60	4.10	**155.14**	Proper water filtration must take place. Periodic analysis must be carried out for verification (ISO requirement).	2.80	8.60	4.00	**96.32**	8.40
	R 122	Nitrite/Nitrate contamination from water	2.60	8.40	6.10	**133.22**		1.50	8.40	3.60	**45.36**	8.40

Table 21: FMEA Results - Process Risks (Part 6/7)

Biological Hazards (1 of 2)													
Coagulation	**R 123**	Improper washing causing the presence of remains from previous production in coagulation vats.	4.20	8.60	3.40	**122.81**	Proper washing and rinsing must take place. Proper staff training must take place. The application of potable water is recommended.	2.20	8.60	2.80	**52.98**	9.00
Adding Starter Culture and Rennet	**R 124**	Microbiological contomination due to mishandling during the addition of culture and rennet	3.00	8.10	3.80	**92.34**	Proper hygiene training must take place	2.20	8.00	3.20	**56.32**	9.00
Curd Treatment	**R 125**	Microbiological contamination due to unhygienic cutting equipment	4.00	7.90	3.40	**107.44**	Proper cleaning of cutting equipment must be done after each use.	2.20	7.90	3.60	**62.57**	9.00
	R 126	Microbiological contamination due to unhygienic manual manipulation	4.20	7.60	3.60	**114.91**	Employees have to maintain proper hygiene. Employees with signs of illness should not be allowed to work with food.	2.90	7.60	4.00	**88.16**	7.90
	R 127	Microbiological contamination due to unhygienic utensils used (such as strainer, spoon and cloths)	4.20	7.80	3.40	**111.38**	Employees have to regularly clean and disinfect utensils. Employeees have to use a new cheese cloth after each use.	2.90	7.80	3.60	**81.43**	9.00
	R 128	Mold development due to poor hygiene of pressing table	3.90	7.40	3.60	**103.90**	Proper disinfection of pressing table must be done. Mold testing should be periodically done.	2.50	7.40	3.40	**62.90**	8.50
Incubation	**R 129**	Growth of pathogens due to inappropriate incubation temperature	3.90	8.20	3.80	**121.52**	Proper temperature management of incubation period must take place through proper staff training.	1.80	8.20	3.60	**53.14**	8.90

Table 22: FMEA Results - Process Risks (Part 7/7)

Biological Hazards (2 of 2)													
Water Addition	**R 130**	Pathogenic microorganisms / Parasites in water	2.70	8.80	7.70	**182.95**	Periodic microbiological analysis must take place. Microbiological treatment must be applied to water by using chemical agents like chlorine, ozone or UV based systems.	1.90	8.20	3.40	**52.97**	7.90
Factory Environment	**R 131**	Contamination due to air coming from the ventilation channels	4.20	6.20	6.70	**174.47**	Positive pressure ventilation systems must be used. Periodical maintenance of ventilation system control is needed.	1.70	6.20	4.60	**48.48**	7.50
Factory Environment	**R 132**	Growth of mold due to improper removal of moisture in production area	4.90	8.10	3.20	**127.01**	Use proper disinfectants (specialized for mold) on all surfaces (stainless tables, refrigerated area, walls, ceilings).	3.10	8.10	2.60	**65.29**	9.00
Unsealed Covers	**R 133**	Contamination due to unsealed container covers	3.90	7.90	3.60	**110.92**	Proper staff training and control must take place.	2.40	7.90	3.00	**56.88**	9.00
Procedure Consistency	**R 134**	Microbial growth due to inconsistency in abiding to procedure instructions (i.e. time spent on each procedure, required temperature for each procedure, etc.)	4.90	7.70	4.70	**177.33**	Proper control must take place. Inner temperature of tanks must regularly be measured. Thermometers used must be calibrated on a regular basis.	3.00	7.90	3.80	**90.06**	8.00
Procedure Consistency	**R 135**	Microbial growth due to prolonged gap in time between successive processes	3.60	7.80	3.00	**84.24**	Verify the application of a manufacturing standard operation procedure (SOP) by employees.	2.30	7.80	2.00	**35.88**	8.00

Table 23: FMEA Results - Logistics Risks (Part 1/3)

