A risk assessment model for Supply Chain Design. Implementation at Kuehne + Nagel Luxembourg

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***Abstract*—Every company may be located at the junction of several Supply Chains (SCs) to meet the requirements of many different end customers. To achieve a sustainable competitive advantage over its business rivals, a company needs to continuously improve its relations to its different stakeholders as well as its performance in terms of integrating its decision processes and hence, its communication and information systems. Furthermore, customers' growing awareness of green and sustainable matters and new national and international regulations force enterprises to rethink their whole system. In this paper we propose a model to quantify the identified potential risks to assist in designing or re-designing a supply chain. So that managers may take adequate decisions to have the continuing ability of satisfying customers' requirements. A case study, developed at kuehne + nagel Luxembourg is provided**

Keywords—Indicators, Logistics, Performance, Risk Management, Supply Chain; Sustainability.

I. Introduction

Nowadays, the sustainability concept has been further developed and companies need to understand that today, it is far more complex than understood by most managers. The literature review performed in the second section, yield that the sustainability concept is far more advanced and complex than admitted by most managers and researchers. Many authors have shown interest in integrating the sustainability concept into their researches by focusing on the economic and ecological aspects, neglecting the societal one. Most managers understood the concept of sustainability being the solely implementation of green practices, which are impossible to measure and to compare. Effectively, many managers frequently fall into old ways of thinking, implementing Total Environmental Quality Management (TEQM), and claiming their companies being sustainable.

A Logistics Service Provider (LSP) needs to evaluate his existent supply chains to get an overview of the current As-Is situation, so that the latter may be corrected in the sense of continuous improvement. This overview is indispensable for managers, taking decisions of how to implement the upcoming proceedings on an operational, tactical or strategic level, i.e. in the short, mid and long term. It must however be noted that each amendment of a SC entails risks. Managers need to decide if the latter are taken, mitigated, or avoided. Consequently, the implementation of a SC's re-design requisites a risk analysis a priori.

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A. *Maintaining the Integrity of the Specifications*

However, it is not possible to manage all the different risks which may occur within a SC at once. Depending on the risk assessment's level of detail, there may be a myriad of risks to analyse. In this paper evaluate the overall degree of sustainability of a given customer's SC. This SC needs to be re-designed so that an improved degree of sustainability can be reached. Our major interest of this re-design process belongs to the risk assessment which constitutes its very first step.

The added value provided by this paper lies in the general risk assessment model considering the risks related to our key topic of sustainability. The latter may be implemented for every SC's sustainability risk assessment, no matter its market served. In addition, since the model is to be considered as a general one, a slight amendment should be sufficient to evaluate each other kind of risks which may appear within a SC.

To achieve a sustainable competitive advantage over its business rivals, a company needs to continuously improve its relations to its different stakeholders as well as its performance in terms of integrating its decision processes and hence, its communication and information systems. Customers' growing awareness of green and sustainable matters and new national and international regulations force enterprises to rethink their whole system [1].

In the next section, we go into detail how to evaluate a SC's degree of sustainability. Then we present our model followed by the case study

II. Sustainability in Supply Chain Management

[2] explains that business is seen as being sustainable if it complies with the Triple Bottom Line of economic prosperity, environmental quality and social justice (fig 1).

Since 2013, carriers need to specify their CO_2 emissions produced during a shipment so that customers may chose the less polluting one. The French government wanted to make traffic users and Logistics Service Providers (LSPs) aware of the climate issue while reducing the GHG emissions produced [3].

Fig. 1. Sustainability as defined by Elkington (1997)

A. The Economic Pillar

The KPI the most reflected concerning the economic matter is the 'Financial Performance & Costs (or savings)' one. As it is used such often in academic works, one could assume that this KPI is the most perceived one in companies, too. [4] criticised "the myopic focus on short-term financial gain", while [5; 6; 7] analysed several assumptions considering the financial performance. [8; 9] evaluated Green Supply Chain Management (GSCM) practices and behavioural research on logistics respectively, including economic performance as an evaluation criteria. The 'Financial Performance & Costs (savings)' indicator is used, as mentioned above, in some articles but those works all considered the companies as a whole but not the different SCs the enterprise actually performs.