LOGISTICS RISKS (32)												
Process		**Risk**	**O**	**S**	**D**	**RPN**	**Corrective actions**	**O**	**S**	**D**	**RPN**	**A**
Lead time	**R 136**	Long lead times with milk suppliers	2.25	6.38		N/A	Get reliable suppliers. Set up contingency plan for suppliers.	1.25	6.38		N/A	7.75
	R 137	Long lead times with packaging suppliers	5.38	7.25		N/A		4.38	6.75		N/A	7.75
	R 138	Significant variability in lead time with milk suppliers	2.00	4.88		N/A		1.50	4.88		N/A	7.75
	R 139	Significant variability in lead time with packaging suppliers	5.38	5.25		N/A		4.25	5.25		N/A	7.75
Reception (Raw Materials and Semi-Finished Goods)	**R 140**	Delays in handling/reception of milk, causing rises in temperature	2.63	5.50		N/A	Set up contingency plan for suppliers. Improve communication with suppliers.	1.63	5.00		N/A	7.63
	R 141	Reception of damaged goods	3.00	3.13		N/A	Work with reliable suppliers.	2.00	3.00		N/A	7.63
	R 142	Reception of an irregular/wrong product	3.25	3.25		N/A		2.25	3.00		N/A	7.63
	R 143	<u>Biological hazard:</u> Presence of spoilage microorganisms in milk due to improper handling during receiving period (e.g. development of unpleasant odors, tastes, and textures)	4.38	7.63	5.38	**179.31**	Supplier must be reliable. Cold chain must be kept from farm to receiving. Biologicial testing must take place upon reception of milk.	2.75	7.63	3.80	**79.68**	7.63
Storage (WIP and Finished Goods)	**R 144**	Lack of sufficient products in storage compared to demand	4.75	5.38		N/A	Improve deamand forecasting.	3.38	5.25		N/A	7.63
	R 145	Excess of products in storage compared to orders (causing waste in inventory)	3.75	5.00		N/A		2.88	4.75		N/A	7.63
	R 146	Product placed in wrong storage location	3.00	3.13		N/A	Proper staff training must take place.	1.75	3.13		N/A	7.63
	R 147	Products stacked in an improper manner	4.00	3.75		N/A		3.25	3.75		N/A	7.63
	R 148	Malfunction of refrigirated storage rooms	2.38	8.13	4.50	**86.84**	Keep track of datalogger to control temperature management.	2.38	7.00	2.40	**39.90**	8.25
	R 149	Biological Hazard: Growth of pathogens and spoilage microorganisms due to improper storage room temperature and improper hygienic conditions	4.13	8.38	3.50	**120.91**	Proper training and refrigiration control must take place.	2.75	8.13	3.20	**71.50**	8.88
	R 150	Products that are still in storage and that are either near-expiry or have reached their expiry dates	4.88	5.88	4.13	**118.14**	Proper implementation of the first-in-first-out (FIFO) rule in storage rooms. Storage rooms must remain organized at all times.	3.50	5.75	3.00	**60.38**	7.50

Table 24: FMEA Results - Logistics Risks (Part 2/3)

Dispatch (movement of products from cold storage rooms to trucks)	**R**	**151**	Excessively long truck loading times causing delays in the distribution to clients	3.25	3.50		N/A	Provide suitable supervision for truck loading.	2.00	3.50		N/A	6.88
	R	**152**	Errors in loading quantities	4.50	2.25		N/A	Communicaton between the transportation team and and the factory team must be improved.	3.75	2.25		N/A	7.75
	R	**153**	Uncertain product temperatures before loading into trucks.	5.75	5.88	3.00	**101.34**	Check cold room temperature before loading. Measure product temperatures before loading. Products must be kept at a minimal time between storage and trucks.	4.00	5.75	2.60	**59.80**	8.13
	R	**154**	Loading of damaged products	4.13	5.00	3.75	**77.34**	Proper staff training must take place to identify damaged goods before loading phase.	3.13	5.00	3.20	**50.00**	7.63
	R	**155**	High temperature of truck refrigeration box prior to loading	5.75	5.13	3.25	**95.77**	Precooling of truck must take place prior to loading (if the vehicle was emplty and turned off).	3.50	5.13	3.20	**57.40**	8.25

Transportation of products (from the factory to the clients) - Part 1	**R**	**156**	Absence of truck drivers due to illness	2.63	6.25		N/A	Establish truck driver absence contingency plan (either replacement or postponement of delivery).	2.63	4.88		N/A	6.75
	R	**157**	Absence of truck drivers due to labor strikes	2.25	7.00		N/A	Recognize and incentivize driver efforts.	1.25	7.00		N/A	7.88
	R	**158**	Damaged products due to incorrect loading technique by workers (affected by potholes or sudden movements by the truck driver)	4.38	4.00		N/A	Proper staff training must take place.	3.00	4.00		N/A	9.00
	R	**159**	Truck breakdown	4.38	5.63		N/A	Proper vehicle maintenance must be applied. If the issue could not be fixed rapidly, a nearby active truck or a nearby idle (used for emergencies) truck should collect and refrigerate the products immediately.	2.88	5.63		N/A	8.63
	R	**160**	Products temperature loss due to unloading delays at delivery	5.25	5.38		N/A	Streghten communication and operation management with clients.	4.25	5.00		N/A	6.13

Table 25: FMEA Results - Logistics Risks (Part 3/3)