B. The Ecologic Pillar

The most analysed part of those topics is the ecological one [10]. In fact, nowadays many European companies are ISO 14000 certified. It is assumed that on these grounds, the '(Inter -) national Regulations and Standards' have been revealed as being the most used indicator. Several authors used this indicator in the same manner by including it as environmental metric helping to measure the environmental performance [11; 12; 13; 14; 10; 15; 16; 17]. It is worrisome that only [14] explicitly highlighted the continuous improvement in environmental performance resulting from the ISO standards. [8] defined the environmental regulations as being the external driving factors, regardless of whether the ordinances are domestic, governmental, or international.

C. The Societal Pillar

Compared to the economical and the ecological pillar, the societal one has only been analysed by a few authors. This may be due to the fact that this pillar is currently the less studied one. In former times, improving the environmental conditions was understood as improving the social costs [18]. Logistics Service Providers (LSPs) need to analyse their SCs and to make a judgment about the out coming values concerning their respective performances.

III. Supply Chain Risk Management

According to [19] the past few years we have seen a significant growth in terms of the topic of Supply Chain Risk Management (SCRM) in both, the industry and the academic research fields. [20] concentrated on SCR, stating that the latter may be seen as "[…] 'the potential occurrences of an incident or failure to seize opportunities with inbound supply in which its outcomes result in a financial loss for the [purchasing] firm'". [21] argue that SCR sources "are critical contextual variables that can be internal and external to supply chains and to the acting firms in a supply chain network". On the other hand, [22] explained that "the concept of 'supply chain risk' refers to those little predictable incidents or events, affecting or originating from one or several partners in a supply chain and/or its processes, and may influence negatively the achievement of organisations' goals". In the same logic, SCR may be defined as "any risk to the information, material and product flow from original supplier to the delivery of the final product" [23].

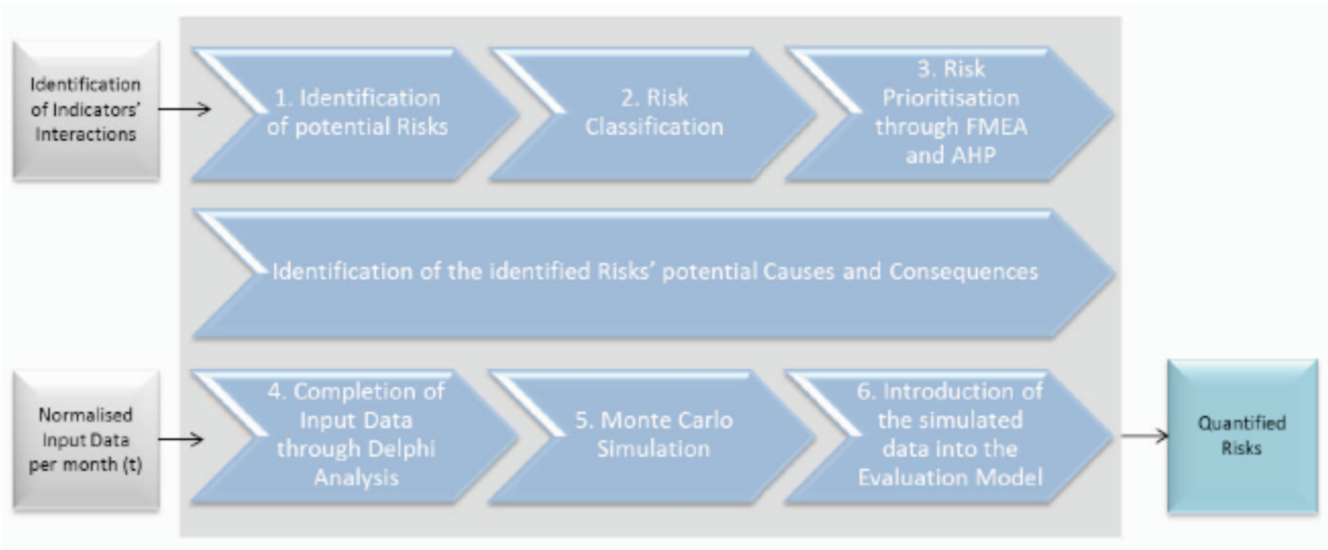
a majority of business researchers seem to use 'risk' as a negative change with respect to performance. The notion of risk management within SCs is a recent subject too [24; 25]. The human perception seems being closer to the negative connotation, than to the perception of danger and opportunity [26]. In fact, risks are usually neither identified, nor treated during management processes but they are assessed independently. Hence, managers need to assembly the different risks with the considered project's critical endeavours.