Transportation of products (from the factory to the clients) - Part 2	**R 161**	Physical hazard: Presence of foreign materials from the transferring equipments (containers, carton boxes, plastic boxes, rackable boxes, truck equipement, etc.)	2.25	6.75	3.50	**53.16**	Proper cleaning procedure must be applied. The sanitary conditions of the equipments must be controlled regularly.	1.25	6.75	3.00	**25.31**	9.00
	R 162	Biological hazard: Microbial contamination due to poor vehicle hygiene	2.25	7.13	4.38	**70.14**	Proper maintenance of vehicle hygiene must be done.	1.00	7.13	3.60	**25.65**	8.25
	R 163	Biological hazard: Microbial contamination due to inappropriate temperatures in the trucks without the knowledge any employee	4.13	7.13	4.00	**117.56**	Cold chain must be maintained throughout every stop in the distribution. Establish real-time temperature and alarm system.	2.50	7.38	2.60	**47.94**	4.50
	R 164	Biological hazard: Microbial contamination due to the simultaneous transportation of different types of food	1.75	7.50	3.00	**39.38**	Physical separation of different types of food must be done at all times.	1.13	7.50	2.60	**21.94**	9.00
Sales	**R 165**	The presence of expired or nearly expired products on supermarket shelves	6.63	5.13	5.63	**190.99**	Staff should regulary search and return nearly expired products from supermarkets.	3.88	5.13	3.00	**59.58**	6.88
	R 166	Clients not providing 24/7 cooling to their refrigerators	4.50	8.25	6.50	**241.31**	Regular refrigeration control must take place.	3.25	8.25	4.80	**128.70**	6.38
Return of goods	**R 167**	Contamination due to the faulty mixture between returned unsold goods with fresh goods	3.00	6.88	4.50	**92.81**	Proper staff training must take place. Damaged/Expired products that are being returned from the retailers need to be properly seperated from fresh products that are being sold at all times.	1.75	7.00	4.20	**51.45**	9.00

Table 26: FMEA Results – Regulatory Risks (Part 1/2)

Regulatory Constraints (24)													
		Risk	O	S	D	RPN	Corrective actions	O	S	D	RPN	A
Water Used (Libnor Standards)	**R 168**	Arsenic (As): Above Maximum Allowable (0.5 mg/kg)	2.00	8.65	X	N/A	Periodically undergo laboratory testing for water used and react accordingly if needed.	1.35	8.65	X	N/A	7.65
	R 169	Copper (Cu): Above Maximum Allowable (2.0 mg/kg)	2.00	8.65	X	N/A		1.00	8.65	X	N/A	7.65
	R 170	Lead (Pb): Above Maximum Allowable (2.0 mg/kg)	2.65	9.00	X	N/A		1.65	9.00	X	N/A	7.65
	R 171	Cadmium (Cd): Above Maximum Allowable (0.5 mg/kg)	2.00	8.65	X	N/A		1.00	8.65	X	N/A	7.65
	R 172	Mercury (Hg): Above Maximum Allowable (0.1 mg/kg)	2.35	8.65	X	N/A		1.35	8.65	X	N/A	7.65
Bacteriology Report for Dairy Products (Libnor Standards)	**R 173**	Staphyllococcus aureus above allowable standards (100 cfu/g)	2.65	8.30	X	N/A	Periodically undergo laboratory bacteriology testing for all products. In case of non-conformity witht the norms, the source of the problem needs to be tracked and handled instantly.	1.65	8.30	X	N/A	8.50
	R 174	Total coliforms above allowable standards (1,000 cfu/g)	3.70	7.15	X	N/A		2.35	7.00	X	N/A	8.50
	R 175	Eshirichia coli above allowable standards (100 cfu/g)	3.00	8.30	X	N/A		2.00	8.30	X	N/A	8.50
	R 176	Salmonella above allowable standards (0 cfu/g)	1.35	8.30	X	N/A		1.00	8.30	X	N/A	8.50
	R 177	Listeria monocytogenes above allowable standards (0 cfu/g)	1.85	8.30	X	N/A		1.35	8.30	X	N/A	8.50
	R 178	Anaerobic-sulfite reducing barcteria above allowable standards (1,000 cfu/g)	1.75	8.00	X	N/A		1.50	8.00	X	N/A	8.75
	R 179	Yeasts & Moldsabove standards (1,000 cfu/g)	4.35	5.25	X	N/A		3.35	5.25	X	N/A	8.50
	R 180	Intestinal Enterococci above allowable standards (1,000 cfu/g)	2.00	8.20	X	N/A		1.00	8.20	X	N/A	8.60

Table 27: FMEA Results - Regulatory Risks (Part 2/2)

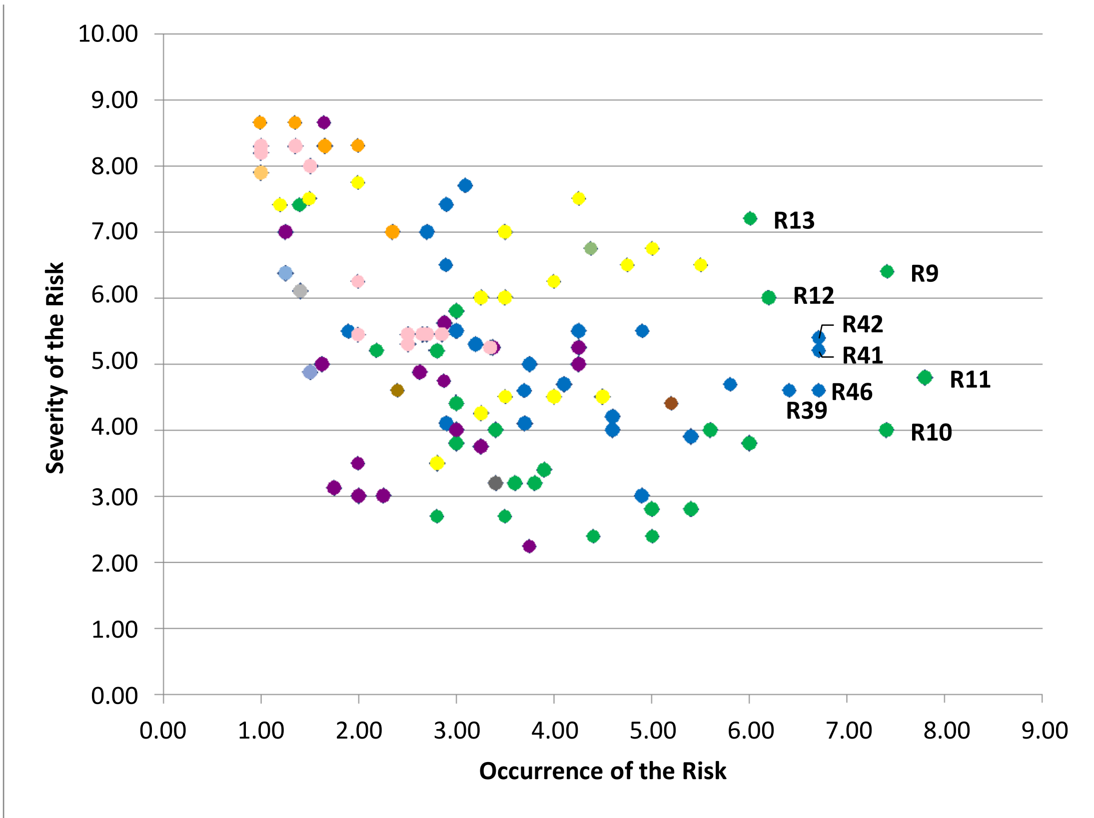
Chemical and Physical Report for Dairy Products (Libnor Standards)	**R 181**	Fat content deos not match nutrition label of product - Method: AOAC 933.05	3.85	5.30		N/A	Periodically undergo laboratory chemical and physical testing for all products. In case of non-conformity witht the norms, the source of the problem needs to be tracked and handled instantly.	2.50	5.30		N/A	8.50
	R 182	Protein does not match nutrition label of product - Method: AOAC 930.29	3.35	5.45		N/A		2.70	5.45		N/A	8.50
	R 183	Total solids does not match nutrition label of product - Method: AOAC 925.23A	3.35	5.45		N/A		2.70	5.45		N/A	8.50
	R 184	Ash content does not match nutrinion label of product - Method: AOAC 945.46	3.00	6.25		N/A		2.00	6.25		N/A	8.25
	R 185	Moisture conent should match nutrition label of product - Method: AOAC 925.23A	3.85	5.45		N/A		2.65	5.45		N/A	8.50
	R 186	Carbohydrates (including sugars and fibers should match nutrition label of products	3.35	5.45		N/A		2.00	5.45		N/A	8.50
	R 187	Calorific value should match nutrition label of products	3.35	5.45		N/A		2.00	5.45		N/A	8.50
	R 188	Sodium (Na) should match nutrition label of products - Method: Ion chromatography	3.85	5.45		N/A		2.50	5.45		N/A	8.50
	R 189	Calcium (Ca) should match nutrition label of products Method: Ion chromatography	4.20	5.45		N/A		2.85	5.45		N/A	8.50
	R 190	Chlorides (NaCl) should match nutrition label of products	3.85	5.45		N/A		2.50	5.45		N/A	8.50
	R 191	The amount of liquid present in the vacuum-packaged exceeds Libnor standards (15% of the product weight).	3.70	5.45		N/A	Proper drying procedure in the cheese pressing phase.	2.70	5.45		N/A	8.15

After assembling the collected data, we organized it into two separate sections (green and red). Below, is a concise overview of the results of both sections.

Table 28: Top 10 Highest RPN

		O	S	D	RPN	O	S	D	RPN	A
1	R 24	7.20	7.40	4.20	**223.78**	6.00	7.00	3.20	**134.40**	3.80
2	R 166	4.50	8.25	6.50	**241.31**	3.25	8.25	4.80	**128.70**	6.38
3	R 81	4.50	9.00	6.75	**273.38**	3.00	9.00	4.40	**118.80**	8.25
4	R 26	5.20	5.30	4.80	**132.29**	4.00	5.30	4.60	**97.52**	7.30
5	R 78	3.50	8.25	5.00	**144.38**	2.50	7.75	5.00	**96.88**	9.00
6	R 76	3.75	8.25	4.50	**139.22**	2.75	8.00	4.40	**96.80**	7.50
7	R 121	4.40	8.60	4.10	**155.14**	2.80	8.60	4.00	**96.32**	8.40
8	R 83	4.50	8.00	4.25	**153.00**	3.00	8.00	4.00	**96.00**	9.00
9	R 105	4.30	8.50	3.10	**113.31**	3.30	8.50	3.40	**95.37**	7.90
10	R 74	5.00	8.25	4.25	**175.31**	3.75	8.25	3.00	**92.81**	8.25

Figure 3: Results of 2x2 Matrix



Green: Economic Risks
Blue: Market Risks
Yellow: Sourcing Risks
Purple: Process Risks
Orange: Logistics Risks
Pink: Regulatory Risks