In this work we define risk as follows: Risk is to be seen as the occurrence of an event, or the occurrence of a combination of events having impacts on at least one of the company's objectives, its overall value, or its reputation.

Supply Chain Risk Management is to be seen as the implementation of strategies, which are continuously improved and intended to antagonise both the risks emerging on a daily basis as well as the particular risks.

IV. Proposed Approach

The proposed risk assessment process consists of six different steps, based on the indicators' interactions (fig 2). The first step of the general model is to be seen as the identification of potential risks. The input factors used for this identification, i.e. the identified indicators' interactions, may of course differ from one case to another. The second step of our risk assessment model consists of the risk classification, helping managers to set the right focuses during the upcoming phases. Since there is a myriad of existent risks, it is not possible to assess all identified risks at once. For this reason, we consider to prioritise them via the FMEA and the AHP methodology. In addition, the identification of the potential risks' causes and consequences needs to be done contemporaneous to the first three phases. Effectively, most causes and consequences can be encountered when processing the first three phases. In order to save time, this task should not be deferred until the third task has been completed. The subsequent step consists of completing the data gathered via the evaluation model by a Delphi analysis. Those completed data will then be used as base for the Monte Carlo Simulation. Those simulated data need then to be introduced into the evaluation model, so that they can be analysed. The end result provided by our risk assessment model will be a snap-shot picture of the 'As-Is' situation



a.

Fig. 2. Approach to assess the risk level

A. *Identifying the Indicators' Interactions*

The techniques to be used are a composition of the HAZOP and the What If methodologies. Indeed, to find the potential interactions between KPIs, several brainstorming meetings with experts who have a complete and detailed knowledge of the considered system and the inherent processes have to be conducted. The process of those meetings is based on the four phases of the HAZOP process. During the Examination phase, the guide words as well as the consequences and causes are defined. In this phase, nevertheless, the main question asked should be: "What if KPI x will be improved?". The guidewords "No", "Not", "More" and "Less" and "Other Than", which are predefined by the HAZOP methodology, will then be used within the given answers. In addition, the experts need to assess the likelihood of the specific consequences. However, for simplicity reasons, we suggest identifying the different interactions and to add the associated factors afterwards.

B. *Identification and own risk classification*

To identify risks, managers need to frame answers to essential questions like: 'What could hamper the company to reach its aims and objectives?' or 'What would defect the company's survival in the market?'. In that way, risk identification techniques, such as brainstorming, SWOT-analysis or scenario analysis are performed.

When targets are denoted in a clear manner and understood by the different participants, a brainstorming session based on the latter's creativity can be used to generate a list of potential risks.

The Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis is then complementary. While strengths and weaknesses are internal to the company, considering its structure and culture, the opportunities and threats are to be understood as primarily external to the company and therefore in most cases out of the company's control. Threats may include, for example, political instability or industry risks (Hay & Castilla, 2006). By concentrating mainly on the weaknesses and threats, potential risks are widely identified.

C. *Prioritisation of the eventual Risks*

The Failure Mode and Effect Analysis (FMEA) methodology, as previously described, is one of the most common quantitative risk assessment methods used [27]. Its approach accepts that there is not one single cause leading to a materialised risk. In our model, we will use a modified FMEA methodology, indicating that the Risk Priority Number (RPN) is calculated via the multiplication of its three inherent components, (1) Severity (Se), (2) Occurrence (Oc), and (3) Detection (De). We apply a 5-point scale to evaluate the three elements Se, Oc, and De.

since some indicators are considered being much more important than other ones, the corresponding risks need to be weighted in the same way by using the $\varkappa$ factor.