As we can see, the risk with the highest RPN is R24, an economic risk, concerning clients exceeding payment deadlines. The main reason behind such risk getting the highest RPN is directly related to the hyperinflation by the country since late 2019. The norm payment terms between companies and retailers involved retailers paying between 30 and 60 days after the end of each month. It is important to note that for a dairy company, their model consists of high turnover and low profit margin per item. The rate of the Lebanese pound to the US Dollar increased in a month by over 10% on numerous occasions from 2019 till 2023. According to lirarate.org, the LBP/USD rate has even increased by over 20% in from the beginning to the end of a month on several occasions, such as:

- June 2020: Estimated from 4180 to 9200 (120%);
- March 2021: Estimated from 9760 to 12700 (30%);
- June 2021: Estimated from 12987 to 17193 (32%);
- October 2021: Estimated from 17462 to 20916 (20%);
- November 2021: Estimated from 20916 to 24750 (23%)

Considering this scenario accompanied by the low profit margins implemented by the company and the industry, payments that were not done on the same day would provoke large monetary losses to the company.

As inflation exponentially and continuously increased, it became imperative for the payment terms to shorten. The company's policy on payment delays had to change due to this unique circumstance. Prior to the crisis, the company only had around 20% of their clients paying either before or the moment of reception. This number has increased to around 70% of their clients by the end of 2022. While it is easier to convince smaller clients to pay in cash at the moment of reception of goods, larger retailers tend to be reluctant of such change. Hence, negotiations had to take place individually for each clients, as the company attempted to reduce all delays by as much as possible.

The second highest risk is R166, a risk that occurs at the point of sale involves clients not providing continuous cooling to their refrigerators. Although, this risk has historically been a rare occurrence, the economic crisis has caused the risk to become more frequent. This scenario may include retailers engaging in unethical practices by cutting off electricity for a few hours at night to reduce cost, leading to inadequate refrigeration, and ultimately the spoilage of the company's product. It can also entail scenarios whereby the retailer's refrigerators either malfunction or fail to retain the optimal cooling conditions (between 2 and 4 degrees Celsius), which is highly problematic considering the high sensitivity of dairy products to poor refrigeration. In order to tackle this problem, it is essential to mitigate the risk by implementing regular refrigeration control. According to the data collected, the corrective action decreased the RPN from 241.31 to 128.70, with an application rate of 6.38. The high severity (8.25) attributed to this risk is not only related to the negative health impact, such risk might have on the end-user, but it is also related to the substantial concern that end-users might purchase the perished goods and inaccurately attribute the spoilage to the dairy company rather than the inadequate refrigeration practices applied by the resellers. This misattribution could ultimately negatively impact the brand image of the company and could also cause the loss of loyal customers. The reason behind the relatively low application rate (6.38) is because the company provides the drivers with thermometers that can be taken if there are any suspicions on specific clientele. However, as this serious issue has become relatively more frequent, we recommend providing each driver with his own thermometer, allowing them to undertake mandatory periodic refrigeration control to all their clients. The control of the client's refrigerators will enable the company to monitor and to better evaluate the temperature conditions of all point of sales. By doing so, they will be able to recognize any divergences from the optimal cooling levels and work collaboratively with the retailers to fix this issue. This proactive solution supports the company's commitment to providing high-quality products and accentuates the company's dedication concerning the well-being of the end-user.

The third highest risk is R81, which is a sourcing risk concerning purchased raw milk. The risk involves contamination of raw milk with pathogenic microorganisms due to improper milk handling. Unlike, R24 and R166, that are heavily correlated with the distinct challenges of the economic situation, we believe that this risk draws on commonalities shared with all dairy companies around the world. The main reason behind the high severity (9.00) of R81 is that the microorganisms may cause significant health hazards to the end-users, such as gastrointestinal infections, some of which can be life-threatening. Compared to all other health hazards with high severity that were analyzed, R81's health issues got a relatively higher occurrence (3.0) in the dairy industry**.** In accordance to the literature and our results on regulatory risks, the company's findings attribute the most common pathogenic microorganisms, as E-Coli, Listeria monocytogenes, Staphylococcus Aureus. First, E-Coli O157:H7, a specific strain of Escherichia coli, could occur during the milking process either from the cow's udder, or from improper milking hygiene, such as inadequate cleaning of milking equipment or contaminated water sources. Second, the germ listeria monocytogenes is bacterium commonly found in the soil and in the water that can cause Listeriosis, which is a serious infection to humans. The main reason for the concern of this specific germ is due to its ability to survive and even multiply at low temperatures. Third, Staphylococcus aureus, a bacterium that can be found on human skin, can also occur due to poor hygiene. However, such microorganisms, unlike the others mentioned, can generate heat-stable toxins that might resist the high temperatures during pasteurization. Moreover, our results concerning LIBNOR standards, have shown that extremely rarely does a product exceed the standards provided by the company. Among the studied bacteria and microorganisms with high levels of severity, we have found that staphylococcus aureus (R173), total coliforms (R174), Escherichia coli (R175) are the ones that most commonly occur. Although less common in the dairy industry, salmonella (R176) and listeria (R177) can still be found in dairy products. It is important to note that these pathogens can cause serious illness in humans. While salmonella tends to be associated with raw milk, listeria can survive and grow in refrigerated environments. As opposed to the previously mentioned pathogenic microorganisms, yeast and molds (R179) do not pose similar severity in health risk to the end-user. However, their presence in the end-product is certainly unfavorable as they would lead to decreased product quality and reduced shelf life. Although pasteurization is considered to be one of the most effective procedures in eradicating contamination through biological hazards, it is essential for any dairy company to have a comprehensive set of corrective actions to mitigate the risk of such contaminations. For instance, ensuring that the milk suppliers, are trustworthy and consistent with the quality of raw milk. Moreover, the farmers need to follow strict hygiene and safety standards in order to avoid any contamination at the source. Furthermore, we advise periodic veterinary control, in order to evaluate the condition of the animals, hence identifying initial contamination. Also, continuous refrigeration of milk at optimal temperatures throughout the entire supply chain is fundamental to tackle the issue of bacterial growth and pathogen proliferation. In addition, monitoring the acidity (pH) of each batch of milk at reception would assist in controlling and detecting any nonconformities that might suggest the occurrence of milk contamination. Plus, regularly undergoing pathogen analysis on raw milk could provide a layer of safety, improving detection (D) of any potential issues.