The RPN value per pillar is obtained by summing the according indicators' RPN values.

D. *Data Completion via Delphi Method*

The Delphi Method, as depicted in Figure 3, is "a very flexible tool which permits to reach a consensus, through the collection of experts' opinions on a given issue during successive stages of questionnaire and feedback" [28]. Effectively, the Delphi Method can be seen as a systematic and interactive approach, which anonymously relies on a panel of a group of independent [29; 30], and which is, according to [31] "well suited as a research instrument when there is incomplete knowledge about a problem or phenomenon".

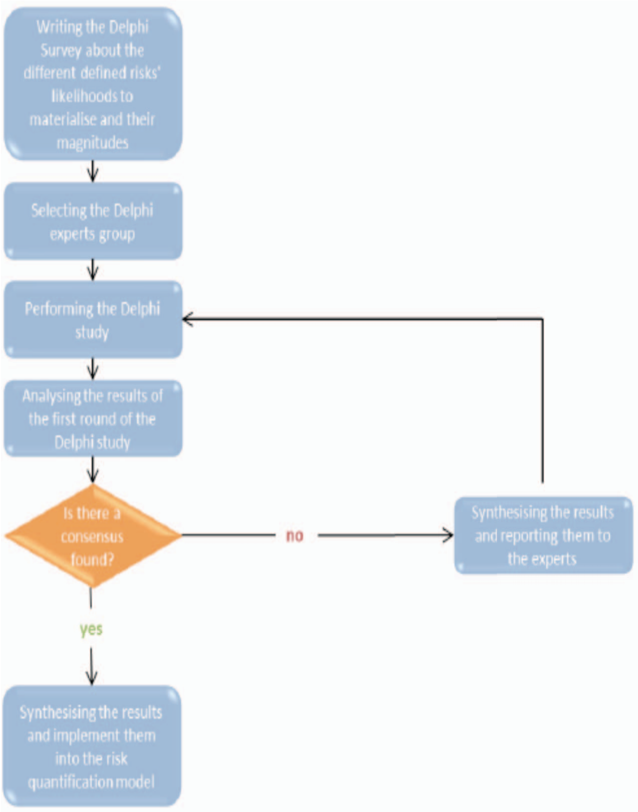


Fig. 3. The proposed Delphi based approach

E. Simulating the Variables through Monte Carlo Methodology

In this work, we rejected the assumption of independence between indicators. Effectively, as explained in detail previously, we detected that each KPI has consequences to at least one other indicator and that each KPI may be the cause of at least one other indicator's variation. Nevertheless, those interactions may be neglected within the Monte Carlo Simulation. De facto, the strong Law of Large Numbers (LLN) advocates that almost surely $\lim_{n \to \infty} \hat{A}n = A$. Thus Ân converges towards A as the sample's size (n) converges towards infinity (∞). This property is what statisticians call 'consistent' [32].

To implement the Monte Carlo Simulation, we will use the Crystal Ball® tool. This tool is able to either provide all the required simulations at once or to do a stepwise simulation, so that the analysts can easily comprehend the different performed steps. As described above, the simulation is based on real data, including the different risks' magnitudes. The first step of the simulation process consists of defining the different indicators' distributions assumed for the simulation.

F. Risk Quantification

The quantified risks help managers in taking future decisions. Because of the application of the Law of Large Numbers (LLN), the identified risks' interactions and hence the different magnitudes gathered via the Delphi Method are neglected within the calculations.

V. CASE STUDY FROM KUEHNE + NAGEL LUXEMBOURG

The Kuehne + Nagel Group is the worldwide leader of air and sea transportations. The Kuehne + Nagel group employs over 63'000 logistics specialists in about 1'000 locations, which are based in more than 100 countries. To implement the case study, we consider the Customer's historical data on the short term timeframe from 2010 to 2013.

The dashboard will hold thirteen indicators, which will all be explained in detail. In this KPI Set, the economical pillar considers four indicators, the ecologic one incorporates three KPIs, and the societal one considers six indicators. The societal pillars indicators are though considered via the detour of its two sub-pillars Work and Ethics, considering each three indicators respectively. The thirteen indicators are:

1. Costs
2. On Time In Full delivery (OTIF)
3. Service Quality (Q)
4. Exception Management (ExM)
5. Greenhouse Gas Emissions (GHG)
6. Waste Management (RRR)
7. Energy Used (EnUs)
8. Trainings per Employee (LLL)
9. Security of Employment (SE)
10. Health, Security, and Safety (HSS)
11. Gender Equality (GE)
12. Actions taken against Xenophobia and Discrimination (AXD)
13. Actions taken to increase Employees' Motivation (EmMo)

A. Identifying the Indicators' Interactions

The interactions could be introduced as consequences into the Event Tree Analysis (ETA) of the BTM. On the other hand, one consequence may have several causes. We define the consequence of one indicator, being the cause of one other indicator as it can be read out of Table I. As an example, the risk of increasing the costs (i.e. the risk of decreasing its performance) may be due to either the occurrence of one of the following incidents, or to the occurrence of a certain combination of the following events.

B. Identification and own risk classification

To identify the potential risks, we organised several individual face to face meetings with the internal experts to ensure common understanding. In a second stage, a semi-structured interview based on the "What-If" methodology has been performed with the group of 14 internal experts. Since the experts have not been questioned individually, one expert's answer has been complemented by the other experts. Interestingly, those verbal additions have mostly been introduced by the wording "Ok, but what if…". In this same meeting, the different risks have been classified in three categories, namely internal, force majeure and external, as presented in Figure 6.

TABLE I. KPI'S POSSIBLE INTERACTIONS

KPI to be Improved	Possible Interactions										
C	OTIF ↓	Q ↓	ExM ↓	SE ↓	HSS ↓						
OTIF	C ↓	Q ↑	GHG ↓	LLL ↓	SE ↑						
Q	C ↓	OTIF ↑	ExM ↑	LLL ↑	SE ↑						
ExM	C ↓	OTIF ↑	Q ↑	SE ↑							
GHG	C ↓	OTIF ↓	SE ↑								
RRR	C ↑	GHG ↑	LLL ↑								
EnUs	C ↑	LLL ↑	HSS ↓								
LLL	C ↓	OTIF ↑	Q ↑	ExM ↑	GHG ↑	RRR ↑	EnUs ↑	SE ↑	HSS ↑	GE ↑	EmMo ↓
SE	C ↓	Q ↑	ExM ↑	HSS ↑	EmMo ↓						
HSS	C ↑	OTIF ↑	Q ↑	ExM ↑							
GE	EmMo ↓										
AXD	C ↓	OTIF ↑	Q ↑	ExM ↑	LLL ↑	EmMo ↓					
EmMo	C ↓	LLL ↑	SE ↑								

b.

C. Prioritisation of the eventual Risks

Since the GHG indicator has shown some major issues in the past and as this KPI has the highest $\varkappa$ within the ecological pillar, it is not surprising that precisely this pillar entails the highest calculated RPN. The other extreme of this ranking is given by the economic pillar's RPN. Considering the immense significance of the Service Quality (Q) and the On Time In Full delivery (OTIF) indicators and taking into account their high performances, it is perfectly logical that RPN calculated for the economical pillar the lowest one. The societal pillar must not be neglected, even though its RPN is much lower than the one calculated for the ecological pillar. This holds also true for the societal pillar's risks. Effectively, the RPN does not prejudge the risks' quantification but only their level of priority.