Furthermore, we have noted that R163, a risk, with a RPN that decreases from 117.56 to 47.94, has a relatively low application rate (4.50). This risk is a logistics-related risk, that refers to microbial contamination due to improper temperatures in the trucks without the knowledge of any employee. The corrective measure provided includes high emphasis on maintaining the cold chain throughout the supply chain, but more specifically establishing real-time temperature systems, as well as alarm systems. The company provides a beneficial strategy by installing a thermometer screen next to the driver seat that consistently displays the temperatures within the box of each truck. As a safety measure, all company drivers are currently required to regularly monitor this screen. However, the application of a an alarm system is still absent. This issue mainly manifests itself when a truck's refrigeration malfunctions, as there is no immediate alert to notify an employee about the situation. Notably, during transportation to the clients, the driver frequently stops and opens the box of the truck, allowing for repeated temperature inspections. Therefore the alarm-system becomes more beneficial during periods of idleness, when there is an absence of personnel overlooking the temperatures of trucks. We believe, that although truck temperature monitoring has always been a priority for the company, there still is room for improvement by enhancing its procedures and integrating such alarm-system. We advise the latter to be activated when the temperature of the box surpasses a critical threshold, such as 10 degrees Celsius, provoking an appropriate corrective action, ultimately safeguarding the quality of the products.

According to the 2x2 matrix, our results have shown that R9, R10, R11, R12, and R13 are among the most threatening risks. These risks all interconnected and aggravated by the looming economic crisis. The mutual theme among the selected risks is the evident inflation of the Lebanese Pound, causing a lack of financial stability through significant and continuous fluctuations in the value of the currency (R13). The decrease in the value of the Lebanese Pound against the US Dollar has cascading consequences, such as the increase in the prices of basic supplies that are required for the company's day-to-day operations (R10). In order for the company to cope with the rising costs associated with the chronic inflation, they have to increase pricing as well (R11). As pricing increases and as the currency loses value, the purchasing power of the end-user decreases, resulting in the decline in sales revenue (income equivalent in US Dollars) for the company (R9). Even though these risks are nation-wide, and are not directly related to the company nor the dairy industry, it is essential to reduce the impact of these interconnected risks by reducing their impact; hence a proactive mitigation strategy needs to take place. The most effective approach in this situation is to minimize holdings of currencies that are constantly vulnerable to inflation, in this case the Lebanese Pound. Therefore, it is critical to convert any excess funds into a more stable foreign currency, the US Dollar in this case, since the Lebanese financial sector is considered to be dollarized. In addition, proper tracking of currency fluctuations is vital, in order to retain a properly informed financial decision-making process. By thoroughly monitoring the changes in the rate, the company will ultimately be able to optimally adjust and modify its pricing strategy. The company was well aware of the situation and how to mitigate the issue. "We went through a period whereby converting our earnings to US dollars was a daily procedure" claimed the COO. However, the application rate (5.40) for R12 and R13 could not be higher, even though proper mitigation strategies were in place, as the company could not react to same-day sudden surges in the rate of the Lebanese Pound.

Moreover, the 2x2 matrix acknowledged two correlated market risks R41 and R42, which refer to the accessibility of substitutes and their availability respectively. Both concepts are strongly intertwined and often used interchangeably. While availability measures the extent to which the manufacturer of a good has the required resources to meet its supply, accessibility refers to geographic attainability, which is identified by how easily the end-user is able to reach the product. For instance, the threat of lower quality substitutes, such as the use of powdered milk or the addition of additives to produce cheese, are sold at a cheaper price compared to the premium natural cheese provided by the company can pose a noteworthy threat. Since these low-quality alternatives provided by the competition are valued at a lower price, they can easily attract price-sensitive consumers, which have become a growing segment of the population since the 2019 economic crisis. However, as consumers focus on the price of the good before buying, they may not be aware of the difference in quality and taste. Therefore, we believe it is important to improve the marketing strategy by better informing the consumers about the benefits of choosing the company's products, such as emphasizing and promoting the high quality, the true authenticity and the numerous health benefits of consuming 100% natural cheeses. The following can be done through strengthening the brand identity by proper branding and packaging and by highlighting the premium image of the products provided by the company. Also, we advise to effectively and regularly engage with the customers by building solid affiliations with the clientele. This can be done through strong engagement on social media, proper feedback collection, and tackling concerns or complaints, if any, efficiently.

Furthermore, the 2x2 matrix identified two other markets risks (R39 and R46) with relative high values for severity and occurrence. Unlike the prior-mentioned risks, this risk is neither industry-wide, nor nation-wide, but rather directly related to the company being studied and their strategy. These two risks, classified as competitive risks in the FMEA, are referring to the large amount of discounts and promotions by other dairy companies (R39), while the company itself is relatively undergoing a neglect towards promotional activities (R46). The low application rate (4.80) may suggest a noteworthy impact on the company's performance as well as its market competitiveness. The presence of a somewhat high occurrence (6.40) for R39 suggests that competitors in the industry are actively undergoing promotional activities, such as discounted pricing, product bundling, and product demonstrators, which are individuals that share information about the company's products to the customers, and that offers potential clients samples, with the goal of promoting the brand. We believe that the high reliance on the long-standing tenure in the industry by the company and its loyal customer base, without actively enhancing promotional strategies, might possibly lead to adverse consequences. Therefore, we advise the company to enhance promotional strategy by conducting a thorough market analysis, allowing them to tailor promotional efforts to match the demand of the consumers, and by examining current successful competitor promotional strategies, such as discounts and promotions and their influence on overall customer engagement.

On another note, through the preliminary interviews that were conducted with managers, we identified two main packaging materials that were used by the company, polypropylene boxes for yogurt-like products and polyamide vacuum bags for cheeses. Interestingly, we have noted a significant difference in RPN between the presence of physical elements between polypropylene boxes (R73) and polyamide vacuum bags (R74), with a respective RPN of 44.80 to 92.81**,** mainly due to the increased occurrence. The identified discrepancy could have different reasonings. With regard to the purchase of packaging material, it is essential to examine the supplier's quality and reliability. In order to do so, the company will need to further look at the storage, transportation, and handling of the packaging materials. For instance, the storage environment for both packaging materials might differ, such as variations in temperature, humidity, and stacking practices, which could potentially increase the possibility of physical elements penetrating the packaging material. Moreover, the packaging might also have an impact, as each material has its own properties and characteristics. Vacuum bags' can be more prone to ruptures compared to polypropylene boxes, leading to a higher occurrence of physical contamination. Handling protocols during loading, unloading, or distribution should be periodically inspected. Although working with different packaging suppliers may have its advantages, it can also be a disadvantage in terms of variation in the quality and durability of the purchased goods. Furthermore, it is also important to note the manner in which these packaging materials are produced. As opposed to the polypropylene boxes, vacuum bags have a different process that involves suction, which has the potential to attract external elements such as spots, dust, and strains of hair between two layers. Hence, it is essential to select the appropriate packaging suppliers, especially for vacuum bags, by ensuring the supplier follows industry quality standards and possesses proper certifications.

Finally, even though the company frequently undergoes heavy metals tests for the water used (Application rate: 7.65), we have found that out of all the heavy metals, the most threatening risk is the occurrence of lead (Pb), due to its relative higher occurrence. Such contamination could occur due to worn-out and neglected plumbing systems or environmental pollution caused by the release of pollutants and wastes from other industrial activities. Notably, if not appropriately supervised and treated, these materials can get into the water used, causing contamination to the end-product. Compared to the other heavy metals that can be found, lead is considered to be among the most toxic heavy metal, particularly for children and pregnant women, causing severe health problems, such as kidney damage, cardiovascular effects, gastrointestinal problems, and other long-term health risks. Hence, constant monitoring procedures and proper water treatment facilities measure should be in place.

8. Discussion and Conclusion

Our research was able to display the prominent risks confronted by dairy companies, through the combination of six main domains, which are, economic risks, market risks, sourcing risks, process risks, logistics risks, and regulatory risks. Evidently, each of these domains offer their own set of challenges and opportunities. With the use of the FMEA, we were able to navigate through these risks by identifying the main threats and providing proactive solutions, by embracing suitable economic policies - especially during an economic crisis, by undertaking proper market analysis and strategies, by performing effective sourcing and processing practices though the application of rigorous quality control, and finally by accurately understanding the limitations of governmental regulations. Since we recognized that not all risks identified could have a detection rate, as required by the FMEA, we divided the risks into two sections. Then, we were able to identify and prioritize for each section, the most threatening risks.

Our research has shown that the economic crisis in Lebanon negatively impacted the dairy industry due to several factors. For instance, the situation caused rising costs mainly due to hyperinflation and the lack of support by the government. In addition, this environment caused disruptions in the supply chain, such as road blockage and fuel shortages. Furthermore, due to the currency devaluation and increased unemployment, the purchasing power of the population significantly decreased, causing a slight decline in demand for dairy products. Moreover, such economic scenario discourages new investments, such as new infrastructure, up-to-date equipment, and improvements in research and development. Excluding the economic risks analyzed that are considered a unique situation, we can label the mentioned corrective measures as general suggestions that are applicable for other dairy companies around the world. It is important to note that the effectiveness of the risk mitigation proposals will vary from one dairy company to the other, depending on its specific management and its environment.