TABLE II. RISK PRIORITY PER INDICATOR

Ranking	KPI	$\varkappa_{KPIi}$	$Se_{KPIi} \cdot Oc_{KPIi} \cdot De_{KPIi}$	RPN
1	GHG	0.62500	24	15
2	SE	0.37162	30	11.14864865
3	EmMo	0.72956	12	8.754716981
4	HSS	0.41216	18	7.418918919
5	RRR	0.22059	30	6.617647059
6	EnUs	0.15441	30	4.632352941
7	Q	0.22326	16	3.572093023
8	C	0.28837	12	3.460465116
9	OTIF	0.41395	8	3.311627907
10	GE	0.15094	12	1.811320755
11	LLL	0.21622	8	1.72972973
12	AXD	0.11950	9	1.075471698
13	ExM	0.07442	12	0.893023256

In this work, the main risk to be considered is the risk of a deterioration of the degree of sustainability (Table II) and the main pillar the Ecologic one (Table III).

TABLE III. RISK PRIORITY PER PILLAR

	RPN
Ecologic	26.25
Societal	15.97
Economic	11.24

TABLE IV. SIMULATION: DEFINED DISTRIBUTIONS PER INDICATOR

KPI	Mean Value μ	Std Dev. σ	Min	Max	**Simulated Value**
C	0,1475	0,0743	0,0001	0,3709	**0,7242**
OTIF	0,9810	0,0105	0,9170	0,9907	**0,9316**
Q	0,8898	0,0168	0,8600	0,9200	**0,9169**
ExM	0,7792	0,0359	0,7123	0,8357	**0,8904**
GHG	0,5401	0,1878	0,0001	0,7223	**0,8023**
RRR	0,9801	0,0105	0,9503	0,9975	**0,9100**
EnUs	0,9647	0,0085	0,9542	0,9910	**0,9532**
SE	0,8367	0,0312	0,8000	0,8800	**0,7981**
HSS	0,9506	0,0528	0,8381	0,9999	**0,9477**
LLL	0,5652	0,2237	0,0400	0,9999	**0,6042**
GE	0,7478	0,0478	0,7000	0,8200	**0,7703**
AXD	0,5395	0,0279	0,4800	0,5800	**0,5554**
EmMo	0,5579	0,0413	0,5200	0,6200	**0,6257**

In Table IV, the first simulated data (i.e.: n = 1) are shown. Nevertheless, in order to apply the strong LLN within our risk quantification model, we run the simulation at 10 000 instances (i.e.: n = 10 000 > 30).

D. Data Completion via Delphi Method

Kuehne + Nagel has not considered sustainability in the way we defined here. It is therefore evident that some data have not been gathered.

Our research methodology has been based on a three-rounded modified Delphi process. Effectively, a group of 14 interviewed experts are the same during the whole study. To set up the anonymous background, which is imperative for a proper implementation of a Delphi study, we explained the importance of individual answering during face to face meetings. During those meetings, we also introduced the questionnaire, which was divided into two sections, namely the risks' probabilities to materialise and their magnitudes. Given the returns we received through the first round, we assume that the experts did not coordinate the answers among themselves. For this reason, we consider the artificial established anonymous background being acceptable for carrying out a Delphi study. The data collected to calculate the SC's global degree of sustainability have then been completed by their respective assumed magnitudes through the modified Delphi Method.

E. Simulating the Variables through Monte Carlo

The risk of not achieving the ecological pillar's target is to be assessed first and will be quantified within this case study. We hence need to concentrate our calculations on this pillar's inherent indicators: CO2 equivalent (GHG), Energy Used (EnUs), and Waste Management (RRR). We hence calculated the 10 000 simulated ecological pillar's degrees of sustainability and analyse the frequencies provided by this calculation. The performed simulation proves that the CLT applies, even though it has not been employed within our calculations. Effectively, despite the fact that we have assigned other distributions than the standard normal distribution to the different indicators' simulations, the chart depicting the simulated ecological degrees of sustainability's frequencies clearly shows a Gaussian like curve as it can be extracted from fig 4.