Moreover, by introducing the application rate, we can establish the extent to which the assigned corrective actions actually mitigate various risks. One of the most compelling insights to emerge from this approach is the detection of noteworthy opportunities for the company. Major opportunities manifest themselves when a risk has a high initial RPN and a low application rate (A), all while simultaneously categorizing the risk as controllable within the company's capacities. The high initial RPN signifies that the risk possesses a substantial potential for adverse effect, while the low application rate indicates that the organization has not fully employed its capability to mitigate the risk in an effective manner. The classification of the risk as controllable highlights the organization's potential ability to employ influence,

effectively manage, and improve the corrective measure for that specific risk. Notably, while many risks fall within the company's ability to control, certain external factors, such as the mentioned economic crisis, serve as examples of circumstances beyond the company's control. First, we identified R166, a risk concerning clients not providing around the clock optimal refrigeration. In this scenario, the corrective measure includes proper refrigeration control. With an initial RPN of 117.56 and low application rate of 4.50, we can determine that this risk still has room for improvement for the company. Therefore we recommend improving refrigeration control by implementing regular mandatory inspections to all clients. Second, we identified R163, a risk concerning the microbial contamination due to inappropriate temperatures in the trucks without the knowledge of any employee.
In this scenario, corrective measures involved cold chain being maintained throughout every stop in the distribution, while establishing real-time temperature and alarm systems. While the initial RPN is valued at 241.31, the application rate was calculated to be 6.38. As we looked at the reasoning behind the low of application rate, we understood the absence of any alarm system by the company. Hence, we see it as a substantial opportunity for the company to integrate alarm systems for their trucks. By pursuing the enhancement of the application rate of these specific risks, the company can allocate resources more efficiently, focusing efforts where they are needed. This strategic approach can reinforce the management of risks and maximize the company's overall performance and resilience.

On another note, we should acknowledge that there are still limitations to the methodology employed in conducting this paper. While the FMEA approach is definitely a useful tool for assessing, prioritizing, and mitigating risks, the method still has some limitations that need to be taken into consideration. For instance, the methodology involves subjective judgements from the participating members, which can vary between different individuals, depending on their experience and their perspectives on the topic at hand, leading to inconsistencies in the results. Moreover, even though the procedure is based heavily on solid historical registered data and personnel expertise, the analysis might not correctly reflect all risks if the relevant data is lacking. Furthermore, the approach assumes that the three main criteria (S, O and D) are independent of each other. However, these criteria might be interconnected. For instance, we have found differences in responses to the reception of bad quality milk from suppliers. Most participants shared extremely high values of severity for risks concerning biological contaminations from purchased raw milk, due to the fact that the continuation could potentially lead to health impacts to the end-user and deteriorate the brand reputation. However, one participant leaned towards a relatively lower severity rate. The reason for the diverse response is that, in the rare occurrence of biological contamination from raw milk, the transformation process from milk to cheese will not take place as anticipated. This procedure undergoes phases that include enzymatic reactions and bacterial cultures that transform the milk's structure. This conversion is necessary for the coagulation and separation of the milk into curds and whey, which are fundamental for the production of cheeses. There are several ways to detect biological contaminations such as the microbiological testing that is in place that allows to potentially reject the milk batch before it enters the production area, the visual and sensory inspection by the trained employees, and the acidity monitoring. However, if the milk happens to be contaminated with microorganisms that remains undetected, the process is usually disrupted by the lack of coagulation. Since the milk is deemed unsuitable in such scenario, the entire batch is sent back to the supplier, hence the contaminated milk will not reach the end-user. Therefore, the participant's perception on the easiness of detection influenced his severity response. Since the situation can be identified during the process, the threat is no longer considered to be have a high severity. Notably, the risk will still have negative impact, as the production process for that specific day will be disrupted, potentially leading to delays in meeting customer demand.

By building upon the foundations established in this paper, we believe that this research may lay the groundwork for future research and exploration. Although this research heavily emphasizes on a specific company by incorporating a comprehensive set of employees, it would be interesting to extend this research to other dairy companies. By conducting the FMEA approach with different players in the industry, we could potentially draw on commonalities and differences concerning risk assessment, as well as the effectiveness of corrective measures. In relation to the financial instability involved in this research, it would be enlightening to apply a comparative FMEA with different players in the industry that encountered similar economic downturn (e.g. dairy companies in Lebanon). Also, the incorporation of the applicate rate “A” for different companies can be further used to better understand how different organizations react to unexpected crises.

In order to further enhance the accuracy and precision of the FMEA, future research could potentially integrate the Delphi method. Since the Delphi method is a structured system that enables the opportunity to build consensus among a group of experts, it can be implemented by allowing each participant to assign the corresponding weights of each employee in relation to the topic at hand. First, the selection of the expert panel must take place. These experts should ideally be representing different departments within the company. Then, initial rounds should allow the experts to incorporate percentages to each topic based on their understanding and their expertise. Later, results can be summarized and provided as feedback to the experts, while maintaining their anonymity. Subsequent rounds of the Delphi method will allow the participants to reconsider their initial assessments, ultimately allowing for the convergence of opinions. Hence, the weights allocated to each topic can ultimately be established with a certain level of consensus among peers.

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