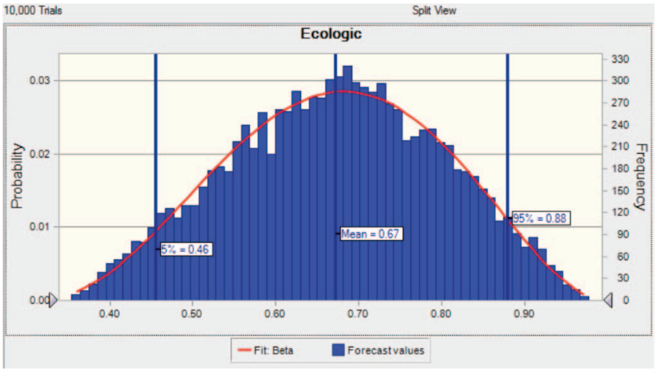


Fig. 4. The Ecological Pillar: Frequencies

F. Risk Quantification

In our specific case study, managers agreed that the target to be set is to achieve an ecological degree of sustainability being equal or greater than 0.75 ceteris paribus. In mathematical terms, this can be expressed as follows: Mean of 10'000 simulated ecological degrees of sustainability ϵ [0.75;1]. Crystal Ball[1] allows defining the precision of the calculation, which we set at 95.00%, as it is shown in figure 5.

[1] Crystal Ball uses an analytical bootstrapping method instead of a mathematical formula to calculate the percentiles confidence interval (Anandan et al., 2009).

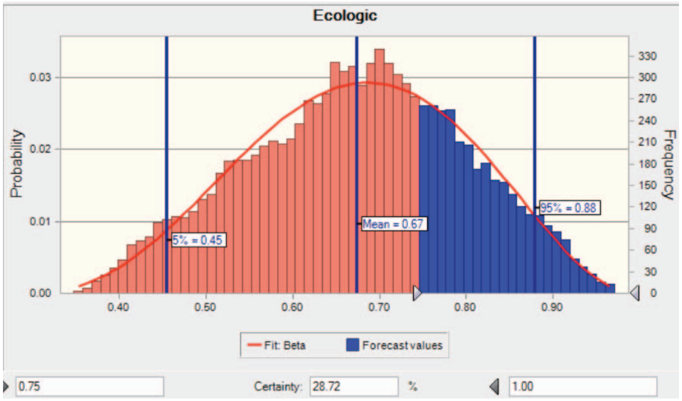


Fig. 5. Ecological Pillar: Risk Quantification

Let P(Ecolsustainability)be the probability of achieving the ecological degree of sustainability predefined by the managers. The risk of not achieving this goal can hence be quantified as by calculating the inverse probability of P(Ecolsustainability):

1 – P(Ecolsustainability)

= 1 – P(0.75)

Using the simulated data provided by the Monte Carlo Simulation including the application of the LLN:

= 1 – 0.2872

= 0.7128

= 71.28 %

Hence, the risk of not reaching the ecological degree of sustainability of 0.75 when the LLN is accepted within the Monte Carlo Simulations amounts 71.28 %, and ceteris paribus.

Using the simulated data provided by the Monte Carlo Simulation neglecting the application of the LLN:

= 1 – 0.28783

= 0.7117

= 71.17 %

Thus, the risk of not reaching the ecological degree of sustainability of 0.75 when neglecting the LLN within the Monte Carlo Simulations amounts 71.17%, and ceteris paribus.

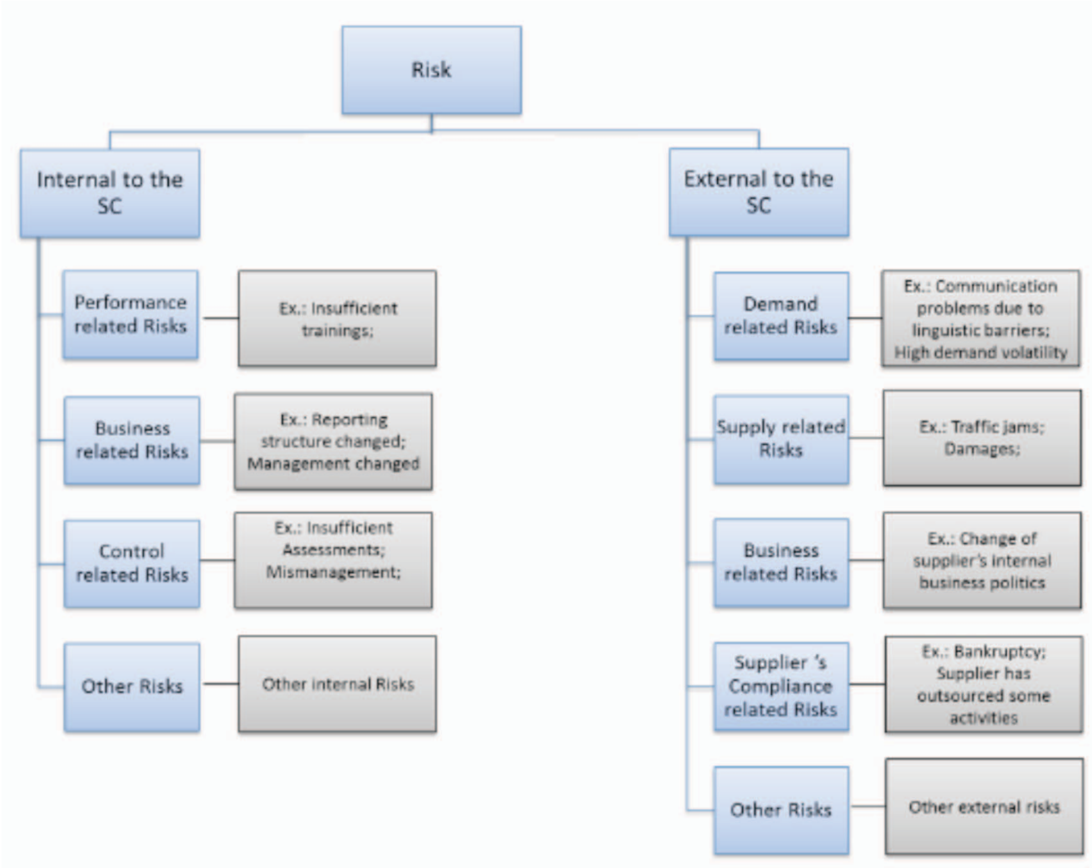


Fig. 6. Approach to assess the risk level

This classification is usually done in an intuitive manner, within the data collection and information gathering processes, present within every process step.

G. Discussion

Managers often have to choose exclusively one strategy in order to work out a global risk level tolerance [33]. This strategy needs to be found through diverse meetings on which SC managers and risk experts participate. The subsequent step of our model consists hence in agreeing on how to dispose the different risks, i.e. what level of risk may be accepted. If the results provided by the above calculation cannot be admitted, managers need to reconcile on how to mitigate the considered risk or on how to avoid it. In other words, the above model needs to be broadened by the implementation of a risk mitigation process. Our Risk Quantification Model has hence achieved the objective of helping managers to take their decisions, relevant for the further course of actions to be taken for assessing the identified risks.

VI. Conclusion

In summary, it can be stated that we developed a tool which enables Kuehne + Nagel to evaluate its customers' SC's performance of sustainability, regardless of the domain served by the specific customer. In addition, Kuehne + Nagel can set up a benchmark, by applying this model on its diverse customers.

During the development phase of the above explained model, some internal managers suggested introducing the Decision Tree (DT) methodology as a last step of our risk assessment model. Effectively, in a LEAN perspective, the companies' respective boards of directors want their managers to save time whenever possible. For this reason, they want to get a clear picture of the different risks' estimated outcomes which is understandable at the first glance and which can support the decision taking process in a more visible way. Though, we consider the DT being ineffective in the logistics environment. The steadily changing state of affairs as well as the immense number of consequences connected to one alteration of the current system would lead to the impossibility of providing the required clear picture and hence to subsequent frustration due to the defeat in evaluating the results' usability obtained therefrom. However, we agree with [34] explaining that a diagram is usually considered being more comprehensible than a written description of a given problem. For this reason, we suggest our model to be succeeded by the definition of a risk mitigation strategy, whereas the latter should be finalised by a Bow-Tie Model (BTM). In the approach of continuous improvement, this risk assessment needs to be done on a regular basis and the end results need to be analysed, i.e. before the improvement of a SC's degree of sustainability and hence, before the re-design of the said SC.

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